

## General characteristics, risk-stratified and sex-stratified clinical outcomes in Bangladeshi people with type 2 diabetes mellitus who fasted during Ramadan 2022: A multicenter, real-world, cross-sectional study

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### Abstract

**Background:** Fasting during Ramadan presents both spiritual significance and physiological challenges, particularly for individuals with type 2 diabetes mellitus (T2DM). While previous research has yielded mixed results, there remains a gap in real-world multicenter data on the clinical impact of fasting in risk- and sex-stratified patients with T2DM.

**Objective:** The study aimed to assess the characteristics and clinical and behavioral outcomes among T2DM patients who fasted during Ramadan 2022, stratified by risk using the International Diabetes Federation-Diabetes and Ramadan (IDF-DAR) criteria 2021, and also stratified by sex.

**Methods:** This cross-sectional, multicenter survey was conducted across 14 tertiary hospitals in Bangladesh following Ramadan 2022. Adult patients with T2DM who had fasted for at least 1 day were included and categorized into low-, moderate-, and high-risk groups using the IDF-DAR risk score (2021). Data were collected on demographics, fasting practices, hypoglycemia, glucose monitoring, and clinical parameters, including HbA1c and comorbidities.

**Results:** Of 2,382 screened patients, 2,304 were included and categorized into low-risk (n=231; 10.0%), moderate-risk (n=660; 28.6%), and high-risk (n=1,413; 61.3%) groups according to IDF-DAR 2021 criteria. Hypoglycemia was more frequent among high-risk patients (26.9%) compared to moderate (14.5%) and low-risk (9.5%) groups. Only 53.4% of high-risk individuals received pre-Ramadan counseling, and 29.6% did not self-monitor blood glucose despite clinical indications. Females were more likely to rely on symptoms rather than glucose testing for hypoglycemia detection (64.7% vs. 44.0%; p<0.001). Furthermore, more females believed that blood glucose testing breaks the fast (20.1% vs. 16.3%; p=0.024).

**Conclusion:** While high-risk individuals faced significantly higher rates of hypoglycemia, the majority fasted without adverse outcomes, suggesting that safe fasting may be achievable even in

high-risk groups. However, the low rates of pre-Ramadan counseling and the prevalence of sex-specific misconceptions regarding glucose monitoring-particularly among women-reveal critical gaps. Bridging these gaps through tailored, culturally sensitive education is essential to minimize risks and optimize the safety of Ramadan fasting in this vulnerable population

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**Keywords:** Type 2 diabetes mellitus, Ramadan fasting, IDF-DAR, risk stratification, hypoglycemia, self-monitoring, Bangladesh

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## Introduction

Ramadan, the ninth month of the Islamic lunar calendar, holds profound spiritual significance for Muslims worldwide. During this period, Muslims observe fasting (Sawm) from dawn until sunset, abstaining from food, drink, and other physical needs.<sup>1</sup> This practice serves not only as an act of worship but also as a means of self-purification and reflection.<sup>2</sup> For individuals with chronic health conditions, such as type 2 diabetes mellitus (T2DM), the observance of Ramadan poses unique challenges and necessitates careful management to maintain health and well-being.<sup>3,4</sup>

The physiological impact of fasting during Ramadan on diabetes management is multifaceted. In healthy individuals, fasting induces a series of metabolic adjustments: decreased insulin secretion, increased glucagon and catecholamine levels, glycogenolysis, gluconeogenesis, and, during prolonged fasting, lipolysis leading to ketogenesis.<sup>5,6</sup> These mechanisms maintain glucose homeostasis. However, in individuals with T2DM, these regulatory processes are impaired, increasing the risk of hypoglycemia, hyperglycemia, and diabetic ketoacidosis during fasting periods.<sup>7,8</sup> Furthermore, dehydration due to fluid restriction can exacerbate these risks, potentially leading to orthostatic hypotension and thrombosis.<sup>5,9</sup>

The existing literature presents a complex picture of the effects of Ramadan fasting on individuals with T2DM. A meta-analysis encompassing 28 observational studies from Middle East, African, and Asian countries reported modest improvements in metabolic profiles post-Ramadan. Specifically, reductions were observed in fasting plasma glucose (FPG) by 15.28 mg/dL, HbA1c by 0.27%, total cholesterol by 12.88 mg/dL, and LDL-C by 4.42 mg/dL. These findings suggest the potential benefits of Ramadan fasting on metabolic parameters in

T2DM patients.<sup>10</sup>

Conversely, the EPIDIAR study, an extensive epidemiological investigation across 13 Islamic countries involving 12,243 individuals with diabetes, highlighted significant risks associated with fasting during Ramadan. The study reported a 4.7-fold increase in severe hypoglycemia incidents among patients with type 1 diabetes (T1DM) and a 7.5-fold increase among those with T2DM. Additionally, a fivefold increase in severe hyperglycemia requiring hospitalization was noted in T2DM patients during Ramadan.<sup>5</sup> These findings underscore the potential dangers of fasting for individuals with diabetes, particularly without appropriate medical guidance and monitoring.

To guide the patient for safe fasting, risk assessment is vital. The 2021 International Diabetes Federation-Diabetes and Ramadan (IDF-DAR) Risk Assessment Tool represented a paradigm shift from previous qualitative models toward a more objective, point-based system.<sup>11</sup> By quantifying 14 distinct Ramadan-, disease-, and patient-specific factors-including glycemic control, treatment regimen, and renal function-this calculator-based approach allows clinicians to stratify individuals into low, moderate, or high-risk categories. In Bangladesh, few clinical studies have evaluated the risk score and its impact on outcomes.<sup>12,13</sup> However, the studies are limited by relatively small sample sizes and may not be representative of the entire country. Beyond clinical risk scores, biological sex and sociocultural gender roles represent critical, yet often overlooked, determinants of fasting outcomes in T2DM. In this context, the objective of this study was to examine the clinical and behavioral outcomes stratified by risk score and sex among patients with T2DM who fasted during Ramadan in 2022. By conducting a post-Ramadan survey across multiple

centers, this study aims to provide valuable data to inform clinical practice and enhance patient care during Ramadan.

## Methods

### Study design

This study was a cross-sectional survey conducted after Ramadan in 2022, aimed at assessing the outcomes of patients with T2DM who observed Ramadan fasting. Fasting-related risk was assessed using the IDF-DAR 2021 risk stratification tool.<sup>11</sup> The IDF-DAR risk score is a clinically validated framework designed to estimate fasting-related complications and guide pre-Ramadan counseling and management in people with diabetes. This tool assigns individuals to one of three risk categories—low, moderate, or high—based on the presence of specific clinical and treatment-related variables prior to Ramadan. Variables include age, duration of diabetes, treatment regimen, history of hyperglycemia, presence of macrovascular or microvascular complications, renal function (eGFR), and comorbidities. The study stratified participants by risk level using the IDF-DAR 2021 risk score to evaluate fasting practices, hypoglycemia management, and associated health outcomes.

### Study setting and duration

The study was conducted across fourteen tertiary care hospitals in Bangladesh, including Bangladesh Medical University (BMU), Dhaka Medical College and Hospital (DMCH), Sir Salimullah Medical College (SSMC), Mymensingh Medical College and Hospital (MMCH), Chittagong Medical College and Hospital (CMCH), Rajshahi Medical College and Hospital (RMCH), Sylhet MAG Osmani Medical College and Hospital (SOMCH), Rangpur Medical College and Hospital (RpMCH), Khulna Medical College and Hospital (KMCH), Khulna Specialized Hospital, Shaheed Ziaur Rahman Medical College and Hospital (SZMCH) and National Institute of Neurosciences (NINS). These healthcare institutions were selected to ensure a diverse representation of patients with T2DM from different regions of the country.

Since Ramadan was observed from April 2 to May 2, 2022, data collection was conducted from May to August 2022, immediately after Ramadan. This timing enabled accurate and timely recall of fasting-related experiences. Risk stratification using the IDF-DAR 2021 criteria was performed retrospectively based on clinical and treatment-related variables present before the onset of Ramadan. Ramadan-specific outcomes, including hypoglycemic events and fasting behaviors, were not

incorporated into the risk score calculation.

### Study participants

A total of 2,382 individuals were initially screened from outpatient departments and private chambers of the participating investigators. After applying the eligibility criteria and excluding participants with incomplete clinical or laboratory data (n=78), a final sample of 2,304 adults with T2DM who fasted for at least one day during Ramadan 2022 was included in the analysis. Eligible participants were adults aged  $\geq 18$  years with a physician-confirmed diagnosis of T2DM who provided written informed consent. All forms of diabetes other than T2DM were excluded, including pregnancy-related diabetes. Participants with acute severe illness requiring hospitalization during Ramadan were also excluded.

### Data collection

Participants were evaluated for multiple demographic and clinical factors, including age, sex, educational background, duration of diabetes, and comorbidities. Fasting and lifestyle modifications, including adherence to pre-Ramadan medical advice and changes in physical activity and dietary habits, were assessed by counting the number of fasting days completed during Ramadan and the occurrence of hypoglycemic events. Healthcare engagement parameters, such as physician counseling and glucose monitoring practices, were recorded. Clinical and metabolic characteristics, including glycated hemoglobin (HbA1c) levels, history of diabetic ketoacidosis (DKA) or hyperglycemic hyperosmolar state (HHS), renal function (estimated glomerular filtration rate), microvascular complications, and the use of multiple daily insulin injections, were documented. Additionally, the study captured the frequency and management of hypoglycemia, adherence to self-monitoring of blood glucose (SMBG), and perceptions regarding fasting interruptions for medical reasons. Hypoglycemia was defined as a blood glucose level  $< 3.9$  mmol/L or the presence of typical symptoms. Severe hypoglycemia was defined as an event requiring third-party assistance, regardless of the glucose reading. The pre-Ramadan counseling was assessed using patients' self-reports of having received medical advice specifically tailored to Ramadan fasting from a healthcare professional. Due to the real-world, multicenter nature of this study, counseling was not standardized across sites.

### Statistical analysis

Data analysis was performed using Stata (version 17). Descriptive statistics were utilized to summarize demographic and clinical variables. Continuous

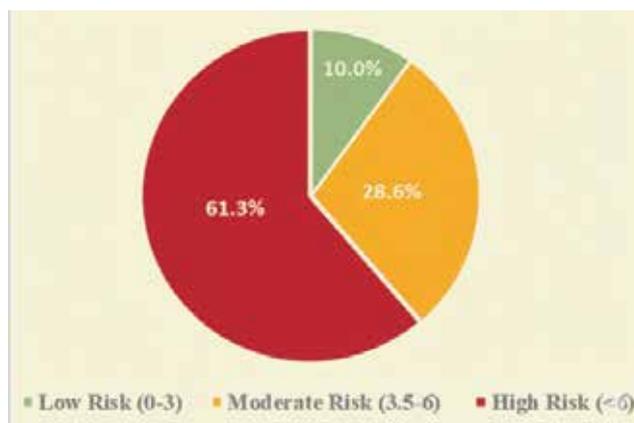
variables were expressed as mean ± standard deviation (SD) and compared across risk groups using t-tests or one-way ANOVA, as appropriate. Categorical variables were presented as counts and percentages, and chi-square tests were conducted to evaluate differences between groups. A p-value of <0.05 was considered statistically significant.

**Ethical considerations**

This study was a non-interventional, observational survey conducted using anonymized data obtained during routine clinical care, with no additional procedures or interventions performed for research purposes. Written informed consent was obtained from all participants prior to data collection, and patient confidentiality was strictly maintained. The study protocol was reviewed by a Technical Committee of the Association of Clinical Endocrinologists and Diabetologists of Bangladesh (ACEDB), which confirmed that the study posed minimal ethical risk. The study was conducted in accordance with the principles of the Declaration of Helsinki.

**Result**

The study included 2,304 participants with T2DM who fasted during Ramadan in 2022, categorized into low-risk (n=231; 10.0%), moderate-risk (n=660; 28.6%), and high-risk (n=1,413; 61.3%) groups based on IDF-DAR criteria (Figure-1).



**Figure-1:** IDF-DAR risk group distribution among participants (n=2,304)

**General characteristics of the study participants**

Age distribution varied significantly across risk groups (p<0.001). The proportion of participants under 40 years decreased from 25.1% in the low-risk group to 10.3% in the high-risk group, whereas those aged 60 years and older were more prevalent in the high-risk group (26.9%) than in the low-risk group (15.2%). Mean age increased with risk category, from 42.5±9.5 years in the low-risk group to 57.3±12.1 years in the high-risk group (p=0.043). Sex distribution showed a higher proportion of females across all groups, increasing from 59.7% in the low-risk category to 66.6% in the high-risk category (p=0.025). Educational attainment differed significantly

**Table-I:** General characteristics of the study participants with T2DM who fasted in 2022 stratified by risk groups according to IDF-DAR 2021 (n=2,304)

Variable	Low risk (n=231)	Moderate risk (n=660)	High risk (n=1413)	*p-value
<b>Age group, n (%)</b>				
Less than 40 years	58 (25.1%)	123 (18.6%)	146 (10.3%)	<b>&lt;0.001</b>
40 – 60 years	138 (59.7%)	435 (65.9%)	887 (62.8%)	
Older than 60 years	35 (15.2%)	102 (15.5%)	380 (26.9%)	
<b>Age (years; Mean ± SD)</b>	42.5 ± 9.5	52.3 ± 12.4	57.3 ± 12.1	<b>0.043</b>
<b>Sex, n (%)</b>				
Male	93 (40.3%)	252 (38.2%)	472 (33.4%)	<b>0.025</b>
Female	138 (59.7%)	408 (61.8%)	941 (66.6%)	
<b>Educational level, n (%)</b>				
Postgraduate	64 (27.7%)	98 (14.8%)	73 (5.2%)	<b>&lt;0.001</b>
Graduate	75 (32.5%)	143 (21.7%)	121 (8.6%)	
HSC	42 (18.2%)	129 (19.5%)	174 (12.3%)	
SSC	38 (16.5%)	261 (39.5%)	845 (59.8%)	
Below SSC	12 (5.1%)	29 (4.4%)	200 (14.1%)	

Percentages are over column total

\*by Chi-square test or ANOVA; as applicable

across risk groups ( $p < 0.001$ ). Postgraduate and graduate education levels were more frequent in the low-risk group (27.7% and 32.5%, respectively), whereas a majority of high-risk participants had SSC (59.8%) or below-SSC (14.1%) qualifications (Table I).

When stratified by sex, the age distribution did not differ significantly between males and females ( $p = 0.245$ ). However, males had a higher mean age ( $53.2 \pm 11.8$  years) than females ( $50.6 \pm 10.9$  years) ( $p < 0.001$ ). In addition, educational attainment differed significantly between males and females ( $p < 0.001$ ). A higher proportion of males had postgraduate (16.8%) and graduate (24.6%) education compared to females (6.6% and 9.3%, respectively). More females had SSC (58.1%) or below-SSC (12.8%) education than males (34.2% and 6.1%, respectively) (Table-II).

**Table-II:** General characteristics of T2DM patients who fasted in 2022 stratified by sex (n=2,304)

Variables	Male (n=817)	Female (n=1487)	*p-value
<b>Age group</b>			
Less than 40 years	104 (12.7%)	223 (15.0%)	0.245
40 – 60 years	484 (59.3%)	976 (65.7%)	
Older than 60 years	229 (28.0%)	288 (19.3%)	
<b>Age (years; Mean <math>\pm</math> SD)</b>	53.2 $\pm$ 11.8	50.6 $\pm$ 10.9	<0.001
<b>Educational level</b>			
Postgraduate	137 (16.8%)	98 (6.6%)	<0.001
Graduate	201 (24.6%)	138 (9.3%)	
HSC	149 (18.3%)	196 (13.2%)	
SSC	280 (34.2%)	864 (58.1%)	
Below SSC	50 (6.1%)	191 (12.8%)	

Percentages are over column total

\*by Chi-square test or unpaired t-test; as applicable

**Table-III:** Perception, practices, and hypoglycemia in T2DM patients who fasted in 2022 stratified by risk groups according to IDF-DAR 2021 (n=2,304)

Variables	Low risk (n=231)	Moderate risk (n=660)	High risk (n=1413)	*p-value
<b>Doctor consultation, n (%)</b>	169 (73.2%)	391 (59.2%)	755 (53.4%)	<0.001
<b>Hypoglycemia incidence, n (%)</b>	22 (9.5%)	96 (14.5%)	380 (26.9%)	<0.001
<b>Belief in breaking fast for Hypoglycemia, n (%)</b>	10 (4.3%)	41 (6.2%)	208 (14.7%)	<0.001
<b>†Glucose testing during Ramadan, n (%)</b>				
Regular	72 (31.2%)	159 (24.1%)	389 (27.5%)	0.076
Irregular	76 (32.9%)	253 (38.3%)	554 (39.2%)	
Not performed	83 (35.9%)	248 (37.6%)	470 (33.3%)	

Percentages are over column total

\*by Chi-square test or ANOVA; as applicable

†Regular: Performing glucose testing as per the clinician's pre-Ramadan recommendation; Irregular: Performing glucose testing only when symptoms of hypo- or hyperglycemia were suspected; Not performed: A total absence of any blood glucose monitoring throughout the month of Ramadan

**Perception, practices, and hypoglycemia in study participants stratified by IDF-DAR risk groups**

Among the 2,304 participants, counseling with doctors was more common in the low-risk group (73.2%) than in the moderate-risk (59.2%) and high-risk (53.4%) groups ( $p < 0.001$ ). Hypoglycemia occurrence increased with risk level, reported in 9.5% of the low-risk group, 14.5% of the moderate-risk group, and 26.9% of the high-risk group ( $p < 0.001$ ).

The participant's belief that fasting should be broken for hypoglycemia was lowest in the low-risk group (4.3%), followed by the moderate-risk group (6.2%), and highest in the high-risk group (14.7%) ( $p < 0.001$ ). Regular glucose testing during Ramadan was reported in 31.2% of the low-risk group, 24.1% of the moderate-risk group, and 27.5% of the high-risk group, with no significant difference across groups ( $p = 0.076$ ). Irregular glucose testing and failure to perform glucose tests were similarly distributed across the risk groups (Table-III).

**Fasting practices, hypoglycemia management, and healthcare engagement in study participants stratified by sex**

Among the 2,304 participants, a higher proportion of females (86.9%) fasted throughout Ramadan compared to males (82.5%) ( $p = 0.001$ ). Hypoglycemia during fasting was reported more frequently in males (14.9%) than in females (9.3%) ( $p < 0.001$ ), and overall hypoglycemia development was also higher in males (26.2%) compared to females (19.1%) ( $p < 0.001$ ).

More males (60.0%) received counseling from doctors compared to females (55.5%) ( $p = 0.037$ ). Males were more likely to use sugar tests to monitor hypoglycemia (56.0%) compared to females (35.3%), while more females relied on symptoms (64.7%) compared to males

(44.0%) (p<0.001).

The belief that breaking fast to treat hypoglycemia was more prevalent among males (16.3%) than among females (8.5%) (p<0.001). Regular glucose testing during Ramadan did not differ significantly between males (28.9%) and females (25.8%) (p=0.163). However, more females (20.1%) believed glucose testing broke the fast compared to males (16.3%) (p=0.024) (Table-IV).

**Table-IV:** Fasting practices, hypoglycemia management, and healthcare engagement of T2DM patients stratified by sex who fasted in 2022 (n=2,304)

Variables	Male (n=817)	Female (n=1487)	*p-value
<b>Fasting duration in Ramadan, n (%)</b>			
Entire Month	674 (82.5%)	1292 (86.9%)	<b>0.001</b>
16 days	91 (11.1%)	147 (9.9%)	
6 – 15 Days	45 (5.5%)	34 (2.3%)	
1 – 5 Days	7 (0.9%)	14 (0.9%)	
<b>Hypoglycemia during fasting hours, n (%)</b>			
	122 (14.9%)	138 (9.3%)	<b>&lt;0.001</b>
<b>Doctor consultation, n (%)</b>			
	490 (60.0%)	825 (55.5%)	<b>0.037</b>
<b>Total hypoglycemia incidence (24h), n (%)</b>			
	214 (26.2%)	284 (19.1%)	<b>&lt;0.001</b>
<b>Method used to confirm suspected hypoglycemia, n (%)</b>			
Glucose test	458 (56.0%)	525 (35.3%)	<b>&lt;0.001</b>
Symptoms	359 (44.0%)	962 (64.7%)	
<b>Affirmative belief that breaking the fast is permissible for</b>			
<b>Hypoglycemia, n (%)</b>			
	133 (16.3%)	126 (8.5%)	<b>&lt;0.001</b>
<b>Glucose test, n (%)</b>			
	133 (16.3%)	299 (20.1%)	<b>0.024</b>
<b>†Glucose testing during Ramadan, n (%)</b>			
Regular	236 (28.9%)	384 (25.8%)	0.163
Irregular	313 (38.4%)	570 (38.3%)	
Not performed	268 (32.7%)	533 (35.9%)	

Percentages are over column total

\*by Chi-square test or unpaired t-test; as applicable

†Regular: Performing glucose testing as per the clinician's pre-Ramadan recommendation; Irregular: Performing glucose testing only when symptoms of hypo- or hyperglycemia were suspected; Not performed: A total absence of any blood glucose monitoring throughout the month of Ramadan

**Comparison of high-risk clinical and metabolic characteristics of study participants stratified by IDF-DAR risk groups**

Among the study population, the proportion of

individuals older than 60 years was highest in the high-risk group (26.9%), compared with the moderate-risk (15.5%) and low-risk (15.2%) groups (p<0.001). Females were more prevalent in the high-risk group (66.6%) than in the moderate-risk (61.8%) and low-risk (59.7%) groups (p=0.025). Diabetes duration greater than 10 years was reported in 46.0% of the high-risk group, 28.8% of the moderate-risk group, and 22.1% of the low-risk group (p=0.046).

HbA1c levels greater than 9% were found in 50.9% of the high-risk group, compared to 18.2% in the moderate-risk group and 3.8% in the low-risk group (p<0.001). Severe hypoglycemia was observed only in the high-risk group (6.9%) (p<0.001). Multiple daily insulin injections were reported in 36.0% of the high-risk group, compared to 6.1% in the moderate-risk group and 3.9% in the low-risk group (p=0.031).

A history of diabetic ketoacidosis (DKA) or hyperglycemic hyperosmolar state (HHS) was more frequent in the high-risk group (8.3%) than in the moderate-risk (3.0%) and low-risk groups (2.6%) (p<0.001). Microvascular disease (MVD) complications were present in 15.9% of the high-risk group, 10.6% of the moderate-risk group, and 9.1% of the low-risk group (p=0.051). Renal impairment (eGFR <60 mL/min) was most prevalent in the high-risk group (16.6%), followed by the moderate-risk (10.6%) and low-risk groups (6.9%) (p=0.041).

A lack of SMBG despite indication was noted in 29.6% of the high-risk group, 14.4% of the moderate-risk group, and 13.0% of the low-risk group (p<0.001). Counseling with physicians was highest in the low-risk group (73.2%) and lowest in the high-risk group (53.4%) (p < 0.001). Hypoglycemia occurrence increased with risk level, reported in 9.5% of the low-risk group, 14.5% of the moderate-risk group, and 26.9% of the high-risk group (p<0.001) (Table V).

**Discussion**

This multicenter study demonstrates a notable discrepancy between clinical risk profiles and the practice of Ramadan fasting among individuals with T2DM in Bangladesh. Although a substantial portion of the cohort met the IDF-DAR 2021 criteria for high risk, the majority successfully completed the fast. Risk stratification proved an effective predictor of clinical challenges, as the incidence of hypoglycemia followed a clear gradient across low-, moderate-, and high-risk groups. Furthermore, sex-stratified analysis revealed distinct patterns in both clinical outcomes and healthcare

**Table-I:** General characteristics of the study participants with T2DM who fasted in 2022 stratified by risk groups according to IDF-DAR 2021 (n=2,304)

Characteristics	Low risk (n=231)	Moderate risk (n=660)	High risk (n=1413)	*p-value
Age in years, n (%)				
Between 40 – 60	138 (59.7%)	435 (65.9%)	887 (62.8%)	<0.001
Older than 60	35 (15.2%)	102 (15.5%)	380 (26.9%)	
Female sex, n (%)	138 (59.7%)	408 (61.8%)	941 (66.6%)	<b>0.025</b>
Diabetes duration >10 years, n (%)	51 (22.1%)	190 (28.8%)	650 (46.0%)	<b>0.046</b>
HbA1c > 9%, n (%)	8 (3.8%)	121 (18.2%)	719 (50.9%)	<0.001
Severe hypoglycemia, n (%)	0 (0.0%)	0 (0.0%)	97 (6.9%)	-
Multiple daily insulin injections, n (%)	9 (3.9%)	40 (6.1%)	508 (36.0%)	<b>0.031</b>
DKA/HHS history, n (%)	6 (2.6%)	20 (3.0%)	118 (8.3%)	<0.001
MVD complications, n (%)	21 (9.1%)	70 (10.6%)	225 (15.9%)	0.051
Renal impairment (eGFR <60 mL/min), n (%)	16 (6.9%)	70 (10.6%)	235 (16.6%)	<b>0.041</b>
No SMBG despite indication, n (%)	30 (13.0%)	95 (14.4%)	418 (29.6%)	<0.001
Counseling with doctors, n (%)	169 (73.2%)	391 (59.2%)	755 (53.4%)	<0.001
Hypoglycemia developed, n (%)	22 (9.5%)	96 (14.5%)	380 (26.9%)	<0.001

Percentages are over column total

\*by Chi-square test or ANOVA; as applicable

DKA: Diabetic ketoacidosis, HHS: hyperglycemic hyperosmolar state, MVD: microvascular disease, eGFR: estimated glomerular filtration rate, SMBG: Self-Monitoring of Blood Glucose

engagement. Although males were more likely to receive pre-Ramadan medical counseling and utilize glucose testing for monitoring, they experienced a higher frequency of hypoglycemia compared to females. Conversely, females were more likely to rely on symptomatic detection rather than biochemical monitoring, often influenced by misconceptions regarding the validity of fasting during blood testing. These findings suggest that while safe fasting is achievable for many high-risk individuals, current clinical support remains underutilized and frequently fails to address sex-specific behavioral barriers.

The mean age of the participants increased progressively with risk level, reflecting the established link between advancing age and higher fasting diabetes-related risk.<sup>14,15</sup> Sex distribution also differed significantly, with females representing a higher proportion across all categories, increasing from 59.7% in the low-risk group to 66.6% in the high-risk group—possibly due to sex-specific differences in disease burden or health-seeking behaviors.<sup>16</sup> Educational attainment showed a strong inverse relationship with risk category. This supports existing evidence that lower education levels may be associated with reduced diabetes awareness, poorer self-care, and worse clinical outcomes.<sup>17</sup>

On the other hand, sex-based comparisons among the participants revealed several significant differences. Males had a higher mean age ( $53.2 \pm 11.8$  years) than females ( $50.6 \pm 10.9$  years), aligning with prior observations that males may delay diabetes diagnosis or have longer disease durations.<sup>18</sup> Educational attainment differed markedly ( $p < 0.001$ ), with males having a higher proportion of postgraduate and graduate qualifications than females, potentially reflecting broader gender disparities in educational access in South Asia.<sup>19,20</sup>

Fasting adherence was higher among females than among males, possibly due to stronger religious motivations or sociocultural norms among women.<sup>20</sup> Despite higher fasting rates, females reported fewer hypoglycemic events, suggesting better glycemic control or differing thresholds for symptom recognition.

Healthcare engagement patterns also varied. More males received pre-Ramadan counseling and used glucose monitoring devices compared to females, while females relied more on symptom recognition. These findings underscore sex-specific gaps in diabetes education and access to self-monitoring tools.<sup>21</sup> Notably, males were more likely to accept breaking the fast for hypoglycemia, while more females believed that glucose testing even warranted breaking the fast. This indicates a

need for clearer patient education aligned with religious and clinical guidelines.

Doctor counseling was significantly more common among low-risk participants than among moderate- and high-risk participants, suggesting better healthcare engagement among those at lower risk, potentially due to fewer comorbidities and greater autonomy in healthcare-seeking behavior.<sup>5</sup> Conversely, the occurrence of hypoglycemia rose sharply with risk level—from 9.5% in low-risk to 26.9% in high-risk groups—indicating that higher-risk individuals are more vulnerable to fasting-related metabolic complications, likely due to longer disease duration, poorer glycemic control, and insulin use.<sup>14</sup>

Perceptions of breaking the fast for hypoglycemia varied significantly by risk group. Only 4.3% of low-risk participants endorsed this practice, compared with 14.7% of high-risk participants, possibly reflecting greater awareness of hypoglycemia's dangers among higher-risk individuals or better counseling in these groups. However, regular glucose monitoring did not significantly differ across risk groups, highlighting a universal gap in adherence to recommended self-monitoring during Ramadan, even among those with clinical indications. High-risk individuals, particularly those with complications, should monitor their glucose more frequently, whereas moderate- to low-risk individuals may monitor less frequently, especially during Ramadan, when fasting is observed.<sup>11</sup>

Clinical and metabolic comparisons further substantiate the risk stratification. The high-risk group had a significantly older population, longer diabetes duration, and more females than the lower-risk categories. Glycemic control was the poorest in the high-risk group, with over half having HbA1c >9%, reinforcing their heightened vulnerability.<sup>11</sup> Severe hypoglycemia occurred exclusively in the high-risk group, and they were more likely to be on multiple daily insulin injections a recognized risk factor during fasting, as reflected in existing literature.<sup>22</sup>

Further complications including prior DKA/HHS, renal impairment, and microvascular disease were most prevalent in the high-risk group, reflecting the cumulative burden of long-standing diabetes.<sup>23,24</sup> Notably, despite these high-risk clinical features, 29.6% of individuals in this group did not perform SMBG despite clear indications, highlighting significant educational and resource gaps, as in our previous study.<sup>25</sup> This real-world experience highlights that even among those who fasted despite being classified as high risk, clinical outcomes were not universally poor,

suggesting that with appropriate support, safe fasting is possible.<sup>26</sup> These findings underscore the importance of targeted, Ramadan-specific education and clinical interventions particularly for high-risk T2DM patients to promote safe fasting practices, improve adherence to glucose monitoring, and mitigate complications.

This study is limited by its cross-sectional design, which precludes causal inferences regarding the relationship between risk stratification and fasting outcomes. Additionally, reliance on self-reported data for hypoglycemia and glucose monitoring may introduce recall and reporting biases, compounded by the absence of baseline data before Ramadan. As we included only patients who fasted for at least one day during Ramadan, high-risk individuals who avoided fasting due to medical advice were excluded, potentially leading to selection bias and an underestimation of adverse outcomes. Including only patients from clinical settings may limit the generalizability of the study findings, as the study cohort of T2DM patients may differ from those managed in primary care or from those who do not seek regular medical care. The current analysis is primarily descriptive, and we did not perform multivariable regression to adjust for potential confounders. Consequently, we cannot definitively rule out the influence of these overlapping variables on the outcomes. Baseline metabolic data (pre-Ramadan) were unavailable, which limits the evaluation of fasting-related changes. Future research should employ longitudinal or interventional designs that include pre-Ramadan baseline assessments. This will help evaluate targeted education and individualized risk stratification and explore digital tools and telemedicine to support safe fasting in high-risk T2DM patients. Clinical guidelines should advocate for the involvement of religious leaders (Imams) and community scholars in preparing patients for safe Ramadan fasting.

## Conclusions

This study underscores a significant implementation gap between clinical risk-stratification and real-world fasting practices among individuals with T2DM in Bangladesh. While the IDF-DAR 2021 criteria effectively identify those at higher clinical risk, many high-risk individuals completed fasting despite elevated rates of hypoglycemia. It suggests that safer fasting may be possible, especially with structured support. However, the high incidence of hypoglycemia and the low rate of pre-Ramadan counseling particularly the sex-specific misconceptions regarding the impact of blood glucose

testing on the validity of the fast highlight the need for a more nuanced approach to patient education. To optimize safety, clinical interventions must move beyond generic advice to incorporate sex-stratified strategies that address specific cultural and behavioral barriers. Future efforts should focus on early, targeted counseling and debunking religious myths to bridge the disconnect between patients' spiritual aspirations and safe metabolic management.

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#### Conflict of interest

The authors have no conflicts of interest to disclose.

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#### Data Availability

Any queries regarding this study should be directed to the corresponding author, and supporting data are available from the corresponding author upon reasonable request.

#### Ethical Approval and Consent to Participate

This study was a non-interventional, observational survey conducted using anonymized data obtained during routine clinical care, with no additional procedures or interventions performed for research purposes. Written informed consent was obtained from all participants prior to data collection, and patient confidentiality was strictly maintained. The study protocol was reviewed by a Technical Committee of the Association of Clinical Endocrinologists and Diabetologists of Bangladesh (ACEDB), which confirmed that the study posed minimal ethical risk. The study was conducted in accordance with the principles of the Declaration of Helsinki.

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