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Glycemic control is worse in rural compared to urban type 2 diabetes in Bangladesh, irrespective of food security status

Md Kamruzzaman[1,2,3], Michael Horowitz[1,2,4], Muhammad Shafiqur Rahman[5], Harshal Deshmukh[6,7], Karen L. Jones[1,2,4], Chinmay S. Marathe[1,2,4]*

[1]Adelaide Medical School, University of Adelaide, Adelaide, South Australia, Australia, [2]Centre of Research Excellence in Translating Nutritional Science to Good Health, University of Adelaide, Adelaide, South Australia, Australia, [3]Department of Applied Nutrition and Food Technology, Islamic University, Kushtia, Bangladesh, [4]Endocrine and Metabolic Unit, Royal Adelaide Hospital, Adelaide, South Australia, Australia, [5]National Health Care Network (An Associated Organization of BIRDEM), Dhaka, Bangladesh, [6]James Cook University, Brisbane, Queensland, Australia, and [7]Mackay Base Hospital, Brisbane, Queensland, Australia

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***Correspondence**
Chinmay S. Marathe
Tel.: +61 883134815
Fax.: +61 83137794
E-mail address:
chinmay.marathe@adelaide.edu.au

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ABSTRACT

Background: Food insecurity (FIS) affects around 25% of Bangladesh's population, and data from developed nations report higher FIS rates among individuals with type 2 diabetes (T2D), potentially worsening glycemic control. The importance of FIS to T2D has not been studied in developing countries such as Bangladesh, with substantial disparities in healthcare access, especially between rural and urban areas. We evaluated the relationships between food insecurity and glycemic control in the context of area of residence among individuals with T2D in Bangladesh.

Methods: A total of 849 individuals with T2D attending diabetes clinics in four districts of Bangladesh completed a validated questionnaire to assess the FIS (a score ≥ 3 is indicative of FIS), which was compared with their sociodemographic and biochemical data. Two-way ANOVA and multiple linear and binary logistic regression analyses were performed.

Results: Both HbA1c levels (10.8% vs 9.5, $P < 0.001$) and the prevalence of FIS (45.8% vs 31.4%, $P < 0.001$) were higher in rural areas. According to two-way ANOVA (0.87–1.78% mean difference, $P < 0.05$) and multiple linear regression model ($\beta = 1.4$, $P < 0.001$), HbA1c levels were also higher among rural than urban dwellers, irrespective of their FIS status. Rural dwellers were also more than twice as likely to have suboptimal glycemic control (HbA1c ≥7%; AOR: 2.26 (1.35–3.97), $P < 0.05$), irrespective of their food security status (AOR: 1.19 (0.78–1.84, $P > 0.05$)).

Conclusions: In Bangladesh, rural residence is associated with poor glycemic control, irrespective of food security status, and thus is an important social determinant of diabetes care that warrants further exploration.

INTRODUCTION

Food insecurity (FIS), defined as a condition in which an individual does not have adequate access to sufficiently safe and nutritious food to maintain an active and healthy lifestyle, is a major public health problem that is considered to affect up to 2 billion people worldwide as of 2021[1]. Food security, as measured via validated questionnaires such as the Household Food Security Survey Module (HFSSM) of the USDA and the Household Food Insecurity Access Scale (HFIAS) of the FAO[2], occurs in 2–15% of the population in the developed world[3]. However, it is much more common in low- and middle-income countries (LMICs) such as Bangladesh, where it is reported to constitute approximately 25% of the general population[4].

People with FIS are at an approximately twofold greater risk of developing type 2 diabetes (T2D)[5], and the prevalence of FIS is higher among those with T2D[6]. While a number of studies have reported that in individuals with T2D, food insecurity is associated with poor glycemic control, the majority of these studies focus on populations from developed countries[7,8] and

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none are from Bangladesh or neighboring South Asian countries.

T2D is a major health problem in Bangladesh. The prevalence has increased ~3-fold over the last three decades[9]. Demographic, epidemiological, and socioeconomic transitions as well as urbanization are recognized as contributing factors. With limited and inefficient government healthcare services and an enormous number of diagnosed cases of diabetes, ~8.4 million (90–95% T2D)[10], the potential burden of improving diabetes outcomes and achieving optimal glycemic control is substantial. In addition to the increasing burden of diabetes, there is evidence of significant inequalities in diabetes outcomes between rural and urban areas in low- to middle-income countries (LMICs)[11]. Although governmental healthcare services are relatively inexpensive, there are profound limitations in diabetes care facilities at the primary healthcare level, particularly in rural settings, where around 60% of Bangladeshis reside[12]. A recent study reported that food insecurity is widespread in rural areas of Bangladesh[13]. The impact of FIS on diabetes care in Bangladesh is not known, and in this study, we explored the relationship between FIS and T2D in the context of place of residence (rural vs urban) in Bangladesh.

MATERIALS AND METHODS

Study population

In a single-visit cross-sectional study, from March 2022 to June 2024, a total of 1,406 individuals with known T2D were recruited from four diabetes clinics run by the Bangladesh Diabetes Association (BADAS). A total of 849 individuals with complete information were included in this study (Figure S1). The study was approved by the "National Research Ethics Committee (NREC)" of the Bangladesh Medical Research Council (BMRC) (Ref: BMRC/NREC/2022-2025/82) as well as from the "Ethical Review Committee (ERC)" (Ref: FBS/ERC/2022/06 and AWEEC/FBS/IU/2023(1)) of the Faculty of Biological Science of Islamic University, Kushtia, Bangladesh. This study was conducted in accordance with the principles of the Declaration of Helsinki (2008).

Study measurements

Sociodemographic data and areas of residence were collected from medical case notes or directly from the participants (Table 1). Occupational status was categorized into eight initial classifications, subsequently consolidated into three broad categories: unemployed/unskilled (unemployed, daily worker or business), skilled (farmer, homemaker), and professional (doctor, teacher, or service holders) Anthropometric measurements, including weight, height, waist circumference, and hip circumference, were obtained following the standard operating procedure (SOP) of the WHO Expert Committee Guidelines on physical examination[14]. Clinical and biochemical information, including hemoglobin A1c levels, was extracted manually from the medical record diaries using values collected within 3 months preceding the date of the completed survey. Household food security was evaluated via the USDA-18 item Household Food Security Survey Module (HFSSM). The participant's household was classified as food insecure if the participant responded to ≥3 affirmative food insecure conditions, irrespective of whether the household included children[15]. Participants residing within a district municipality or city corporation area were considered 'urban dwellers,' whereas those residing outside these areas were considered "rural dwellers[16]."

Statistical analysis

The data were managed and analyzed using RStudio (v.2023.09.1 Build-494) in R (v4.4.1). Two-way analysis of variance (ANOVA) was employed to compare HbA1c levels among those with and without food insecurity in rural and urban areas, and a nonparametric alternative to two-way ANOVA (Kruskal–Wallis test) was used when normality was violated. To evaluate the potential difference in glycemic control (HbA1c) between rural and urban dwellers and between food secure and insecure individuals, multivariable linear regression models were employed. For the linear regression covariates, area of residence and food security score (HFSSM) were included in the model, adjusting for age, sex, and BMI. The R package "glmulti" was used to select the best linear regression model. Binary logistic regression analysis was employed to identify the likelihood of poor glycemic control (HbA1c >7%) among rural versus urban dwellers and in relation to food security score, with adjustments for age, sex, and BMI. Model assumption and performance were evaluated utilizing the R package "performanc." The normality and homoscedasticity of the residuals were deemed acceptable, and model fit was assessed based on Akaike information criterion (AIC), Bayesian information criterion (BIC), and log-likelihood. This sample size (N = 849) provided 80–90% power to detect a difference in HbA1c level of at least t = 0.2% (small effect size t = 0.2)[17]. Statistical significance was set at $P \leq 0.05$.

RESULTS

A total of 27.3% (n = 232) of the participants resided in rural areas and 72.7% (n = 617) resided in urban areas (Table 1). Overall, food insecurity was reported by 35.1% of the respondents and was more common among rural residents (rural 45.8% vs urban 31.4%, $P < 0.05$). The percentage of glycated hemoglobin was 9.8% (95% CI: 9.6–10.0%), which was greater in rural residents than in urban residents (Table 1).

Overall, HbA1c was higher among rural dwellers (10.8% vs 9.5%, $P < 0.001$; Figure 1a) and those with FIS (10.2% vs 9.6%, $P < 0.01$; Figure 1b). The majority of the participants (85.3%) had suboptimal to poor glycemic control (HbA1c 7–9% or >9%; Figure 2 and Table S1). When compared pairwise, HbA1c was higher among rural residents (mean difference: 0.87–1.78%, $P < 0.05$), irrespective of their food security status (Figures 1c and 3). In both rural and urban areas separately, HbA1c levels did not exhibit a significant difference between individuals with and without FIS ($P > 0.05$; Figure 1c and Figure 3).

Table 1 | Sociodemographic, clinal, and biochemical profiles of individuals with T2D in Bangladesh (N = 849)

	Total Mean [95%CI] or *n* (%)	Rural Mean [95%CI] or *n* (%)	Urban Mean [95%CI] or *n* (%)	*P* value
Total	849 (100)	232 (27.3)	617 (72.7)	<0.05
Age (years)	51.7 [50.8–52.5]	48.9 [47.2–50.6]	52.7 [51.7–53.7]	<0.001
Gender				
Males	374 (44.1)	86 (37.1)	287 (46.7)	<0.05
Females	475 (55.9)	146 (62.9)	329 (53.3)	
Education				
None to class 5	306 (36.1)	146 (62.9)	160 (26.0)	<0.001
Up to class 12	385 (45.4)	77 (33.2)	308 (50.0)	
Graduate and Higher	157 (18.5)	9 (3.9)	148 (24.0)	
Marital status				
Never married	8 (1.0)	1 (0.4)	7 (1.1)	>0.05
Divorced/separated/Widowed	61 (7.3)	23 (10.2)	38 (6.2)	
Married	769 (91.8)	201 (89.4)	568 (92.7)	
Occupation[†]				
Unemployed/unskilled/business	156 (19.9)	37 (16.4)	119 (21.3)	<0.001
Skilled	453 (57.7)	171 (75.7)	282 (50.4)	
Professional	176 (22.4)	18 (7.9)	158 (28.3)	
Annual family income in USD (median ± SE)	6,066.7 [5,630.5–6,502.9] [4,672.9 ± 222.2]	3,783.5 [2,906.4–4,662.6] [2,336.0 ± 445.6]	6,923.5 [6,438.1–7,408.9] [5,607.5 ± 247.2]	<0.001
BMI (kg/m^2)	24.8 [24.6–25.1]	24.0 [23.4–24.6]	25.1 [24.9–25.4]	<0.001
WHR	0.93 [0.92–0.94]	0.96 [0.95–0.98]	0.91 [0.91–0.92]	<0.001
Duration of known diabetes (years)	7.2 [6.7–7.7]	8.0 [6.9–9.1]	6.9 [6.3–7.4]	<0.05
Fasting blood glucose (mmol/L)	10.6 [10.3–11.0]	10.0 [9.2–10.8]	10.8 [10.4–11.1]	>0.05
HbA1c (%) {mmol/mol}	9.8 [9.6–10.0] {84.1 [82–86]}	10.8 [10.4–11.2] {95 [90–99]}	9.5 [9.2–9.7] {80 [78–83]}	<0.001
HbA1c category				
Optimal control (HbA1c <7.0%)	125 (14.7)	22 (9.5)*	103 (16.7)*	<0.001
Suboptimal control (HbA1c 7–9%)	258 (30.4)	53 (22.8)**	205 (33.2)**	
Poor control (HbA1c >9%)	466 (54.9)	157	309	
Suboptimal to poor control (>7%)	724 (85.3)	(67.7)*** 210 (90.5)*	(50.1)*** 514 (83.3)*	
Total cholesterol (mg/dl)	187.8 [183.0–192.7]	212.6 [200.4–224.9]	185.1 [180.0–190.2]	<0.001
LDL (mg/dL)	104.8 [101.1–108.4]	114.8 [105.4–124.3]	103.6 [99.6–107.6]	<0.05
HDL (mg/dL)	38.3 [37.3–39.2]	47.3 [44.8–49.8]	37.1 [36.1–38.1]	<0.001
Triglycerides (mg/dL)	233.4 [214.9–252.0]	218.7 [176.6–260.8]	235.1 [214.5–255.6]	>0.05
Systolic BP (mmHg)	123.3 [122.2–124.4]	119.8 [117.7–121.9]	124.8 [123.6–126.1]	<0.001
Diastolic BP (mmHg)	79.6 [78.9–80.3]	76.9 [75.6–78.2]	80.8 [80.1–81.5]	<0.001
Food Security Score (HFSSM)	2.2 [1.9–2.4]	3.1 [2.6–3.7]	1.8 [1.6–2.00]	<0.001
Food Security Status				
Food secure	551 (64.9)	128 (55.2)***	423 (68.6)***	<0.001
Food insecure	298 (35.1)	104 (44.8)***	194 (31.4)***	

Columns with *P* values indicate statistically significant differences between rural and urban dwellers; asterisks indicate differences in proportions between rural and urban dwellers. *$P < 0.05$. **$P < 0.01$. ***$P < 0.001$. [†]Occupation level: unemployed/unskilled = unemployed, daily worker, or business, skilled = farmer or homemaker, and professional = doctor, teacher, or service holders. Abbreviations: BMI, body mass index; HbA1c, glycated hemoglobin; HDL, high-density lipoprotein; HFSSM, household food security survey module United States Department of agriculture; LDL, low-density lipoprotein; SE, standard error; USD, United States Dollars; WHR, waist-hip ratio.

The proportion of individuals with suboptimal to poor glycemic control was greater in rural areas (90.5% vs 83.3%, $P < 0.05$), but not in those with and without FIS (87.2% vs 84.2%, $P > 0.05$; Figure 2a). Moreover, when the interaction effect was considered individually in rural and urban areas, the proportion of people with suboptimal to poor glycemic control (HbA1c >7.0%) did not differ between those with and without food security (Figure 2a).

Table 2 presents the results from multiple linear and logistic regression models to predict the level of HbA1c and the risk of worse glycaemic control. In the multiple linear regression model, the intercept was 7.17 (95% CI: 5.4–8.8, $P < 0.001$),

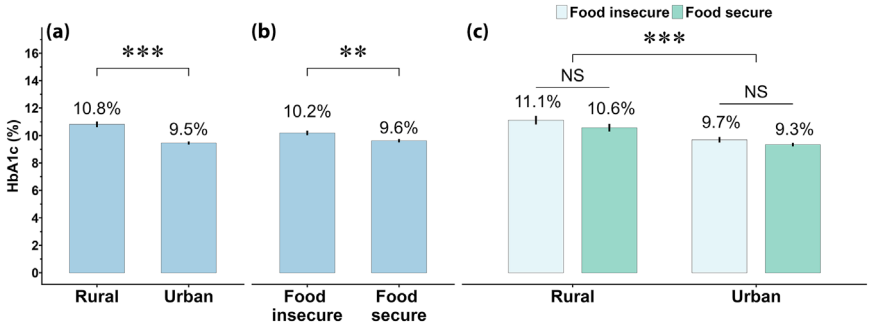

Figure 1 | Glycaemic control or level of HbA1c by area of residence (a), food security (b), and by interaction effect of area of residence and food security status (c) in T2D in Bangladesh [*$P \leq 0.05$, **$P \leq 0.01$, ***$P \leq 0.001$].

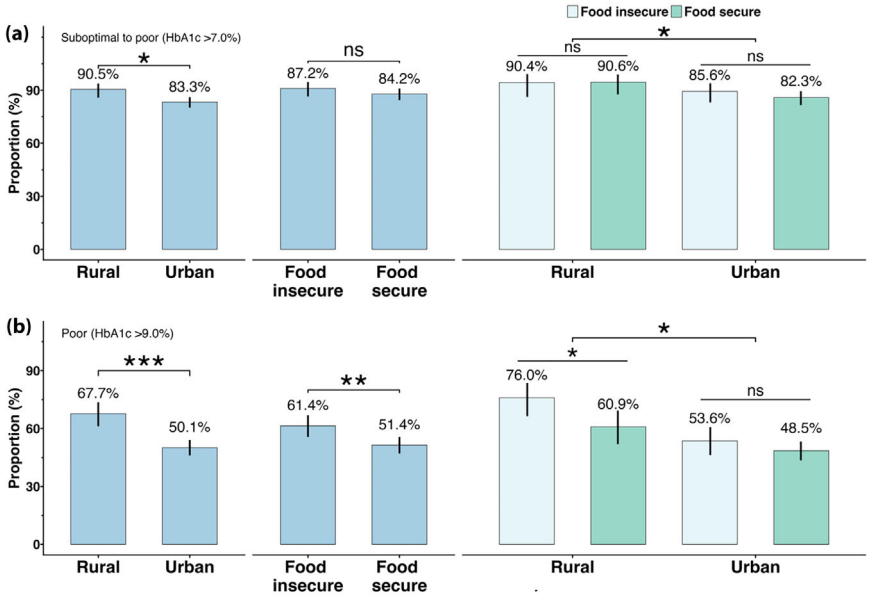

Figure 2 | Proportion of people with suboptimal to poor (HbA1c >7.0%) (a) and poor (HbA1c >9.0%) (b) glycemic control by area of residence and food security status in T2D in Bangladesh [*$P \leq 0.05$, **$P \leq 0.01$, ***$P \leq 0.001$].

indicating the baseline level of HbA1c in urban areas, while the food security score is 0. Residing in a rural area was significantly associated with higher HbA1c levels ($\beta = 1.4$, 95% CI: 0.70–1.8, $P < 0.001$). In the logistic regression model assessing the risk of suboptimal to poor glycemic control (HbA1c >7%), residing in a rural area was significantly associated with increased odds (OR: 2.26, 95% CI: 1.35–3.97, $P < 0.01$). However, the food security score did not have a significant effect on the risk of poor glycemic control (OR: 1.02, 95% CI: 0.96–1.10, $P = 0.498$).

DISCUSSION

In this study, we evaluated the relationship between food security and glycemic control in people with T2D in Bangladesh, in the context of their place of residence. Rural dwellers exhibited poorer glycemic control than urban dwellers, irrespective of their food security status. We also demonstrated that people with FIS and T2D had worse glycemic control, which is consistent with previous observations.

There is increasing appreciation for the impact of FIS on chronic metabolic diseases, such as diabetes. Multiple studies, mainly from higher-income countries (the majority of which are cross-sectional), have reported an increased prevalence of FIS in those with diabetes[18,19]. Beltran *et al.* summarized the potential underlying mechanisms linking FIS to diabetes: (i) Insufficient access to fresh and healthy foods may lead individuals with FIS to choose low-cost, unhealthy food products high in salt, fats, and carbohydrates and low in dietary fiber and

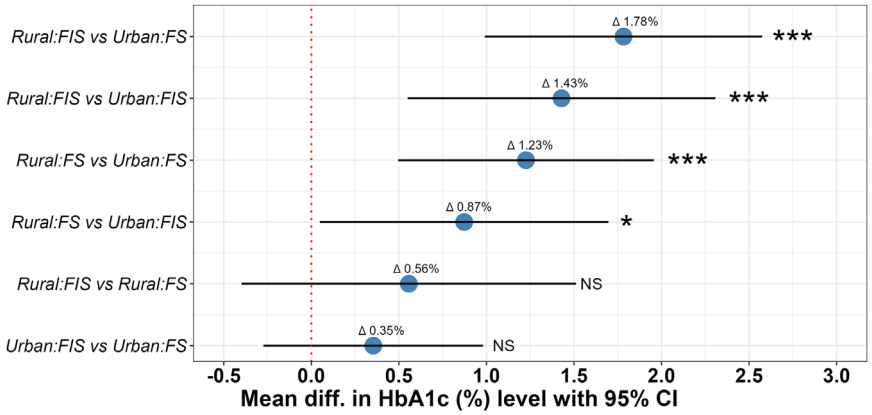

Figure 3 | Pairwise comparison of glycaemic control (HbA1c%) in people with T2D according to their site of residence and food security status in Bangladesh. FIS, Food Insecure; FS, Food Secure [Result presented from pairwise comparison of two-way ANOVA with interaction of area of residence and food security status; *$P \leq 0.05$, **$P \leq 0.01$, ***$P \leq 0.001$].

Table 2 | Parameter estimates from a multiple linear regression model predicting HbA1c (%) and the risk of poor glycemic control (HbA1c >7%) from a logistic regression model

Predictors	Multiple linear regression model			Logistic regression model		
	Estimates	95% CI	*P* value	OR	95% CI	*P* value
Intercepts	7.17	5.4–8.8	<0.001			
Area of residence						
Rural	1.4	0.70–1.8	<0.001	2.26	1.35–3.97	<0.001
Food security score (0–18)	0.04	−0.02 to 0.10	0.220	1.02	0.96–1.10	0.498

Multiple linear regression and logistic regression models were adjusted for age, sex, and BMI.

proteins[20,21], thus altering the processes of food purchase, meal planning, and preparation. Individuals with FIS often resort to 'coping strategies' to overcome periods of limited food availability and overconsumption when food is abundant. (ii) Reduced quality of life and increased levels of toxic stress and anxiety due to FIS is possibly linked to increased levels of inflammatory markers such as cortisol and C-reactive protein (CRP), which may exacerbate impaired glucose tolerance and insulin sensitivity[22,23]. The relationship between FIS and diabetes in an LMIC such as Bangladesh is intuitively more complex and distinct from that in a higher-income country due to the following differences: (i) people in LMICs do not have effective food or healthy safety programs, (ii) there is inequitable access to basic healthcare within regions with largely ineffective government-run national health services, and (iii) financial stress is generally greater in rural regions. Despite these differences, we found that glycemic control was significantly worse (approximately 0.6% (6.6 mmol/mol) increase in HbA1c) in people with T2D who reported FIS. A recent study from Bangladesh reported an association between poor glycemic control and low socioeconomic status, where nonadherence to medication due to financial inability was suggested as a major factor[24]. However, in another study from Bangladesh, there was no apparent association between family income and HbA1c levels in people with diabetes[25]. In our cohort, we found that the average annual household income in rural areas (3,783.5 vs 6,923.5 USD, Table 1) was almost 50% less than that in their urban counterparts. Rural areas had significantly lower proportions of individuals with graduate or higher education (3.9% vs 24.0%, $P < 0.001$) and professional workforce participation (7.9% vs 28.3%, $P < 0.001$). Mean total and LDL cholesterol levels were elevated in rural residents (212.6 vs 185.1 mg/dL, $P < 0.001$ and 114.8 vs 103.6 mg/dL, $P < 0.05$) compared to urban residents (Table 1). In higher-income countries, people from rural regions, especially those residing in so-called food deserts, have a greater risk of FIS, as well as worse glycemic control[26]. However, in LMICs such as Bangladesh, there has been an increase in urbanization associated with mass migration to rapidly growing urban centers in recent decades. These often lack basic civic facilities and fail to cope with or plan adequately for this expansion, thus placing them at greater risk of FIS. Thus, it is likely that FIS is also higher in urban residents, especially those residing on the outskirts of sprawling megacities, although we did not assess this in our study.

A large, pooled study from 42 LMICs, including Bangladesh, reported that individuals with T2D from rural areas were less likely to achieve optimal glycemic control (HbA1c <8%; OR, 0.86; 95% CI: 0.80–0.93, $P < 0.001$)[11]. Consistent with this, we found that chronic glycemic control was worse in those residing in rural regions, irrespective of their food security status.

Our findings indicate that, while reducing FIS in people residing in rural centers is a priority, addressing other factors may be equally important. There are systemic 'roadblocks' to initiating effective strategies to optimally prevent and manage the diabetes epidemic in LMICs. These include patient factors (lack of health literacy and awareness, 'fatalistic' attitudes, non-adherence to treatment, taboos, gender inequity, etc.), healthcare staff factors (lack of adequately trained staff, poor resources and financial incentives, etc., lack of timely specialist care and remoteness from tertiary care services, etc.), and policy factors (lack of locally relevant diet and exercise guidelines, universal school lunch programs, lack of effective community preventative programs, limited diabetes-focused education, ineffective and inconsistent regulation of pharmaceutical industry practices, food labelling, etc.)[27]. Local factors also disproportionately affect rural residents, such as the seasonal variability in caloric intake due to the low availability of food during the nonharvesting season and at the end of the month[28].

A strength of our study is that, to the best of our knowledge, this is the first study to explore the relationship between FIS and glycemic control in an LMIC, such as Bangladesh. We also employed a validated questionnaire on food security status, a large representative sample, and multiple recruitment sites. Limitations include the cross-sectional nature of the study; therefore, the inference of causal relationships was not possible. Moreover, data were obtained from specialized diabetes clinics, and the participants had an overall poor mean HbA1c level (9.8, 95% CI: 9.6–10.0). Accordingly, our findings may not be generalizable to people with well-controlled T2D living in the community.

In summary, rural residence is an important social determinant of glycemia and is associated with worse control in T2D in Bangladesh, irrespective of food security status. Further studies are needed to determine the impact of improvement in rural public health on diabetes-related outcomes.

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DISCLOSURE

The authors declare no conflict of interest.
Approval of the research protocol: Approval was granted by the National Research Ethics Committee (NREC) of the Bangladesh Medical Research Council (BMRC) (Ref: BMRC/NREC/2022-2025/82) as well as by the Ethical Review Committee (ERC) (Ref: FBS/ERC/2022/06 and AWEEC/FBS/IU/2023 (1)) of the Faculty of Biological Science of Islamic University, Kushtia, Bangladesh.
Informed consent: All participants provided written consent prior to the commencement of data and sample collection. The study was performed in alignment with the Code of Ethics of the World Medical Association Declaration of Helsinki[29].
Registry and the registration no. of the study: N/A.
Animal studies: N/A.

DATA AVAILABILITY STATEMENT

The data will be provided upon request by the corresponding authors.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Figure S1. Flowchart of study population.

Table S1. HbA1c Values and percentages among glycaemic control groups according to area of residence and food security status.