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Association between Six-Year Fasting Plasma Glucose Trajectories and the Risk of Chronic Diabetic Complications Among Community-Dwelling Older Adults With Type 2 Diabetes: A Retrospective Cohort Study

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Abstract

Purpose

To identify six-year fasting plasma glucose (FPG) trajectories among community-dwelling older adults with type 2 diabetes mellitus (T2DM) and to examine the associations between distinct trajectories and the risk of chronic diabetic complications.

Methods

This retrospective cohort study included 1,692 older adults with T2DM who received community-based health management in Kaiyang County, Guizhou Province, China, between 2019 and 2024 and had valid FPG monitoring data for six consecutive years. Group-based trajectory modelling (GBTM) was applied to identify long-term FPG trajectories. Multinomial logistic regression was used to determine factors associated with trajectory group membership, and Cox proportional hazards regression models were fitted to examine the associations between trajectory groups and the risk of chronic diabetic complications.

Results

Three distinct FPG trajectory groups were identified: a low-level stable group (86.3%), a high-level decreasing group (6.3%), and a high-level increasing group (7.4%). Compared with the low-level stable group, the high-level decreasing group was associated with a higher risk of chronic diabetic complications (HR = 2.17, 95% CI: 1.33–3.55), including diabetic eye disease (HR = 3.17, 95% CI: 1.57–6.39) and diabetic foot disease (HR = 5.92, 95% CI: 1.78–19.67). No significant association was observed between the high-level increasing group and the risk of chronic diabetic complications. Older age, central obesity, physical activity, and medication adherence were associated with FPG trajectory group membership.

Conclusions

Long-term FPG patterns exhibited substantial heterogeneity among community-dwelling older adults with T2DM. Despite a gradual decline in FPG levels over time, patients in the high-level decreasing group remained at increased risk of chronic diabetic complications. Long-term FPG trajectory analysis may help identify older adults with T2DM at high risk of complications in community settings and inform longitudinal glycaemic management and complication risk assessment.

Introduction

Diabetes mellitus represents a major global public health challenge, and the burden of type 2 diabetes mellitus (T2DM) is increasing rapidly as populations age [1, 2]. Dysglycaemia plays a pivotal role in the development and progression of chronic diabetic complications. Diabetes-related complications—including diabetic retinopathy, nephropathy, neuropathy, cardiovascular and cerebrovascular diseases—can lead to functional impairment, increased mortality, and substantial healthcare burdens [3–5]. Primary care organisations are integral to the long-term management and follow-up of patients with diabetes, particularly those enrolled in community-based health management programmes. Consequently, enhancing the capacity to comprehensively evaluate glycaemic control patterns and complication risks using longitudinal follow-up data is essential for optimizing diabetes management in primary care settings.

Fasting plasma glucose (FPG) is a key indicator for assessing glucose metabolism and glycaemic control, and is among the most widely used parameters in the follow-up of diabetes at the primary care level. Previous studies have demonstrated that elevated FPG is associated with increased risks of diabetes-related complications, cardiovascular disease, and mortality [6–9]. However, most prior studies have evaluated glycaemic status using a single FPG measurement [10–15], which may not adequately capture longitudinal changes in glycaemic patterns. As such, the long-term trajectories of FPG and their associations with disease outcomes remain insufficiently explored.

In recent years, longitudinal trajectory analysis methods based on repeated measurements have been increasingly applied in chronic disease research. Group-based trajectory modelling (GBTM) is a statistical approach that identifies latent subgroups of individuals exhibiting similar longitudinal patterns of change, thereby revealing heterogeneous trajectories that single measurements may fail to capture[16]. Previous studies have demonstrated that FPG dose not follow a uniform pattern during follow-up, but instead exhibit heterogeneous trajectories [7, 17]. Most existing FPG trajectories studies have been conducted in general populations, with outcomes focused primarily on all-cause mortality and cardiovascular disease [7, 17–20]. Nevertheless, evidence remains limited as to whether distinct FPG trajectories are associated with the risk of chronic diabetic complications among individuals with established T2DM, particularly community-dwelling older adults.

Primary care institutions have long managed large number of patients with established T2DM, and continuous follow-up data provide an opportunity to evaluate long-term glycaemic changes. Given that chronic diabetic complications develop over prolonged period, a single blood glucose measurement may not adequately reflect long-term disease progression. Therefore, analysing FPG trajectories using continuous monitoring data and further exploring their associations with the risk of chronic diabetic complications, may yield a more comprehensive understanding of long-term glycaemic patterns among older adults with T2DM and offer valuable insights for diabetes management in primary care settings.

Accordingly, this study utilised community health management records from a community health service centre in Kaiyang County, Guizhou Province, China, encompassing six consecutive years of FPG monitoring data from 2019 to 2024. GBTM was applied to identify long-term FPG trajectories among

community-dwelling older adults with T2DM, and Cox proportional hazards models were used to investigate the associations between FPG trajectory patterns and the risk of chronic diabetic complications. The findings may inform evidence-based strategies for longitudinal glycaemic management and complication prevention among older adults with T2DM in primary care settings.

Research Design and Methods

Study Design and Participants

This retrospective cohort study was based on routinely collected community health management data from the electronic health record system of a community health service centre in Kaiyang County, Guizhou Province, China. In accordance with the National Basic Public Health Service Standards (Third Edition), the centre provides standardised follow-up management for residents with T2DM, including regular health assessments and glycaemic monitoring. Participants were eligible for inclusion if they met the following criteria: (1) aged ≥ 60 years; (2) diagnosis of T2DM and enrolment in the community health management programme; and (3) at least one valid FPG measurement in each calendar year from 2019 to 2024, yielding six consecutive years of FPG data. January 1, 2019, was defined as the cohort entry date. Participants who completed continuous community-based health management throughout the study period were included in the analysis.

Baseline Data Collection

Baseline data were extracted from the electronic health record system of the community health service centre and comprised the following variables: (1) demographic characteristics, including sex, age, marital status, educational level, and health insurance type; (2) clinical characteristics and family history, including history of hypertension, family history of diabetes, waist circumference, and body mass index (BMI); and (3) lifestyle factors and disease-management behaviours, including smoking status, alcohol consumption status, physical activity level, medication adherence, treatment adherence, and psychological adjustment. Central obesity was defined according to Chinese criteria as a waist circumference ≥ 85 cm in men and ≥ 80 cm in women, overweight and obesity were defined as BMI ≥ 24 kg/m². Follow-up management was conducted by trained staff at the community health service centre in accordance with the National Basic Public Health Service Standards (Third Edition). FPG was measured using a glucometer based on finger-prick blood samples collected after an overnight fast of 8–12 hours.

Outcome Definitions

Outcome Definitions

Follow-up data were collected using a follow-up form developed by the research team with reference to the National Basic Public Health Service Standards (Third Edition) of China. The form was used to supplement and verify information on chronic diabetic complications during follow-up and was intended

as a clinical information collection tool rather than a psychometric scale; therefore, no composite score was generated. An English-language version of the follow-up form is provided in Supplementary File 1.

The follow-up outcomes comprised cardiovascular and cerebrovascular events and diabetes-related events. (1) Cardiovascular and cerebrovascular events included coronary heart disease, acute myocardial infarction, stroke, and heart failure. (2) Diabetes-related events included diabetic retinopathy, diabetic peripheral neuropathy, diabetic foot disease, and diabetic kidney disease. Reported outcomes obtained during follow-up were subsequently verified against community health records and relevant clinical documentation.

The primary outcome was chronic diabetic complications. The occurrence of any one of the following conditions was considered indicative of the development of chronic diabetic complications: coronary heart disease, stroke, heart failure, myocardial infarction, diabetic retinopathy, diabetic neuropathy, diabetic foot disease, and diabetic kidney disease. For participants who developed multiple complications, the date of the earliest diagnosed complication was defined as the date of outcome occurrence.

The observation period commenced on January 1, 2019, and ended on the date of the first diagnosis of chronic diabetic complications. Participants who did not develop chronic diabetic complications during follow-up were censored at the date of their last follow-up visit. Follow-up time was defined as the interval between the observation start date and the date of the first occurrence of chronic diabetic complications or censoring, and was calculated in years.

Identification of Fasting Plasma Glucose Trajectories

Group-based trajectory modelling (GBTM) was applied to identify long-term FPG patterns among community-dwelling older adults with T2DM. With 2019 as the baseline year, FPG measurements collected over six consecutive years (2019–2024) were included. To reduce within-year variability, the median of all valid FPG measurements for each participant in each calendar year was calculated and used as the representative annual value, yielding six sequential time points for trajectory modelling. Models with one to five latent trajectory groups were fitted using linear, quadratic, and cubic polynomial functions. Model selection was guided by the following criteria: (1) the Bayesian information criterion (BIC), with lower values indicating better fit; (2) an average posterior probability (AvePP) ≥ 0.70, indicating acceptable classification accuracy; and (3) a minimum group membership of at least 5% of the study population. The optimal trajectory model was determined through comprehensive consideration of these criteria.

Statistical Analysis

Normally distributed continuous variables are presented as means ± standard deviations (SDs) and were compared using independent-samples t tests for two groups or analysis of variance (ANOVA) for

multiple groups. Non-normally distributed continuous variables are presented as medians with interquartile ranges (IQRs) and were compared using the Wilcoxon rank-sum test or Kruskal–Wallis test, as appropriate. Categorical variables are presented as frequencies and percentages and were compared using the chi-square test or Fisher's exact test.

Multinomial logistic regression models were fitted to identify factors associated with FPG trajectory group membership, with the low-level stable trajectory group as the reference category. Odds ratios (ORs) and 95% confidence intervals (CIs) were calculated. Cox proportional hazards regression models were fitted to evaluate the associations between FPG trajectory groups and the risk of chronic diabetic complications. Hazard ratios (HRs) and 95% CIs were estimated. The proportional hazards assumption was assessed using Schoenfeld residuals, no evidence of violation was observed (global test, $P = 0.20$). Three progressively adjusted models were constructed: Model 1 was unadjusted; Model 2 was adjusted for age and sex; and Model 3 was further adjusted for marital status, educational level, health insurance type, history of hypertension, family history of diabetes, BMI, smoking status, alcohol consumption, and physical activity level. All statistical analyses were performed using R software (version 4.4.0). All statistical tests were two-sided, and $P < 0.05$ was considered statistically significant.

Results

FPG Trajectory Groups

Based on six consecutive years (2019–2024) of FPG monitoring data, GBTM was applied to identify long-term FPG change patterns among community-dwelling older adults with T2DM. Through comprehensive evaluation of model fit indices (BIC and AvePP) and the sample proportions of each trajectory group, the three-group trajectory model was identified as the optimal solution (Fig. 1B). Group 1 comprised 7.4% of participants. Patients in this group had moderately high baseline FPG levels, showed little change during the early follow-up period, and subsequently exhibited a continuous increasing trend, reaching higher FPG levels in the later follow-up period; therefore, this group was therefore classified as the high-level increasing group. Group 2 comprised 86.3% of the total study population. Participants in this group exhibited relatively low FPG levels throughout follow-up, with minimal fluctuations and an overall stable pattern; this group was therefore classified as the low-level stable group. Group 3 comprised 6.3% of participants. Those in this group had relatively high baseline FPG levels, followed by a gradual decline during follow-up, and maintained a relatively stable level during the later follow-up period; this group was therefore classified as the high-level decreasing group.

Baseline Characteristics of the Study Participants

A total of 1,692 community-dwelling older adults with T2DM were included. Significant differences were observed across different FPG trajectory groups in age groups ($P = 0.007$), central obesity ($P < 0.001$), overweight and obesity ($P = 0.002$), physical activity level ($P = 0.047$), and medication adherence ($P =$

0.010). Specifically, the proportions of central obesity and overweight and obesity were higher in both the high-level decreasing and high-level increasing groups than in the low-level stable group. The proportion of participants engageing in daily physical activity was higher in the high-level increasing group, whereas the high-level decreasing group had a higher proportion of intermittent medication use. No statistically significant differences were found across trajectory groups in sex, educational level, marital status, health insurance type, history of hypertension, family history of diabetes, smoking status, alcohol consumption, treatment adherence, or psychological adjustment (all $P > 0.05$). Detailed results are presented in Table 2.

Table 1
Model selection criteria for trajectory models with two to five groups using second-order polynomial functions

Model	**BIC**	**AvePP**				
		Class1	**Class2**	**Class3**	**Class4**	**Class5**
Model 1	33714.34	0.92	0.99			
Model 2	32841.20	0.98	0.91	0.91		
Model 3	32339.87	0.97	0.91	0.97	0.91	
Model 4	32106.18	0.91	0.90	0.97	0.97	0.94

Model 1–Model 4 represent models with 2, 3, 4, and 5 trajectory groups, respectively. BIC, Bayesian information criterion; lower BIC values indicate better model fit. AvePP, average posterior probability of assignment; values ≥ 0.70 indicate acceptable classification accuracy.

Table 2
Baseline characteristics of participants according to fasting plasma glucose trajectory groups [n (%)]

Characteristics	Total (N = 1692)	FPG trajectory			χ^2	*P*
		low-level stable group (N = 1460)	high-level decreasing group (N = 106)	high-level increasing group (N = 126)		
Sex					0.886	0.642
Male	614 (36.3)	528 (36.2)	36 (34.0)	50 (39.7)		
Female	1078 (63.7)	932 (63.8)	70 (66.0)	76 (60.3)		
Age groups					14.050	0.007
60–64 years	390 (23.0)	326 (22.3)	29 (27.4)	35 (27.8)		
65–74 years	964 (57.0)	822 (56.3)	67 (63.2)	75 (59.5)		
≥ 75 years	338 (20.0)	312 (21.4)	10 (9.4)	16 (12.7)		
Educational level					7.938	0.094
Junior high school or below	1027 (60.7)	892 (61.1)	65 (61.3)	70 (55.6)		
Senior high school or above	70 (4.1)	59 (4.0)	1 (0.9)	10 (7.9)		
Others	595 (35.2)	509 (34.9)	40 (37.7)	46 (36.5)		
Marital status					4.971	0.083
Married	1459 (86.2)	1253 (85.8)	99 (93.4)	107 (84.9)		
Other	233 (13.8)	207 (14.2)	7 (6.6)	19 (15.1)		
Health insurance type					9.060	0.060
New Rural Cooperative Medical Scheme	1411 (83.4)	1206 (82.6)	99 (93.4)	106 (84.1)		

Characteristics	Total (N = 1692)	FPG trajectory			χ^2	*P*
		low-level stable group (N = 1460)	high-level decreasing group (N = 106)	high-level increasing group (N = 126)		
Urban Employee Basic Medical Insurance	64 (3.8)	57 (3.9)	1 (0.9)	6 (4.8)		
Other	217 (12.8)	197 (13.5)	6 (5.7)	14 (11.1)		
History of hypertension					2.370	0.306
Yes	1356 (80.1)	1173 (80.3)	88 (83.0)	95 (75.4)		
No	336 (19.9)	287 (19.7)	18 (17.0)	31 (24.6)		
Family history of diabetes					0.458	0.795
Yes	41 (2.4)	36 (2.5)	3 (2.8)	2 (1.6)		
No	1651 (97.6)	1424 (97.5)	103 (97.2)	124 (98.4)		
Central obesity					19.290	<0.001
Yes	609 (36.0)	496 (34.0)	54 (50.9)	59 (46.8)		
No	1083(64.0)	964 (66.0)	52 (49.1)	67 (53.2)		
Overweight/obesity					12.780	0.002
Yes	815 (48.2)	678 (46.4)	62 (58.5)	75 (59.5)		
No	877(51.8)	782 (53.6)	44 (41.5)	51 (40.5)		
Physical activity level					6.127	0.047
Daily	254 (15.0)	208 (14.2)	18 (17.0)	28 (22.2)		
Occasional or none	1438 (85.0)	1252 (85.8)	88 (83.0)	98 (77.8)		

Characteristics	Total (N = 1692)	FPG trajectory			χ^2	*P*
		low-level stable group (N = 1460)	high-level decreasing group (N = 106)	high-level increasing group (N = 126)		
Smoking status					3.255	0.196
Never smoker	1182 (69.9)	1015 (69.5)	82 (77.4)	85 (67.5)		
Current or former smoker	510 (30.1)	445 (30.5)	24 (22.6)	41 (32.5)		
Alcohol consumption status					1.113	0.573
Non-drinker	1329 (78.5)	1141 (78.2)	87 (82.1)	101 (80.2)		
Current or former drinker	363 (21.5)	319 (21.8)	19 (17.9)	25 (19.8)		
Medication adherence					13.380	0.010
Regular	552 (32.6)	493 (33.8)	25 (23.6)	34 (27.0)		
Intermittent	626 (37.0)	534 (36.6)	51 (48.1)	41 (32.5)		
No medication	514 (30.4)	433 (29.7)	30 (28.3)	51 (40.5)		
Treatment adherence					2.580	0.275
Yes	522 (30.9)	445 (30.5)	40 (37.7)	37 (29.4)		
No	1170 (69.1)	1015 (69.5)	66 (62.3)	89 (70.6)		
Psychological adjustment					2.424	0.298
Yes	570 (33.7)	486 (33.3)	43 (40.6)	41 (32.5)		
No	1122 (66.3)	974 (66.7)	63 (59.4)	85 (67.5)		

Factors Associated With FPG Trajectory-Group Membership

Using the low-level stable group as the reference, variables that demonstrated statistical significance in univariate analyses were entered into the multivariable logistic regression model (Table 3). Compared with the low-level stable group, participants with central obesity were more likely to be classified into the high-level decreasing group (OR = 1.89, 95% CI: 1.15–3.12, *P* = 0.012), as were those with intermittent medication use (OR = 1.82, 95% CI: 1.11–2.99, *P* = 0.018). Conversely, participants aged ≥ 75 years were less likely to be classified into the high-level decreasing group (OR = 0.38, 95% CI: 0.18–0.81, *P* = 0.012). In the high-level increasing group, participants aged ≥ 75 years were less likely than those in the low-level stable group to belong to this trajectory group (OR = 0.52, 95% CI: 0.28–0.97, *P* = 0.040), and individuals with occasional or no physical activity had a lower likelihood of being classified into this group (OR = 0.61, 95% CI: 0.39–0.97, *P* = 0.034). Additionally, participants without medication use had a higher likelihood of belonging to the high-level increasing group (OR = 1.67, 95% CI: 1.06–2.64, *P* = 0.028).

Table 3
Multinomial logistic regression analysis of factors associated with FPG trajectory group membership

Factors	high-level decreasing group vs low-level stable group		high-level increasing group vs low-level stable group	
	OR(95% *CI*)	*P*	OR(95% *CI*)	*P*
Sex				
Female	Reference		Reference	
Male	1.01 (0.66, 1.55)	0.963	1.26 (0.86, 1.85)	0.229
Age groups				
60–64 years	Reference		Reference	
65–74 years	0.90 (0.57, 1.42)	0.655	0.82 (0.53, 1.25)	0.352
≥ 75 years	0.38 (0.18, 0.81)	0.012	0.52 (0.28, 0.97)	0.040
Central obesity				
No	Reference		Reference	
Yes	1.89 (1.15, 3.12)	0.012	1.52 (0.96, 2.40)	0.071
Overweight/obesity				
No	Reference		Reference	
Yes	1.04 (0.63, 1.71)	0.892	1.26 (0.80, 2.00)	0.315
Physical activity level				
Daily	Reference		Reference	
Occasional or none	0.85 (0.50, 1.45)	0.544	0.61 (0.39, 0.97)	0.034
Medication adherence				
Regular	Reference		Reference	
Intermittent	1.82 (1.11, 2.99)	0.018	1.10 (0.68, 1.76)	0.701
No medication	1.31 (0.75, 2.27)	0.339	1.67 (1.06, 2.64)	0.028

Associations of FPG Trajectories With All-Cause Mortality and Chronic Diabetic Complications

Using the low-level stable group as the reference, multivariable Cox regression analysis indicated that participants in the high-level decreasing group had a significantly increased risk of developing chronic diabetic complications. After adjustment for age, sex, marital status, educational level, health insurance

type, history of hypertension, family history of diabetes, BMI, smoking status, alcohol consumption, and physical activity level, the risk of chronic diabetic complications in the high-level decreasing group was approximately 2.17 times that in the low-level stable group (HR = 2.17, 95% CI: 1.33–3.55). Conversely, the high-level increasing group showed no statistically significant difference in the risk of chronic diabetic complications compared with the low-level stable group (HR = 1.13, 95% CI: 0.62–2.05). Further analyses of specific complication outcomes revealed that, relative to the low-level stable group, the high-level decreasing group had significantly higher risks of eye disease (HR = 3.17, 95% CI: 1.57–6.39) and diabetic foot disease (HR = 5.92, 95% CI: 1.78–19.67), whereas no statistically significant differences were observed in the risks of all-cause mortality, cardiovascular disease, or kidney disease (Table 4).

Table 4
Associations between FPG trajectory groups and clinical outcomes among older adults with T2DM

Outcome	Cases	Total	HR(95% *CI*)		
			Model 1	Model 2	Model 3
All-cause mortality					
low-level stable group	90	1460	Reference	Reference	Reference
high-level decreasing group	5	106	0.76 (0.31–1.87)	1 (0.4–2.46)	1.08 (0.43–2.69)
high-level increasing group	5	126	0.51 (0.19–1.39)	0.63 (0.23–1.71)	0.72 (0.26-2)
Chronic diabetic complications					
low-level stable group	122	1460	Reference	Reference	Reference
high-level decreasing group	19	106	2.25 (1.39–3.65)***	2.19 (1.35–3.55)**	2.17 (1.33–3.55)**
high-level increasing group	12	126	1.15 (0.64–2.08)	1.1 (0.61–1.99)	1.13 (0.62–2.05)
CVD					
low-level stable group	77	1460	Reference	Reference	Reference
high-level decreasing group	8	106	1.44 (0.7–2.99)	1.38 (0.67–2.86)	1.41 (0.67–2.94)
high-level increasing group	5	126	0.75 (0.3–1.85)	0.71 (0.29–1.75)	0.69 (0.28–1.73)
Eye disease					
low-level stable group	43	1460	Reference	Reference	Reference
high-level decreasing group	10	106	3.32 (1.67–6.61)***	3.19 (1.6–6.37)**	3.17 (1.57–6.39)**
high-level increasing group	5	126	1.36 (0.54–3.43)	1.33 (0.52–3.36)	1.4 (0.55–3.56)

Model 1: Unadjusted.

Model 2: Adjusted for age and sex.

Model 3: Adjusted for age, sex, marital status, educational level, health insurance type, history of hypertension, family history of diabetes, overweight/obesity, smoking status, alcohol consumption status, and physical activity level.

Significance levels: *P < 0.05, **P < 0.01, ***P < 0.001

Outcome	Cases	Total	HR(95% *CI*)		
			Model 1	**Model 2**	**Model 3**
Kidney disease					
low-level stable group	10	1460	Reference	Reference	Reference
high-level decreasing group	2	106	2.78 (0.61–12.69)	2.79 (0.61–12.78)	4.66 (0.92–23.62)
high-level increasing group	2	126	2.32 (0.51–10.59)	1.89 (0.41–8.64)	1.72 (0.36–8.24)
Diabetic foot complications					
low-level stable group	11	1460	Reference	Reference	Reference
high-level decreasing group	4	106	5.09 (1.62-16)**	5.36 (1.69–17.01)**	5.92 (1.78–19.67)**
high-level increasing group	0	126	0 (0-Inf)	0 (0-Inf)	0 (0-Inf)
Model 1: Unadjusted.					
Model 2: Adjusted for age and sex.					
Model 3: Adjusted for age, sex, marital status, educational level, health insurance type, history of hypertension, family history of diabetes, overweight/obesity, smoking status, alcohol consumption status, and physical activity level.					
Significance levels: *P < 0.05, **P < 0.01, ***P < 0.001					

Discussion

This study was based on real-world health management data from community settings. The findings demonstrated substantial heterogeneity in long-term FPG trajectories among older adults with T2DM, with three distinct trajectory patterns identified: the low-level stable group, the high-level decreasing group, and the high-level increasing group. These findings are consistent with previous studies [18, 19], suggesting the presence of individual variation in long-term glycaemic control. Furthermore, this study confirmed that long-term FPG trajectories also exhibited considerable heterogeneity among community-dwelling older adults with T2DM. Although different studies have identified varying trajectory patterns, these discrepancies may be attributable to differences in study populations and research designs [18, 21, 22]. Some previous studies included patients recruited from hospital settings, whose glycaemic changes may have been influenced by disease progression and treatment adjustments. In contrast, the present study was based on a community health management database and included participants with continuous six-year FPG monitoring records, who may have received relatively stable chronic disease management during follow-up. In addition, differences in patient age, diabetes duration, FPG

measurement frequency, follow-up duration, and trajectory model specifications may also contribute to variations in the trajectory patterns identified across studies.

This study found that patients aged ≥ 75 years were less likely to belong to the high-level decreasing and the high-level increasing groups. This finding may be related to the characteristics of older populations and long-term health management patterns [23]. Age not only reflects differences in patients' physiological status but may also represent variations in metabolic characteristics and disease progression across different stages of T2DM [24]. FPG variation is regulated by multiple physiological factors [25]. T2DM patients with younger age at onset often exhibit more pronounced obesity-related insulin resistance, metabolic abnormalities, and β-cell dysfunction, which may contribute to more rapid disease progression [26]. In contrast, glucose metabolism disorders in older adults with T2DM are more strongly influenced by age-related declines in pancreatic β-cell function, reduced insulin secretory capacity, decreased skeletal muscle function, and multimorbidity. Moreover, older adults with T2DM generally have different disease management characteristics compared with younger patients. Their treatment goals and management strategies emphasise individualised treatment, maintenance of glycaemic stability, and reduction of hypoglycemia risk rather than intensive glucose-lowering therapy alone [2]. Conversely, owing to their longer expected survival, younger adults with T2DM typically require greater emphasis on long-term metabolic control and the prevention of future diabetes-related complications [27]. Therefore, in clinical practice, glucose-lowering strategies for older adults are often adjusted according to functional status, comorbidities, and treatment conditions. This management approach, which prioritizes glycaemic stability, may reduce the likelihood of substantial increases or decreases in FPG over time. In addition, because participants included in this study were required to complete six consecutive years of FPG follow-up, those who completed the follow-up may differ from individuals who were not included in long-term follow-up, and therefore the potential influence of selection bias cannot be excluded [28].

Central obesity is an important metabolic characteristic involved in the development and progression of T2DM and is closely associated with insulin resistance, adipose tissue dysfunction, and chronic low-grade inflammation. Previous studies have demonstrated that excessive expansion of adipose tissue can promote abnormal adipokine secretion, increased release of free fatty acids, and activation of inflammatory responses, thereby impairing insulin signaling pathways, reducing insulin sensitivity, and exacerbating glucose metabolism disorders [29, 30]. Therefore, patients with central obesity generally exhibit a greater metabolic burden and may present with higher FPG levels during the early follow-up period, whilst elevated baseline glucose levels may also provide greater potential for subsequent glycaemic improvement. In this study, central obesity was associated with the high-level decreasing group, whereas no significant association was observed between central obesity and the high-level increasing group. T2DM is characterized by substantial metabolic heterogeneity, with considerable differences among patients in the degree of insulin resistance, β-cell function, and metabolic burden. T2DM associated with central obesity is typically characterized by pronounced insulin resistance, whereas some patients may predominantly exhibit β-cell dysfunction and impaired insulin secretion. These distinct pathophysiological phenotypes may influence patients' glycaemic responses to glucose-

lowering medications and lifestyle interventions [31, 32]. Previous studies have suggested that patients with predominant insulin resistance may benefit more from therapeutic strategies aimed at improving insulin sensitivity, whereas progressive β-cell dysfunction may reduce endogenous insulin secretion capacity and limit the glycaemic benefits of certain glucose-lowering therapies [33–35]. Furthermore, during community-based chronic disease management, patients with higher FPG levels or greater metabolic risks generally require more intensive glucose monitoring and treatment adjustments, including modifications of glucose-lowering medications, dietary management, and exercise guidance. These interventions may further contribute to reductions in blood glucose levels. Therefore, the association between central obesity and the high-level decreasing group may reflect the combination of a greater initial metabolic burden and subsequent glycaemic improvement following clinical interventions, rather than a complete reversal of obesity-related metabolic abnormalities. Even when FPG levels decline during follow-up, persistent visceral adiposity and insulin resistance may continue to contribute to metabolic risk. Thus, in community-based diabetes management, attention should be paid not only to longitudinal glycaemic trajectories but also to weight control and waist circumference management.

This study found that participants with occasional or no physical activity were less likely to belong to the high-level increasing group. Previous studies have demonstrated that regular physical activity can improve insulin sensitivity, enhance glucose uptake by skeletal muscle, and contribute to better glycaemic control among patients with T2DM [36, 37]. Therefore, lower levels of physical activity are generally considered to be associated with an increased risk of poor glycaemic control. However, in the present study, participants with occasional or no physical activity did not show a higher risk of increasing FPG levels; instead, they were less likely to belong to the high-level increasing group. This finding may reflect the complex relationship between physical activity behaviours and disease status among older adults with T2DM. Physical activity level not only reflects lifestyle behaviours but is also influenced by multiple factors, including ageing, functional status, muscle function, and disease burden [38]. Some individuals with lower physical activity levels may have distinct disease characteristics or health management patterns, resulting in relatively stable FPG trajectories. Conversely, patients with poorer glycaemic control or a higher disease burden may have greater healthcare needs and receive more intensive lifestyle interventions, which may lead to the coexistence of higher physical activity levels and unfavorable glycaemic trajectories. This association may be influenced by reverse causality and residual confounding, as disease status may affect patients' physical activity behaviours, and the observed association between physical activity level and FPG trajectories may not necessarily represent a direct causal relationship [39, 40]. Therefore, among older adults with T2DM, physical activity level may simultaneously reflect health behaviours, functional status, and disease characteristics, and its relationship with long-term FPG changes may be jointly influenced by multiple factors. Future studies incorporating long-term physical activity monitoring, exercise intensity assessment, and information on disease progression are warranted to further validate these findings.

Glucose-lowering medication therapy is an important strategy for improving glycaemic control among patients with T2DM. Appropriate medication management can contribute to reductions in blood glucose

levels and glycaemic variability. Previous studies have demonstrated that the use of oral glucose-lowering medications is associated with glycaemic variability, suggesting that pharmacological treatment may influence long-term glycaemic stability [41]. In addition, insulin and oral glucose-lowering medications are among the most effective therapies for reducing hyperglycemia and have been shown to improve glycaemic levels in patients with T2DM [42, 43]. Higher medication adherence is generally associated with better glycaemic control, whereas insufficient adherence may increase the risk of glycaemic fluctuations [44]. In the present study, patients with regular medication use were more likely to belong to the low-level stable group, those with intermittent medication use were more likely to belong to the high-level decreasing group, and those without medication use were more likely to belong to the high-level increasing group. Further analyses indicated that, compared with patients with regular medication use, those without medication use were more likely to be classified into the high-level increasing group. This finding may be explained by the lack of continuous glycaemic management among patients not receiving pharmacological treatment, which may hinder the maintenance of long-term glycaemic stability and increase the likelihood of an increasing FPG trajectory. Notably, patients with intermittent medication use were more likely to belong to the high-level decreasing group. This finding does not indicate that intermittent medication use has a glucose-lowering effect; rather, it may reflect dynamic changes during the treatment process. Some patients may initiate glucose-lowering therapy after poor glycaemic control or disease progression, followed by reductions in FPG levels due to treatment adjustments or short-term intensified management. Therefore, intermittent medication use may reflect both inadequate treatment adherence and therapeutic adjustments during disease management, rather than simply insufficient medication exposure. Furthermore, in observational studies, the association between medication use patterns and glycaemic trajectories may be influenced by confounding related to disease severity [45, 46]. Patients with more severe disease may be more likely to receive pharmacological treatment or treatment modifications whilst also having a higher risk of abnormal glycaemic patterns. Future studies should incorporate specific types of glucose-lowering medications, treatment intensity, and timing of treatment adjustments to further clarify the effects of medication management patterns on long-term glycaemic trajectories.

This study further investigated the associations between different FPG trajectories and the risk of chronic diabetic complications. Previous studies based on long-term glycaemic measurements have demonstrated that patients with T2DM exhibit heterogeneous glycaemic trajectories, and that different trajectory patterns are closely associated with clinical outcomes. Persistently high or gradually increasing FPG trajectories have generally been associated with higher risks of CVD and mortality, whereas patients with a low-level stable trajectory tend to have relatively lower risks of adverse outcomes [7, 47]. Further studies have shown that abnormal FPG trajectories are also associated with an increased risk of diabetes-related complications, such as chronic kidney disease [48, 49], suggesting that long-term FPG dynamics may reflect cumulative metabolic burden and may provide potential value for identifying individuals at higher risk of chronic diabetic complications.

Patients in the high-level decreasing group were associated with a higher risk of chronic diabetic complications, suggesting that a decline in FPG levels during follow-up does not necessarily indicate

complete reversal of pre-existing hyperglycemia-related damage. Previous studies have demonstrated that long-term hyperglycaemic exposure is closely associated with the development of diabetic microvascular and macrovascular complications. Hyperglycemia can promote endothelial dysfunction and microvascular injury through oxidative stress, inflammatory responses, and advanced glycation end-product accumulation. Even after subsequent improvements in glycaemic control, pre-existing tissue damage may continue to influence disease progression [50, 51]. These findings are consistent with the concepts of “metabolic memory” and the “legacy effect.” Previous studies have shown that prolonged hyperglycaemic exposure during the early stages of diabetes can induce persistent molecular and cellular alterations, including persistent oxidative stress, enhanced inflammatory responses, and abnormal epigenetic regulation, resulting in persistently elevated risks of microvascular and CVD complications despite subsequent improvements in glycaemic control [50, 52, 53]. Therefore, the high-level decreasing group may represent a subgroup of patients who had a history of poor glycaemic control and experienced improvements in FPG levels following treatment or health management, but whose cumulative metabolic burden remained substantial. For older adults with T2DM, focusing solely on current glycaemic status may underestimate their long-term risk of complications. Incorporating long-term glycaemic trajectories into risk assessment may therefore provide important clinical and public health implications.

Further analyses revealed that the high-level decreasing group was significantly associated with increased risks of diabetic eye disease and diabetic foot, whereas no significant association was observed with macrovascular complications. Diabetic microvascular complications mainly affect the retina, kidneys, and peripheral nervous system, and their development and progression are closely related to long-term hyperglycaemic exposure [54]. Chronic hyperglycemia can lead to endothelial dysfunction, microvascular injury, and structural tissue alterations. Owing to their unique vascular characteristics and high metabolic demands, the microvasculature is particularly sensitive to abnormal glucose levels and glycaemic variability [55]. Previous studies have shown that among patients with long-term poor glycaemic control, intensive glucose-lowering therapy may be followed by short-term progression of diabetic retinopathy, known as the “early worsening phenomenon,” suggesting that rapid improvement in glycaemic control does not necessarily result in immediate reversal of existing microvascular damage and that some patients may experience transient worsening of microvascular complications [56, 57]. Therefore, although patients in the high-level decreasing group exhibited declining FPG levels during follow-up, their risk of microvascular complications may still have been influenced by previous glycaemic exposure and disease progression, consistent with the increased risks of diabetic eye disease and diabetic foot observed in this study. In contrast, CVD primarily involves the initiation and progression of atherosclerosis, with pathological processes influenced by multiple factors, including endothelial injury, lipid accumulation, inflammatory responses, and vascular remodelling [58]. Moreover, cardiovascular risk factors, including age, hypertension, dyslipidemia, obesity, and smoking, play important roles in the development of macrovascular diseases [59, 60]. Compared with microvascular injury, atherosclerosis generally develops through a prolonged cumulative process. Therefore, within a relatively limited follow-up period, a single FPG trajectory may have limited

explanatory power for macrovascular disease risk. These findings highlight the differences in the underlying mechanisms and progression timelines among different types of diabetic complications.

It is noteworthy that no significant association was observed between the high-level increasing group and the risk of chronic diabetic complications in this study. This finding is not entirely consistent with previous studies showing that long-term hyperglycaemic exposure increases the risk of diabetic complications. Several potential explanations may account for this discrepancy. First, the development of chronic diabetic complications is closely associated with cumulative glycaemic exposure and disease duration. Vascular and tissue damage induced by chronic hyperglycemia is typically a gradual cumulative process rather than an immediate consequence of short-term glucose elevation [61, 62]. FPG trajectories primarily reflect glycaemic changes during the study period and may not fully capture patients' long-term glycaemic exposure throughout the course of diabetes. Therefore, although patients in the high-level increasing group exhibited progressively elevated FPG levels during follow-up, the development and progression of chronic diabetic complications involve cumulative biological processes and time-lag effects [63, 64]. Within the relatively limited follow-up period of this study, the risk of complications associated with long-term hyperglycaemic exposure may not have been fully manifested. Second, competing risks may have influenced the observed associations between FPG trajectories and chronic diabetic complications among older adults with T2DM. Older adults with T2DM often have high disease burden and multiple comorbidities, and individuals with persistent glycaemic abnormalities may also have increased risks of CVD, infections, and other severe health events [65, 66]. During follow-up, some patients may have died or experienced severe health events before the occurrence of chronic diabetic complications, thereby affecting the estimation of complication risks. In addition, participants included in this study were required to complete six consecutive years of FPG follow-up. Some patients with poor glycaemic control, rapid disease progression, or severe comorbid conditions may have died or been unable to complete long-term follow-up and therefore were not included in the trajectory analysis. These excluded individuals may have had higher risks of CVD and diabetes-related complications, and their exclusion may have resulted in an underestimation of the true risk among patients in the high-level increasing group. Furthermore, differences in complication screening practices and healthcare management strategies may also have affected the study findings, particularly for early-stage retinopathy, neuropathy, and diabetic kidney disease, which often have limited clinical manifestations and require standardised screening for detection [33]. Differences in healthcare follow-up and complication assessment frequency among FPG trajectory groups may have influenced complication ascertainment. Meanwhile, patients with poor glycaemic control often require further adjustment of glucose-lowering treatment regimens, and treatment intensification may subsequently affect longitudinal glycaemic trajectories [67]. Therefore, the lack of a significant association between the high-level increasing group and increased risk of chronic diabetic complications in this study does not completely exclude potential long-term risks. Future studies with longer follow-up periods, detailed longitudinal treatment information, and standardised complication screening are needed to further clarify the long-term associations between different FPG trajectory patterns and diabetic complication risk.

This study has several limitations. First, as a retrospective cohort study, although it was based on routinely collected community health management data, the potential influences of selection bias and unmeasured confounding factors could not be completely excluded. Due to the limited availability of information in community health records, this study did not include several potential factors that may affect FPG trajectories and the risk of chronic diabetic complications, such as diabetes duration, specific glucose-lowering medication regimens, and lipid levels. Therefore, the findings require further validation in prospective cohort studies. Second, annual median FPG values were used to construct FPG trajectories. Although this approach can capture long-term FPG trends, it cannot capture within-day or short-term glycaemic variability. Finally, some outcome events, such as kidney disease and diabetic foot, had a limited number of events, which may have affected the precision of risk estimates. Future studies with larger sample sizes and multicentre designs are warranted to further validate these findings.

Conclusion

This study demonstrated substantial heterogeneity in long-term FPG trajectories among community-dwelling older adults with T2DM, with three distinct patterns identified: the low-level stable, the high-level decreasing, and the high-level increasing groups. These trajectories were associated with differing risks of chronic diabetic complications. Notably, although patients in the high-level decreasing group exhibited progressively declining FPG levels during follow-up, they remained at significantly increased risk of chronic diabetic complications. This indicates that assessing complication risk based solely on current FPG levels may underestimate the impact of prior long-term hyperglycaemic exposure. Relative to a single FPG measurement, longitudinal FPG trajectories offer additional insights into glycaemic control patterns and long-term health risks. In community-based diabetes management, greater attention should be directed towards patients' long-term glycaemic patterns, particularly high-risk individuals with a history of poor glycaemic control who have recently achieved improved glycaemic control. Integrating regular complication screening with comprehensive management strategies may help reduce the risk of adverse diabetes-related outcomes. Future studies with larger sample sizes, multicentre designs, and longer follow-up periods are warranted to further validate the value of FPG trajectories for assessing the risk of chronic diabetic complications.

Declarations

Ethical approval and consent to
Funding Declaration

There was no Funding.

Clinical Trial

Not applicable.

Clinical Trial number

Not applicable.

Data Availability

The datasets generated and/or analysed during the current study are not publicly available due to privacy/ethical restrictions protecting participant confidentiality per IRB requirements but are available from the corresponding author on reasonable request.

Ethical approval and consent to participate

This study was approved by the medical ethics committee of the Guiyang Center for Disease Control and Prevention. Our study adhered to the Declaration of Helsinki. The medical ethics committee of the Guiyang Center for Disease Control and Prevention has agreed to waive the consent of the participants.

Author Contribution

M.C., Z.X. and Z.T. contributed to the study conception and design. M.C., Z.X. and Z.T. contributed to writing-review and editing. Z.X. contributed to project administration. All authors wrote the manuscript. All authors contributed to investigation. M.C. and H.J. prepared figure 1 and contributed to formal analysis. M.C., H.J. and Y.Q. prepared all tables.

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Figures

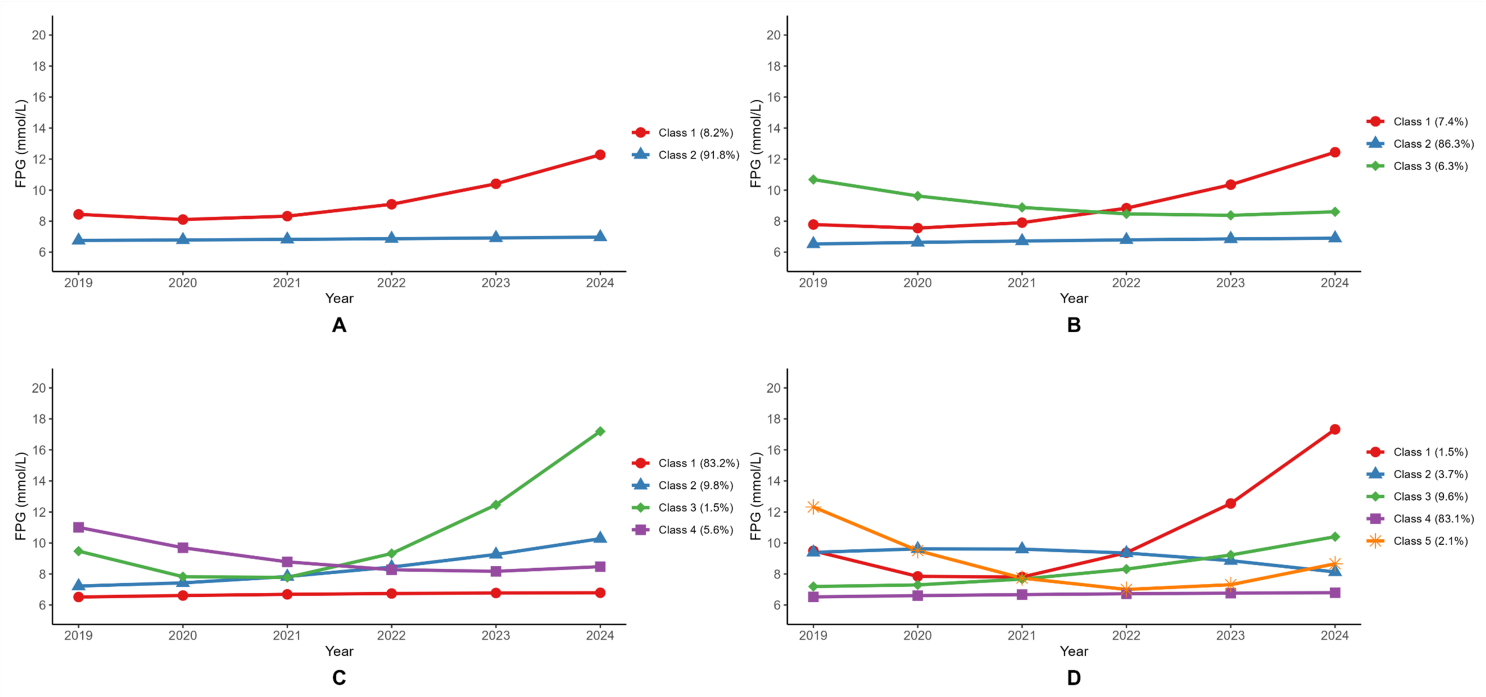


Figure 1

Trajectory curves of fasting plasma glucose among patients with type 2 diabetes

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- SupplementaryFile1.FollowupFormforChronicDiabeticComplications.pdf