

Diabetic complications and healthy diets are related to glycemic levels among type 2 diabetes patients in Nairobi County, Kenya; A 3-month follow up study

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Abstract

Introduction: Diabetes is a chronic metabolic disease, caused by prolonged high blood sugars, resulting from inadequate insulin or reduced sensitivity to its action. Understanding longitudinal trends of glycemic levels among Type 2 Diabetes (T2DM) patients could improve their quality of care and related-costs.

Methods: This study was conducted from August to November 2023. We assessed glycemic trends among patients with Type 2 Diabetes Mellitus (T2DM) using a longitudinal study design. Two public health hospitals in Nairobi County were purposively selected due to their high burden of T2DM. A total of 122 patients attending the diabetes clinics at these facilities were censured and followed up for three months. Using an interviewer-administered questionnaire we gathered patients' characteristics, while their Hemoglobin A1C (HbA1c) levels, determining their glycemic levels, were measured through blood tests. Multilevel logistic regression analysis was performed at $p < 0.05$ to identify predictors of glycemic levels.

Results: In the 3-month follow-up, we obtained 323 hemoglobin A1C (HbA1c) test reports from 122 T2DM patients. 237 (74%) of these HbA1c reports had elevated glycemic levels defined as HbA1C of ≥ 7.0 , regardless of the follow-up month. Elevated glycemic levels were frequent among females (70%) and patients aged above 50 years (68%). Over time, proportion of patients with elevated glycemic levels increased from 66% to 79%. Additionally, the use of combination therapies that included Metformin, Glibenclamide, or insulin rose from 47% to 80%. Diabetes complications (Odds ratio (OR)=9.4, 95% Confidence Interval (CI) 1.04, 85.2), daily fruits and vegetable servings (OR=0.2, 95% CI 0.04, 0.6) independently predicted elevated glycemic levels among T2DM patients.

Conclusion: We establish association between elevated glycemic levels with diabetes complications and fruits and vegetable diets, underscoring the importance of implementing patient centered interventions promoting early complication detection, effective treatment, nutrition counselling and optimal glycemic control for T2DM patients' while improving their quality of life.

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Introduction

Globally, Type 2 Diabetes (T2DM) poses a significant public health challenge, with approximately 462 million cases reported [1]. T2DM is associated with increasing morbidity rates, premature deaths, and decreased life expectancy, particularly in developing countries. These issues are often associated with rapid urbanization, shifts in lifestyle, unhealthy diets, high Body Mass Index (BMI), poor medication adherence, and limited access to healthcare [2-5]. Patients with T2DM face a higher risk of complications, including neuropathies, retinopathies, diabetic foot problems, leg amputations, kidney disease, hypoglycemia, hyperglycemia, and various heart-related complications. These complications are all worsened by patients' low economic status and educational levels [6,7]. Such health challenges significantly impact patients' quality of life, diminishing their physical, psychological, and social well-being [8,9]. Maintaining a Hemoglobin A1C (HbA1c) level of less than 7% is critical for managing diabetes effectively and reducing the risks of complications associated with increased hospital visits and healthcare costs [10-14].

Patients with T2DM consuming unhealthy diets and not adhering to their prescribed diabetic medications are at an increased risk of having elevated glycemic levels, often reflected by an HbA1c greater than 7% [15-18]. In Sub-Saharan Africa, particularly in Kenya, awareness of T2DM management is further hampered by several barriers to patient care. These include limited access to quality healthcare services, incomplete prescriptions, inadequate knowledge about diabetes care, and poor record-keeping, which limits follow-up data on patient management [19]. Recognizing these gaps and understanding the longitudinal trends in glycemic levels among T2DM patients provide valuable insights for designing effective, patient-centered interventions aimed at achieving optimal glycemic control [20-22]. This study aimed to achieve two interconnected objectives: 1) to identify longitudinal patterns of glycemic status over time and (2) determine associated independent variables for elevated glycemic levels.

Methods

Study site

This study was conducted at Mbagathi and Mama Lucy Kibaki hospitals in Nairobi City County, among the largest urban centers in Kenya. These hospitals are the largest public Level 5 facilities in Nairobi County and operate specialized outpatient clinics for diabetes patients, handling the highest volume of diagnosed diabetes cases in the area. Mbagathi

Hospital has a bed capacity of 227, while Mama Lucy Kibaki Hospital has a capacity of 197. Each facility hosts a monthly specialized diabetic outpatient clinic, serving to a range of 30 to 50 patients weekly at Mbagathi Hospital and 100 to 150 patients at Mama Lucy Kibaki Hospital. Mbagathi Hospital is in the Lang'ata constituency, while Mama Lucy Kibaki Hospital is situated in the Embakasi central constituency of Nairobi County.

Study design and sampling

This study adopted a longitudinal study design to follow 122 censored patients over the age of 18 years, and followed them for 3 months, all sampled using a sampling frame obtained from the patients records from Mbagathi and Mama Lucy Kibaki hospitals. During follow up, all patients were evaluated for diabetes complications and their glycemic levels monitored.

Study variables

We collected data on demographic and economic characteristics from patients using an interviewer-administered questionnaire. This included details such as age, sex, occupation, education level, income, and marital status. Additionally, we documented clinical factors related to the patients, including the duration of diabetes treatment, the medications used, their dosages, and any side effects experienced. Other characteristics obtained included the patient's body mass index, family history of diabetes, and complications/comorbidities associated with the condition. We obtained behavioral factors including physical exercise categorized into short or long intensity, diet, self-blood sugar monitoring, and medication adherence.

A clinical assessment included measuring blood pressure (BP) in mm/Hg using a sphygmomanometer. Body Mass Index (BMI) was calculated based on the weights and heights obtained from a weighing machine. For glucose monitoring, Glycosylated Hemoglobin (HbA1c) levels were assessed to determine glycemic control. During each follow-up for three months, 2 ml of venous blood was drawn from patients and placed into an EDTA bottle labeled with the patient's code. This blood was then analyzed for HbA1c levels using a cobas analyzer with a cobas Integra hemolyzing reagent, employing a turbidimetric inhibition immunoassay for hemolyzed whole blood [23,24]. Results for HbA1c are provided as a percentage, calculated as the ratio of HbA1c to hemoglobin. A HbA1c level of 7% or more is considered to indicate elevated glycemic levels for patients with type 2 diabetes [25,26]. All laboratory tests investigations were conducted at Mama

Lucy Kibaki and Mbagathi Hospitals which are registered and certified by the Laboratory Board of Kenya, employing trained laboratory professionals.

Data analysis

Clustering analyses of glycemic measurements: We collected repeated measures data monthly from the same subjects, allowing us to define each patient as a cluster that consists of multiple temporal observations. To quantify these correlations, we estimated Intra-cluster Correlation Coefficients (ICC) using the residual variance, which is approximately 3.29, a value commonly used in the standard logistic distribution. This was assumed to represent the Level 1 variance component, along with the patient-level variance, which was derived from fitting mixed-effects multilevel logistic regression models [27].

Estimating the association between elevated glycemic level and independent variables: Adjusting for patient-level clustering, we fitted Generalized Mixed effect Models (GLMM) with a binomial distribution and a logit function to examine how independent variables affect glycemic level. In the first step, we constructed multilevel univariable models using a less stringent significance level of $P \leq 0.1$ to identify individual significant variables associated with elevated glycemic levels. In the next step, to evaluate the assumption that the log-odds of glycemic status occurrence increases with a variable, we created a quadratic term for continuous variables such as fruit servings and age (the variable squared) and assessed whether the linearity assumption was violated.

In the second step, we extended these models to create multilevel-multivariable models that control independent variables related to glycemic levels. All GLMMs were fitted using the maximum likelihood method with Laplace approximation,

incorporating patient identification as random effects. In the multivariable analysis we included sex and age in the models to account for their potential confounding effects. The final model was selected through a backward-stepwise selection process, during which variables not significantly predicting risks associated with glycemic levels were gradually removed based on low values of the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC), indicating a better-fitting model. All analyses were conducted using R software version 4.5.0.

Ethical review statement

We sought ethical clearance for this study from AMREF Health Africa Ethics and Scientific Review Committee, approval number ESRC P1416/2023. Research permits were also sought from the National commission for science technology and innovation (NACOSTI) under License number NACOSTI/P/23/26755. All the patients aged above 18 years provided their consent to participate in the study.

Results

Type 2 diabetic (T2DM) patient characteristics

Of the 122 patients with types 2 diabetes (T2DM), a majority (64%) were females. The average patient's age was 57 ± 13 years, ranging between 25 and 85 years. Most (62%) of the patients attained secondary or post-secondary education. About two-thirds (77%) of the patients were married, while the remaining patients were either single, divorced or widowed. Additionally, most (55%) of the patients were employed in informal employment, while the rest worked in formal occupations, retired, or unemployed. About 68% of the participants were earning less than 10,000 Kenya shillings a month (Table 1).

Table 1: T2DM patient characteristics (n=122).

Variable	Levels	Frequency	%
Sex	Female	78	63.9
	Male	44	36.1
Age in years	Below 50	37	30.3
	50 to 65	56	45.9
	Above 65	29	23.8
Education level	No education, Primary	46	37.7
	Secondary	51	41.8
	Post secondary	25	20.5
Marital status	Divorced, single, widowed	28	23.0
	Married	94	77.0
Occupation	Formal employment	14	11.5
	Informal employment	68	55.7
	Unemployed, retired	40	32.8
Monthly income	<10,000	82	67.2
	≥10,000	40	32.8

The median and Interquartile range in years for patients living with diabetes was 7 and 8 respectively. These patients were on diabetes treatment for a median and Interquartile range in years 10 and 12, respectively. The monthly median and interquartile range for diabetic treatment costs in Kenya Shillings (KES) was 1800 and 2000, respectively, ranging to a maximum of 25,000.

Diabetes status among T2DM patients

Table 2 describes diabetic status of the 122 T2DM patients. Half of the patients (52%) came from families with a history of diabetes. One in five (21%) of the patients were admitted to the hospital due to diabetes-related complications, with a median admission time of 2 months and an interquartile range of 4 months, extending to a maximum of about one year. Most (69%) of the patients were using oral medication, while the rest using insulin injections or a combination of both. Additionally, 70% of patients could identify their medications by color, shape, and labels. In terms of storage, 40% of patients kept their medications in cupboards, 23% in bags, and 9% in the fridge, with the rest using a combination of these locations. Almost all patients (97%) were aware of their daily medication doses and the timing for taking them. Most patients (83%) had been taking their medication for more than three months prior to the start of this study. However, one in three patients (34%) reported occasionally forgetting to take their medication, with a median of two days and an interquartile range of one day for missed doses. Only 9 patients (7%) reported experiencing side effects from their diabetes medications, which included diarrhea, dizziness, general body itchiness, nausea and vomiting, heartburn, hypoglycemia, and increased thirst.

Moreover, more than half (50%) of the patients were diagnosed with hypertension with a majority (95%) receiving treatment. Other chronic conditions identified in the patients' clinical records included heart disease, hyperlipidemia, and osteoarthritis, among others. Most patients (52%) followed healthy diet plans involving cutting or reducing sweet carbohydrates and fatty meals. Additionally, a majority (62%) of these patients were obese or overweight, while the remaining patients having normal body weight. Over 55% of the patients engaged in physical activity. Notably, only one patient smoked cigarettes and seven patients (6%) consumed alcohol. Fewer than 14% of the patients reported diabetes complications including nerves complication (35%), eye and dyslipidemia (17%), and diabetic foot (12%) among others. Of the 17 patients with current complications, only 3(18%) required hospitalization. The diabetes status of patients during follow-up is shown in Table 2.

Longitudinal follow up and retention of patients.

During the 3-month follow-up period, from August to November 2023, we collected a total of 323 reports out of the expected 366, resulting in a response rate of 88%. We received reports consistently each week, with data obtained from 89 out of the 122 participants (73%). Only 10 participants were lost to follow-up (Figure 1).

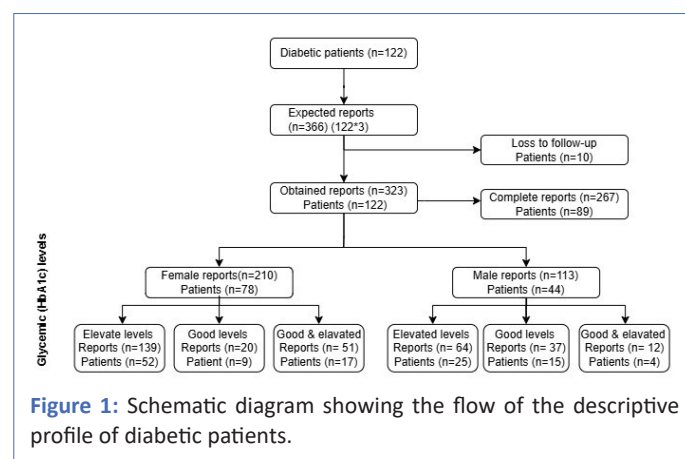


Figure 1: Schematic diagram showing the flow of the descriptive profile of diabetic patients.

Table 2: T2DM patient characteristics (n=122).

Variable	Levels	Baseline (n=122)		1 st follow up (n=109)		2 nd follow up (n=92)	
		Freq ¹	(%)	Freq ¹	(%)	Freq ¹	(%)
Treatment mode of payment	Cash payment	54	44	44	40	38	41
	Insurance	68	56	65	60	54	59
Family member with DB	No, don't know	58	48	53	49	43	47
	Yes	64	52	56	51	49	53
Ever admitted for DB complication	No	97	80	85	78	72	78
	Yes	25	20	24	22	20	22
DB Complications admitted for	Uncontrolled sugar	15	60	14	59	11	55
	Diabetic coma, foot	6	24	6	25	6	30
	Stroke	2	8	2	8	2	10
	Hyperglycemia, BP2	1	4	1	4	1	5
	Eye problem	1	4	1	4	0	0
DB treatment	Oral medication	85	70	78	71	63	69
	injection	15	12	16	15	14	15
	Combined Insulin and orals	22	18	15	14	15	16
Name DB medications	No	36	30	30	27	21	23
	Yes	86	70	79	73	71	77
Identify their medication	Label	39	32	48	44	38	41
	Shape color	23	19	12	11	1	1
	Color	17	14	16	15	17	19
	Shape color label	12	10	10	9	7	8
	Depend on others	10	8	6	6	4	4
	Color label	9	7	6	6	8	9
	Shape	6	5	9	8	12	13
	Shape label	6	5	2	1	5	5
Where to store DB meds	Cupboard	49	40	45	41	34	37
	Bag	28	23	29	27	25	27
	Fridge	11	9	10	9	9	10
	Tin	4	3	4	4	4	4
	Combined	30	25	21	19	20	22
Dose taking daily	No	4	3	3	3	1	1
	Yes	118	97	106	97	91	99
Aware time take meds	No	4	3	1	1	0	0
	Yes	114	97	105	99	91	100
How long taking DB medication	<3months	22	18	8	7	18	20
	>3months	100	82	101	93	74	80
Forgot taking DB medication	No	80	66	91	83	75	82
	Yes	42	34	18	17	17	18
Current DB complication	No	105	86	101	93	88	96
	Yes	17	14	8	7	4	4
Complication	Uncontrolled sugars	4	23	1	12.5		0
	Neuropathy	3	18	4	50	4	100
	Retinopathy	2	12	1	12.5		0
	Dyslipidemia	2	12	2	25		0
	Other complications3	6	35	0	0	0	0
Hypertensive	Yes	62	59	68	62	51	55
	No	44	41	41	38	41	45
	Missing	16					
Have glucometer strips	No	59	48	47	43	35	38
	Yes	63	52	62	57	57	62

Chronic condition	Heart disease	4	3	0	0	2	2
	hyperlipidemia	5	4	3	3	16	17
	Osteoarthritis	17	14	13	12	13	14
	Cancer	1	1		0		0
	Other conditions ⁴	23	19	19	17	20	22
	No condition	72	59	74	68	41	45
Follow healthy diet plan.	No	34	28	20	18	18	20
	Yes	88	72	89	82	74	80
Healthy diet plan involve.	Cutting sweet carbs and fatty meals	46	52	-	0	69	93
	Reducing sweet carbs	31	35	8	9	3	4
	Cutting fatty meals	11	13	81	91	2	3
	Missing	34		20		18	
Engage in physical activity	No	55	45	49	45	37	40
	Yes	67	55	60	55	55	60
Smoke cigarettes	No	121	99	108	99	90	98
	Yes	1	1	1	1	2	2
Take alcohol	No	115	94	106	97	91	99
	Yes	7	6	3	3	1	1
BMI5	Healthy weight	45	37	31	28	35	38
	Obese	30	25	33	30	27	29
	Overweight	47	38	45	42	30	33

¹Freq refers to Frequency; ²Blood pressure; ³Other complications include diabetic foot, heart complications, kidney complications, leg amputation and nephropathy each with less than ≤ 2 occurrences; ⁴Other conditions include asthma, eye problem, HIV, stroke, skin condition, Kidney disease, Neuropathy, Prostate hypertrophy, Stroke and Thyroid each with less than ≤ 3 occurrences; ⁵ BMI refers for body mass index.

Longitudinal glycemic levels

During the 3-month follow-up, we obtained 323 reports of glycemic measurements (HbA1c). Of these, 86 reports (27%) indicated good glycemic levels, while 237 reports (73%) showed elevated glycemic levels. Among the reports of good glycemic levels, 44(51%) came from females, and the majority, 70 reports (81%), were from individuals aged under 65 years (Figure 2). Over time, the number of good glycemic measurement reports slightly decreased among females and males (Figure 2A). For the 237 reports of poor glycemic level, 166(70%) were from females, and 176(70%) were from participants aged under 65 years. At the patient level, the proportion of patients with low glycemic levels decreased from 34% to 23% over time, regardless of age or sex. Conversely, the proportion of patients with elevated glycemic levels increased from 66% to 79% over the same period (Figure 2). Elevated glycemic levels were frequent among females compared to males and among those aged below 65 years. On the other hand, good glycemic levels were frequent among male compared to female and those aged above 50 years.

Distribution of diabetes medication and their comorbidity

The commonly used antidiabetic medications among patients included Metformin, insulin, and Glibenclamide, among others. Over time, the proportion of patients using insulin or combination therapy, which consists of Metformin and other medications, increased.

Conversely, the number of patients primarily using Metformin decreased from 36% to 17%. Among the various insulin prescriptions, Insulin Mixtard was the most frequently prescribed, accounting for 70% of prescriptions, while Humulin was prescribed in less than 18%. The use of Insulin Mixtard increased from 71% to 83%, while the prescription rate for Humulin rose from 2% to 18% over time (Table 3). Overall, more

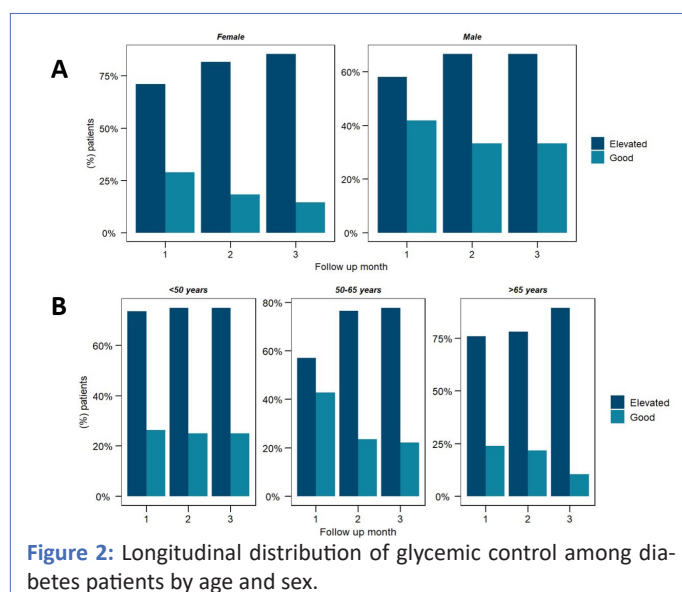


Figure 2: Longitudinal distribution of glycemic control among diabetes patients by age and sex.

than 85% of diabetes patients were prescribed more than two types of medications. The percentage of patients prescribed only one diabetes drug slightly decreased from 15% to 13%, while those prescribed more than two drugs increased slightly. Additionally, the incidence of comorbidities among patients rose significantly, from 25% to 59% during the follow-up period. Patients receiving medication for comorbidities also increased, from 38% to 46% over time (Table 3).

Univariate analysis

Univariate analysis associated months of diabetes medication use, diabetes treatment type, diabetes complications and daily fruits and vegetable servings, to glycemic levels, with significance at $p < 0.1$ (Table 4).

Table 3: Distribution of Diabetes comorbidity and prescribed medication.

Variable	Level	Baseline (n=122)		1 st follow up (n=109)		2 nd follow up (n=92)	
		Freq	(%)	Freq	(%)	Freq	(%)
Comorbidity	No	91	75	59	54	38	41
	Yes	31	25	50	46	54	59
Antidiabetic medication	Metformin	47	39	23	21	16	18
	Metformin, glibenclamide	38	31	35	32	25	27
	Insulin	13	11	12	11	13	14
	Metformin, other ¹	9	7	17	15	23	25
	Metformin, insulin	7	6	14	13	9	10
	Metformin, glibenclamide, insulin	3	2	4	4	4	4
	Glibenclamide	1	1	1	1		0
	None	4	3	3	3	2	2
	Other ¹	0	0	0	0	0	0
Insulin prescribed.	Insulin mixtard	9	69	9	82	10	77
	Humulin	2	15	2	18	-	0
	Regular insulin humulin	1	8	-	0	-	0
	Soluble insulin	1	8	-	0	-	0
	Humulin insulin mixtard	-	0	-	0	3	23
Taking comorbidity medication	No	75	61	71	65	50	54
	Yes	47	39	38	35	42	46
No. prescribed drugs	1	18	15	13	12	12	13
	2 to 4	76	62	66	61	57	62
	>5	28	23	30	27	23	25
HBA1AC	Good	43	35	25	23	19	21
	Poor	79	65	84	77	73	79

¹Other antidiabetic medications include dapagliflozin, Diamicon, Empiget, Sitagliptin, Trevi met, Amlodipine, pregabalin, Rovista, Varinil and Losartan.

Table 4: Univariate analysis of factors associated with glycemic control among type two diabetes patients.

Variable	Level	OR	OR 95% CI	P value
Month		0.21	0.09, 0.50	0.000
Sex	Male	Ref.	-	-
	Female	0.32	0.03, 3.53	0.353
Age in years	≤50	Ref.	-	-
	50-65	1.03	0.08, 13.91	0.984
	≥65	0.83	0.04, 18.66	0.908
Education level	Primary	Ref.	-	-
	Secondary	0.86	0.07, 10.75	0.906
	Tertiary	1.13	0.05, 24.28	0.936
Marital status	Divorced, single, widowed	Ref.	-	-
	Married	1.29	0.09, 19.60	0.853
Occupation	Unemployed, retired	Ref.	-	-
	Formal	1.62	0.03, 87.15	0.811
	Informal	0.63	0.05, 7.50	0.712
Income cat	≤10000	Ref.	-	-
	>10000	0.88	0.08, 9.83	0.916
Years taking DB treatment		0.92	0.77, 1.09	0.331
Years of living with DB		0.91	0.74, 1.11	0.349
DB treatment payment	Cash payment	Ref.	-	-
	Insurance	1.39	0.14, 13.58	0.776
Diabetic Family member	Don't know, no	Ref.	-	-
	Yes	0.75	0.08, 7.14	0.804
DB complication admittance	No	Ref.	-	-
	Yes	0.74	0.05, 11.85	0.832
Weight (Kgs)	Mean=73.4±13.6	0.97	0.90, 1.05	0.436
Height (M)	Mean=1.61±0.09	758.6	337.6, 1704	0.1946

BMI	Mean= 27.2±4.5	0.82	0.65, 1.03	0.09
Systolic BP		0.98	0.94, 1.02	0.234
Diastolic BP		0.99	0.94, 1.06	0.904
Diabetic treatment type	Injection and oral	Ref.	-	-
	Injection	0.08	0.001, 5.05	0.232
	Oral	1.61	0.17, 14.88	0.0674
Months taking medications	<3 months	Ref.	-	-
	≥3 months	8.05	0.78, 83.16	0.08
Forgot taking medication	No	Ref.	-	-
	Yes	0.53	0.09, 3.11	0.485
Medication side effect	No			
	Yes	8.74	0.64, 0.01	0.103
DB complication reports	No			
	Yes	6.52	1.02, 41.68	0.048
Complication admittance	No	Ref.	-	-
	Yes	1.67	0.13, 21.73	0.697
Hypertensive	No	Ref.	-	-
	Yes	4.84	0.60, 39.35	0.14
Test blood sugar	No			
	Yes	0.15	0.01, 2.34	0.175
Have glucometer strips	No	Ref.	-	-
	Yes	0.65	0.15, 2.86	0.57
Follow healthy diet plan	No	Ref.	-	-
	Yes	0.32	0.07, 1.54	0.155
Daily fruits vegetable servings		0.17	0.05, 0.66	0.010
Engage physical activity	No	Ref.	-	-
	Yes	3.36	0.76, 14.92	0.111
Take alcohol	No	Ref.	-	-
	Yes	1.73	0.02, 0.01	0.807
No. prescribed drugs	>1	Ref.	-	-
	4-Feb	0.49	0.07, 3.52	0.48
	>5	0.53	0.04, 6.46	0.622
Fasting blood sugar	Diabetic	Ref.	-	-
	Normal	0.67	0.24, 1.90	0.457
	Pre-diabetic	1.89	0.48, 7.39	0.362

DB: Refers to diabetes

Table 5: Multivariate analysis of factors associated with glycemic levels among diabetes patients.

Variable	Level	OR ¹	OR (95% CI) ²	P-value
Diabetes complication reports	No	Ref	-	-
	Yes	9.39	1.04, 85.23	0.047
Daily fruits vegetable servings		0.15	0.04, 0.61	0.008
Age categories	<50	Ref	-	-
	50-65	1.19	0.05, 30.6	0.915
	>65	1.53	0.03, 78.6	0.832
Sex	Female	0.28	0.02, 5.45	0.404
	Male	Ref	-	
Parameters				
	AIC	277		
	BIC	303.5		
	Log-Likelihood	-131.5		
Variance	Patients (Level 2)	180.1		
	Residual (Level 1)	3.29		

¹OR-Odds ratio; ²CI -confidence interval.

Multivariate analysis

In multivariate analysis, glycemic level is independently associated with diabetes complications and daily fruits and vegetable servings at $p < 0.05$. Patients with diabetes who had diabetes complications were nine-fold likely to have elevated glycemic levels when controlling for other factors. Additionally, patients taking daily fruits and vegetable servings were at 85% reduced risk of elevated glycemic levels holding all factors constant (Table 5). While the risk of elevated glycemic levels decreases among female patients, it increases with age when controlling for other factors, though this finding is not statistically significant at $p > 0.05$.

Considering significant risk factors, the variance estimate that measured the variation in the frequency of the outcome among the 122 patients was 180.1. In contrast, the residual variance (Level 1), which accounted for the variation in repeated measures of the outcome over time, was 3.29. Only 2% of the overall variation occurred across the repeated measures, resulting in an Inter-Cluster Correlation Coefficient (ICC) of 0.02. This was calculated using the formula $3.29 / (180.1 + 3.29)$ for Level 1. On the other hand, 98% of the overall variation was observed at the patient level, yielding an ICC of 0.98, calculated as $180.1 / (180.1 + 3.29)$ for Level 2. This latter ICC represents the correlation of the outcome for a random subject at two different time points, t and t' , where $t \neq t'$.

Discussion

This study established a longitudinal trend of glycemic levels among type 2 diabetes patients in an urban setting. Elevated glycemic levels are associated with diabetes complications and intake of fruits and vegetables. Risks of elevated glycemic levels increases with age, highlighting the need for age- and sex-specific interventions for better glycemic control, similar to findings from a study conducted in Ethiopia [28]. Given that half of the patients reported neuropathies, retinopathies, diabetic foot, among other complications from diabetes, a holistic approach integrating complication management is essential. To improve or maintain glycemic targets for diabetics, patient-centered interventions are necessary. These should include early diagnosis, treatment of complications, and nutrition counseling promoting healthy food choices and eating patterns rich in fruits and vegetables [29,30].

Diabetes complications were related to increased risk of elevated glycemic levels among diabetics by ninefold, suggesting a likelihood of high pill burden for complications treatment. Consequently, this raises the risk of medication non-adherence. Indeed, three in ten diabetes patients with complications used combined therapy medication and often forgot to take their medications. Consistent with our findings, studies in Turkey and Ethiopia show high pill burden is linked to elevated glycemic levels among patients with type 2 diabetes [31,32]. Moreover, diabetes complications lead to additional healthcare costs, which include expenses for dialysis, renal transplants, hospital admissions, emergency visits, and medications. These costs affect the overall accessibility of diabetes healthcare services [33,34]. Providing timely diabetes care while addressing medication costs and side effects is essential for ensuring medication adherence. This approach promotes patient-centered therapy combinations and appropriate prescriptions for maintaining recommended glycemic levels, as well as improving access to quality care [35,36].

Consuming daily servings of fruits and vegetables were associated with reduced risk of elevated glycemic levels by 85%, suggesting their protective role in managing blood glucose. These foods are rich sources of soluble dietary fiber, which slows down the digestion and absorption of sugar in the body's cells. This slows metabolism, aiding in blood sugar regulation and lowering cholesterol levels [37-39]. Most patients with good glycemic control reported consuming at least five servings of fruits and vegetables daily, which is consistent with findings from a study conducted in Saudi Arabia [40]. Promoting access to and adherence to a healthy diet rich in fruits and vegetables is crucial for managing type 2 diabetes. Additionally, it helps reduce the risk of metabolic diseases such as obesity and cardiovascular disease, supports intestinal health, and decreases incidence of certain types of cancers [41,42]. Fruits and vegetables serve as functional foods to alleviate symptoms of diabetes [43].

Patients who have been on diabetes medication for over three months are more likely to experience elevated glycemic levels, perhaps indicating disease progression. This advancement is often associated with the long duration of medication use or the choice of treatment, such as oral medications and injections, which can lead to side effects and issues with treatment compliance. These factors have been linked to higher glycemic levels, as indicated by studies conducted in Sub-Saharan Africa [44-46]. Additionally, fewer patients (7%) with poor glycemic control reported experiencing

side effects from their medications, including nausea, vomiting, flatulence, and diarrhea. These side effects can negatively impact their treatment adherence [46]. Strengthening of the healthcare systems and facilities providing timely care, addressing treatment intensification, managing medication costs or side effects and ensuring medication compliance while improving overall quality of care [35].

We acknowledge several limitations in our study. First, since our study sites being the primary referral hospitals in the county, our findings may not fully represent the entire population, as we cannot rule out missing population-level representation. However, the three-month follow-up period assessed the relationship between associated factors linked to elevated glycemic levels. Second, the weekly self-reported data on diet, physical activity, and self-care may be subject to recall bias. Nevertheless, the weekly data collected has been found to be relatively credible and reliable. Third, although we lost 10% of patients during the study period, our high response rate of 88% significantly minimized non-responder and selection bias. Moreover, the multilevel analysis statistically accounted for the missing data.

Conclusion

In conclusion, this study found that glycemic levels were associated with diabetic complications and unhealthy dietary practices among type 2 diabetes patients in an urban setting. Implementing appropriate patient-centered interventions is essential for maintaining optimal glycemic control, nutrition counselling as well as preventing and facilitating early detection and treatment of diabetes complications improving the quality of life.

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