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Glycemic Control and Lifestyle-Related Factors Among Adults With Type 2 Diabetes Attending Primary Health Care Centers in Wad Madani Grand Locality, Sudan

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Abstract

Background: Glycemic control is frequently suboptimal among adults with type 2 diabetes mellitus (T2DM).

Objective: To describe HbA1c-defined glycemic control as the primary outcome; assess lifestyle-related knowledge, attitudes, practices, and reported barriers as secondary descriptive outcomes; and explore associated factors among adults with T2DM attending primary health care centers in Wad Madani Grand Locality, Gezira State, Sudan.

Methods: This analytical cross-sectional baseline study included 260 adults attending Al-Daraja and Abu Sunun centers from May 4 to August 1, 2026. Questionnaire responses and recorded HbA1c and blood glucose (fasting status unverified) were analyzed. Control categories were derived from HbA1c. Exploratory analyses included chi-square tests with Monte Carlo p-values for sparse tables, Kruskal-Wallis tests, correlations, and multivariable regressions using 256 complete cases. Conclusions were restricted to descriptive findings because of model and measurement limitations.

Results: Mean HbA1c was 10.5±2.5%. Poor control (HbA1c >9%) occurred in 178 (68.5%) participants, moderate control (7-9%) in 55 (21.2%), and good control (<7%) in 27 (10.4%). Recorded knowledge and attitude responses were generally favorable. Weight-management behaviors and daily fruit and vegetable intake were less consistently reported than medication use and follow-up. Cultural dietary habits, 218 (85.8%), and financial constraints, 212 (83.5%), were the most frequent barriers among 254 respondents. Practice-score interpretation was limited by differences between printed response options and stored coding. The logistic model failed calibration assessment (Hosmer-Lemeshow p=0.008); its odds ratios were not used for independent-predictor or clinical inference. The small diet-only group (n=9), low explained variance, and other limitations also restricted interpretation of the exploratory linear model.

Conclusion: Poor glycemic control was common in these two centers. Reported cultural and financial barriers and less consistently reported dietary and weight-management behaviors warrant further assessment in primary care. The cross-sectional design and measurement and model limitations prevent causal or treatment-effect conclusions.

Categories: Family/General Practice, Epidemiology/Public Health, Endocrinology/Diabetes/Metabolism
Keywords: attitude and practice, glycemic control, hba1c, knowledge, lifestyle practices, primary health care, sudan, type 2 diabetes mellitus

Introduction

Diabetes has become substantially more prevalent worldwide. World Health Organization estimates indicate that the number of people living with diabetes increased from about 200 million in 1990 to 830 million in 2022, with the increase occurring particularly rapidly in low- and middle-income countries; diabetes and diabetes-related kidney disease accounted for more than two million deaths in 2021 [1]. The International Diabetes Federation estimated 589 million adults aged 20-79 years living with diabetes in 2024 and projects approximately 853 million by 2050 [2]. In the WHO African Region, 54 million adults aged 18 years or older were estimated to have diabetes in 2022, and more than half were reported to be undiagnosed and untreated [3].

HbA1c provides an established measure of longer-term glycemic exposure and is central to monitoring treatment response in adults with type 2 diabetes mellitus (T2DM). The American Diabetes Association recommends an HbA1c goal below 7% for many nonpregnant adults while emphasizing that the appropriate target should be individualized according to clinical circumstances, treatment burden, hypoglycemia risk, and patient preferences [4]. Current diabetes care recommendations also address nutrition, physical activity, weight management, self-management education and support, and other health behaviors rather than

relying on medication alone [5].

Evidence from Sudan consistently indicates that inadequate glycemic control is common. In a population-based study involving 387 Sudanese adults with T2DM, 85% had HbA1c values above 7% [6]. In Northern Sudan, Abdel Bagi and Ewis found uncontrolled diabetes in 65.2% of 2,047 patients with diabetes [7]. Earlier population-based research in Northern Sudan also documented a substantial burden of T2DM and an increase in prevalence over time [8]. More recently, a facility-based study in Khartoum reported that 99.0% of participants had good dietary knowledge and 99.5% had a positive attitude, while 80% reported poor dietary practice; cost and social circumstances were among the reported barriers [9]. Evidence syntheses from low- and middle-income countries and the WHO African Region indicate that diabetes self-management education and support can reduce HbA1c, although the magnitude of benefit varies between interventions and populations [10,11].

The available Sudanese literature has not fully characterized, within a single primary-care population in Gezira State, glycemic control together with lifestyle-related knowledge, attitudes, practices, and reported barriers. The primary outcome was the distribution of HbA1c-defined glycemic-control categories. Secondary descriptive outcomes were lifestyle-related knowledge, attitude, and practice scores, and frequencies of reported barriers. Associations with clinical and sociodemographic characteristics were exploratory. Regression estimates are reported for transparency and are not used to establish independent predictors, treatment effects, or clinical recommendations.

Materials And Methods

Study design and setting

A facility-based analytical cross-sectional study was conducted at two primary health care centers providing structured diabetes services in Wad Madani Grand Locality, Gezira State, Sudan: Al-Daraja Health Care Centre and Abu Sunun Health Care Centre. Baseline data were collected from May 4, 2026, to August 1, 2026. The two centers were purposively selected based on diabetes clinic attendance and the availability of laboratory support for HbA1c measurement. The present analysis uses the single-point baseline assessment collected at enrollment in an unpublished parent study evaluating an integrated structured lifestyle modification program. Outcomes related to the subsequent intervention phase are outside the scope of this cross-sectional analysis.

Study population and eligibility criteria

The study population comprised adults aged 18 years or older with confirmed T2DM attending follow-up care at the selected centers. Participants were included if they had confirmed T2DM, were registered for follow-up at one of the two centers, and provided written informed consent. Adults with gestational diabetes, severe cognitive impairment precluding informed consent, or critical illness preventing completion of the interview were excluded.

Sample size and sampling technique

The sample-size calculation used the single-population-proportion formula with a planning proportion of 0.19, 95% confidence, and a 5% margin of error. A published population-based study reported diabetes mellitus prevalence of 19.1% in urban communities of northern Sudan [12]; this regional estimate is not a national estimate specifically for T2DM. The original planning source could not be established from the available records. The stated assumptions yield a minimum of 237 participants; a 10% increase yields a target of approximately 261. Eligible participants were recruited by systematic random sampling from daily clinic attendance lists, using an interval determined from the eligible attendees and a randomly selected starting point. The analysis included 260 participants: 226 from Al-Daraja and 34 from Abu Sunun.

Data collection instrument

Data were collected using a structured interviewer-administered questionnaire covering sociodemographic characteristics, clinical and diabetes-related information, knowledge, attitude, and practice regarding lifestyle modification, and perceived barriers to lifestyle adherence (Appendix A). Content validity was established through expert review by specialists in family medicine, endocrinology, public health, and epidemiology, and face validity was assessed for clarity and cultural appropriateness. A pilot study involving 26 participants (approximately 10% of the calculated sample), drawn from the same target population but excluded from the final analysis, was used to refine wording, assess administration time, and provide a preliminary assessment of internal consistency. Trained data collectors administered the questionnaire in a private setting to protect confidentiality.

Study variables

Study variables comprised sociodemographic characteristics (age, sex, marital status, educational level, employment status, monthly income, residence, and study center); clinical and disease-related characteristics (duration since diagnosis, current treatment modality, diabetes-related complications,

frequency of follow-up visits, regularity of prescribed treatment use, use of herbal or traditional treatment, smoking status, and body mass index (BMI)); anthropometric and biochemical measures (weight, height, BMI, blood glucose, and HbA1c); lifestyle-related knowledge, attitude, and practice; and perceived barriers to lifestyle adherence.

Assessment of glycemic control

Glycemic control was assessed from the baseline HbA1c values recorded in the study dataset; blood glucose was analyzed separately. Laboratory investigations were conducted specifically for the study. A mobile physician experienced in blood sample collection invited participants to a local laboratory within the study area. Before collecting samples, the physician explained the study objectives and participant protections and obtained explicit informed consent. Blood samples were then collected, followed by completion of the questionnaire for each participant. Participant confidentiality was maintained, and safety precautions were followed during sample collection. HbA1c and blood glucose results were recorded in the study dataset for all 260 participants. Venous blood samples were obtained from the arm. The physician performed the laboratory measurements using an automated laboratory analyzer, and HbA1c results were available during the visit after approximately 40 minutes. Blood glucose was also measured using a laboratory analyzer. Fasting status was not verified; therefore, glucose measurements are reported as blood glucose rather than confirmed fasting blood glucose. Although the questionnaire requested a fasting value, that wording does not establish fasting status. The laboratory name, analyzer make and model, and specific assay principles were not recorded in the available documentation. Assay standardization and quality-control procedures also cannot be verified; none is assumed. Fasting uncertainty affects interpretation of the separate glucose measurement, rather than the HbA1c-based definition of control. For descriptive and bivariate analyses, groups were derived directly from recorded HbA1c: good <7%, moderate 7-9%, and poor >9%. Sixteen pre-entered questionnaire categories disagreed with these thresholds and were replaced by the derived categories for analysis without changing the HbA1c observations. Poor control was defined as HbA1c >9% for logistic regression. The operational categories have been used in previous Sudanese research [13].

Knowledge, attitude, and practice assessment

Knowledge was scored using the 11-question key in the supplied IBM SPSS Statistics for Windows (IBM Corp., Armonk, New York, United States) syntax: one point per correct question, with multiple-response questions requiring the complete correct selection pattern. The percentage score was $totalcorrect/11 \times 100$. The information-source item was not scored. The key is reproduced in Appendix B. Attitude scores used 15 items (Q31-Q45), coded 2=disagree, 3=neutral, and 4=agree in the observed data. Practice scores used 18 frequency items, coded 1=never, 2=rarely, 3=sometimes, 4=often, and 5=always in the analysis file. Item means used available responses; the fruit and vegetable item had one missing response. The supplied questionnaire displays three attitude options and four practice options, without never; the analysis retained the response labels and numerical codes documented in the original SPSS file, without adding a response option to the printed questionnaire or shifting stored scores. The author confirmed that the supplied printed questionnaire was the instrument administered in the field; its four practice choices therefore differ from the five response labels stored in SPSS. The Diploma category was retained as recorded in the education data, although it is absent from the printed options. These instrument documentation differences are acknowledged as limitations. Cronbach's alpha assessed internal consistency. Barriers were recorded as multiple selections. The original knowledge categories were poor <60%, moderate 60% to <80%, and good ⩾80%; no unvalidated categorical thresholds were imposed on attitude or practice scores. The four-versus-five-option discrepancy cannot be assumed to represent a uniform additive shift. Its effect on individual practice scores, response meanings, and associations cannot be quantified from the available documentation. Scores were not retrospectively recoded and should not be interpreted as validated levels of adherence. Internal consistency does not resolve this documentation discrepancy.

Ethical considerations

Ethical approval for the parent study was granted by the Health-Sector Ethical Review Committee, University of Gezira, Wad Madani, Sudan (Approval No. 26/2026; dated May 3, 2026). The present cross-sectional baseline analysis is derived from the approved study, "The Effect of Integrated Structured Lifestyle Modifications Program on Glycemic Control among Adults with Type 2 Diabetes Attending Primary Health Care Centers in Wad Madani Grand Locality, Gezira State, Sudan." Administrative permission was obtained from the local health authorities and participating centers. Written informed consent was obtained from all participants after explanation of the study purpose and procedures. Participants were informed of their right to withdraw without affecting access to routine health care. Confidentiality was maintained throughout, and findings were reported in aggregate form.

Statistical analysis

Data were initially coded and analyzed in IBM SPSS Statistics for Windows, Version 24 (Released 2016; IBM Corp., Armonk, New York, United States). Revision analyses used Python 3.12 (Python Software Foundation, Fredericksburg, VA) and SciPy 1.17.0, with the supplied raw workbook and SPSS data and syntax checked against each other. Categorical summaries use valid-response denominators. Pearson chi-square tests compared categorical characteristics across HbA1c-derived groups; conditional Monte Carlo p-values used

100,000 fixed-margin tables (seed 20261011) when any expected count was <1 or more than 20% were <5. Continuous comparisons used tie-corrected Kruskal-Wallis tests and median (25th-75th percentiles), given skewness and ceiling effects. Pearson correlations were retained from the verified output; Spearman correlation assessed the practice association as a sensitivity analysis. The original simultaneous linear regression modeled HbA1c using age, BMI, sex, complications, residence, center, treatment indicators, and knowledge, attitude, and practice scores. Binary logistic regression was re-estimated using HbA1c >9% versus ⩽9%, with the same covariates and the original two treatment indicators. Treatment reference categories differ between the models and are specified in their legends. Both regressions used 256 complete cases, excluding four participants with missing age, residence, or complication responses. Missing questionnaire and regression covariate responses were not imputed. BMI was retained for the 238 participants with a recorded BMI and calculated as weight (kg)/height (m) squared for the 22 participants with a blank BMI but valid recorded weight and height. These calculations reproduce the supplied SPSS BMI variable and derive BMI from existing measurements rather than estimate missing measurements. Three raw height entries (106, 107, and 170 in a field labeled meters) were excluded from the height summary because their units or intended values could not be verified. The corresponding heights reconstructed from weight and BMI in the supplied SPSS file were not treated as measured heights. The height summary therefore uses 257 observations; the recorded BMI values for those three participants were retained. Raw source values were preserved. Tests were two-sided with $p<0.05$; bivariate comparisons were exploratory without multiplicity adjustment. Strengthening the Reporting of Observational Studies in Epidemiology (STROBE)-guided reporting [14]. All listed covariates were entered simultaneously; stepwise significance-based selection was not used. In response to peer review, conclusions are restricted to descriptive findings. Previously fitted regression estimates are retained solely for transparent reporting of exploratory analyses, without independent-predictor, causal, or clinical inference. The logistic model failed its calibration assessment (Hosmer-Lemeshow $p=0.008$), so its odds ratios are not interpreted as reliable evidence of association. No newly calibrated or validated prediction model is claimed. The linear model is also exploratory, with low explained variance and unverified residual assumptions; its coefficients do not establish treatment benefit.

Results

Of the 260 participants, 226 (86.9%) were recruited from Al-Daraja Health Care Centre and 34 (13.1%) from Abu Sunun Health Care Centre. The mean age was 60.8±11.5 years (range, 26-96 years), and 148 (57.1%) were aged 60 years or older. Females constituted 175 (67.3%) of the sample, and 190 (73.1%) were married. Just over half, 134 (51.5%), had no formal education or only primary schooling, while 39 (15.0%) held a university degree or higher. Most participants were housewives, 155 (59.8%), reported a low monthly income, 153 (58.8%), and resided in urban areas, 205 (79.2%). The sociodemographic distribution is presented in Table *1*.

Variable	Category	n	%
Study center	Al-Daraja	226	86.9
	Abu Sunun	34	13.1
Sex	Male	85	32.7
	Female	175	67.3
Age group (years)	<40	7	2.7
	40-49	33	12.7
	50-59	71	27.4
	60-69	83	32.0
	≥70	65	25.1
Marital status	Married	190	73.1
	Single	9	3.5
	Widowed	50	19.2
	Divorced	11	4.2
Educational level	No formal education	62	23.8
	Primary	72	27.7
	Intermediate	26	10.0
	Secondary	59	22.7
	Diploma	2	0.8
	University	35	13.5
	Postgraduate	4	1.5
Employment status	Employee	24	9.3
	Self-employed	38	14.7
	Housewife	155	59.8
	Retired	31	12.0
	Unemployed	11	4.2
Monthly income	Low	153	58.8
	Medium	106	40.8
	High	1	0.4

TABLE 1: Sociodemographic characteristics of study participants (N=260)

Percentages are based on valid responses. Age and employment each had 259 valid responses and one missing response; the other variables displayed had 260 valid responses. Residence, reported in the text, also had 259 valid responses and one missing response. Percentages may not total 100% because of rounding.

Clinical and disease-related characteristics

More than half of participants, 142 (54.6%), had been diagnosed with T2DM for more than 10 years, and 79 (30.4%) for six to 10 years. Oral medication was the predominant treatment modality, used by 193 (74.2%) participants, followed by insulin, used by 57 (21.9%). Diabetes-related complications were reported by 197 (76.4%) participants, and 253 (97.3%) attended follow-up visits monthly. More than half, 140 (53.8%), reported using herbal or traditional remedies alongside conventional treatment,

and none reported current smoking. Clinical and disease-related characteristics are summarized in Table 2; anthropometric and biochemical measurements are shown in Table 3.

Variable	Category	n	%
Duration since diagnosis	<1 year	14	5.4
	1-5 years	25	9.6
	6-10 years	79	30.4
	>10 years	142	54.6
Current treatment	Diet only	9	3.5
	Oral medication only	193	74.2
	Insulin	57	21.9
	Both oral and insulin	1	0.4
Diabetes-related complications	No	61	23.6
	Yes	197	76.4
Frequency of follow-up visits	Monthly	253	97.3
	Every 6 months	3	1.2
	Irregular	4	1.5
Regular use of prescribed treatment	Regular	259	99.6
	Sometimes	1	0.4
BMI category	Underweight	2	0.8
	Normal	77	29.6
	Overweight	90	34.6
	Obese	91	35.0
Use of herbal/traditional treatment	No	120	46.2
	Yes	140	53.8
Current smoking	No	260	100.0

TABLE 2: Clinical and disease-related characteristics of study participants (N=260)

Percentages are based on valid responses. Diabetes-related complications had 258 valid responses (197 yes and 61 no); two participants had missing responses. This was a single yes/no item, not a multiple-response category. Other variables shown have 260 valid responses.

BMI: body mass index

Variable	Mean±SD	Median	Min	Max
Age (years)	60.8±11.5	61.0	26.0	96.0
Weight (kg)	70.7±13.9	70.0	28.0	112.0
Height (m)	1.59±0.09	1.60	1.40	1.80
BMI (kg/m²)	28.3±5.4	27.5	17.3	49.8
Blood glucose (mg/dL)	238.2±105.9	221.0	27.0	629.0
HbA1c (%)	10.5±2.5	10.7	5.4	15.0

TABLE 3: Anthropometric and biochemical characteristics of study participants (N=260)

Age: n=259 (one missing); height: n=257 (three unverified raw entries excluded); other variables: n=260. The three heights reconstructed from weight and BMI in the supplied IBM SPSS Statistics for Windows (IBM Corp., Armonk, New York, United States) file were excluded from the height summary; their recorded BMI values were retained. BMI was recorded for 238 participants and derived as weight (kg)/height (m) squared for 22 participants with a blank BMI and valid recorded weight and height. Rounded height summary values are unchanged after exclusion.

SD: standard deviation; BMI: body mass index; HbA1c: glycated hemoglobin; Min: minimum; Max: maximum

Baseline mean HbA1c was 10.5%, above the usual treatment target of <7% for most nonpregnant adults [4]. Mean BMI was 28.3 kg/m², within the overweight range.

Glycemic control

Based on the prespecified thresholds applied directly to recorded HbA1c, 178 (68.5%) participants had poor control (HbA1c >9%), 55 (21.2%) had moderate control (HbA1c 7-9%), and 27 (10.4%) had good control (HbA1c <7%). Sixteen questionnaire classifications were discordant with the corresponding HbA1c values; analyses therefore used categories derived from the recorded laboratory values. The distribution is shown in Figure *1*.

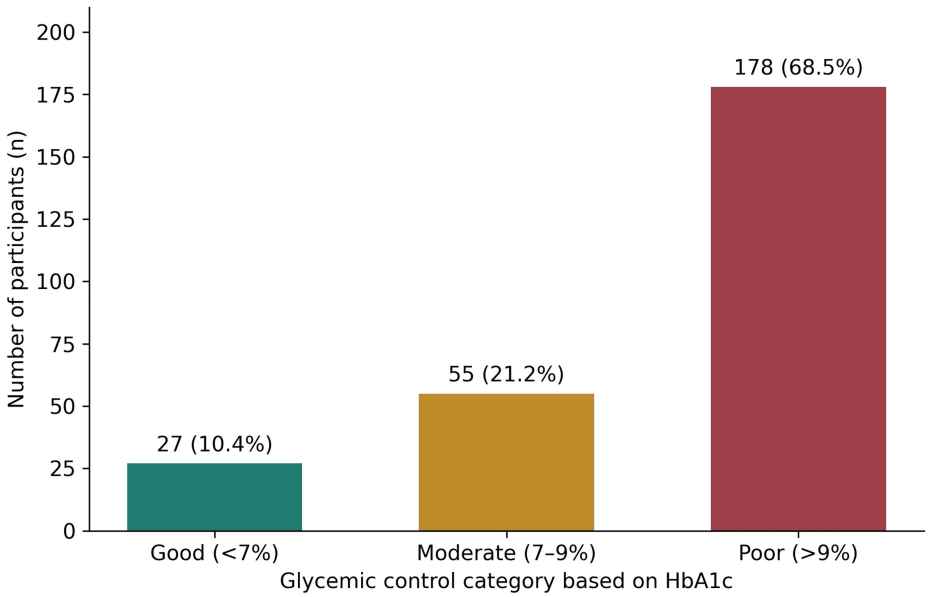


FIGURE 1: Distribution of glycemic control status among study participants (N=260)

Values are n (%), with a denominator of N=260. Glycemic-control categories were derived directly from recorded HbA1c: good <7%, moderate 7-9%, and poor >9%. All participants had recorded HbA1c values. Percentages may total 100.1% because of rounding.

HbA1c: glycated hemoglobin

Knowledge regarding lifestyle modification

Knowledge of diabetes lifestyle modification was high overall. A healthy diet was correctly identified as beneficial by 258 (99.2%) participants, and regular physical activity and weight control by 260 (100.0%) each. Recognition of individual hyperglycemia symptoms ranged from 247 (95.0%) to 258 (99.2%), and hypoglycemia symptoms from 243 (93.5%) to 258 (99.2%). Selected item-level responses are presented in Table 4. The overall mean knowledge score was 80.1±4.7%.

Knowledge item	Correct, n (%)
Healthy diet helps control blood glucose	258 (99.2)
Regular physical activity lowers blood glucose	260 (100.0)
Weight gain worsens glycemic control	260 (100.0)
Smoking increases risk of complications	260 (100.0)
Lifestyle modification can reduce medication need	260 (100.0)
Recommended diet includes complex carbohydrates	256 (98.5)
Correctly excludes sugary/refined sweets	256 (98.5)
Correctly excludes high-intensity exercise	259 (99.6)
Hyperglycemia symptom - headache	247 (95.0)
Hyperglycemia symptom - thirst	258 (99.2)
Hyperglycemia symptom - increased urination	257 (98.8)
Hyperglycemia symptom - blurred vision	257 (98.8)
Hypoglycemia symptom - tremor	243 (93.5)
Hypoglycemia symptom - rapid heartbeat	250 (96.2)
Hypoglycemia symptom - sweating	258 (99.2)

TABLE 4: Selected item-level knowledge responses regarding diabetes lifestyle modification (N=260)

Values are n (%) with N=260. The table presents selected item-level correct selections, not the total score. The total knowledge score comprises 11 questions, with one point per correct question; multiple-response questions require the complete correct selection pattern. The information-source question is descriptive and excluded from scoring. The scoring key is provided in Appendix B.

Attitude toward lifestyle modification

Attitude responses were represented by codes 4 (agree), 3 (neutral), and 2 (disagree) in the analysis file. The 15-item domain had good internal consistency (Cronbach's alpha=0.896). The overall mean recorded attitude score was 3.99±0.07 (total score, 59.9±1.1). Agreement with a healthy lifestyle helps glycemic control was reported by 258 (99.2%) participants; confidence in maintaining healthy changes and support from health care providers were each reported by 256 (98.5%).

Lifestyle practice

Lifestyle practice scores were calculated from 18 frequency-coded items in the analysis file (Cronbach's alpha=0.759). The overall mean recorded score was 4.62±0.28; the total score was 83.2±5.0. Self-reported adherence was highest for taking medication as prescribed, 243 (93.5%) always; avoiding sugar and sweetened drinks, 244 (93.8%); measuring glucose at home when symptoms of high or low glucose occur, 252 (96.9%); and attending scheduled follow-up appointments, 236 (90.8%). Weight-related behaviors had lower adherence: 160 (61.5%) always followed medical advice on weight management, 155 (59.6%) took action to control weight, 151 (58.1%) made a sustained effort to control weight, and 154 (59.2%) monitored weight regularly. Daily fruit and vegetable intake had the lowest adherence, with five (1.9%) reporting always and 254 (98.1%) reporting less than always among 259 valid responses. Selected behaviors are summarized in Table 5.

Practice item	"Always", n (%)	Not always, n (%)
Adherence to medical nutrition advice	230 (88.5)	30 (11.5)
Following the recommended diet	231 (88.8)	29 (11.2)
Eating regular meals	232 (89.2)	28 (10.8)
Avoiding sugar and sweetened drinks	244 (93.8)	16 (6.2)
Avoiding harmful fats	243 (93.5)	17 (6.5)
Eating vegetables and fruit daily	5 (1.9)	254 (98.1)
Following advice on exercise	216 (83.1)	44 (16.9)
Exercising ≥30 min on several days/week	205 (78.8)	55 (21.2)
Following medical advice on weight management	160 (61.5)	100 (38.5)
Taking action to reduce/maintain weight	155 (59.6)	105 (40.4)
Regular weight measurement/monitoring	154 (59.2)	106 (40.8)
Regular home glucose monitoring	214 (82.3)	46 (17.7)
Adherence to medication dose/schedule	243 (93.5)	17 (6.5)
Attendance at scheduled follow-ups	236 (90.8)	24 (9.2)
Home glucose measurement when high or low glucose symptoms occur	252 (96.9)	8 (3.1)

TABLE 5: Frequency of selected lifestyle practice behaviors among study participants (N=260)

Values are n (%), with percentages based on valid item responses. The daily fruit and vegetable item had 259 valid responses and one missing response. All other items displayed had 260 valid responses. Not always combines often, sometimes, rarely, and never.

Barriers to lifestyle adherence

Participants most frequently selected cultural dietary habits, 218 (85.8%), and financial constraints, 212 (83.5%). Less frequent selections were lack of family support, 20 (7.9%); lack of motivation, 10 (3.9%); lack of knowledge, four (1.6%); physical limitations, three (1.2%); and other barriers, one (0.4%). No participant selected lack of time (0.0%), and 21 (8.3%) selected no barriers (Figure *2*).

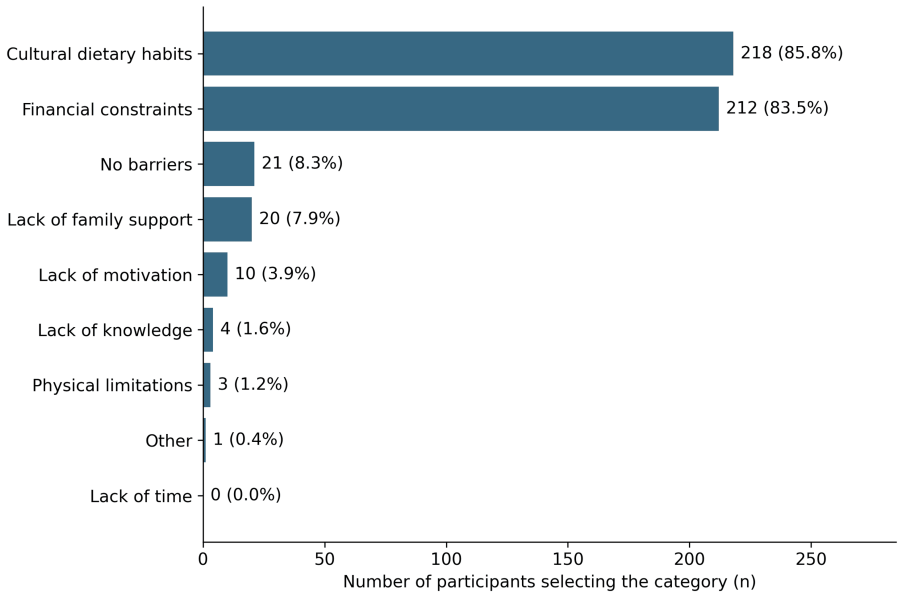


FIGURE 2: Reported barriers to lifestyle adherence among study participants (multiple responses; N=254)

Values are n (%), with percentages based on 254 participants with at least one recorded selection. Six of the 260 participants had no recorded selection for this item and were excluded from the percentage denominator; a blank response was not interpreted as an absence of barriers. Multiple selections were permitted (489 selections), so percentages do not sum to 100%. The figure includes no barriers, other, and lack of time as recorded categories.

Associations between glycemic control and participant characteristics

Participant characteristics associated with the corrected glycemic-control categories were sex (p=0.046), employment status (p=0.005), current treatment (p=0.046), follow-up frequency (p=0.026), and age category (p=0.003). Diet-only treatment included four of nine (44.4%) participants with good control; 43 of 57 (75.4%) participants receiving insulin had poor control. Poor control was present in six of 14 (42.9%) participants diagnosed for less than one year and 100 of 142 (70.4%) diagnosed for more than ten years, although the overall association with duration was not statistically significant (p=0.085). Complications were not significantly associated with the corrected categories (p=0.156). The remaining comparisons were not statistically significant (Table *6*).

Variable	Category	Valid n	Good (n=27), n (%)	Moderate (n=55), n (%)	Poor (n=178), n (%)	χ^2 (df)	p-value
Sex	Male	85	14 (16.5)	20 (23.5)	51 (60.0)	6.162 (2)	0.046*
	Female	175	13 (7.4)	35 (20.0)	127 (72.6)		
Marital status	Married	190	19 (10.0)	44 (23.2)	127 (66.8)	5.034 (6)	0.540†
	Single	9	2 (22.2)	1 (11.1)	6 (66.7)		
	Widowed	50	6 (12.0)	7 (14.0)	37 (74.0)		
	Divorced	11	0 (0.0)	3 (27.3)	8 (72.7)		
Education	No formal education	62	6 (9.7)	11 (17.7)	45 (72.6)	8.413 (12)	0.751†
	Primary	72	10 (13.9)	15 (20.8)	47 (65.3)		
	Intermediate	26	3 (11.5)	8 (30.8)	15 (57.7)		
	Secondary	59	5 (8.5)	9 (15.3)	45 (76.3)		
	Diploma	2	0 (0.0)	0 (0.0)	2 (100.0)		
	University	35	3 (8.6)	11 (31.4)	21 (60.0)		

	Postgraduate	4	0 (0.0)	1 (25.0)	3 (75.0)		
Employment	Employee	24	0 (0.0)	9 (37.5)	15 (62.5)	22.291 (8)	0.005*†
	Self-employed	38	5 (13.2)	6 (15.8)	27 (71.1)		
	Housewife	155	15 (9.7)	26 (16.8)	114 (73.5)		
	Retired	31	6 (19.4)	13 (41.9)	12 (38.7)		
	Unemployed	11	1 (9.1)	1 (9.1)	9 (81.8)		
Monthly income	Low	153	17 (11.1)	29 (19.0)	107 (69.9)	1.691 (4)	0.677†
	Medium	106	10 (9.4)	26 (24.5)	70 (66.0)		
	High	1	0 (0.0)	0 (0.0)	1 (100.0)		
Residence	Urban	205	22 (10.7)	46 (22.4)	137 (66.8)	1.088 (2)	0.580
	Rural	54	5 (9.3)	9 (16.7)	40 (74.1)		
Duration since diagnosis	<1 year	14	3 (21.4)	5 (35.7)	6 (42.9)	11.065 (6)	0.085†
	1-5 years	25	4 (16.0)	8 (32.0)	13 (52.0)		
	6-10 years	79	9 (11.4)	11 (13.9)	59 (74.7)		
	>10 years	142	11 (7.7)	31 (21.8)	100 (70.4)		
Treatment	Diet only	9	4 (44.4)	2 (22.2)	3 (33.3)	13.700 (6)	0.046*†
	Oral medication only	193	19 (9.8)	43 (22.3)	131 (67.9)		
	Insulin	57	4 (7.0)	10 (17.5)	43 (75.4)		
	Both	1	0 (0.0)	0 (0.0)	1 (100.0)		
Diabetes-related complications	No	61	10 (16.4)	14 (23.0)	37 (60.7)	3.713 (2)	0.156
	Yes	197	17 (8.6)	39 (19.8)	141 (71.6)		
Follow-up	Irregular	4	1 (25.0)	1 (25.0)	2 (50.0)	12.398 (4)	0.026*†
	Every six months	3	0 (0.0)	3 (100.0)	0 (0.0)		
	Monthly	253	26 (10.3)	51 (20.2)	176 (69.6)		
Regular treatment use	Regular	259	27 (10.4)	55 (21.2)	177 (68.3)	0.462 (2)	1.000†
	Sometimes	1	0 (0.0)	0 (0.0)	1 (100.0)		
BMI category	Underweight	2	1 (50.0)	0 (0.0)	1 (50.0)	5.487 (6)	0.470†
	Normal	77	7 (9.1)	15 (19.5)	55 (71.4)		
	Overweight	90	10 (11.1)	23 (25.6)	57 (63.3)		
	Obese	91	9 (9.9)	17 (18.7)	65 (71.4)		
Age category (years)	<40	7	0 (0.0)	1 (14.3)	6 (85.7)	24.173 (8)	0.003*†
	40-49	33	5 (15.2)	4 (12.1)	24 (72.7)		
	50-59	71	1 (1.4)	23 (32.4)	47 (66.2)		
	60-69	83	8 (9.6)	11 (13.3)	64 (77.1)		
	≥70	65	13 (20.0)	16 (24.6)	36 (55.4)		

TABLE 6: Association between glycemic control status and sociodemographic and clinical characteristics (N=260)

Values are n (%); percentages are within each category row. Groups were recalculated from recorded HbA1c: good <7%, moderate 7-9%, and poor >9%. Pearson chi-square tests were used. † denotes a conditional Monte Carlo p-value for the Pearson statistic, using 100,000 tables with fixed margins and seed 20261011, when any expected count was <1 or more than 20% were <5. Other p-values are asymptotic Pearson chi-square p-values. Employment, residence, and age each had 259 valid responses (one missing); complications had 258 (two missing); other variables had 260. * denotes p<0.05.

HbA1c: glycated hemoglobin; BMI: body mass index; χ^2: Pearson chi-square statistic; df: degrees of freedom

Continuous variables by glycemic control group

Overall, age and blood glucose differed across the corrected glycemic-control groups (p=0.020 and p<0.001, respectively). Median blood glucose was 135.0 mg/dL in the good-control group, 180.0 mg/dL in the moderate-control group, and 262.0 mg/dL in the poor-control group. BMI, knowledge percentage, attitude score, and practice score did not differ significantly (Table 7). Figure 3 presents mean HbA1c and blood glucose in separate panels, with units and group sizes shown. The HbA1c gradient reflects the thresholds defining the groups and is descriptive.

Variable	Good (n=27)	Moderate (n=55)	Poor (n=178)	Test statistic	p-value
Age (years)	69.0 (62.0-73.5)	59.0 (52.0-70.5)	60.0 (53.0-66.0)	H=7.794	0.020*
BMI (kg/m²)	26.6 (24.5-31.6)	27.7 (24.4-30.4)	27.5 (24.0-31.6)	H=0.122	0.941
Blood glucose (mg/dL)	135.0 (108.5-176.0)	180.0 (125.0-214.5)	262.0 (197.3-343.5)	H=66.253	<0.001*
Knowledge (%)	81.8 (81.8-81.8)	81.8 (81.8-81.8)	81.8 (81.8-81.8)	H=3.848	0.146
Attitude mean score	4.00 (4.00-4.00)	4.00 (4.00-4.00)	4.00 (4.00-4.00)	H=1.559	0.459
Practice mean score	4.72 (4.58-4.89)	4.78 (4.61-4.83)	4.67 (4.46-4.83)	H=2.612	0.271

TABLE 7: Comparison of continuous baseline variables by glycemic control group (N=260)

Values are median (25th-75th percentiles). All comparisons use the two-sided Kruskal-Wallis test with tie correction; H is the test statistic, with 2 degrees of freedom. A consistent nonparametric analysis was used because several measures were skewed or had marked ceiling effects. Groups were recalculated from recorded HbA1c: good <7%, moderate 7-9%, and poor >9%. Age had 259 valid observations (good n=27, moderate n=55, poor n=177); all other variables had 260. HbA1c is omitted as a comparison variable because it defines the groups. * denotes p<0.05.

BMI: body mass index; HbA1c: glycated hemoglobin

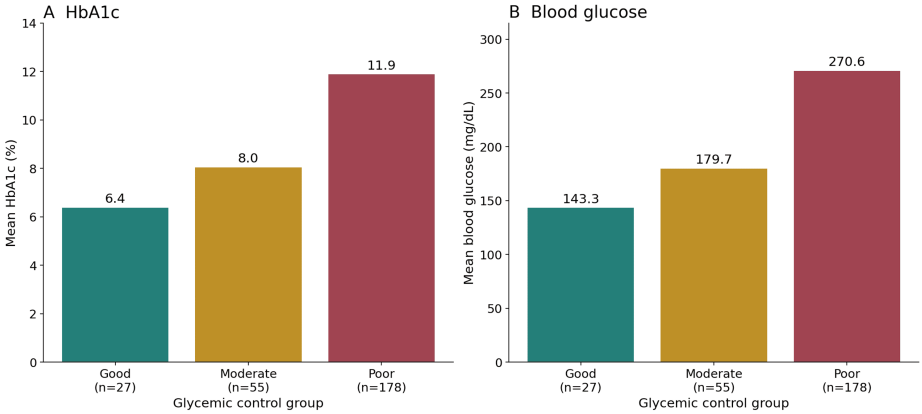


FIGURE 3: Mean HbA1c and blood glucose by glycemic control group

Panel A shows mean HbA1c (%); panel B shows mean blood glucose (mg/dL), using separate y-axes to preserve the original units. Groups were derived directly from recorded HbA1c: good <7% (n=27), moderate 7-9% (n=55), and poor >9% (n=178); total N=260, with no missing laboratory values. Mean HbA1c values were 6.4%, 8.0%, and 11.9%; mean blood glucose values were 143.3, 179.7, and 270.6 mg/dL, respectively. The HbA1c gradient is descriptive because HbA1c defines the groups.

HbA1c: glycated hemoglobin

Correlation between HbA1c and selected variables

HbA1c was positively correlated with blood glucose (r=0.575, p<0.001) and weakly negatively correlated with age (r=-0.169, p=0.006). No significant Pearson correlations were observed between HbA1c and BMI (r=-0.002, p=0.975), knowledge percentage (r=-0.079, p=0.207), or attitude score (r=-0.030, p=0.629). The Pearson correlation between HbA1c and practice score was borderline (r=-0.121, p=0.052), whereas the corresponding Spearman correlation was significant (ρ=-0.127, p=0.041), indicating a weak inverse association that was sensitive to the choice of correlation statistic (Table *8*).

Variable	r with HbA1c	p-value
Blood glucose (mg/dL)	0.575	< .001*
Age (years)	-0.169	.006*
BMI (kg/m²)	-0.002	0.975
Knowledge (%)	-0.079	0.207
Attitude (mean score)	-0.030	0.629
Practice (mean score)	-0.121	0.052

TABLE 8: Correlation coefficients between HbA1c and selected variables (N=260)

Pearson correlation was used with pairwise valid observations: age n=259; all other comparisons n=260. r, Pearson correlation coefficient; * denotes p<0.05.

HbA1c: glycated hemoglobin; BMI: body mass index

The previously fitted logistic model failed its calibration assessment (Hosmer-Lemeshow p=0.008), despite an overall likelihood-ratio p-value of 0.029. Numerical outputs in Table *9* document the analysis and its limitations rather than reliable evidence of independent association. The diet-only estimate (AOR=0.167, 95% CI 0.037-0.764; p=0.021) arose from nine participants and is not interpreted as a protective effect. No clinical or confirmatory inference is drawn from this model.

Predictor	AOR	95% CI	p-value
Age (years)	0.975	0.949-1.001	0.059
BMI (kg/m²)	0.985	0.931-1.041	0.588
Female vs male	1.598	0.856-2.983	0.141
Complications present vs absent	1.613	0.841-3.095	0.150
Rural vs urban	1.679	0.810-3.483	0.164
Abu Sunun vs Al-Daraja	1.282	0.541-3.040	0.573
Diet only vs reference treatment	0.167	0.037-0.764	0.021*
Insulin only vs reference treatment	1.349	0.657-2.767	0.415
Knowledge (%)	0.981	0.914-1.054	0.600
Attitude mean score	0.116	0.000065-206.488	0.572
Practice mean score	0.436	0.147-1.290	0.134

TABLE 9: Multivariable logistic regression for predictors of poor glycemic control (HbA1c >9%; N=256)

Binary logistic regression was re-estimated after deriving poor control directly from recorded HbA1c >9%; the comparison outcome was HbA1c ≤9%. All 11 predictors were entered simultaneously. Reference categories are stated in the predictor labels. The reference treatment group combines oral medication only with the single participant taking both oral medication and insulin; separate indicators represent diet-only and insulin-only treatment. Complete-case analysis included 256 participants; four were excluded. Likelihood-ratio $\chi^2(11)=21.433$, p=0.029; Nagelkerke $R^2=0.113$; Hosmer-Lemeshow $\chi^2(8)=20.789$, p=0.008; overall classification accuracy=73.0%. The Hosmer-Lemeshow result indicates a lack of adequate calibration. Diet-only treatment comprised nine participants in the full sample; its estimate is imprecise. * denotes p<0.05. The attitude score was calculated as the mean of 15 items, coded from 2 (disagree) to 4 (agree). A pronounced ceiling effect was observed, with 247 of 256 participants (96.5%) achieving the maximum score of 4.00. This limited variability may have contributed to the highly imprecise adjusted odds ratio (AOR = 0.116, 95% CI: 0.000065–206.488, p = 0.572). Therefore, this estimate should be interpreted with considerable caution and does not provide reliable evidence of an independent association with poor glycemic control.

AOR: adjusted odds ratio; CI: confidence interval; BMI: body mass index; HbA1c: glycated hemoglobin

The linear-model outputs in Table *10* are exploratory numerical results. Recorded coefficients were negative for age, diet-only treatment, and practice score (nominal p=0.004, 0.001, and 0.028, respectively). These do not establish independent predictors or treatment effects: explained variance was low ($R^2=0.125$; adjusted $R^2=0.081$), the diet-only subgroup contained nine participants, and practice-score coding and model-assumption limitations remain unresolved. Conclusions rely on descriptive findings rather than these coefficients.

Predictor	B	SE	β	95% CI for B	t	p-value
Constant	20.605	8.575	-	3.714 to 37.496	2.403	0.017*
Age (years)	-0.041	0.014	-0.190	-0.070 to -0.013	-2.877	0.004*
BMI (kg/m²)	-0.020	0.030	-0.042	-0.080 to 0.040	-0.658	0.511
Female vs male	0.502	0.350	0.094	-0.188 to 1.191	1.433	0.153
Complications present vs absent	0.625	0.370	0.106	-0.104 to 1.353	1.689	0.092
Rural vs urban residence	0.474	0.380	0.077	-0.274 to 1.222	1.247	0.213
Abu Sunun vs Al-Daraja	0.524	0.465	0.070	-0.393 to 1.441	1.126	0.261
Diet only vs oral medication only	-2.906	0.844	-0.214	-4.569 to -1.243	-3.442	0.001*
Insulin vs oral medication only	0.258	0.374	0.042	-0.479 to 0.996	0.690	0.491
Both vs oral medication only	1.161	2.446	0.029	-3.658 to 5.980	0.475	0.636
Knowledge (%)	-0.021	0.036	-0.039	-0.091 to 0.049	-0.595	0.552
Attitude mean score	-0.136	2.197	-0.004	-4.463 to 4.191	-0.062	0.951
Practice mean score	-1.241	0.562	-0.136	-2.349 to -0.134	-2.209	0.028*

TABLE 10: Multivariable linear regression of baseline HbA1c (N=256)

Multiple linear regression with all 12 predictors entered simultaneously. Outcome: HbA1c (%). Reference categories: male sex, no diabetes-related complications, urban residence, Al-Daraja center, and oral medication only. Both denote oral medication plus insulin. Four participants were excluded by complete-case analysis. R^2=0.125; adjusted R^2=0.081; F(12,243)=2.883; model p=0.001; residual standard error=2.40662. * denotes p<0.05.

B: unstandardized coefficient; SE: standard error; β: standardized coefficient; CI: confidence interval; BMI: body mass index; HbA1c: glycated hemoglobin

Discussion

In this study population, 178 (68.5%) participants had poor glycemic control after deriving categories directly from recorded HbA1c, and the mean HbA1c was 10.5%. This mean exceeded the usual target of <7% for many nonpregnant adults [4]. Published Sudanese studies have also reported substantial inadequate control, including the population-based study by Noor et al. and the Northern Sudan study by Abdel Bagi and Ewis [6,7]. Direct prevalence comparisons are limited by differences in setting, eligibility, measurements, and definitions of inadequate control.

A notable finding was the coexistence of strong lifestyle-related knowledge and positive attitudes with a high prevalence of inadequate glycemic control. The Khartoum study by Mohamed and Sidahmed reported a similar knowledge-attitude pattern alongside poor dietary practice [9]. Within the present sample, self-reported practice was generally favorable, but adherence to weight-management behaviors and daily fruit and vegetable intake was substantially less consistent than medication use and attendance at scheduled follow-up. This pattern indicates that knowledge and favorable attitudes did not, by themselves, correspond to uniformly favorable metabolic status in this population.

Cultural dietary habits and financial constraints were the two barriers reported most often in the present study. The finding is compatible with the Khartoum literature, in which cost and social circumstances were also reported as important barriers to dietary practice [9]. Because the present study measured perceived barriers at one point in time, these responses should be interpreted as reported obstacles rather than proof that the barriers caused poor glycemic control.

Exploratory comparisons and regression outputs are presented for transparency and are not the basis of the study conclusions. The logistic model failed its calibration assessment (Hosmer-Lemeshow p=0.008); its adjusted odds ratios cannot support claims of independent association or guide clinical decisions. The linear model explained little variation in HbA1c and is not a validated prediction model. The nine participants receiving diet-only treatment form a small, clinically selected subgroup. Treatment choice may reflect disease severity, duration, previous response, and unmeasured factors; neither model establishes a benefit of diet-only treatment or a reason to change prescribed medication. The practice-score relationship is also vulnerable to the coding discrepancy and ceiling effects. Evidence that diabetes self-management education can improve glycemic outcomes comes from intervention studies [10,11], rather than from these exploratory models.

Overall, these findings are cross-sectional associations and do not establish treatment effects. Intervention evidence provides context: the DiRECT trial demonstrated that an intensive primary-care weight-management program can achieve diabetes remission in selected adults [15], whereas a randomized trial in urban Ghana found no significant between-group HbA1c difference after structured diabetes education [16]. These differing results underline the importance of intervention content, setting, and participant selection. Neither trial establishes the effectiveness of the unpublished parent program in the present population.

Limitations

The cross-sectional baseline design precludes causal inference. Self-reported practices and barriers may be affected by recall and social desirability bias, with score ceiling effects limiting discrimination. Two purposively selected centers limit generalizability and may introduce selection bias. The printed practice questionnaire has four response options, whereas the stored SPSS labels specify five. The available records do not permit a verified participant-level mapping between these formats. The discrepancy may affect absolute practice scores, item interpretations, and associations; its direction and magnitude cannot be quantified, and internal consistency does not resolve it. No retrospective recoding or validated adherence classification is claimed. Missing covariates, the nine-person diet-only subgroup, the single participant receiving combined treatment, residual confounding, and inadequate logistic calibration make regression estimates unsuitable for confirmatory or clinical inference. Linear-model residual assumptions have not been independently verified, and low explained variance limits its usefulness. Fasting status was not verified, so blood glucose cannot be interpreted as a confirmed fasting measurement; control categories were defined using HbA1c alone. Unrecorded analyzer, assay, standardization, and quality-control details limit laboratory reproducibility and independent assessment of measurement accuracy. Three unverified raw height entries were excluded from the height summary; BMI derivation did not establish measurement accuracy.

Conclusions

Poor glycemic control affected 178 (68.5%) of the 260 adults with T2DM attending the two participating primary health care centers. Recorded lifestyle-related knowledge and attitude responses were generally favorable, but interpretation of practice scores is limited by discrepancies between the printed questionnaire and stored coding. Cultural dietary habits and financial constraints were the most frequently reported barriers; weight-management behaviors and daily fruit and vegetable intake were less consistently reported than medication use and scheduled follow-up. These descriptive findings identify topics for further assessment and culturally appropriate, affordable diabetes support in primary care. The exploratory regressions do not establish independent predictors, treatment benefit, or a validated prediction tool and are not the basis of these conclusions. Prospective studies using consistently documented instruments and laboratory methods are needed to test potential interventions.

Appendices

Appendix A

Survey Questionnaire

English translation of the Arabic questionnaire supplied by the authors. Response options reproduce the printed form; completed participant responses are omitted.

Center name: _____ Participant number: _____
Participation statement
Dear participant, you are invited to participate in this research. The questionnaire aims to examine the effect of lifestyle modification on blood glucose levels. Participation is voluntary, and all responses will remain confidential. Expected completion time: 10-15 minutes.
Consent: I agree to participate / I do not agree.
Questionnaire title
The Effect of an Integrated Structured Lifestyle Modification Program on Glycemic Control Among Adults With Type 2 Diabetes Attending Primary Health Care Centers in Wad Madani Grand Locality, Gezira State, Sudan (March 2026-February 2027).

Sociodemographic characteristics
1. Age in completed years: _____
2. Sex: Male / Female.
3. Marital status: Single / Married / Divorced / Widowed.
4. Educational level: Primary / Intermediate / Secondary / University / Postgraduate / No formal education.
5. Employment status: Employee / Retired / Self-employed / Housewife / Unemployed.
6. Monthly income: Low / Moderate / High.
7. Residence: Urban / Rural.
8. Current weight (kg): _____
9. Current height (m): _____
10. Body mass index (BMI): _____

11. Telephone number: _____

Medical history and disease-related information
12. Type of diabetes: Type 1, affecting younger people / Type 2, affecting older people / Not sure.
13. Time since diagnosis: Less than one year / One to five years / Six to ten years / More than ten years.
14. Current treatment: Oral medications only / Insulin / Dietary control only / Both.
15. Do you have complications of diabetes? Yes / No.
16. If yes, specify: Neuropathy / Retinopathy / Nephropathy / Diabetic foot problems / Delayed wound healing / Do not know.
17. How often do you attend medical follow-up visits? Monthly / Every three months / Every six months / Irregularly.
18. Do you take the prescribed treatment regularly? Yes, regularly / No / Sometimes.

Knowledge
19. A healthy diet helps control blood glucose. Yes / No / Do not know.
20. Which of the following is a healthy diet that helps control diabetes? Complex carbohydrates, such as whole grains and potatoes / Simple sugars, such as sweets and soft drinks / Healthy protein, such as fish, legumes, eggs and skinless chicken / Eating vegetables / Drinking water regularly.
21. Regular physical activity reduces blood glucose levels. Yes / No / Do not know.
22. Which of the following activities reduces blood glucose? Moderate aerobic exercise, such as brisk walking, swimming and cycling / Resistance and strength exercise, such as lifting weights and squats / Relaxation exercise, such as prayer, yoga and breathing exercises / High-intensity exercise, such as fast running.
23. Increased weight worsens glycemic control. Yes / No / Do not know.
24. The normal BMI range is: 18.5-24.9 / 25-29.5 / 30-34.9 / 35-39.9 / Do not know.
25. Smoking increases the risk of diabetes complications. Yes / No / Do not know.
26. Lifestyle modification can reduce the need for medication. Yes / No / Do not know.
27. What is your source of information about diabetes? Doctor / Internet / Television channels / Diabetes educator / Other: _____
28. Which of the following are symptoms of high blood glucose? Headache / Thirst / Increased urination / Blurred vision / Do not know.
29. Which of the following are symptoms of low blood glucose? Tremor / Rapid heartbeat / Sweating / Do not know.
30. Regular physical activity helps reduce blood glucose. Yes / No / Do not know.

Attitudes
For each statement in items 31-45, select: Agree / Neutral / Disagree.
31. I believe that adhering to a healthy lifestyle helps me control blood glucose.
32. I feel confident in my ability to maintain the required healthy changes.
33. I feel that support from health care providers helps me adhere to a healthy lifestyle.
34. I believe that following dietary recommendations for diabetes is worth the effort.
35. I consider regular physical activity an important part of controlling diabetes.
36. I believe that lifestyle modification is more effective than medication in controlling diabetes.
37. I feel that adopting a healthy lifestyle can improve my quality of life.
38. I believe that good glycemic control reduces the risk of complications.
39. I consider regular follow-up with the health care team necessary for managing diabetes.
40. I believe that adherence to health recommendations is worth the time and effort involved.
41. I feel responsible for maintaining my health by controlling diabetes.
42. I believe that family members can play an important role in supporting a healthy lifestyle.
43. I believe that small lifestyle changes can make a large difference in glycemic control.
44. I believe that maintaining a healthy weight helps me improve control of diabetes.
45. I feel motivated to continue adopting healthy behaviors related to diabetes.

Practices
For frequency items 46-55, 57, 59-60, 63-64 and 66-68, the printed response options are: Always / Often / Sometimes / Rarely.
46. I follow dietary advice related to nutrition.
47. I follow the recommended diet.
48. I eat regular meals during the day.
49. I limit consumption of sugar and sweetened beverages.
50. I avoid foods rich in harmful fats.
51. I eat vegetables and fruit daily.
52. I apply advice from health care providers concerning physical activity.
53. I practice physical activity for 30 minutes per day or at least four days per week.
54. How often do you exercise?
55. I follow advice directed to me about managing excess weight.
56. Identify the main source of advice you received about weight: Treating physician / Nutritionist / Media / Other.
57. I take actual steps to reduce excess weight or maintain an ideal weight.

58. Identify the main method you use to manage weight: Diet / Exercise / Medication / Surgery.
59. I make a continuous and sustained effort to control my current weight.
60. I measure and monitor my weight regularly.
61. Do you currently smoke? Yes / No.
62. If yes, have you been advised to stop smoking? Yes / No.

Self-care and monitoring
63. I apply advice related to diabetes self-care and monitoring.
64. I measure my blood glucose at home regularly.
65. How often do you measure blood glucose at home? Daily / Several times per week / Monthly.
66. I take my diabetes medication according to the prescribed dose and schedule.
67. I make sure to attend all scheduled regular medical follow-up appointments.
68. When symptoms occur that could indicate high or low blood glucose, I measure my blood glucose at home, if a glucose meter is available.
69. When I have a mild episode of hypoglycemia, without loss of consciousness, I usually take the following to correct it: Fruit juice / Biscuits / Sweets / Tea with sugar / Other: _____
70. I can identify the correct medical measures to take when blood glucose rises. Strongly agree / Agree / Neutral / Disagree / Strongly disagree.
71. I know the correct medical measures to take when blood glucose falls. Strongly agree / Agree / Neutral / Disagree / Strongly disagree.
72. How many times have you experienced severe high blood glucose during the past month? Never / Once or twice / Three to four times / Five times or more.
73. How many times have you experienced severe low blood glucose during the past month? Never / Once or twice / Three to four times / Five times or more.
74. Do you use herbal treatment for diabetes? Yes / No.
75. If yes, specify: Cinnamon / Fenugreek / Garlic / Hibiscus / Other: _____
76. What are the main barriers you face in controlling blood glucose? Lack of knowledge / Financial constraints / Dietary cultural habits / Lack of motivation / Lack of family support / Physical disability / Lack of time / No barriers / Other, specify: _____

Blood glucose assessment for researchers only
77. Most recent fasting blood glucose reading (mg/dL): _____
78. Most recent glycated hemoglobin reading (HbA1c, %): _____
79. Glycemic control status: Good control / Moderate control / Poor control.

Appendix B

Scoring Key Reproduced From the Supplied SPSS Syntax

Knowledge: one point for each of 11 questions, zero otherwise.
Q19: Yes.
Q20: Select complex carbohydrates, healthy protein, vegetables, and regular water intake; do not select simple sugars.
Q21: Yes.
Q22: Select moderate aerobic, resistance/strength, and relaxation exercises; do not select high-intensity exercise.
Q23: Yes.
Q24: 18.5-24.9.
Q25: Yes.
Q26: Yes.
Q28: Select headache, thirst, increased urination, and blurred vision; do not select do not know.
Q29: Select tremor, rapid heartbeat, and sweating; do not select do not know.
Q30: Yes.
Q27 (information source) is unscored. Multiple-response questions receive a point only for the complete specified selection pattern; unselected options are coded zero in the original syntax. Knowledge percentage=correct questions/11 ×100. Original score categories: poor <60%, moderate 60% to <80%, good ⩾80%.
Attitude: Q31-Q45, 15 items. Observed response codes are 2=disagree, 3=neutral, and 4=agree; total and mean scores retain these original codes.

Practice: Q46-Q55, Q57, Q59-Q60, Q63-Q64, and Q66-Q68, 18 items. Stored codes are 1=never, 2=rarely, 3=sometimes, 4=often, 5=always. Means use available item responses. One Q51 response is missing. The supplied printed form lists four frequency options and omits never; the form is reproduced unchanged, and the discrepancy is reported in Methods. This key describes the original study coding and does not constitute a general clinical recommendation.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

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Disclosures

Human subjects: Informed consent for treatment and open access publication was obtained or waived by all participants in this study. Health-Sector Ethical Review Committee, University of Gezira issued approval 26/2026. **Animal subjects:** All authors have confirmed that this study did not involve animal subjects or tissue. **Conflicts of interest:** In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

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The data supporting the findings of this study are available from the corresponding author upon reasonable request. The data are available in de-identified form to protect participants' privacy.

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