Trend, Level, and Predictors of Glycemic Control among Iranians with Type 2 Diabetes: A 12-Year Retrospective Cohort Study

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Abstract

Objective We aimed to determine the trend, level, and predictors of glycemic control among adult type 2 diabetes on regular follow-up.

Material and Method A 12-year unmatched retrospective cohort study was conducted at Imam Khomeini Hospital, Tehran, Iran.

Statistical Analysis Descriptive statistics was computed for most variables, such as sociodemographic factors, medication-related factors, and disease-related factors. Multivariate logistic regression analysis was conducted to identify the functional independent predictors of good glycemic control among type 2 diabetes.

Results A total of 297 patients with regular follow-up were included in this study. Patients' mean body mass index was 28.51 ± 4.61 kg/m^2. The mean glycated hemoglobin (HbA1c %) was 7.4 ± 1.25%. One hundred thirteen (30%) patients achieved the glycemic control target (i.e., HbA1c < 7.0%). The mean systolic blood pressure level was 132.88 ± 16.23 mm Hg. The mean diastolic blood pressure level was 76.58 ± 9.2 mm Hg. The mean level of low-density lipoprotein (LDL)-cholesterol was 79.23 ± 28.69 mg/dL. The highest trend of glycemic control was recorded in 2014 to 2015 (49.5%). Age less than 50 years, taking oral antidiabetic monotherapy, having blood pressure (BP) less than 140/90 mm Hg, and having LDL-cholesterol level < 70 mg/dL were independently associated with good glycemic control.

Conclusion Glycemic control levels among type 2 diabetes on regular follow-up were low. Young age was negatively associated with good glycemic control. Taking oral antidiabetic monotherapy, achieving BP, and meeting LDL-cholesterol targets were positively associated with good glycemic control. Therefore, addressing these factors can improve glycemic control and reduce associated complications.

Keywords
- ABC control
- type 2 diabetes
- trends
- predictors of good glycemic control
- Iran

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Introduction

Diabetes is characterized by increased glycemia due to either failure of pancreatic β-cells to produce insulin and/or insulin resistance.[1] In 2019, the global prevalence of diabetes was 9.3%, estimated to be 10.2% by 2030 and 10.9% by 2045.[2] Type 2 diabetes mellitus (T2DM) accounts for 90 to 95% of all diabetes cases.[3] The prevalence of T2DM is rising due to the global rise in obesity, sedentary lifestyles, and the aging population.[4] In 2017, approximately 462 million individuals were affected by type 2 diabetes. The global prevalence is projected to increase to 7,079 individuals per 100,000 by 2030.[5]

Optimal management of type 2 diabetes requires control of the "ABCs," namely, A1C, blood pressure (BP), and cholesterol, which is believed to minimize the risk of complications and disease progression.[6] Maintaining an A1C level of approximately 7%, keeping BP < 140/90 mm Hg, and maintaining low-density lipoprotein (LDL) at < 100 mg/dL (with no cardiovascular disease) and an LDL of < 70 mg/dL with any cardiovascular complications are critical proponents of diabetes management.[7]

Despite an observed trend toward better control, there is an unmet need for glycemic control.[8] For example, only 24.4 to 26% of type 2 diabetes patients achieved the hemoglobin A1c (HbA1c) target (7.0%) in Saudi Arabia.[2,9] Similarly, in Malaysia, only 20% of patients with type 2 diabetes achieved HbA1c levels of < 7%[10]; in Jordanian 597 (65.1%) of patients had poor glycemic control (HbA1c ≥ 7%).[11] There is little evidence of ABC control and glycemic control trends among people with type 2 diabetes at Imam Khomeini Hospital, Tehran, Iran. Therefore, valid and consistent evidence on glycemic control and trends is necessary to evaluate the effect of interventions, compare trends in different countries, and measure progress toward the ABC control target. Thus, this unmatched retrospective cohort study was conducted to determine the trend, level, and predictors of glycemic control among adult type 2 diabetes on regular follow-up at Imam Khomeini Hospital.

Patients and Methods

Settings and Design

A 12-year facility-based unmatched retrospective cohort study was conducted from September to October 2020 at Imam Khomeini Hospital to determine the level and trend of glycemic control and associated factors among T2DM patients on regular follow-up.

Study Population

The study populations for this study were adult patients with type 2 diabetes and on regular follow-up (i.e., at least five successive fasting blood sugar [FBS] and glycated HbA1c %) at Imam Khomeini Hospital. Documents of all nonpregnant adult type 2 diabetes patients on regular follow-up (at least five successive FBS or HBA1c % recordings) were reviewed. Records of patients with less than five successive FBS and/or HBA1c % were excluded.

Outcome Measures

The dependent variables were (1) the level of glycemic control and (2) trends of glycemic control. The independent variables included (1) sociodemographic characteristics (sex, age, height, weight, body mass index [BMI], smoking status, family history of type 2 diabetes, social drug use), (2) comorbidities and risk factors (hypertension, chronic kidney disease (CKD), heart failure, hyperthyroidism, hypothyroidism, dyslipidemia, serum creatinine), (3) medications (oral antidiabetics, insulin, angiotensin-converting enzyme inhibitors [ACEIs], angiotensin receptor blockers [ARBs], β-blockers, calcium channel blockers, lipid-lowering agents), (4) disease-related factors (family history of diabetes, duration of diabetes, types of treatment, adherence to treatment, presence of comorbidities), (5) comprehensive care process-related factors (urine analysis for albumin, serum creatinine, neuropathy screening, and ophthalmic examination), and (6) complications (macro- and microvascular complications).

Sample Size and Sampling Technique

Out of 2,680 type 2 diabetes patients on follow-up at Imam Khomeini Hospital, we identified 297 patients on regular follow-up after applying our inclusion criteria. These 297 patients' data were followed for 12 years. All patient information relevant to our study variables was abstracted by principal investigators using a predefined checklist.

Data Processing and Analysis

The principal investigator checked the abstracted data daily for completeness and consistency. Then, data entry, processing, and analysis were done using SPSS version 20.0. Descriptive statistics were computed for most variables, such as sociodemographic, medication, and disease-related factors. A bivariate analysis was done to determine the presence of an association between independent variables and glycemic control. To avoid many variables and unstable estimates in the subsequent model, only variables that reached a *p*-value less than 0.05 at bivariate analysis were kept in the subsequent model analysis. Multivariate logistic regression analysis was done to identify the functional independent predictors of good glycemic control among type 2 diabetes patients on regular follow-up at Imam Khomeini Hospital. A point estimate of odds ratio (OR) with a 95% confidence interval (CI) was determined to assess the strength of association between independent and dependent variables. A *p*-value of < 0.05 was used as a cutoff point for all statistically significant tests.

Results

Baseline Patient Factors

A total of 297 patients with regular follow-ups were included in this study. About two-thirds, 66%, were females. The population's mean age was 60.15 ± (standard deviation) 9.88 years, ranging from 35 to 87. 89(30%) patients were obese, and 134 (45.1%) were overweight. The mean BMI of patients was 28.51 ± 4.61 kg/m^2, ranging from 18.47 to 44 kg/m^2. Ethnic groups influence waist circumference measurement. Using European data are suggested for the Middle Eastern and Asian countries (i.e., men: ≥ 94 cm [> 40 inches], women: ≥ 80 cm [> 35 inches] cut point).[12] The mean waist circumference was 95.74 ± 12.744 cm, ranging from 69 to 190 cm. More than 9 out of 10 women, 183 (93.4%), and about half of men, 51 (51.5%), had waist circumference above the recommended cut point value, indicating central or abdominal obesity. More than one-third of patients, 106 (36.4%), had intermediate 10-year atherosclerotic cardiovascular disease (ASCVD) risk, and 16 (5.4%) had high risk. The mean vitamin D level was 28.87 ± 19.01 ng/mL, ranging from 4 to 140 ng/mL. Mean uric acid was 5.61 ± 5.42 mg/dL ranging from 2.10 to 45 mg/dL. The mean blood urea nitrogen level was 32.45 ± 13.6 mg/dL, ranging from 2.90 to 88.0 mg/dL.

Liver function test ranges were taken from studies proposing 10 to 40 IU/L for alanine aminotransferase (ALT) and aspartate aminotransferase (AST) levels and 40 to 112 U/L for alkaline phosphatase (ALP).[13] The mean AST level was 22.57 ± 9.67 IU/L, ranging from 10 to 80 IU/L. The mean ALT level was 24.49 ± 13.24 IU/L, ranging from 10 to 89 IU/L. The mean ALP level was 148.9 ± 62.4, ranging from 41 to 335 U/L (►**Table 1**).

Table 1 Baseline characteristics of type 2 diabetes patients on regular follow-up for at Imam Khomeini Hospital ($n = 297$)

Baseline characteristics		Frequency	Percent
Gender	Female	196	66.0
	Male	101	34.0
Age	Less than 45 y	24	8.1
	45–54 y	68	22.9
	55–64 y	51	17.2
	65–74 y	143	48.1
	75 y and above	11	3.7
BMI	18–24.9 kg/m^2	70	23.6
	25–29.9 kg/m^2	134	45.1
	30–39.9 kg/m^2	89	30.0
	40 kg/m^2 and above	4	1.3
Waist Circumference	Less than 94 cm male	52	17.5
	94 cm and above male	49	16.5
	Less than 80 cm female	13	4.4
	80 cm and above female	183	61.6
Smoking status	No	267	89.9
	Yes	30	10.1
Vitamin D level ($n = 132$)	< 20 ng/mL	30	22.7
	≥ 20 ng/mL	102	72.3
Uric acid level ($n = 185$)	6 mg/dL and less	155	83.8
	Above 6 mg/dL	30	16.2
BUN level ($n = 291$)	Less than 8 mg/dL	2	.7
	8–20 mg/dL	45	16.4
	20 mg/dL and above	244	83.2
AST level ($n = 290$)	10–40 IU/L	277	95.5
	Above 40 IU/L	13	4.5
ALT level ($n = 290$)	10–40 IU/L	262	92.4
	Above 40 IU/L	28	7.6
ALP level ($n = 34$)	40–112 U/L	13	38.2
	Above 112 U/L	21	61.8
Family history of T2DM	No	118	39.7
	Yes	179	60.3

Abbreviations: ALP, alkaline phosphatase; ALT, alanine aminotransferase; AST, aspartate aminotransferase; BMI, body mass index; BUN, blood urea nitrogen; T2DM, type 2 diabetes mellitus.

Table 2 Disease-related factors of type 2 diabetes patients on regular follow-up (*n* = 297)

Disease related		Mean, frequency (%)
Mean duration of diabetes years		13.1 ± 7.14
Duration of type 2 diabetes	0–5 y	16 (5.4)
	6–10 y	109 (36.7)
	11–15 y	88 (29.6)
	16–20 y	45 (15.2)
	21 and above years	39 (13.1)
Presence of hypertension	No	114 (38.4)
	Yes	183 (61.6)
Mean duration of hypertension in years		5.96 ± 5.06
Duration of hypertension	Less than 5 y	92 (50.3)
	5–10 y	70 (38.3)
	11–15 y	9 (4.9)
	16–20 y	8 (4.4)
	21 y and above	4 (2.2)
Presence of CKD	No	216 (72.2)
	Yes	81 (27.3)
Mean serum creatinine (mg/dL)		1.04 ± 0.33
Mean estimated GFR (mL/min/m^2)		76.86 ± 27.36
Presence of cancer	Yes	20 (6.7)
	No	277 (93.3)
Type of cancer (*n* = 20)	Breast cancer	16 (80.0)
	Colorectal cancer	2 (10)
	Miscellaneous cancer	2 (10)
Antidiabetic drug regimen (*n* = 297)	Oral antidiabetic monotherapy	121 (40.7)
	Oral antidiabetics combination	97 (32.7)
	Insulin	24 (8.1)
	Insulin + oral antidiabetics	55 (18.5)
Drugs prescribed for hypertension (*n* = 183)	ACEI monotherapy	51 (27.9)
	ARB monotherapy	123 (67.2)
	CCB monotherapy	3 (1.6)
	ACEI/ARB + CCB	2 (1.1)
	ACEI/ARB + Diuretic	3 (1.6)
	ACEI + BB	1 (0.5)
Taking statins (*n* = 297)	Yes	235 (79.2)
	No	62 (20.8)

Abbreviations: ACEI, angiotensin-converting enzyme inhibitor; ARB, angiotensin receptor blocker; BB, beta-blocker; CCB, calcium channel blocker; CKD, chronic kidney disease; GFR, glomerular filtration rate.

Disease-Related Factors

The mean duration of type 2 diabetes was 13.1 ± 7.14 years, ranging from 3 to 47 years. Hypertension was the most common comorbidity, 183 (61.6%), followed by obesity, 89 (30%), and CKD, 81 (27. 3%). The mean duration of hypertension was 5.96 ± 5.06 years, ranging from 1 to 25 years (►**Table 2**). Concerning kidney disease, the mean serum creatinine level was 1.04 ± 0.33 mg/dL, ranging from 0.5 to 3.0 mg/dL. We estimated the glomerular filtration rate (GFR) using the Cockcroft and Gault equation.[14,15] An estimated GFR was 76.86 ± 27.36 mL/min/m^2 ranging from 21.3 to 171.1 mL/min/m^2. We defined CKD as a GFR of < 60 mL/min/1.73 m^2. Based on this definition, 81 (27.3%) patients had an estimated GRR value of less than 60 mL/min/1.73 m^2 (►**Table 2**). Regarding ASCVD risk, we estimated a 10-year ASCVD based on a 10-year ASCVD risk estimator for 291

(97.8%) patients.[16] One hundred twelve (38.5%) patients had low risk, 57 (19.7%) had borderline risk, 83 (28.5%) had intermediate risk, and 39 (13.4%) patients had high 10-year ASCVD risk (i.e., ≥ 15%).

Complications

Concerning complications, diabetic neuropathy, 62 (20.8%), was the most commonly documented microvascular complications, followed by diabetic retinopathy, 31 (10.4%), microalbuminuria, 18 (7.4%), and diabetic foot ulcer, 5 (1.6%). Concerning macrovascular complications, 50 (16.8%) patients had coronary artery disease; out of these, 31 (62.0%) had myocardial infarction. Only 5 (1.6%) patients had cerebrovascular accidents. This finding was similar to a systematic review conducted to evaluate the prevalence of micro- and macrovascular complications among type 2 diabetes patients in Iran. The systemic review authors stated retinopathy and neuropathy as major microvascular complications and cardiac complications as major macrovascular complications.[17]

Level of Glycemic Control

We evaluated diabetes control based on ABC (A1C, BP, and LDL-cholesterol) control.[18] We defined good glycemic control according to the American Diabetes Association guidelines, FBS level of 80 to 130 mg/dL or glycosylated HbA1c level ≤ 6.5% (48 mmol/mol) is considered optimal, but higher targets (< 7.0%) may be appropriate for certain individuals.[8,19] We used glycosylated HbA1c level < 7.0% for good control. The mean of five successive HbA1c and FBS values were used to determine the level of glycemic control. Mean HbA1c % was 7.4 ± 1.25%, ranging from 5.10 to 19.6%. One hundred eighty-four (62%) patients did not achieve % glycemic control target of HbA1c % < 7.0%. The mean FBS level was 153.08 ± 37.7 mg/dL, ranging from 81 to 423 mg/dL. 208 (70%) adults with type 2 diabetes on regular follow-up had uncontrolled blood glucose (i.e., > 130 mg/dL) based on mean FBS level.

We defined BP control targets based on the recommendations of the American Association of Clinical Endocrinologists (AACE). The AACE recommends that BP control be individualized but that a < 130/80 mm Hg target is appropriate for most patients. Less-stringent goals may be considered for frail patients with complicated comorbidities or those who have adverse medication effects, whereas a more intensive goal (e.g., < 120/80 mm Hg) should be considered for some patients if this target can be reached safely without adverse effects from medication.[20] The mean systolic BP level was 132.88 ± 16.23 mm Hg, ranging from 89 to 183 mm Hg. The mean diastolic BP level was 76.58 ± 9.2 mm Hg, ranging from 52 to 102 mm Hg. One hundred ninety-six (66%) patients had uncontrolled hypertension (< 130/80 mm Hg). One hundred five (36%) patients had uncontrolled hypertension if a less stringent BP control target (i.e., ≥ 140/90 mm Hg) was considered. The mean level of LDL-cholesterol was 79.23 ± 28.69 mg/dL, ranging from 27 to 198 mg/dL. Fifty seven (19%) of patients did not achieve the LDL-cholesterol target (LDL-cholesterol < 100 mg/dL) (►**Fig. 1**).

Medications Used for ABC Control of Type 2 Diabetes

One hundred twenty-one (40.7%) patients were taking oral antidiabetic monotherapy followed by oral antidiabetic combination, 97 (32.7%), and insulin + oral antidiabetic

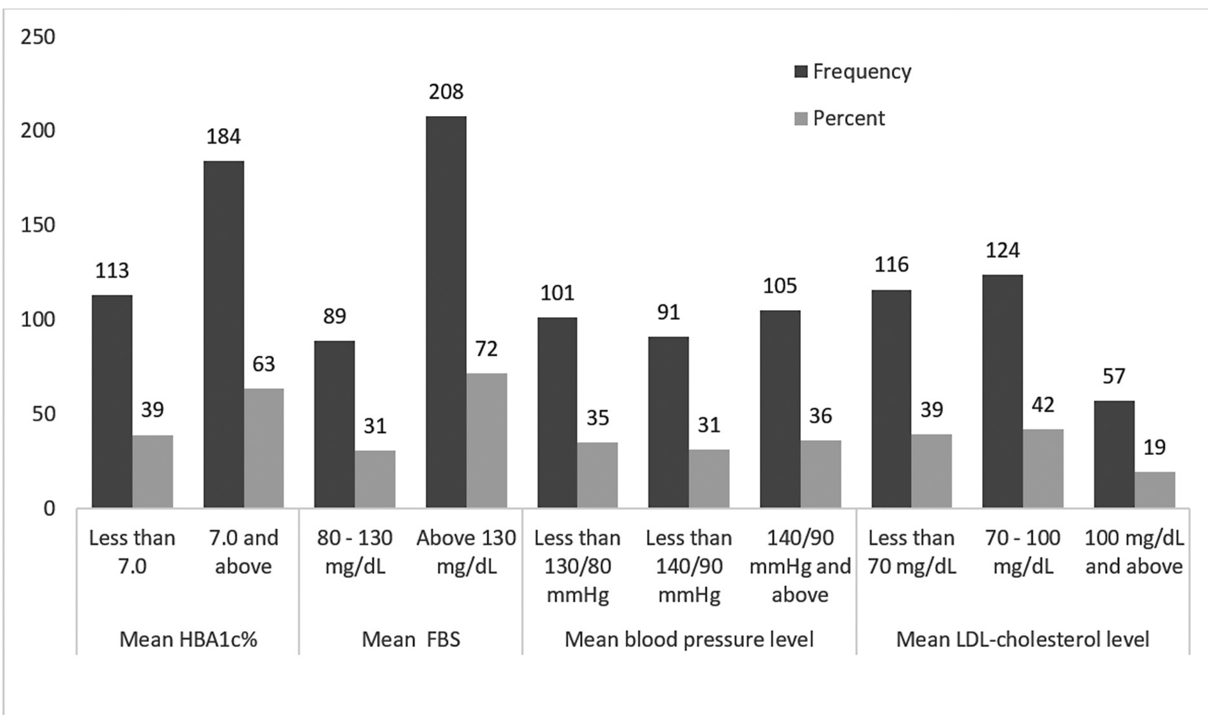

Fig. 1 Level of glycated hemoglobin (HbA1c %), blood pressure, and low-density lipoprotein (LDL)-cholesterol control among type 2 diabetes patients on regular follow-up at Imam Khomeini hospital ($n = 297$).

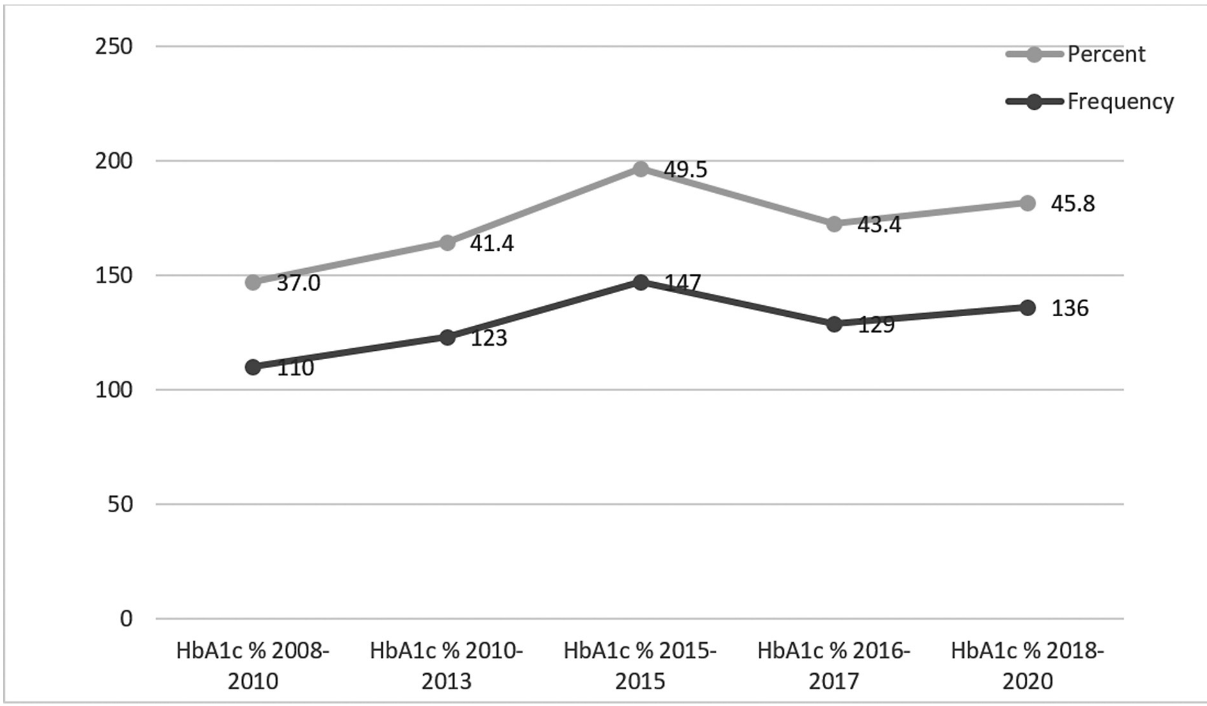

Fig. 2 Trend of glycemic control type 2 diabetes patients on regular follow-up from 2011 to 2020 at Imam Khomeini Hospital, Tehran, Iran, based on hemoglobin A1c (HbA1c) % ($n = 297$).

combination, 55 (18.5%). Metformin was the most commonly prescribed oral antidiabetic monotherapy, 103 (34.7%). The majority of 123 (67.2%) patients were taking ARB monotherapy, followed by ACEIs monotherapy, 51 (27.9%). Concerning dyslipidemia management, more than one half, 124 (52.8%), patients were taking intermediate intensity statin (i.e., atorvastatin 20 mg) followed by atorvastatin 10 mg, 81 (34.5%), and atorvastatin 40 mg, 28 (11.9%). Concerning dyslipidemia management, 235 (79.1%) patients were taking statins medication. Statins are recommended to reduce the risk of cardiovascular events and death in patients with type 2 diabetes[20] (►**Table 2**).

Trends of Glycemic Control

We determined the trend of blood glucose control based on the most recent records of HbA1c %. Concerning the trend of glycemic control, from 2008 to 2020, the highest improvement was shown in 2014 to 2015 (i.e., 12.5% change). For example, in the year 2008 to 2010, the level of good glycemic control (HbA1c% < 7.0%) was 110 (37.0%), in 2011 to 2013 was 123 (41.4%), in 2014 to 2015 was 147(49.5%), 2016 to 2017 was 129 (43.4%), and 2018 to 2020 was 136 (45.8%) (►**Fig. 2**).

Factors Associated with Glycemic Control

Concerning factors associated with good glycemic control, we conducted a binary logistic regression analysis to identify factors associated with glycemic control. Age less than 50 years, crude OR (COR) = 2.12 (95% CI for COR, 1.051–4.27, $p = 0.036$), when compared with age ≥ 65 years, the male having a waist circumference of 94 cm and above, COR = 0.508 (95% CI for COR, 0.268–0.963, $p = 0.038$), when compared with female having waist circumference of 80 cm and above, taking oral antidiabetic monotherapy, COR = 0.255 (95% CI for COR, 0.123–0.530, $p = 0.000$), having BP less than 130/80 mm Hg, COR = 0.398 (95% CI for COR, 0.221–0.715, $p = 0.002$), having BP less than 140/90 mm Hg, COR = 0.462 (95% CI for COR, 0.252–0.844, $p = 0.012$), when compared with patients having BP ≥ 140/90 mm Hg, having LDL-cholesterol < 70 mg/dL, COR = 0.589 (95% CI for COR, 0.365–0.951, $p = 0.03$), when compared with those having LDL-cholesterol ≥ 70 mg/dL, having triglyceride level < 150 mg/dL, COR = 0.479 (95% CI for COR, 0.285–0.804, $p = 0.005$), when compared with those having triglyceride level ≥ 150 mg/dL were associated with glycemic control.

Multivariable logistic regression analysis was conducted to identify independent predators of good glycemic control. After adjusting for confounding factors, age less than 50 years, adjusted OR (AOR) = 0.399 (95% CI for AOR, 0.186–0.855, $p = 0.018$), when compared with age ≥ 65 years, taking oral antidiabetic monotherapy, AOR = 3.606 (95% CI for AOR, 1.659–7.841, $p = 0.001$), having BP less than 130/80 mm Hg, AOR = 2.112 (95% CI for AOR, 1.126–3.959, $p = 0.020$), having BP less than 140/90 mm Hg, AOR = 2.995 (95% CI for AOR, 1.039–3.830, $p = 0.038$), when compared with patients having BP ≥ 140/90 mm Hg, and having LDL-cholesterol level < 70 mg/dL, AOR = 1.815 (95% CI for AOR, 1.051–3.135, $p = 0.032$) were independently associated with good glycemic control (►**Table 3**).

Discussion

This unmatched retrospective cohort study assessed glycemic control levels and trends among adult type 2 diabetes,

Table 3 Predictors of good glycemic control among adults with type 2 diabetes on regular follow-up at Imam Khomeini hospital, Tehran, Iran ($n = 297$)

Dependent variable: HbA1c %[a]			HbA1c % versus associated factors		COR	95% CI, COR		p-Value	AOR	95% CI, COR	
			< 7.0%	≥ 7.0%		Lower	Upper			Lower	Upper
Less than 7.0%	Age of respondents	Less than 50 y	13 (23.6%)	42 (76.4%)	2.119	1.051	4.271	0.018*	0.399	0.186	0.855
		50–64 y	39 (44.3%)	49 (55.7%)	0.824	0.485	1.400	0.881	1.045	0.586	1.866
		65 y and above ref.	61 (39.6%)	93 (60.1%)	1			1			
	Waist circumference	Male < 94 cm	22 (42.3%)	30 (57.7%)	0.665	0.354	1.250	0.682	1.161	0.568	2.370
		Male ≥ 94 cm	24 (48.9%)	25 (51.1%)	0.508	0.268	0.963	0.288	1.461	0.726	2.941
		Female < 80 cm	7(53.8%)	6 (46.2%)	0.418	0.135	1.299	0.153	2.455	0.717	8.402
		Female ≥ 80 cm ref.	60 (32.8%)	123 (67.2%)	1			1			
	Drug treatment for diabetes	Oral antidiabetic monotherapy	63 (52.1%)	58 (47.9%)	0.255	0.123	0.530	0.001*	3.606	1.659	7.841
		Oral antidiabetics combination	31 (40%)	66 (60%)	0.563	0.262	1.209	0.221	1.657	0.738	3.722
		Insulin	7 (29.2%)	17 (70.8%)	0.623	0.209	1.861	0.538	1.437	0.454	4.545
		Insulin + metformin ref.	12 (21.8%)	43 (78.2%)	1			1			
	BP control	< 130/80 mm Hg	47 (46.5%)	54 (53.5%)	0.398	0.221	0.715	0.020*	2.112	1.126	3.959
		< 140/90 mm Hg	39 (42.8%)	52 (57.2%)	0.462	0.252	0.844	0.038*	1.995	1.039	3.830
		≥ 140/90 mm Hg ref.	27 (25.7%)	78 (74.3%)	1						
	LDL-cholesterol	< 70 mg/dL	53 (45.6%)	63 (54.3%)	0.589	0.365	0.951	0.032*	1.815	1.051	3.135
		≥ 70 mg/dL ref.	60 (33.1%)	121 (66.9%)	1						
	Triglycerides	< 150 mg/dL	85 (43.8%)	109 (56.2%)	0.479	0.285	0.804	0.105	1.591	0.907	2.790
		≥ 150 mg/dL ref.	28 (27.2%)	75 (72.8%)	1						

Abbreviations: AOR, adjusted odds ratio; BP, blood pressure; CI, confidence interval; COR, crude odds ratio; HBA1c, hemoglobin A1c; LDL, low-density lipoprotein.
[a]The reference category is: 7.0 and above.
*indicates missing or redundant data where the parameter could not be calculated or is not applicable for this specific comparison.

including 297 patients on regular follow-up. Our study's glycemic control was superior to reports from other studies in Iran and various countries. A cross-sectional study in Iran showed that only 23.1% of patients achieved the glycemic control target (HbA1c < 7%).[21] Another study among 380 Iranian type 2 diabetes patients reported mean A1C levels of $7.78 \pm 1.7\%$.[22] In Saudi Arabia, only 24.4% of patients achieved the HbA1c target, and 74% had poor glycemic control.[2] Similarly, in Malaysia,[10] just 20% of patients reached HbA1c levels < 7%, and in Lebanon,[23] 31.8% attained A1C control. In China, a multicenter survey showed that 32.3% of patients achieved HbA1c < 7.0%.[24] In Ghana, 70% of people with type 2 diabetes had poor glycemic control.[25] This variation could be due to the type of patients in our study, who were on regular follow-up and received comprehensive care, likely leading to better glycemic control.[26]

However, our glycemic control levels were lower than those in Germany and Japan. A German study on social inequalities in type 2 diabetes showed that 45% of patients achieved HbA1c levels < 7.0%.[27] In China, a multicenter study found that 45.82% of patients achieved glycosylated HbA1c control,[28] while the NHANES survey in the United States indicated that approximately 50% of American adults with diabetes achieved HbA1c < 7.0%.[29] The differences in glycemic control could be attributed to variations in research methodology and patient characteristics. In our study, patients with regular follow-up likely experienced better glycemic control.

The most significant improvement in glycemic control trends from 2008 to 2020 was in 2014 to 2015 (a 12.5% change). For instance, good glycemic control rates were 37.0% in 2008 to 2010, 41.4% in 2011 to 2013, 49.5% in 2014 to 2015, 43.4% in 2016 to 2017, and 45.8% in 2018 to 2020. The improvement in 2014 to 2015 exceeded the trends observed in the United States from 1999 to 2010, where glycemic control rates increased by 7.9%.[29] These differences might be due to variations in study populations, socioeconomic factors, geographical locations, and methodologies.

Younger patients (< 50 years) were 0.39 times less likely to achieve good glycemic control compared with those ≥ 65 years. Similar findings have been observed in other studies, where younger age was associated with poor glycemic control and obesity in urban African Americans,[30] and mean HbA1c and LDL-cholesterol were lower among older adults in Singapore.[31] In Northwest Iran, older patients were less likely to report poor glycemic control.[32] A study in Hawaii also linked younger age with sustained poor glycemic control.[33] Tailoring interventions for younger populations is crucial to improving glycemic control and reducing complications.

Patients on oral antidiabetic monotherapy were 3.6 times more likely to achieve good glycemic control than those on insulin and oral antidiabetic combination therapy. This finding aligns with other studies where patients on insulin therapy had higher A1C levels. In Singapore, patients on insulin were more likely to have poor glycemic control.[31] A multicenter survey in China showed varying glycemic control rates among patients on different therapies, with those on monotherapy faring better.[24] Similarly, studies in Germany,[34] Malaysia,[10] and Ethiopia[35] found that patients on monotherapy or oral antidiabetics were more likely to achieve good glycemic control compared with those on insulin.

Patients with BP < 130/80 mm Hg were 2.1 times more likely to achieve good glycemic control than those with BP ≥ 140/90 mm Hg. Similarly, those with BP < 140/90 mm Hg were two times more likely to achieve good glycemic control than those with BP ≥ 140/90 mm Hg. These findings are supported by studies in China,[28] Saudi Arabia,[1] Singapore,[31] and Ghana,[25] where BP and hypertension were significant predictors of glycemic control.

Patients having LDL-cholesterol level < 70 mg/dL were 1.8 times (AOR = 1.815 [95% CI for AOR, 1.051–3.135], $p = 0.032$) more likely to achieve glycemic control target when compared with patients having LDL-cholesterol ≥ 70 mg/dL. There is a bidirectional relationship between lipid profile and glycemic control. Good control of lipid profiles was an important factor influencing glycemic control in patients with type 2 diabetes. In addition, achieving controlled glycemia contributes to controlling lipid profiles for type 2 diabetes patients.[36] A study identifying the association between glycemic control and serum lipid profile in type 2 diabetes patients in Nepal showed a significant correlation between HbA1c with total cholesterol and LDL-cholesterol.[37] Another study conducted to determine the association between unfavorable lipid profile and glycemic control in patients with T2DM showed that 1 mmol/L increase in total cholesterol, triglycerides, and LDL-cholesterol reduced the probability of higher HbA1c by 56%.[38]

In our study, having triglyceride level < 150 mg/dL, COR = 0.479 (95% CI for COR, 0.285–0.804, $p = 0.005$), when compared with those having triglyceride level ≥ 150 mg/dL, was associated with glycemic control in binary logistic regression. However, the association was not maintained in multivariable logistic regression. This is against findings from other studies. A study conducted to assess the effect of glycemic control, achieved by metformin, glibenclamide, and insulin, on lipid profile in type 2 diabetes patients showed a significant correlation between HbA1c and serum triglyceride ($r = 0.28$, $p < 0.05$), and between HbA1c and total cholesterol ($r = 0.310$, $p < 0.05$).[39] Another study on the association between triglyceride levels and glycemic control among Insulin-treated type 2 diabetes patients in China showed a strong association between triglyceride levels and inadequate glycemic control.[40] More strong multicenter-based studies are required to determine the association between glycemic control and triglyceride levels among adult type 2 diabetes in our study population.

Conclusion

In conclusion, ABC control of type 2 diabetes patients on regular follow-up was low. Young age was negatively associated with good glycemic control. Taking oral antidiabetic monotherapy, achieving BP control, and achieving LDL-cholesterol level < 70 mg/dL were positively associated with good glycemic control. Therefore, addressing these factors with due attention to ABC control can improve glycemic control and reduce associated complications.

Declaration of Helsinki

The study was conducted following the ethical principles of the Declaration of Helsinki. Ethical clearance was obtained from Tehran University of Medical Sciences, and an official letter of approval was received from Imam Khomeini Hospital prior to the commencement of the research.

Authors' Contributions

All authors read and approved the manuscript. A.G.A. conceived the study, conducted data collection, framed the research design, and conducted data analysis. M.M.S. participated in data analysis and developed the manuscript. S.R., M.A., G.A., E.A., and M.N. reviewed the manuscript and polished the manuscript language.

Ethical Approval

Ethical clearance was obtained from the Tehran University of Medical Sciences, and Imam Khomeini Hospital prior to the commencement of the research.

Availability of Data Statement

Data concerning this manuscript is available upon reasonable request to the corresponding author.

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None.

Conflict of Interest

None declared.

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