Journal of Population Therapeutics & Clinical Pharmacology

RESEARCH ARTICLE
DOI:10.69980/vdd18f44

GLYCEMIC CONTROL AND ITS DETERMINANTS: AN ANALYSIS OF RISK FACTORS AND TREATMENT OUTCOMES IN DIABETES MELLITUS

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Abstract
Diabetes mellitus remains a major global health challenge, with suboptimal glycemic control contributing significantly to disease burden and complications. This study aimed to assess glycemic control and its determinants among adults with diabetes mellitus. A cross-sectional analytical approach was used, including 1,602 participants with complete glycohemoglobin (HbA1c) measurements. Glycemic control was classified as good (HbA1c <7%) or poor (HbA1c ≥7%). Descriptive statistics, chi-square tests, independent t-tests, analysis of variance, and multivariable logistic regression were performed. The prevalence of poor glycemic control was 47.88%, with a mean HbA1c of 7.40 ± 1.67%. Significant associations were observed between glycemic control and age, race/ethnicity, dyslipidemia, treatment group, and diabetes duration. Participants with poor glycemic control had higher total cholesterol, triglycerides, and longer disease duration, along with lower high-density lipoprotein levels. Treatment patterns indicated that individuals receiving insulin-based therapies had higher HbA1c levels, likely reflecting disease severity. Multivariable analysis identified dyslipidemia, age, and treatment group as independent predictors of poor glycemic control. These findings highlight the multifactorial nature of glycemic regulation and emphasize the need for integrated management strategies targeting both glycemic and metabolic risk factors. Early identification of high-risk individuals and optimization of treatment approaches are essential to improve outcomes and reduce the burden of diabetes.

Keywords: Glycemic control, Diabetes mellitus, Dyslipidemia, HbA1c, Treatment outcomes

1. Introduction

Diabetes mellitus is a significant worldwide general health issue that is marked with enduring hyperglycemia and related metabolic disorders. It is now a significant contributor to morbidity and mortality in the world due to urbanization, aging of the population and changes in lifestyles over the past few decades. Long-term complications of the disease are substantial to the healthcare systems, such as retinopathy, neuropathy, nephropathy, and cardiovascular disease. Moreover, diabetes is a major contributor to economic gains as well as diminished quality of life especially in resource-constrained environments.[1] The glycemic control, which is assessed via glycated hemoglobin

(HbA1c), is the focus of diabetes management. A significant percentage of patients do not meet the recommended glycemic levels, which means that there are still gaps in care.[2]
The determinants of glycemic control are multifactorial and sociodemographic, clinical, metabolic and behavioral. The sociodemographic variables, including age, sex, and ethnicity, contribute to variability, and clinical variables, such as the duration of diabetes, obesity, and comorbidities, further contribute to variability. Metabolic disorders, especially dyslipidemia and insulin resistance are strongly related to impaired glycemic regulation. Behavioral variables such as adherence to medications, smoking and lack of exercise are also critical determinants of outcomes as diabetes management is multifaceted.[3] Despite the inconsistent results in some studies which identified predictors like longer disease duration, complications, and poor adherence, the findings are not consistent because of the variation in the study population and methods.[4] Massive studies have demonstrated that demographic and metabolic considerations play a key role in deciding on glycemic results. It has been indicated that lipid abnormalities, age and patterns of treatment are some of the factors that can greatly influence glycemic control, hence the need to have integrated approaches that consider various interacting variables.[5] Although there is heightened awareness, optimum glycemic control is still difficult to achieve even in various healthcare environments. It has been reported to have very high prevalence of poor control and it is often associated with poor management, poor access to health care and poor compliance.[6] The inconsistency of results obtained by different populations adds to the importance of having nationally representative analyses.[7]

The glycemic control is greatly impacted by complications and comorbidities. Kidney disease is one of the conditions that complicate care and increase the burden of the disease, which is why the comprehensive approach to care is crucial.[8,9] Obesity and associated metabolic imbalances are also associated with insulin resistance and altered glycemic metabolism but the relation between the two on glycemic outcomes is complex and population-dependent.[10] Research in different areas all indicate high levels of suboptimal control, with predictors such as young age, prolonged disease duration, and lack of adherence to treatment.[11] Factors that pertain to treatment are also very crucial determinants of glycemic outcomes. Control is influenced by lifestyle modification, oral hypoglycemic agents, and insulin therapy interventions, but patients with poorer outcomes receive insulin treatment, rather than the intervention having ineffective efficacy on the patient.[12] Glycemic control has been linked to poor vulnerability to infections and other adverse health effects, which further bears the value of effective glycemic control.[13] Trends in glycemic control have proved to be variable over time due to the variations in the practice of treatment and provision of healthcare which require constant monitoring and evaluation.[14]

Even in the specialized care environments, the optimal glycemic control is challenging to achieve, which is why the need to improve the glycemic control using individualized treatment approaches is justified.[15] New treatments promise to make things better, although they should be used with caution, depending on the patient characteristics.[16] Moreover, the inability to have glycemic control leads to the development of bad outcomes in patients with comorbid conditions, which is why it is necessary to use integrated management strategies.[17] Although there is a wealth of research, they still show gaps in the understanding of the combined impact of sociodemographic, clinical, metabolic, and treatment-related factors on glycemic control. Thus, the aim of the study was to evaluate glycemic control and its predictors in adults with diabetes mellitus and provide a comprehensive analysis of the risk factors and treatment outcomes to guide the development of effective strategies of managing diabetes.[18]

Objectives of the Study

1. To assess the prevalence of glycemic control and its sociodemographic and clinical determinants among adults with diabetes mellitus.
2. To examine the association of metabolic factors and treatment patterns with glycemic outcomes, including predictors of poor glycemic control.

2. Methodology

2.1 Study Design

In this study, the analytical design of the study was cross-sectional using secondary data, the National Health and Nutrition Examination Survey (NHANES), conducted by the National Center of Health Statistics under the umbrella of the Centers of Disease Control and prevention, United States.[19] NHANES used to guarantee national representativeness in the civilian, non-institutionalized population, a sophisticated, multi-phase probability sampling design. The 2017-March 2020 pre-pandemic cycle was used as the foundation of the current analysis and combined various years of data to make it one dataset. The data was an excellent source of demographic, clinical, laboratory and behavioral data applicable to the assessment of diabetes and glycemic control.

2.2 Data Integration and Variable Selection

A set of NHANES data were extracted and merged using the unique participant identifier (SEQN) to create a single analytical dataset. These were demographic (DEMO), diabetes questionnaire (DIQ), glycohemoglobin laboratory (GHB), anthropometric measurements (BMX), blood pressure measurements (BPX) and lipid profile information, such as triglycerides, low-density lipoprotein, high-density lipoprotein, and total cholesterol. The behavioral variables were collected using the smoking questionnaire (SMQ), alcohol questionnaire (ALQ), and physical activity questionnaire (PAQ). The choice of variables was determined by their clinical significance and the existing literature on those variables, particularly in relation to glycemic control, metabolic risk factors, lifestyle habits, and therapy regimens associated with diabetes outcomes.

2.3 Study Population and Inclusion Criteria

For the research study, the subject of investigation is an individual adult patient diagnosed with diabetes mellitus using the questionnaire or medical records. Participants whose glycohemoglobin (HbA1c) values are not available have been excluded from the study to ensure accurate classification of glycemic control status. The total number of individuals in the raw data set is 1,769 out of which only 1,602 individuals had available HbA1c values and thus were included for further analysis. Through multivariate regression analysis, only those participants who had data on all covariates under consideration were selected.

2.4 Outcome Variable Definition

The glycemic control was the main outcome variable and it was assessed using glycohemoglobin (HbA1c) levels measured in the laboratory. According to existing clinical standards, the study subjects were grouped into two based on their glycemic control, where HbA1c <7% was classified as good glycemic control while HbA1c ≥7% was considered poor glycemic control. This dichotomous categorization made it possible to find the factors that were related to insufficient management of diabetes. Also, the HbA1c was being subjected to analysis as a continuous variable in order to test the differences between the treatment groups. The categorical and continuous measures used in a dual manner gave a complete analysis of the glycemic status of the study population.

2.5 Independent Variables

The independent variables were sociodemographic, clinical, behavioral, and treatment-related variables. Among sociodemographic characteristics were age, gender, ethnicity/race, educational status, and income-to-poverty ratio. The clinical variables were body mass index, waist circumference, blood pressure, and parameters of the lipid profile; presence or absence of hypertension, dyslipidemia, and time since diagnosis of diabetes were also taken into account. Dyslipidemia was determined based on either abnormal lipid profile readings or self-reporting of the disease by the patient. Behavioral variables were smoking, alcohol intake, physical exercise, and sedentary behavior. Among treatment-related variables were patients receiving insulin only, oral medications only, or combined medications and those not receiving any medication.

2.6 Statistical Analysis

For examining the relationships between glycemic control and the other variables of interest, the following statistical tests were conducted. Descriptive statistics such as mean and standard deviation were used for continuous variables, while the frequency and percentage were obtained for categorical variables. Chi-square tests were performed in order to test the relationships between categorical variables and glycemic control. Independent sample t-test was used in order to compare means of continuous variables among different groups of glycemic control. Analysis of variance was performed to determine whether there were any significant differences among levels of HbA1c among different treatment groups. Logistic regression was performed to identify the predictors of poor glycemic control, and the findings are reported in odds ratios and their respective 95% CI.

3. Results

3.1 Study Population Characteristics

The quantity of participants analyzed was 1,602 participants out of 1,769 participants who were diabetic and had complete data of HbA1c. The The average age was 61.40 ± 13.04 years, and mostaged ≥60 years (61.17%). The percentage of males in the sample was 52.56. The prevalence rate of obesity (58.43) and dyslipidemia (50.44) was high, and it suggests a significant cardiometabolic burden (Table 1).

Table 1. Baseline Characteristics of Study

Variable	Category	n (%)
Sex	Male	842 (52.56)
	Female	760 (47.44)
Age group	18–39	102 (6.37)
	40–59	520 (32.46)
	≥60	980 (61.17)
BMI	Obese	936 (58.43)
	Overweight	442 (27.59)
	Normal	179 (11.17)
Dyslipidemia	Yes	808 (50.44)
Hypertension	Yes	472 (29.46)

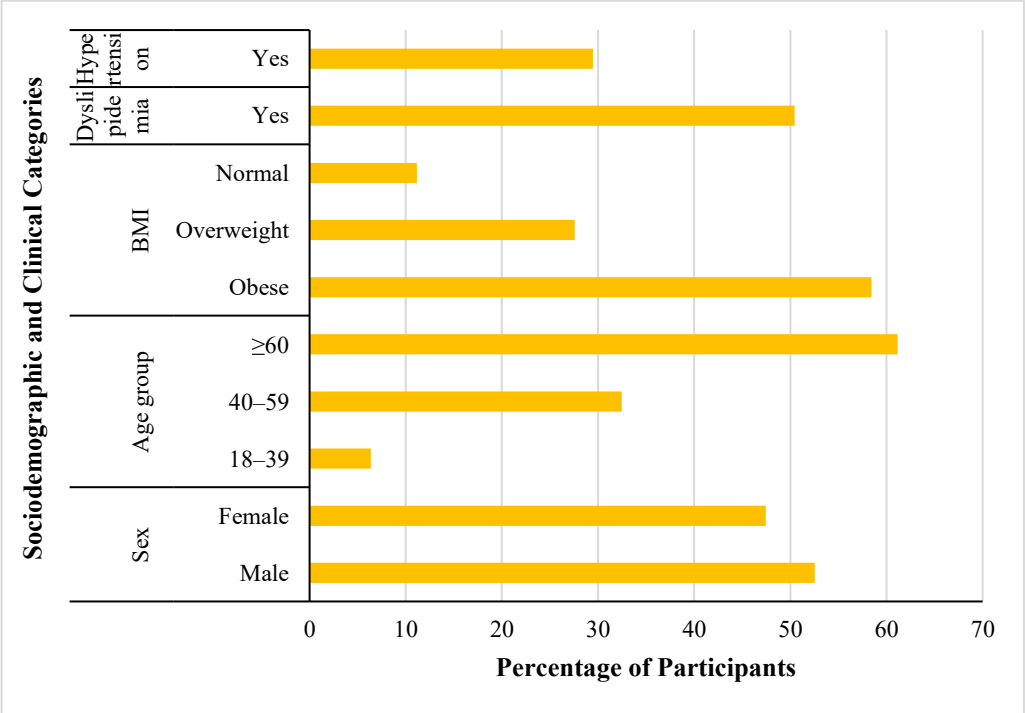


Figure 1. Distribution of Sociodemographic and Clinical Characteristics

Figure 1 shows the representation of subjects based on major sociodemographic and clinical groups such as gender, age group, body mass index classification, and dyslipidemia status. The figure emphasizes the composition of the study sample and emphasizes the inclusion of specific metabolic and sociodemographic attributes pertinent to the study of glycemic regulation.

3.2 Distribution of Glycemic Control

Among 1,602 participants, 835 (52.12%) had good glycemic control, while 767 (47.88%) exhibited poor control. The overall mean HbA1c was 7.40 ± 1.67%. These findings indicate that nearly half of the research participants had inadequate glycemic control, reflecting a considerable clinical burden as shown in Figure 2.

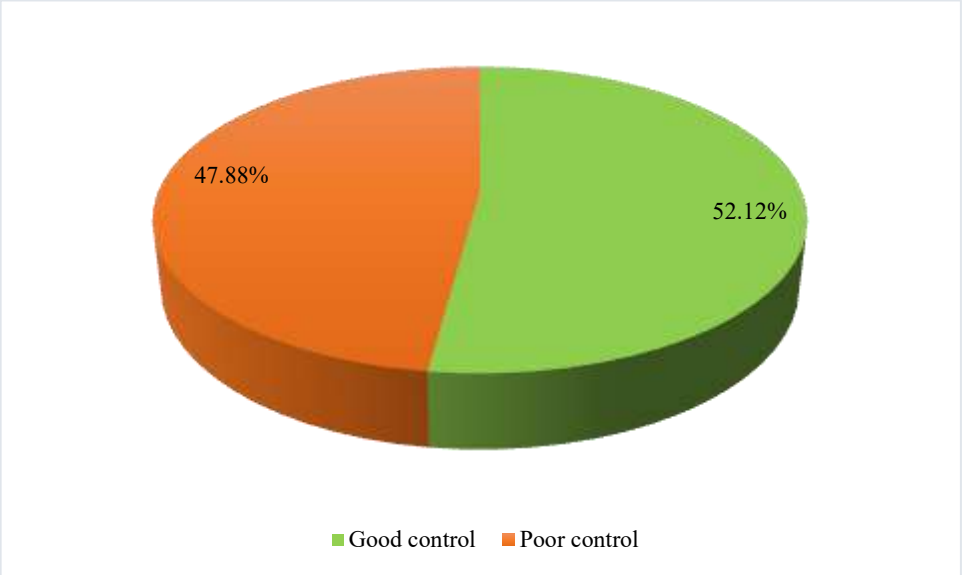


Figure 2. Distribution of Glycemic Control Status

Figure 2 depicts the number of participants categorized on the basis of their glycemic control status. This figure represents the comparison between the participants who have achieved adequate glycemic control and those with poor glycemic control. The chart depicts the overall balance among the glycemic results obtained from the participants in the study.

3.3 Association Between Categorical Variables and Glycemic Control

There was a relationship at the level of significance of $p < 0.001$ between glycemic control and age group, treatment group, dyslipidemia, and duration of diabetes. There was also a relationship at the level of significance of $p = 0.0387$ between glycemic control and race or ethnicity. Other factors examined were not statistically significant (Table 2).

Table 2. Chi-Square Association with Glycemic Control

Variable	χ^2	p-value
Age group	23.43	<0.001
Race/ethnicity	11.73	0.0387
Dyslipidemia	16.53	<0.001
Treatment group	151.82	<0.001
Duration group	17.53	0.0005

3.4 Comparison of Continuous Variables

The independent t-test results revealed that people with inadequate glycemic control had higher total cholesterol levels, higher triglycerides, longer diabetes duration, and low HDL cholesterol levels. The

age variable was slightly lower among those with poor glycemic control. No significant differences were recorded for BMI, waist circumference, blood pressure, LDL cholesterol, and sedentary behavior (see Table 3).

Table 3. Comparison of Continuous Variables

Variable	Good Control Mean	Poor Control Mean	p-value
Age	62.19	60.54	0.0108
Total cholesterol	172.75	180.45	0.0008
HDL	49.90	46.23	<0.001
Triglycerides	114.57	163.29	<0.001
Diabetes duration	12.36	13.94	0.0116

3.5 Treatment Patterns and Glycemic Control

The treatment group and glucose control were substantially correlated ($p < 0.001$). The groups receiving treatment taking insulin therapy had the largest number of participants with poor glycemic control compared to those not under any medication. However, those under oral medications only or not on any medication had relatively higher glycemic control levels is illustrated in Figure 3.

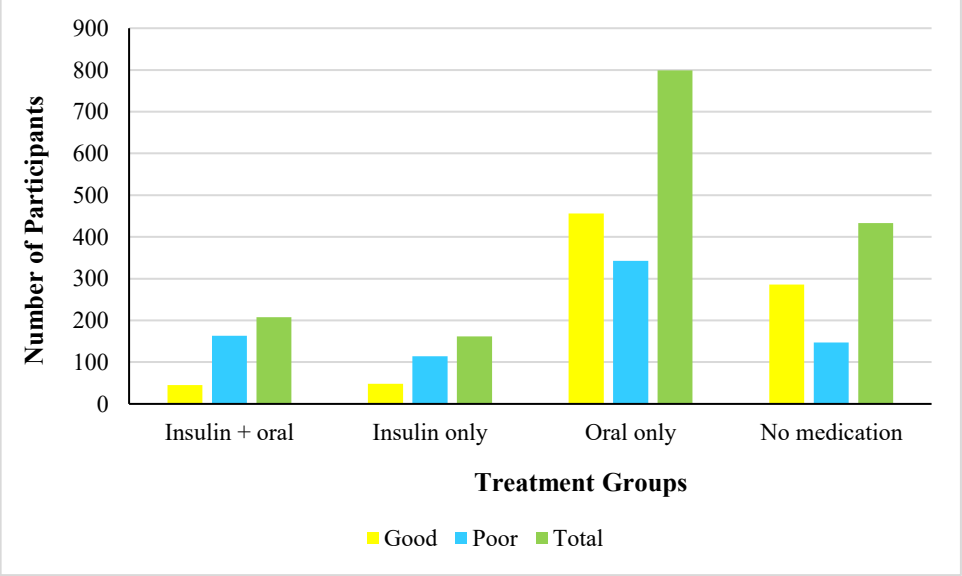


Figure 3. Glycemic Control Distribution Across Treatment Groups

Figure 3 shows the frequency distribution of patients who had adequate and inadequate glycemic control based on their treatment methods. The figure brings out the differences in terms of glycemic control for people on insulin, oral medications, and those not on any form of medication.

3.6 HbA1c Levels Across Treatment Groups

The ANOVA analysis revealed found the HbA1c values of the therapy groups varied statistically significantly ($F = 43.51$, $p < 0.001$). Individuals who were under insulin treatment exhibited higher levels of HbA1c than individuals on oral medications and those not under any treatment at all. This study shows a correlation between treatment and diabetes management (Table 4).

Table 4. HbA1c by Treatment Group

Treatment Group	Mean HbA1c	SD
Insulin + oral	8.30	1.77
Insulin only	8.16	1.80
Oral only	7.14	1.40
No medication	7.17	1.79

3.7 Multivariable Regression Analysis

Dyslipidemia (OR=1.81, p<0.001), age (OR=0.98, p=0.002), and drug use were found to be the predictors for poor glycemic control through multivariate logistic regression analysis. Those patients under oral drugs and those without any drug use were significantly less likely to develop poor control. No significant influence was observed with other factors like body mass index, educational level, and lifestyle, as seen in Table 5.

Table 5. Regression Results

Variable	Odds Ratio	95% CI	p-value
Dyslipidemia	1.81	1.37–2.41	<0.001
Age	0.98	0.97–0.99	0.002
Oral medication	0.28	0.19–0.42	<0.001
No medication	0.08	0.05–0.15	<0.001

4. Discussion

The study established a high rate of ineffective management of glycemic management in individuals with diabetes mellitus meaning that there are significant gaps in the effective management of the disease. Another important determinant was age, with the younger people having poorer control, possibly because of the difference in control of treatment and lifestyle behaviors. The close correlation between lipid deviations and the regulation of glycemic parameters indicated that metabolism factors, especially dyslipidemia, were strongly correlated with poor glycemic outcomes. Even though the incidence of obesity was high, it was not an independent predictor indicating that the metabolic disturbances could be more crucial than anthropometric measurements. The patterns of treatments indicated a poorer glycemic control among insulin users, which could be explained by the fact that a more severe disease leads to a worse glycemic control.

The new study's findings are consistent with other research showing an enormous burden in poor glycemic control or the impact of several variables. The associations identified in this analysis are supported by previous studies that have shown that sociodemographic and healthcare-related factors have a significant impact on glycemic outcomes.[20] Equally, social determinants and health behaviors have an impact on glycemic control that has been highlighted in the context of real-world evidence, but, again, the effects of these determinants and health behaviors may differ between populations.[21] The close relationship between the metabolic abnormalities, and glycemic control that was identified in this study fits the findings that attribute the connection between obesity and lipid disorders to poor metabolic control.[22] Moreover, the absence of a direct relationship between BMI and glycemic control observed in this study has been reported by previous studies to have complex relationships between anthropometric measures and glycemic outcomes.[23] Differences in the response to treatment and differences in the glycemic control in the different treatment groups have also been reported which supports the interpretation that insulin use may be reflective of the severity of the disease, as opposed to the actual treatment effects.[24] Moreover, the inconsistent relationships between the lifestyle factors and glycemic control that have been reported in other studies are also consistent with the non-significant results obtained in this study.[25] All these comparisons point to the multifactorial and context-dependent nature of the glycemic control in the process of diabetes management.[26]

However, the implications of the results of the present research for clinical practice and public health cannot be overlooked. The prevalence of poor glycemic control indicates the need for comprehensive strategies that would address both glycemic and metabolic risk factors. Early identification of individuals who are at increased risk, particularly those suffering from dyslipidemia or receiving insulin, can contribute to the development of interventions that will positively affect outcomes. The cornerstone of glycemic control is effective patient education and adherence to treatment. Also, regular evaluation of lipid profiles into diabetes care could offer a more holistic way of caring. Although it has some strengths, there are several drawbacks to this study. The cross-sectional approach limits the ability to demonstrate a causal relationship between variables. The use of self-reported information on some behavioral aspects could bring about reporting bias. More so, lack of

survey weighting might have an impact on the results' applicability to the entire population. Lack of information on certain variables also led to a smaller sample size to be used in multivariate analysis which could affect the strength of the findings.

The future studies need to involve longitudinal studies so as to have a better understanding of the causal paths and time relationships in glycemic control. Adding more specific indicators of the behavioral and treatment-associated variables can give a better understanding of the determinants that can be modified. Also, considering individual treatment approaches and incorporating metabolic risk control into the everyday management of diabetes can contribute to better outcomes. Further studies based on large, representative data sets are necessary to guide evidence-based interventions on how to enhance glycemic management and reduce the impact of diabetes.

5. Conclusion

In this study, the examination of glycemic control and its determining factor among individuals suffering from diabetes mellitus will involve thorough evaluation. The findings suggest that nearly half of the studied group had poor glycemic control which showed substantial difference in management of diabetes effectively. Several sociodemographic and clinical factors such as age and duration of diabetes mellitus had impact on glycemic control. Particularly, it was found out that metabolic factors played the role of predictors of poor glycemic control. The outcome highlights the vital significance of healthy metabolism with regard to influence on glycemic control. It has been also found out that treatment patterns have significant impact on glycemic control, especially when the treatment involved insulin. As a matter of fact, it might be an indicator of the gravity of the disease and does not indicate the inefficiency of the treatment. In other words, the importance of the timely diagnosis and intervention is emphasized by this finding. Moreover, since some lifestyle factors are found to be statistically insignificant for the glycemic control, further investigation into behavioral determinants of the problem is required. There are several implications that can be made with regard to the clinical aspects of the studied problem. First of all, the regular testing of lipid levels is essential. In addition, special approaches to treatment are important. With respect to the public health level, interventions for those patients who belong to high-risk group can be considered.

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