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ORIGINAL RESEARCH

Determinants of Glycemic Control in Thai Adults with Insulin-Treated Type 2 Diabetes Mellitus: A Cross-Sectional Study

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Introduction: Insulin is an effective treatment for achieving glycemic control and delaying diabetes-related chronic complications. Even with receiving insulin therapy, adults with type 2 diabetes (T2DM) may still struggle to reach their glycemic targets.

Objective: This study aimed to determine factors associated with glycemic control in Thai adults with insulin-treated T2DM.

Methods: A cross-sectional study was conducted among adults with insulin-treated T2DM between July 2021 - May 2022. Glycemic control is measured by Hemoglobin A1C (HbA1C), and good glycemic control was defined as HbA1C < 7%. Characteristics of adults with T2DM were analyzed using descriptive statistics. Determinant factors of glycemic control, including diabetes self-management, attitude toward insulin treatment, social support, patient-healthcare providers communication, self-monitoring blood glucose (SMBG), insulin injection technique, self-reported hypoglycemia, and lipohypertrophy, were analyzed using binary logistic regression.

Results: Of the 273 participants, the mean age was 62.1 (SD = 10.7) years, 60.8% were females, and 41.8% achieved good glycemic control. Binary logistic regression analyses after adjusting for gender, age, BMI, education level, and health benefits show that performing better diabetes self-management (Adjusted odds ratio (AOR) = 1.15; 95% CI: 1.10–1.21, $p < 0.001$), had a less negative attitude toward insulin treatment (AOR = 0.92; 95% CI: 0.89–0.96, $p < 0.001$), demonstrated better insulin injection techniques (AOR = 1.35; 95% CI: 1.13–1.60, $p < 0.001$), and performed SMBG at least 3 times per week (AOR = 9.80; 95% CI: 2.88–33.33, $p < 0.001$) were more likely to achieve good glycemic control in Thai adults with insulin-treated T2DM.

Conclusion: Diabetes self-management, attitude toward insulin treatment, insulin injection technique, and SMBG were significantly associated with glycemic control in Thai adults with insulin-treated T2DM.

Keywords: type 2 diabetes, insulin-treated, self-management, attitude toward insulin, glycemic control

Introduction

Maintaining optimal glycemic control is crucial in preventing or delaying complications associated with diabetes. Diabetes is among the most serious health issues worldwide. The global prevalence of diabetes is anticipated to increase from 537 million people in 2021 to 783 million people by 2045.[1] Type 2 diabetes (T2DM) accounts for approximately 90% of all cases of diabetes.[1] Diabetes has various long-term complications that affect the quality of life, the burden on the healthcare system, and healthcare expenditures. Insulin therapy is an effective treatment in diabetes for achieving glycemic targets.[2] However, adults with insulin-treated T2DM have unmet glycemic targets.[3] Various factors are associated with glycemic control in adults with insulin-treated T2DM, such as diabetes self-management, proper insulin injection technique, self-monitoring blood glucose (SMBG), hypoglycemic events, social support, and attitude toward insulin treatment.[4–7]

Glycated hemoglobin (HbA1c) is a standard for measuring diabetes control and is the clinical marker for predicting long-term diabetes-related complications. HbA1C greater than 7% is associated with a significantly enhanced risk of

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macrovascular and microvascular complications.[8] Diabetes self-management is recognized as a cornerstone of glycemic control and generally embraces diet, physical activity, and medication adherence. Proper diabetes self-management is associated with improving glycemic control and delaying diabetes complications.[9]

There are many challenges associated with insulin therapy, including the attitudes of adults toward insulin treatment and the fear of injecting insulin.[10] Attitudes toward insulin treatment commonly are negative perceptions regarding insulin therapy, such as fear of hypoglycemic events, worsened diabetes conditions, or stigma due to insulin injections,[5] and this might lead to noncompliance with insulin injections.

Also, the effectiveness of the insulin injection technique is an essential skill for adults with insulin-treated diabetes and is required for achieving glycemic control.[11] The insulin injection technique encompasses many steps and activities, such as preparing insulin before injection, rotating injection sites, proper needle use, and checking skin before injection to ensure that the patient receives a dose of insulin as prescribed and avoids insulin-related complications.[11–13]

Hypoglycemia is one of the most concerning complications of diabetes treatment, particularly in individuals receiving insulin therapy, and is characterized by abnormally low blood glucose levels.[8,14] It is reported as the most common patient-reported insulin-related complication, medication-related hospitalization, emergency department visits, and consequences of diabetes control.[15] Adults undergoing insulin treatment may fear hypoglycemic events and attempt to avoid them by skipping some insulin doses. This behavior negatively impacts insulin therapy adherence and diabetes control achievement.[16]

Lipohypertrophy is a tumor-like lump of adipose tissue that is observable and palpable in the area where insulin is administered. Lipohypertrophy is one of the complications associated with inadequate insulin injection technique, specifically insufficient rotation of injection sites. Lipohypertrophy may reduce, unpredictably affect the absorption of insulin, and negatively affect glycemic control.[17]

SMBG is recommended as a tool for adults with insulin-treated T2DM to manage their diabetes. It facilitates lifestyle modification, detects undesirable symptoms, and promotes individual diabetes self-management and diabetes control.[18] However, SMBG might not be regularly performed due to some barriers, such as the cost related to it, individuals' knowledge, patient-healthcare provider communication, and attitude toward diabetes.[6,18]

Social support is an essential factor in individuals' coping with diabetes and contributes to diabetes management. Individuals with diabetes must manage their diet, adhere to medication, and engage in physical activity.[19] However, social support might be insufficient to support individuals with diabetes due to a lack of some support skills, such as communication and problem-solving, and a lack of effective understanding and involvement in self-management.[20]

Improving engagement in diabetes self-management requires effective patient-healthcare provider communication, which is fundamental for assisting individuals with diabetes in understanding and actively managing their condition through education and engagement.[19]

Patient-healthcare provider communication barriers have been reported, such as time limitations, insufficient communication skills, healthcare providers focusing on a number of clinical results rather than patient self-management concerns,[21] and the impact of the lockdown protocol during COVID-19 in particular. However, telemedicine plays an influential role in compensating for the communication between healthcare providers and patients during the lockdown period and demonstrates its benefits in diabetes management.[22]

Despite insulin being a key component in the clinical management of T2DM to prevent diabetes-related complications, glycemic control remains inadequate in a significant proportion of adults with T2DM receiving insulin therapy. Although previous studies have investigated factors associated with glycemic control in adults with T2DM, most have focused on diverse populations using various medication regimens. There is a marked scarcity of research that examines explicitly adults with T2DM receiving insulin therapy, especially within the Thai healthcare context. Moreover, a few studies have addressed how the pandemic may have influenced patient adherence, self-management behaviors, and psychosocial factors that impact insulin use and glycemic outcomes.

Addressing this gap is critical for developing patient-centered interventions that enhance adherence and self-management behaviors among adults with insulin-treated T2DM. Research focused on this population can provide valuable insights into the preferences, challenges, and support needs of this group, thereby contributing to improved clinical management strategies and outcomes during and beyond public health crises.

Materials and Methods

Study Design

This cross-sectional study was conducted at the diabetes clinic, the medical outpatient department of Siriraj Hospital, Thailand.

Population and Sample

The study population consisted of male and female adults with T2DM who were receiving insulin treatment. A convenience sampling method was employed to recruit participants who met the study's predefined inclusion and exclusion criteria. Participants were selected based on their accessibility and willingness to participate, from among individuals receiving care at the diabetes clinic, the medical outpatient department of Siriraj Hospital, Thailand. This method was selected for its feasibility and alignment with real-world clinical practice, particularly given the ongoing challenges posed by the COVID-19 pandemic. Eligible patients were approached and recruited in the study based on the inclusion and exclusion criteria. The inclusion criteria were: 1) adults with T2DM who were aged 18 years or older, 2) receiving insulin treatment for at least six months, and 3) being able to communicate in Thai. The exclusion criteria included 1) pregnancy, 2) those with severe illnesses that impaired self-management capabilities, and 3) individuals over 60 years of age with cognitive impairments, as indicated by a Mini-Cog score of less than 3.

Sample Size Calculation

The sample size was determined using the single population proportion formula, based on data from a previous study by Dedefo et al,[23] which reported that 13.49% of T2DM patients with social support achieved good glycemic control, compared to 26.38% of those without support (OR = 1.99; 95% CI: 1.13–3.55). To detect a similar difference with a 95% confidence level ($\alpha = 0.05$) and a power of 80% ($1 - \beta = 0.80$), and assuming that 25.4% of the sample would report receiving social support, the required minimum sample size was calculated to be 273 participants.

Study Instruments

The Data Collection Tools Consisted of Two Parts

Part 1: Participant Screening Tool

The Mini-Cog. This tool, developed by Borson et al,[24] is a brief cognitive screening instrument comprising a clock drawing test and a three-item recall test. It demonstrates high sensitivity and specificity for detecting cognitive impairment. The Thai version, translated and culturally adapted by Trongsakul,[25] has shown good interrater reliability when used among older Thai adults with T2DM (Kappa = 0.80, $p < 0.001$, 95% CI: 0.50–1.00).

Part 2: Data Collection Instruments

Demographic and Clinical Data Form. This form captures participant characteristics including gender, age, body mass index (BMI), education level, employment status, health benefit type, duration of T2DM and insulin use, type of insulin device, number of daily injections, and most recent HbA1c level within the last three months.

Summary of Diabetes Self-Care Activities Measure (SDSCA). Developed by Toobert and Glasgow,[26] the SDSCA assesses diabetes self-management behaviors. The SDSCA Thai version,[26] translated and culturally adapted, consists of 19 items covering diet, physical activity, blood glucose monitoring, foot care, and medication adherence. It uses a 7-point Likert scale, and the internal consistency reliability (Cronbach's alpha) was reported as 0.73. Scores range from 0 to 133, with interpretations as follows: 0–47 = poor, 48–96 = moderate, and 97–133 = good self-management.[27]

Insulin Treatment Appraisal Scale (ITAS). This 12-item tool, developed by Snoek et al,[28] assesses attitudes toward insulin therapy. The Thai version demonstrated acceptable reliability (Cronbach's alpha = 0.77).[29] It uses a 5-point Likert scale, where higher scores indicate a more negative attitude. Scores are interpreted as: <49 = mild, 49–62 = moderate, 63–75 = severe, and >75 = very severe negative attitude.

ENRICHD Social Support Instrument (ESSI). A 7-item tool developed by Vaglio et al to measure perceived social support.[30] The Thai version has high internal consistency (Cronbach's alpha = 0.93).[31] It is rated on a 5-point Likert scale with total scores ranging from 6 to 30: 6–14 = low, 15–22 = moderate, and 23–30 = high social support.

Patient–Healthcare Provider Communication Scale. This 23-item self-administered questionnaire, originally developed by Schillinger et al,[32] was translated into Thai and demonstrated excellent internal consistency (Cronbach's alpha = 0.95).[33] It uses a 5-point Likert scale. Total scores are categorized as follows: 23–53 = poor, 54–83 = good, and 84–115 = very good communication.

Insulin Injection Skill Assessment Form. This 12-item observational checklist was developed by the research team based on clinical guidelines and literature on insulin injection techniques.[34] Skills were evaluated by a certified diabetes educator using a 3-point Likert scale (0 = not performed, 1 = partially correct, 2 = correctly performed). Scores range from 0–24: 0–8 = poor, 9–16 = moderate, and 17–24 = good injection skill. Content validity was reviewed by three experts in diabetes care.

Self-Reported Hypoglycemia Form. A researcher-developed self-administered tool to assess experiences of hypoglycemia over the past six months. It categorizes hypoglycemia into: No hypoglycemia: No symptoms reported; Level 1: blood glucose 54–70 mg/dL, with mild symptoms (eg, shakiness, irritability), self-treated; Level 2: blood glucose <54 mg/dL, with moderate symptoms (eg, confusion, vision changes), self-treated; Level 3: severe symptoms (eg, unconsciousness, seizure), requiring external assistance. Content validity was ensured through three experts in diabetes care.[2]

Lipohypertrophy Assessment Form. A researcher-developed observational checklist used to document the presence of lipohypertrophy at injection sites. Two certified diabetes educators, trained in palpation techniques, independently assessed and verified lipohypertrophy. Outcomes were recorded as "Yes" (present) or "No" (absent). The tool was based on current clinical recommendations and literature.[17] Content validity was ensured through three experts in diabetes care.

Self-Monitoring of Blood Glucose (SMBG) Frequency Form. This self-reported questionnaire, developed by the researcher, measures the frequency of SMBG. Participants were asked to select one of the following categories: no SMBG, SMBG 1–2 times/week, SMBG ≥3 times/week, or SMBG only during hypoglycemic episodes. The tool's content was validated by three experts in diabetes care.

Data Collection

Data collection was conducted from July 2021 to May 2022. Initially, registered nurses screened adults with T2DM attending the diabetes clinic, the medical outpatient department to identify those meeting the inclusion criteria. Upon obtaining permission, the researcher provided potential participants with detailed information about the study, including its objectives, protocol, potential benefits, associated risks, privacy considerations, and confidentiality. To address exclusion criteria, the researcher asked the potential participants aged over 60 years to screen for cognitive impairment using the Mini-Cog. After this screening process, eligible participants provided informed consent and were invited to complete the questionnaires. Participants were informed of their right to withdraw from the study at any time before the completion of data collection.

The data collection process requires approximately 120 minutes per participant. After completing the questionnaires, participants underwent an assessment and verification for lipohypertrophy by two certified diabetes educators. A certified diabetes educator assessed the insulin injection technique through the participant demonstration, and clinical data were retrieved from their medical records with their consent. The data collection procedures mentioned above were repeated until the researchers achieved the target sample size of 273 participants.

Data Analysis

Descriptive statistics, including frequency, percentage, mean, and standard deviation, were performed for continuous and categorical variables to describe the participants' demographic and clinical characteristics. *T*-test and chi-square assessed the association between the demographic data and HbA1C. Binary logistic regression tests assessed the association between independent variables and HbA1C. A *p-value* of 0.05 was used to determine the statistical significance level. The IBM SPSS statistical package version 22.0 was used for data analysis.

Ethical Consideration

This study adhered to the ethical principles outlined in the Declaration of Helsinki and received ethical approval from the Institutional Review Board of the Faculty of Medicine, Siriraj Hospital, Mahidol University, Thailand (COA No. Si 387/2021) before participant recruitment began.

Results

Demographic Characteristics

This study included 273 participants, of whom 60.8% were female. The mean age was 62.1 years (SD = 10.7), and the mean body mass index (BMI) was 27.9 kg/m² (SD = 5.6). The majority of participants (80.6%) were married. Regarding education level, approximately one-third (38.8%) had completed only elementary school. Less than half (45.4%) were either retired or unemployed.

In terms of healthcare coverage, the two most common benefit schemes were government (38.5%) and health coverage scheme (37.4%). Fewer than half of the participants (41.8%) achieved the glycemic control target (HbA1c < 7%). Most participants (87.5%) self-administered insulin, with the vast majority (95.2%) using an insulin pen. More than half (56%) injected insulin at least twice per day. The mean duration of diabetes was 16.4 years (SD = 9.9), and the mean duration of insulin therapy was 6.9 years (SD = 6.6).

There were no statistically significant differences in demographic characteristics, including age (p = 0.517), sex (p = 0.936), BMI (p = 0.306), education level (p = 0.881), employment status (p = 0.309), type of health benefit (p = 0.614), or duration of diabetes (p = 0.437), between participants with good glycemic control (HbA1c < 7%) and those with poor control (HbA1c ≥ 7%) (Table 1).

Determinant Factors According to Glycemic Control

Among all participants, they had a strongly negative attitude toward insulin treatment (mean = 76.08, SD=15.26), moderate level of diabetes self-management (mean = 74.79, SD = 18.80), moderate level of social support (mean = 18.03, SD = 8.40), good level of patient-healthcare providers communication (mean = 95.43, SD = 14.20), good level of

Table 1 Sociodemographic and Clinical Characteristics of Adults with T2DM, Stratified by Glycemic Control

Demographic Characteristics	**Total (N = 273) n (%)**	**Poor Glycemic Control n = 159 (58.2%)**	**Good Glycemic Control n = 114 (41.8%)**	**χ^2 / t-test**	***p-value***
Gender, n (%)				$0.01^{\chi2}$	0.936^{ns}
Male[ref]	107 (39.2%)	62 (22.7%)	45 (16.5%)		
Female	166 (60.8%)	97 (35.5%)	69 (25.3%)		
Age in a year, mean (SD) Min-Max 36–89	62.1 (10.7)	61.8 (10.9)	62.6 (10.4)	-0.65^{t}	0.517^{ns}
Body mass index (kg/m^2), mean (SD) Min-Max 16.6–48.4	27.9 (5.6)	27.6 (5.6)	28.4 (5.6)	-1.03^{t}	0.306^{ns}
Education, n (%)					
Elementary[ref]	106 (38.8%)	59 (21.6%)	47 (17.2%)	$1.18^{\chi2}$	0.881^{ns}
High school	64 (23.4%)	38 (13.9%)	26 (9.5%)		
Diploma	35 (12.8%)	23 (8.4%)	12 (4.4%)		
Bachelor's degree	50 (18.3%)	29 (10.6%)	21 (7.7%)		
Master's degree	18 (6.6%)	10 (3.7%)	8 (2.9%)		

(*Continued*)

Table 1 (Continued).

Demographic Characteristics	**Total (N = 273) n (%)**	**Poor Glycemic Control n = 159 (58.2%)**	**Good Glycemic Control n = 114 (41.8%)**	**χ^2 / *t*-test**	***p-value***
Employment, n (%)					
Retirement/ unemployed[ref]	124 (45.4%)	67 (24.5%)	57 (20.9%)	$4.80^{\chi 2}$	0.309^{ns}
Government officer	62 (22.7%)	36 (13.2%)	26 (9.5%)		
Self-employed	45 (16.5%)	30 (11.0%)	15 (5.5%)		
Private company employee	36 (13.2%)	24 (8.8%)	12 (4.4%)		
Farmer	6 (2.2%)	2 (0.7%)	4 (1.5%)		
Health benefits, n (%)					
Government[ref]	105 (38.4%)	63 (23.1%)	42 (15.3%)	$1.80^{\chi 2}$	0.614^{ns}
Healthcare coverage scheme	102 (37.4%)	56 (20.5%)	46 (16.8%)		
Social security scheme	38 (13.9%)	21 (7.7%)	17 (6.2%)		
Self-payment	28 (10.3%)	19 (7.0%)	9 (3.3%)		
Duration of T2DM (yrs.), mean (SD) Min-Max 1–50	16.4 (9.9)	16.0 (9.5)	16.9 (10.3)	-0.78^{t}	0.437^{ns}
Duration of receiving insulin therapy (yrs.), mean (SD) Min-Max 1–42	6.9 (6.6)	6.5 (6.4)	7.6 (7.8)	-1.34^{t}	0.181^{ns}
Insulin injection, n (%)					
Self-injection[ref]	239 (87.5%)	137 (50.2%)	102 (37.4%)	$0.67^{\chi 2}$	0.414^{ns}
Care-giver	34 (12.5%)	22 (8.1%)	12 (4.4%)		
Insulin injection devices, n (%)					
Syringe insulin[ref]	13 (4.8%)	8 (2.9%)	5 (1.8%)	$0.06^{\chi 2}$	0.805^{ns}
Insulin pen	260 (95.2%)	151 (55.3%)	109 (39.9%)		
The number of insulin injections per day, n (%)				$3.09^{\chi 2}$	0.079^{ns}
Once daily[ref]	120 (44.0%)	77 (28.2%)	43 (15.8%)		
Twice daily and more	153 (56.0%)	82 (30.0%)	71 (26.0%)		

Note: *p-value < 0.05.
Abbreviations: χ^2, chi-square test; t, independent *t*-test, ref, reference; ns, non-significance.

insulin injection technique (mean = 24.06, SD = 4.25), approximately half of them (50.9%) not performed SMBG, more than half of them (66.3%) reported that they had no hypoglycemic symptoms within the last six months. A majority (75.5%) of participants did not detect lipohypertrophy.

The Chi-square test found that among the variables of this study, diabetes self-management, attitudes toward insulin treatment, patient-healthcare providers communication, insulin injection technique, SMBG, and self-reported hypoglycemia had a significant statistical difference between the groups exhibiting good and poor glycemic control ($p < 0.001$). Lipohypertrophy had a significant statistical difference between these two groups at $p < 0.01$. However, there were no significant statistical differences in social support between these two groups (Table 2).

Table 2 Determinants Factors According to Glycemic Control in Adults with Insulin-Treated T2DM

Variables	Total (N = 273)	Poor Glycemic Control n = 159 (58.2%)	Good Glycemic Control n = 114 (41.8%)	χ^2 / t-test	*p-value*
Diabetes self-management[a], mean (SD)	74.79 (18.80)	64.73 (14.54)	88.82 (14.65)	−13.46[t]	0.000**
Attitude toward insulin treatment[b], mean (SD)	76.08 (15.26)	82.06 (8.34)	67.74 (18.50)	8.62[t]	0.000**
Social support[c], mean (SD)	18.03 (8.40)	17.38 (8.36)	18.95 (8.40)	−1.53[t]	0.128[ns]
Patient-healthcare provider's communication[d], mean (SD)	95.43 (14.20)	92.85 (14.47)	99.04 (13.04)	−3.63[t]	0.000**
Insulin injection technique[e], mean (SD)	24.06 (4.25)	22.60 (4.44)	26.10 (2.95)	−7.32[t]	0.000**
SMBG, n (%)				49.43[χ2]	0.000**
Not performed[ref]	139 (50.9%)	99 (36.3%)	40 (14.7%)		
Performed 1–2 times/week	57 (20.9%)	30 (11.0%)	27 (9.9%)		
Performed at least 3 times/week	60 (22.0%)	14 (5.1%)	46 (16.8%)		
Performed SMBG when having hypoglycemic symptoms	17 (6.2%)	16 (5.9%)	1 (0.4%)		
Self-reported hypoglycemia, n (%)				44.60[χ2]	0.000**
No[ref]	136 (49.8%)	52 (19.0%)	84 (30.8%)		
Yes	137 (50.2%)	107 (39.2%)	30 (11.0%)		
Lipohypertrophy, n (%)				8.10[χ2]	0.004*
No[ref]	206 (75.5%)	110 (40.3%)	96 (35.2%)		
Yes	67 (24.5%)	49 (17.9%)	18 (6.6%)		

Notes: *p < 0.01, **p < 0.001. [a]Diabetes self-management scores were categorized as: 0–47 = poor, 48–96 = moderate, and 97–133 = good. [b]Attitude toward insulin treatment scores, where higher values indicate more negative attitudes, were classified as: <49 = mild, 49–62 = moderate, 63–75 = severe, and >75 = very severe. [c]Social Support scores are categorized as: 6–14 = low, 15–22 = moderate, and 23–30 = high social support. [d]Patient–healthcare provider communication scores are categorized as: 23–53 = poor, 54–83 = good, and 84–115 = very good communication. [e]Insulin injection skill scores are categorized as: 0–8 = poor, 9–16 = moderate, and 17–24 = good injection skill.

Results of Binary Logistic Regression

The binary logistic regression analysis showed that both models significantly predicted glycemic control. Model II, which controlled for demographic and contextual covariates, demonstrated a marginally improved model fit over Model I, as reflected by a reduction in −2 Log Likelihood (from 147.293 to 139.961) and an increase in Nagelkerke R^2 (from 0.753 to 0.764). Assumption checks confirmed that key assumptions of binary logistic regression were adequately met in both models, with no indication of multicollinearity, outlier influence, or violation of linearity in the logit.

Model I identified several significant predictors of good glycemic control among insulin-treated adults with type 2 diabetes. Participants with higher diabetes self-management scores were 15% more likely to achieve good glycemic control for each unit increase in their self-management score (AOR = 1.15; 95% CI: 1.10–1.20; $p < 0.001$). Similarly, those with a less negative attitude toward insulin therapy were significantly more likely to achieve good glycemic control, with each unit decrease in negative attitude associated with a 7% increase in the odds of good control (AOR = 0.93; 95% CI: 0.90–0.97; $p < 0.001$).

Better insulin injection technique was also positively associated with glycemic control: each unit increase in the insulin injection technique score corresponded to a 33% increase in the odds of achieving target glucose levels (AOR = 1.33; 95% CI: 1.13–1.57; $p = 0.001$). In terms of SMBG, participants who performed SMBG at least three times per week had more than eleven times higher odds of achieving good glycemic control (AOR = 11.10; 95% CI: 3.57–34.58; $p < 0.001$), while those performing SMBG 1–2 times per week had over four times higher odds (AOR = 4.41; 95% CI: 1.55–12.57; $p = 0.005$), compared to those who did not perform SMBG.

In contrast, no statistically significant associations were found between glycemic control and the following variables: social support (AOR = 1.00; 95% CI: 0.95–1.06; p = 0.982), patient–healthcare provider communication (AOR = 1.01; 95% CI: 0.98–1.04; p = 0.515), performing SMBG when experiencing hypoglycemia (AOR = 0.07; 95% CI: 0.00–1.48; p = 0.088), self-reported hypoglycemia (AOR = 2.42; 95% CI: 0.98–5.99; p = 0.056), and lipohypertrophy (AOR = 1.14; 95% CI: 0.43–3.02; p = 0.793) (see Table 3).

Model II, which adjusted for potential confounders including gender, age, body mass index (BMI), education level, and health benefit type, confirmed the significance of the same key predictors identified in Model I. The binary logistic regression model demonstrated a strong explanatory power, with a Nagelkerke R^2 value of 0.764, indicating that approximately 76.4% of the variance in the dependent variable was accounted for by the predictor variables. Specifically, participants who reported higher diabetes self-management scores were 15% more likely to achieve good glycemic control for each unit increase (AOR = 1.15; 95% CI: 1.10–1.21; $p < 0.001$). Similarly, individuals with a less negative attitude toward insulin therapy had 8% higher odds of achieving glycemic targets per unit reduction in negative attitude (AOR = 0.92; 95% CI: 0.89–0.96; $p < 0.001$), suggesting a negative relationship between insulin-related stigma and glycemic control.

Better insulin injection technique was associated with a 35% increase in the likelihood of good glycemic control (AOR = 1.35; 95% CI: 1.13–1.60; $p < 0.001$). Regarding SMBG frequency, participants who performed SMBG at least three times per week were nearly 10 times more likely to achieve glycemic targets compared to those who did not perform SMBG (AOR = 9.80; 95% CI: 2.88–33.33; $p < 0.001$). Those who performed SMBG 1–2 times per week also had significantly higher odds of good glycemic control (AOR = 4.96; 95% CI: 1.56–15.80; p = 0.007).

In contrast, the following factors were not significantly associated with glycemic control in Model II: social support (AOR = 1.00; 95% CI: 0.94–1.06; p = 0.962), patient–healthcare provider communication (AOR = 1.02; 95% CI: 0.98–1.05; p = 0.348), performing SMBG when experiencing hypoglycemia (AOR = 0.05; 95% CI: 0.00–1.17; p = 0.062), self-reported hypoglycemia (AOR = 2.37; 95% CI: 0.91–6.18; p = 0.079), and detected lipohypertrophy (AOR = 1.13; 95% CI: 0.40–3.22; p = 0.814) (Table 3).

Table 3 Binary Logistic Regression Predicting Glycemic Control in Adults with Insulin-Treated T2DM

Variables (N=273)	**Model I**			**Model II**		
	AOR	**95% CI**	***p-value***	**AOR**	**95% CI**	***p-value***
Diabetes self-management	1.15	1.10–1.20	0.000**	1.15	1.10–1.21	0.000**
Attitude toward insulin	0.93	0.90–0.97	0.000**	0.92	0.89–0.96	0.000**
Social support	1.00	0.95–1.06	0.982	1.00	0.94–1.06	0.962
Patient-healthcare providers communication	1.01	0.98–1.04	0.515	1.02	0.98–1.05	0.348
Insulin injection technique	1.33	1.13–1.57	0.001**	1.35	1.13–1.60	0.001**
SMBG (Not performed = ref)						
Performed SMBG 1–2 times/week	4.41	1.55–12.57	0.005*	4.96	1.56–15.80	0.007*
Performed SMBG at least 3 times/week	11.10	3.57–34.58	0.000**	9.80	2.88–33.33	0.000**
Performed SMBG when having hypoglycemic symptoms	0.07	0.00–1.48	0.088	0.05	0.00–1.17	0.062
Self-reported hypoglycemia (No = ref)	2.42	0.98–5.99	0.056	2.37	0.91–6.18	0.079
Lipohypertrophy (No = ref)	1.14	0.43–3.02	0.793	1.13	0.40–3.22	0.814

Notes: *$p < 0.05$, **$p < 0.001$. Model I = Initial model, Cox & Snell R^2 = 0.559, Nagelkerke R^2 = 0.753, −2 Log likelihood = 147.293; Model II = Controlled by gender, age, BMI, education level, health benefits, Cox & Snell R^2 = 0.567, Nagelkerke R^2 = 0.764, −2 Log likelihood = 139.961.
Abbreviations: AOR, adjusted odd ratio; 95% CI, 95% Confidence Interval; SMBG, self-monitoring blood glucose.

Discussion

This study found that performing better diabetes self-management is more likely to be associated with good glycemic control. Its findings correspond with those of the systematic reviews, demonstrating that enhanced diabetes self-management improves glycemic control in T2DM.[35–37] Diabetes self-management, which includes dietary management, regular physical activity performance, and medication adherence, is the basis for glycemic control. Although insulin therapy effectively lowers blood glucose levels, diabetes self-management remains vital in attaining glycemic targets.[38] The study in adults with insulin-treated T2DM in Taiwan confirmed that diabetes self-management has a significant negative correlation with HbA1c levels. An improvement in diabetes self-management scores is associated with a corresponding reduction in HbA1c levels.[37] During the COVID-19 pandemic, individuals with diabetes faced significant challenges in adhering to self-management routines, particularly regarding meal planning and engaging in group or outdoor physical activities. Social distancing and isolation disrupted established routines, requiring individuals to adjust their self-management strategies.[39] While participation in group physical activities declined, many individuals adapted by performing physical activity independently, demonstrating resilience in sustaining diabetes self-management practices despite the restrictive circumstances. This is consistent with the study conducted in Saudi Arabia, revealing that individuals with diabetes in Saudi Arabia could maintain a good level of diabetes self-management and diabetes control during COVID-19.[40] It remains essential to encourage adults with insulin-treated T2DM to engage in diabetes self-management.

For attitude toward insulin treatment, this study found that most participants with a less negative attitude toward insulin treatment were more likely to achieve glycemic control. This finding aligns with the previous study conducted in adults with insulin-treated T2DM in Dubai, which found statistically significant negative correlations between the participants' attitudes and HbA1C levels.[41] Receiving insulin therapy affects an individual's attitude, which reflects a worsening in their diabetes condition, receiving stigmatized treatment, and causing more difficulties in daily life when using insulin injections.[10,42] These, along with individual perception and anxiety about the adverse effects of insulin, will affect their quality of life, such as hypoglycemia, painful injections, and sleep disturbance.[43] Consequently, a negative attitude toward insulin treatment shows potential effects on suboptimal glycemic control in adults with insulin-treated T2DM.

Effective insulin therapy is pivotal for achieving glycemic targets. However, the effectiveness of insulin therapy depends on the correct insulin injection technique.[7] This study observed that adults with T2DM who employed proper insulin injection technique were more likely to attain better glycemic control. This aligns with prior research indicating that appropriate insulin injection techniques, such as rotating injection sites, ensuring correct dosing, and maintaining proper needle changing times, are associated with improved glycemic control.[7,13]

While accurate insulin injection techniques are essential for effective glycemic control, the quality of communication between patients and healthcare providers significantly influences patients' understanding, adherence, and confidence in managing their condition. Effective communication encompasses clear explanations of treatment plans, attentive listening to patient concerns, and collaborative decision-making.[44] Such interactions not only enhance patient understanding but also empower them to manage their condition proactively. This collaborative approach ensures that patients are well-informed about proper insulin injection techniques and feel supported in their diabetes self-management, ultimately leading to improved glycemic outcomes.[13,45]

Therefore, patient–healthcare provider communication plays a complementary role by reinforcing the technical aspects of insulin therapy with personalized support and education, fostering better adherence and glycemic control. Participants reporting effective communication with healthcare providers demonstrated better adherence to insulin regimens and a higher likelihood of achieving glycemic targets.[13,46] The COVID-19 pandemic introduced challenges to traditional healthcare delivery, necessitating a shift towards telemedicine.[47,48] Despite initial concerns, telehealth services have proven effective in providing diabetes education for maintaining continuity of care and supporting glycemic control during periods of restricted in-person consultations.[49,50]

Participants who self-reported hypoglycemia were found to be less likely to achieve their glycemic targets. The previous study highlighted hypoglycemia as a significant concern among adults undergoing insulin treatment, emphasizing its impact on psychological well-being, daily activities, and engagement with insulin treatment.[51,52] Consequently,

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they try to maintain high blood glucose levels or occasionally omit insulin doses to prevent hypoglycemia, thereby contributing to the challenge of controlled diabetes.[53]

This study found that less than half of the participants (42.9%) regularly performed SMBG to check their blood sugar levels. Nevertheless, the participants who performed SMBG at least 3 times per week were more likely to have better glycemic control than those who did not perform SMBG. SMBG facilitates diabetes self-management modification, and its benefits have been shown to be an essential, integral part of glycemic control in individuals with T2DM undergoing insulin treatment.[54] The finding of this study is also congruent with the meta-analysis study, which demonstrated that SMBG was statistically significantly associated with decreased HbA1c at 12 and 24 weeks.[55] SMBG assists adults with insulin-treated T2DM in applying SMBG to modify their self-management to control their blood glucose.

Moreover, the literature informed that individuals who perform regular SMBG often have higher motivation levels to achieve glycemic targets.[18] However, the structured SMBG demonstrated its short-term benefits of less than 12 months in glycemic control.[55,56] The different results could be attributed to the long-term financial challenges faced by individuals with T2DM, as they may find it difficult to sustain the ongoing costs associated with glucometer devices and glucose strips and the discomfort related to performing SMBG.[56]

Nevertheless, this study's findings show that lipohypertrophy did not show a statistically significant association with achieving glycemic control. Of the participants, lipohypertrophy was detected at 24.5%. The poor glycemic control group exhibited a higher lipohypertrophy occurrence (17.9%) compared to the good glycemic control group (6.6%), with a statistically significant difference. This observation aligns with other studies suggesting that lipohypertrophy could hinder insulin absorption, potentially resulting in unexplained hypoglycemia and suboptimal glycemic control.[57,58] There are some factors related to increasing the risk of lipohypertrophy occurrence, such as not rotating the site of injection, not spacing injections, increasing insulin doses, and longer duration of insulin therapy.[59,60] To prevent lipohypertrophy, healthcare professionals should educate individuals undergoing insulin treatment to follow standard guidelines for insulin injection techniques.[7]

This study found that social support was not a statistically significant predictor of good glycemic control among Thai adults with insulin-treated T2DM. A possible explanation is that many participants had long-standing diabetes and had developed sufficient self-management skills, including independent insulin administration, reducing their reliance on external support.[61] Additionally, the study was conducted during the COVID-19 pandemic, a period marked by social distancing and restrictions on in-person gatherings. These factors likely disrupt traditional forms of face-to-face social support from family, peers, and healthcare professionals. Research during the pandemic has shown that while social networks may remain intact, the functional or emotional quality of support can deteriorate due to physical separation, stress, or communication fatigue.[62,63]

Current studies have highlighted that the impact of social support on diabetes outcomes is influenced more by its perceived quality, relevance, and emotional responsiveness than by its mere frequency or availability. High-quality support that is emotionally and practically aligned with the needs of adults with diabetes can facilitate self-management behaviors and enhance adherence to treatment regimens.[64,65] Among adults with long-standing T2DM who demonstrate high levels of self-management autonomy, the effectiveness of social support is likely to depend more on its type, timing, and perceived usefulness than on its quantity.[66]

Study Limitations

This study has some limitations, including the data being collected in one setting, which might limit the generalizability of the findings to all healthcare settings or broader populations. Additionally, participant responses included self-reported hypoglycemia events that might not have been objectively verified by blood glucose level. The self-reported hypoglycemia events and SMBG data might introduce the potential of recall bias, as participants may not have correctly remembered or recorded their glucose levels.

Furthermore, the study was conducted during COVID-19, which was characterized by unique challenges and disruptions in healthcare access and care delivery, day-to-day diabetes self-management practices, people contacts and interactions, and psychological stress. These factors may have influenced participant behaviors and responses, making the findings less applicable to normal or non-pandemic conditions.

Implications for Practice

This study highlights key factors influencing glycemic control, with direct implications for diabetes care. First, improved self-management behaviors were strongly linked to better glycemic outcomes, emphasizing the need for ongoing patient education and support. Second, proper insulin injection technique was a significant predictor, suggesting that practical training and skill assessments should be routinely integrated into care. Third, effective communication with healthcare providers enhanced adherence, reinforcing the value of patient-centered interactions.

Future Research Implementation

Future research should be conducted across diverse healthcare settings and multiple healthcare settings to provide a broader representation of population characteristics and healthcare practices. This approach will help validate the findings across different contexts of adults with insulin-treated T2DM and healthcare settings and increase the findings' generalizability.

Additionally, future studies should be conducted under normal circumstances rather than during extraordinary situations like the COVID-19 pandemic. Therefore, researchers can obtain findings that are more reflective of routine self-management and healthcare services, thereby improving the applicability of the results to develop typical interventions to improve glycemic control in adults with insulin-treated T2DM.

Conclusion

The findings of this study indicate that diabetes self-management, attitude toward insulin therapy, insulin injection technique, and the frequency of self-monitoring of blood glucose (SMBG) are significantly associated with good glycemic control among Thai adults with insulin-treated T2DM. Notably, these factors are modifiable, yet the frequency of regular SMBG remains suboptimal in this population. Therefore, healthcare providers should implement multifaceted, patient-centered interventions that emphasize tailored diabetes self-management education, hands-on training in insulin injection techniques, and psychological support. Such interventions are critical to strengthening these modifiable behaviors and improving glycemic outcomes in this population.

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