



ความถี่ในการตรวจวัดระดับน้ำตาลด้วยตนเองกับการควบคุมระดับน้ำตาลในเลือดของผู้ป่วยเบาหวานชนิดที่ 1: การศึกษาย้อนหลัง ณ โรงพยาบาลขอนแก่น

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Association Between Self-Monitoring Blood Glucose Frequency and Glycemic Control in Type 1 Diabetes Patients: A Retrospective Study at Khon Kaen Hospital

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บทคัดย่อ

หลักการและวัตถุประสงค์: การตรวจน้ำตาลปลายนิ้วด้วยตนเอง (self-monitoring of blood glucose; SMBG) เป็นองค์ประกอบสำคัญของการดูแลผู้ป่วยเบาหวานชนิดที่ 1 (T1DM) โดยเฉพาะในบริบทที่การตรวจติดตามระดับน้ำตาลแบบต่อเนื่องยังไม่แพร่หลาย ข้อมูลจากต่างประเทศแสดงถึงความสัมพันธ์เชิงผกผันระหว่างความถี่ของ SMBG และระดับน้ำตาลเฉลี่ยสะสม (HbA1c) แต่ข้อมูลในประเทศไทยยังมีจำกัด การศึกษานี้จึงมีวัตถุประสงค์เพื่อประเมินความสัมพันธ์ระหว่างความถี่ในการตรวจ SMBG และการควบคุมระดับน้ำตาลในเลือดในผู้ป่วยเบาหวานชนิดที่ 1 ที่มารับการรักษา ณ โรงพยาบาลขอนแก่น

วิธีการศึกษา: ผู้วิจัยได้ทำการศึกษาย้อนหลังเชิงกลุ่ม โดยใช้ข้อมูลเวชระเบียนอิเล็กทรอนิกส์ช่วงเดือนมกราคม พ.ศ. 2567 ถึง มกราคม พ.ศ. 2568 ในผู้ป่วยที่มีอายุ ≥ 15 ปี ได้รับการวินิจฉัยว่าเป็น T1DM และมีมารยาพบแพทย์อย่างน้อย 2 ครั้งที่บันทึกความถี่ SMBG และระดับ HbA1c ข้อมูลที่เก็บรวบรวม ได้แก่ ลักษณะประชากร โรคร่วม ภาวะแทรกซ้อนจากเบาหวาน และสูตรการใช้อินซูลิน การจำแนกความถี่ SMBG อาศัยค่าที่ได้จากการวิเคราะห์เส้นโค้ง ROC เพื่อแยกแยะผู้ที่มีการควบคุมระดับน้ำตาลไม่ดี (HbA1c $>9\%$) สถิติที่ใช้ประกอบด้วย Wilcoxon rank sum test, การทดสอบ chi-square หรือ Fisher's exact test และการวิเคราะห์ univariate logistic regression

ผลการศึกษา: ผู้ป่วยจำนวน 50 ราย (102 ครั้งที่รับบริการ) เข้าเกณฑ์การศึกษา อายุเฉลี่ย 22 ปี และส่วนใหญ่เป็นเพศหญิง ค่าความถี่ SMBG ที่เหมาะสมที่สุดในการทำนายการควบคุมระดับน้ำตาลที่ไม่ดีคือ 2.5 ครั้ง/วัน จึงใช้เกณฑ์ <3 ครั้ง/วัน เทียบกับ ≥ 3 ครั้ง/วัน ผู้ที่ตรวจ SMBG ≥ 3 ครั้ง/วัน มีค่า HbA1c ต่ำกว่าอย่างมีนัยสำคัญเมื่อเทียบกับผู้ที่ตรวจน้อยกว่า (8.4% เทียบกับ 9.5%, $p=0.014$) ระดับการศึกษาที่สูงขึ้นสัมพันธ์กับความถี่ SMBG สูง (OR 9.00, 95% CI 1.46–55.48) และค่าที่สูงขึ้นของ HbA1c มีความสัมพันธ์กับโอกาสที่ผู้ป่วยจะตรวจ SMBG ≥ 3 ครั้ง/วันลดลง (OR 0.80 ต่อการเพิ่มขึ้นของ HbA1c 1%, 95% CI 0.66–0.95) ความถี่ SMBG ยังมีความแตกต่างอย่างมีนัยสำคัญตามช่วงของ HbA1c โดยผู้ที่ควบคุมระดับน้ำตาลได้ดี (HbA1c $<7\%$) มีแนวโน้มตรวจ ≥ 4 ครั้ง/วันมากที่สุด

สรุป: การตรวจ SMBG บ่อยขึ้น โดยเฉพาะตั้งแต่ 3 ครั้งต่อวันขึ้นไป มีความสัมพันธ์กับการควบคุมระดับน้ำตาลที่ดีกว่าในผู้ป่วย T1DM ชาวไทย ผลการศึกษานี้ยืนยันแนวโน้มจากงานวิจัยนานาชาติ และชี้ให้เห็นถึงความจำเป็นของการเสริมสร้างความรู้ด้านเบาหวาน การเพิ่มการเข้าถึงอุปกรณ์ตรวจ และการสนับสนุนเชิงเป้าหมายสำหรับผู้ที่มีระดับการศึกษาต่ำ เพื่อให้บรรลุผลลัพธ์ด้านการควบคุมระดับน้ำตาลที่ดีขึ้น

คำสำคัญ: เบาหวานชนิดที่ 1, การตรวจระดับน้ำตาลในเลือดด้วยตนเอง, น้ำตาลสะสมในเลือด, การควบคุมระดับน้ำตาล, ประเทศไทย, การให้ความรู้ผู้ป่วยเบาหวาน

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Abstract

Background and Objective: Self-monitoring of blood glucose (SMBG) is an essential component of type 1 diabetes mellitus (T1DM) management, particularly in settings where continuous glucose monitoring remains inaccessible. Evidence from international cohorts suggests a strong inverse relationship between SMBG frequency and glycated hemoglobin (HbA1c), yet local data in Thailand remain limited. This study aimed to examine the association between SMBG frequency and glycemic control among adults with T1DM attending Khon Kaen Hospital.

Methods: A retrospective cohort study was conducted using electronic medical records from January 2024 to January 2025. Adults aged ≥ 15 years with T1DM and at least two clinic visits that documented SMBG frequency and HbA1c were included. Demographic characteristics, comorbidities, diabetes complications, and insulin regimens were recorded. SMBG frequency was categorized based on receiver operating characteristic analysis to discriminate poor glycemic control (HbA1c $>9\%$). Statistical analyses included Wilcoxon rank sum tests, chi-square or Fisher's exact tests, and univariate logistic regression.

Result: Fifty patients with 102 visits met eligibility criteria. The median age was 22 years, and most were female. The optimal SMBG threshold predicting poor glycemic control was 2.5 checks/day; this informed the categorization of SMBG <3 versus ≥ 3 times/day. Patients performing SMBG ≥ 3 times/day had significantly lower HbA1c values compared with those monitoring less frequently (8.4% vs. 9.5%, $p=0.014$). Higher education level was strongly associated with frequent SMBG (OR 9.00, 95% CI 1.46–55.48). Higher HbA1c was associated with reduced odds of frequent SMBG (OR 0.80 per 1% HbA1c increase, 95% CI 0.66–0.95). SMBG frequency also varied significantly across HbA1c categories, with patients achieving HbA1c $<7\%$ most likely to report ≥ 4 tests/day.

Conclusion: More frequent SMBG, especially three or more times a day, is associated with better glycemic control in Thai adults with T1DM. These findings align with global research and highlight the need for enhanced diabetes education, improved access to monitoring supplies, and targeted support for individuals with lower educational attainment to optimize glycemic outcomes.

Keywords: type 1 diabetes mellitus, SMBG, HbA1c, glycemic control, Thailand, diabetes education

Introduction

Type 1 diabetes mellitus (T1DM) is a chronic condition associated with severe acute and long-term complications when glycemic control is suboptimal.¹ Achieving tight glycemic control, typically measured by glycated hemoglobin (HbA1c), is crucial to reduce the risk of microvascular and macrovascular diabetic complications. Clinical guidelines recommend maintaining HbA1c around 7% for most adults with T1DM to prevent these outcomes.²⁻⁴ Self-monitoring of blood glucose (SMBG) is a cornerstone of T1DM management, enabling patients to adjust insulin dosing, diet, and activity in response to blood glucose levels. While continuous glucose monitoring (CGM) technology has become widely used in some settings, it remains costly and not universally available; thus, traditional finger-stick SMBG remains the primary glucose monitoring method for many patients, especially in low-resource environments.

There is increasing evidence that more frequent SMBG is strongly associated with better glycemic control in T1DM. Observational studies have consistently found an inverse relationship between SMBG frequency and HbA1c levels.⁵ Each additional SMBG check per day has been estimated to confer approximately a 0.2% absolute reduction in HbA1c, reflecting the impact of intensive monitoring on glycemic averages.⁶ Conversely, performing SMBG fewer than 3.5 times per day is associated with higher odds of poor glycemic control (HbA1c $\geq 8\%$).⁷ Patients who test blood glucose more frequently also tend to experience fewer acute diabetes-related events; prior studies have documented lower rates of severe hypoglycemia and diabetic ketoacidosis among those adhering to frequent SMBG.⁶ These findings underscore that thorough self-monitoring is a key determinant of successful diabetes management.

In Thailand, however, data on SMBG practices and their relationship to glycemic outcomes remain limited. To date, aside from a recent national registry study highlighting generally low SMBG frequency in

Thai T1DM patients,⁵ there is a paucity of detailed analyses examining how SMBG frequency correlates with HbA1c in the local context. No study has specifically focused on this issue in northeastern Thailand or at our institution. Therefore, we conducted a retrospective study of T1DM patients at Khon Kaen Hospital to investigate the association between SMBG frequency and glycemic control. This study aims to provide much-needed local evidence on whether patients who self-monitor more frequently achieve better HbA1c levels, thereby informing future strategies to improve diabetes education and glycemic management in Thailand.

Methods

Study design and setting

This retrospective cohort study was conducted at Khon Kaen Hospital, Thailand. We reviewed electronic medical records of adults with T1DM aged ≥ 15 years who attended the outpatient diabetes clinic between 1 January 2024 and 1 January 2025.

Eligibility criteria

Patients were included if they had at least two recorded clinic visits with documentation of SMBG frequency and HbA1c values. Patients who relied exclusively on CGM without SMBG records were excluded.

Data collection

Extracted data included demographic characteristics (age, sex, education level), anthropometric measurements (weight, body mass index (BMI)), insulin regimen, comorbidities, and diabetes-related complications.

- SMBG frequency was documented as the number of capillary glucose tests per day and categorized as <1, 1, 2, 3, or ≥ 4 times/day.
- HbA1c values within ± 30 days of each clinic visit were used for analysis of glycemic control.

Definitions of variables

- Hypertension: physician-documented diagnosis, use of antihypertensive medication, or repeated clinic blood pressure $\geq 130/80$ mmHg, consistent with the 2025 AHA/ACC Guideline for the Prevention, Detection, Evaluation, and Management of High Blood Pressure.⁸
- Obesity: BMI ≥ 25 kg/m², in accordance with the Asia-Pacific classification.⁹
- Dyslipidemia: defined as low-density lipoprotein cholesterol (LDL-C) ≥ 160 mg/dL, triglycerides ≥ 200 mg/dL, or current use of a lipid-lowering agent.¹⁰
- Autoimmune thyroid disease: physician-diagnosed thyroid dysfunction (e.g., Hashimoto thyroiditis or Graves' disease) with abnormal thyroid function tests and/or positive thyroid autoantibodies.
- Diabetic retinopathy: ophthalmologist-confirmed diagnosis based on retinal examination or fundus photography.¹¹
- Diabetic nephropathy: persistent albuminuria (urine albumin-to-creatinine ratio ≥ 30 mg/g), estimated glomerular filtration rate (eGFR) < 60 mL/min/1.73 m², or nephrologist-confirmed diagnosis, consistent with American Diabetes Association 2025 and KDIGO 2022 guidelines.^{12,13}
- Diabetic neuropathy: physician-documented peripheral neuropathy based on clinical examination (e.g., abnormal 10-g monofilament testing or vibration perception).¹¹

Outcomes

The primary outcome was the association between SMBG frequency and glycemic control (HbA1c). Poor glycemic control was defined as HbA1c $> 9\%$. A receiver operating characteristic (ROC) curve analysis was performed to identify the optimal cutoff of SMBG frequency to discriminate poor glycemic control.

Statistical analysis

Data presented as n (%) for categorical variables and median (Q1, Q3) for continuous variables. Comparisons between groups were performed using the Wilcoxon rank sum test for continuous variables and Fisher's exact test or Pearson's Chi-squared test for categorical variables, as appropriate. Univariate logistic regression analysis was conducted to evaluate factors associated with frequent SMBG (≥ 3 vs. < 3 times/day). Results are reported as odds ratios (OR) with 95% confidence intervals (CI). Statistical significance was defined as $p < 0.05$. The minimum required sample size, calculated for comparing two independent means, was 42 participants (29 in the frequent SMBG group and 13 in the infrequent group). All analyses were performed using R software version 4.2.2 (R Foundation for Statistical Computing, Vienna, Austria).

Ethics

This study was conducted in accordance with the principles of the Declaration of Helsinki. The research protocol was reviewed and approved by the Ethics Committee of Khon Kaen Hospital, Thailand (Approval No. KEXP68020). Written informed consent was not required because the study involved retrospective analysis of existing medical records, and all data were anonymized prior to analysis. Patient confidentiality was strictly maintained, and no identifiable personal information was collected or reported.

Results

A total of 95 adults with T1DM and 269 outpatient visits between 1 January 2024 and 1 January 2025 were screened. After exclusions (Figure 1), 102 visits from 50 patients were included in the final analysis. The median number of visits per patient was 2 (IQR 1–2). Baseline characteristics of the analytic cohort are summarized in Table 1. The median age was 22 years (IQR 20–25), and two-thirds were female (65.7%). The median BMI was 21.1 kg/m² (IQR 19.0–23.4).

Nearly half of the visits were from patients who were currently studying (46.1%), while 44.1% of visits were associated with at least one comorbidity, most commonly dyslipidemia (34.3%). Almost all patients

(93.1%) were treated with a basal-bolus insulin regimen. The overall median HbA1c was 9.1% (IQR 7.4–11.0). The overall distribution of SMBG frequency is shown in Figure 2.

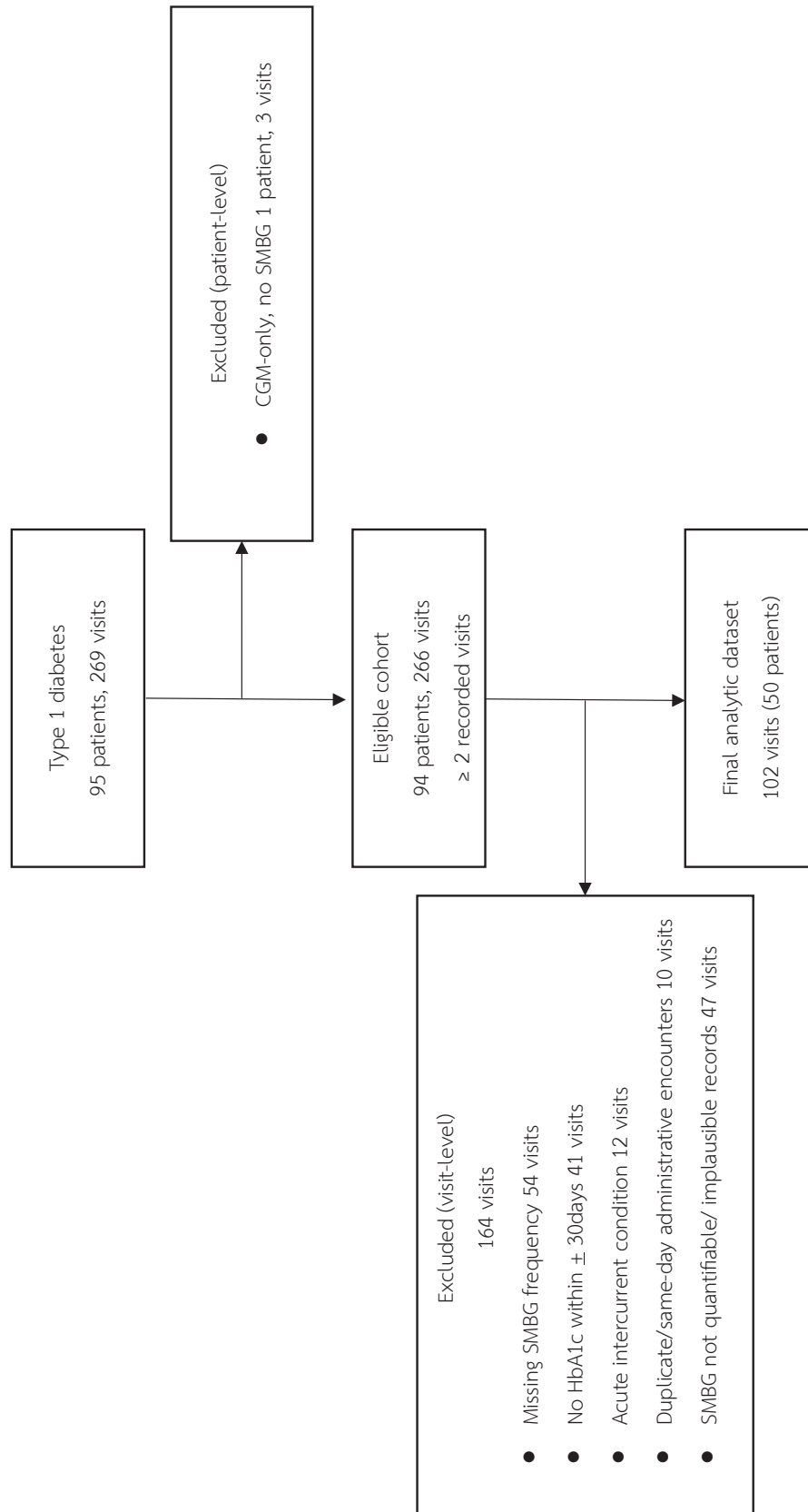


Figure 1 Study flow

Table 1 Baseline characteristics of type 1 diabetes visits included in this study.

Characteristics	Overall n = 102 n (%)
Age (years) ¹	22 (20, 25)
Female	67 (65.7)
BMI (kg/m ²) ¹	21.1 (19.0, 23.4)
Education level	
Primary school or below	11 (10.8)
Secondary school or equivalent	26 (25.5)
Bachelor's degree or equivalent	18 (17.6)
Currently studying	47 (46.1)
Comorbid disease	
Patient with at least 1 comorbid disease	45 (44.1)
Hypertension	9 (8.8)
Dyslipidemia	35 (34.3)
Obesity	16 (15.7)
Autoimmune thyroid disease	4 (3.9)
Mental/ affective disorder	4 (3.9)
Insulin regimen	
Basal-bolus regimen	95 (93.1)
Basal-bolus regimen combines antidiabetic agent (Metformin)	7 (6.9)
HbA1c (%) ¹	9.1 (7.4, 11.0)
Frequency of SMBG	
< 1 time/day	19 (18.6)
1 time/day	13 (12.7)
2 times/day	26 (25.5)
3 times/day	30 (29.4)
≥ 4 times/day	14 (13.7)
Diabetic retinopathy	7 (6.9)
Diabetic nephropathy	9 (8.8)
Diabetic neuropathy	1 (1.0)
Prevalence of DKA per 6 months	4 (3.9)
Prevalence of severe hypoglycemia per 6 months	2 (2.0)

¹ Median (Q1, Q3)

BMI, body mass index; DKA, diabetic ketoacidosis; SMBG, self-monitoring of blood glucose.

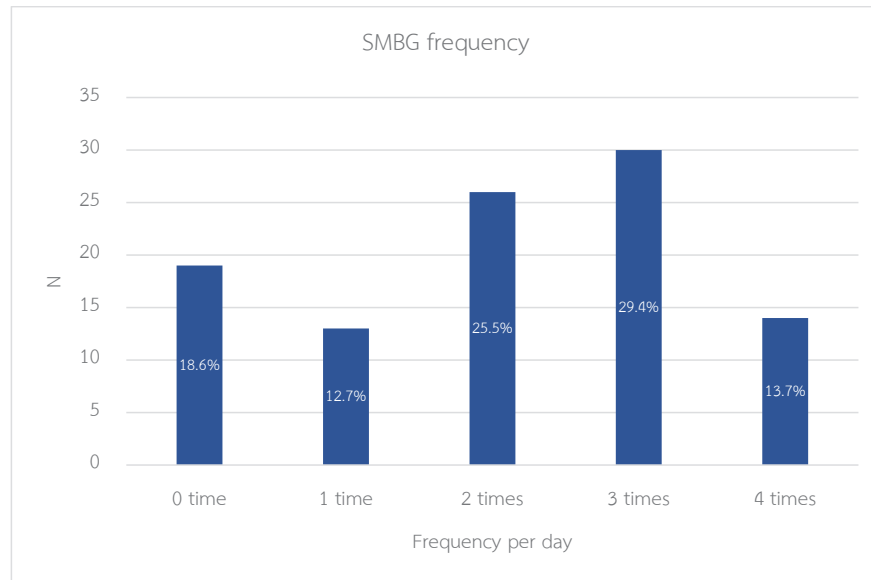


Figure 2 Distribution of self-monitoring of blood glucose frequency among type 1 diabetes visits

To determine an appropriate cutoff for categorizing SMBG frequency, ROC analysis was performed to predict poor glycemic control (HbA1c >9%). A threshold of 2.5 SMBG checks/day provided the best discrimination, corresponding to a sensitivity of 47% and specificity of 84%. Based on this finding, visits were stratified into SMBG <3 vs. ≥3 times/day for subsequent analyses.

When stratified by SMBG frequency (Table 2), patients with SMBG ≥3 times/day (n=44) had significantly lower HbA1c compared to those with SMBG <3 times/day (8.4% vs. 9.5%, p=0.014). Higher education level was more frequent among patients with SMBG ≥3 times/day (p=0.043). Hypertension tended to be less common in this group (2.3% vs. 13.8%, p=0.074). Interestingly, diabetic ketoacidosis (DKA) within the prior 6 months was more often reported in the frequent SMBG group (9.1% vs. 0.0%, p=0.032). The relationship between SMBG frequency and HbA1c is further shown in Figure 3.

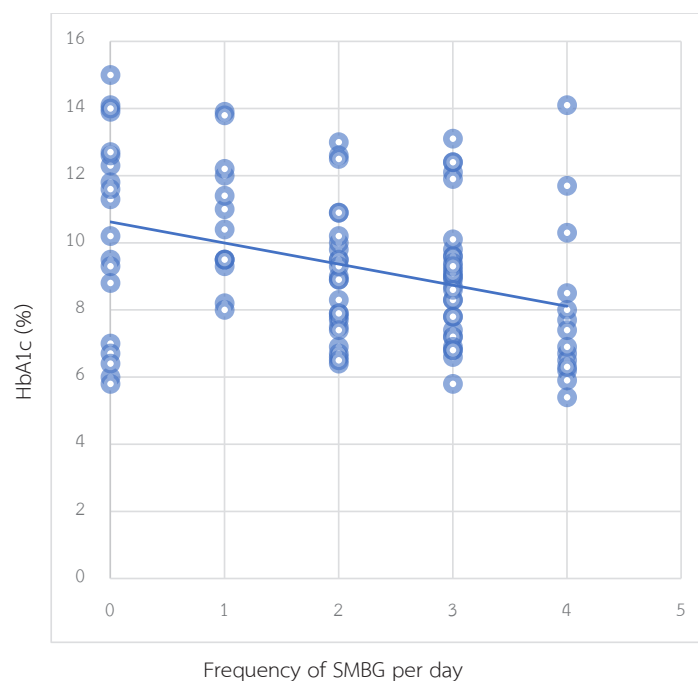


Figure 3 Relationship between self-monitoring of blood glucose frequency and glycated hemoglobin

Table 2 Baseline characteristics of type 1 diabetes patients stratified by self-monitoring of blood glucose frequency (<3 vs. ≥3 times/day)

Characteristics	Overall (n = 102) n (%)	SMBG < 3 times/day (n = 58) n (%)	SMBG ≥ 3 times/day (n = 44) n (%)	p-value ²
Age (years) ¹	22 (20, 25)	22 (20, 30)	22 (20, 25)	0.699
Female	67 (65.7)	35 (60.3)	32 (72.7)	0.192
BMI (kg/m ²) ¹	21.1 (19.0, 23.4)	20.9 (18.9, 23.4)	21.4 (19.2, 23.5)	0.769
Education level				0.043
Primary school or below	11 (10.8)	9 (15.5)	2 (4.5)	
Secondary school or equivalent	26 (25.5)	13 (22.4)	13 (29.5)	
Bachelor's degree or equivalent	18 (17.6)	6 (10.3)	12 (27.3)	
Currently studying	47 (46.1)	30 (51.7)	17 (38.6)	
Comorbid disease				
Patient with at least 1 comorbid disease	45 (44.1)	24 (41.4)	21 (47.7)	0.523
Hypertension	9 (8.8)	8 (13.8)	1 (2.3)	0.074
Dyslipidemia	35 (34.3)	16 (27.6)	19 (43.2)	0.100
Obesity	16 (15.7)	7 (12.1)	9 (20.5)	0.249
Autoimmune thyroid disease	4 (3.9)	1 (1.7)	3 (6.8)	0.313
Mental/ affective disorder	4 (3.9)	3 (5.2)	1 (2.3)	0.632
Insulin regimen				0.461
Basal-bolus regimen	95 (93.1)	55 (94.8)	40 (90.9)	
Basal-bolus regimen combines antidiabetic agent (Metformin)	7 (6.9)	3 (5.2)	4 (9.1)	
HbA1c (%) ¹	9.1 (7.4, 11.0)	9.5 (7.9, 11.8)	8.4 (6.9, 9.6)	0.014
Frequency of SMBG				<0.001
< 1 time/day	19 (18.6)	19 (32.8)	0 (0.0)	
1 time/day	13 (12.7)	13 (22.4)	0 (0.0)	
2 times/day	26 (25.5)	26 (44.8)	0 (0.0)	
3 times/day	30 (29.4)	0 (0.0)	30 (68.2)	
≥ 4 times/day	14 (13.7)	0 (0.0)	14 (31.8)	
Diabetic retinopathy	7 (6.9)	2 (3.4)	5 (11.4)	0.234
Diabetic nephropathy	9 (8.8)	4 (6.9)	5 (11.4)	0.494
Diabetic neuropathy	1 (1.0)	1 (1.7)	0 (0.0)	1.000
Prevalence of DKA per 6 months	4 (3.9)	0 (0.0)	4 (9.1)	0.032
prevalence of severe hypoglycemia per 6 months	2 (2.0)	1 (1.7)	1 (2.3)	1.000

¹ Median (Q1, Q3)² Wilcoxon rank sum test; Fisher's exact test; Pearson's Chi-squared test

Analysis stratified by HbA1c categories (<7%, 7–9%, >9%) is presented in Table 3. Patients achieving HbA1c <7% were more likely to hold a bachelor's degree (47.6%) compared with those with HbA1c >9% (5.9%) ($p<0.001$). SMBG frequency also differed significantly across HbA1c categories ($p=0.010$). Patients with HbA1c <7% most frequently reported ≥ 4 SMBG checks/day, while those with HbA1c >9% more often reported fewer checks.

Univariate logistic regression (Table 4) demonstrated that higher education was associated with increased odds of SMBG ≥ 3 times/day. Compared with primary school or below, a bachelor's degree was significantly associated with frequent SMBG (OR 9.00, 95% CI 1.46–55.48). Higher HbA1c was associated with reduced odds of frequent SMBG (OR 0.80 per 1% increase in HbA1c, 95% CI 0.66–0.95). Hypertension was inversely associated with frequent SMBG (OR 0.15, 95% CI 0.01–0.84).

Table 3 Baseline characteristics of type 1 diabetes patients stratified by HbA1c categories (<7%, 7–9%, >9%)

Characteristics	Overall (n = 102)	HbA1c			p-value ²
		< 7% (n=21) n (%)	7-9% (n=30) n (%)	> 9% (n=51) n (%)	
Age (years) ¹	22 (20, 25)	24 (21, 26)	22 (20, 24)	21 (19, 30)	0.257
Female	67 (65.7)	15 (71.4)	23 (76.7)	29 (56.9)	0.159
BMI (kg/m ²) ¹	21.1 (19.0, 23.4)	21.8 (20.7, 23.1)	20.3 (19.0, 23.6)	21.1 (18.1, 23.5)	0.527
Education level					<0.001
Primary school or below	11 (10.8)	0 (0.0)	1 (3.3)	10 (19.6)	
Secondary school or equivalent	26 (25.5)	5 (23.8)	7 (23.3)	14 (27.5)	
Bachelor's degree or equivalent	18 (17.6)	10 (47.6)	5 (16.7)	3 (5.9)	
Currently studying	47 (46.1)	6 (28.6)	17 (56.7)	24 (47.1)	
Comorbid disease					
Patient with at least 1 comorbid disease	45 (44.1)	10 (47.6)	16 (53.3)	19 (37.3)	0.348
Hypertension	9 (8.8)	2 (9.5)	3 (10.0)	4 (7.8)	0.906
Dyslipidemia	35 (34.3)	9 (42.9)	10 (33.3)	16 (31.4)	0.641
Obesity	16 (15.7)	2 (9.5)	3 (10.0)	11 (21.6)	0.344
Autoimmune thyroid disease	4 (3.9)	1 (4.8)	1 (3.3)	2 (3.9)	>0.999
Mental/ affective disorder	4 (3.9)	0 (0.0)	3 (10.0)	1 (2.0)	0.123
Insulin regimen					0.218
Basal-bolus regimen	95 (93.1)	21 (100.0)	26 (86.7)	48 (94.1)	
Basal-bolus regimen combines antidiabetic agent (Metformin)	7 (6.9)	0 (0.0)	4 (13.3)	3 (5.9)	
HbA1c (%) ¹	9.0 (7.4, 11.0)	6.5 (6.2, 6.7)	8.0 (7.7, 8.7)	11.0 (9.5, 12.5)	<0.001

Table 3 Baseline characteristics of type 1 diabetes patients stratified by HbA1c categories (<7%, 7–9%, >9%) (Cont.)

Characteristics	Overall (n = 102)	HbA1c			p-value ²
		< 7% (n=21) n (%)	7-9% (n=30) n (%)	> 9% (n=51) n (%)	
< 1 time/day	19 (18.6)	4 (19.0)	2 (6.7)	13 (25.5)	
1 time/day	13 (12.7)	0 (0.0)	2 (6.7)	11 (21.6)	
2 times/day	26 (25.5)	5 (23.8)	10 (33.3)	11 (21.6)	
3 times/day	30 (29.4)	5 (23.8)	12 (40.0)	13 (25.5)	
≥ 4 times/day	14 (13.7)	7 (33.3)	4 (13.3)	3 (5.9)	

Characteristics	Overall (n = 102)	HbA1c			p-value ²
		< 7% (n=21) n (%)	7-9% (n=30) n (%)	> 9% (n=51) n (%)	
Diabetic nephropathy	9 (8.8)	2 (9.5)	3 (10.0)	4 (7.8)	0.906
Diabetic neuropathy	1 (1.0)	0 (0.0)	0 (0.0)	1 (2.0)	1.000
Prevalence of DKA per 6 months	4 (3.9)	1 (4.8)	1 (3.3)	2 (3.9)	1.000
prevalence of severe hypoglycemia per 6 months	2 (2.0)	0 (0.0)	0 (0.0)	2 (3.9)	0.703

¹Median (Q1, Q3)²Wilcoxon rank sum test; Fisher's exact test; Pearson's Chi-squared test**Table 4** Univariate logistic regression analysis of factors associated with self-monitoring of blood glucose frequency (≥3 vs. <3 times/day) in type 1 diabetes patients

Variables	Univariate	
	Odd Ratio	(95% CI)
Female	1.75	0.76 – 4.18
Education level		
Primary school or below	Ref	Ref
Secondary school or equivalent	4.50	0.81 - 24.99
Bachelor's degree or equivalent	9.00	1.46 - 55.48
Currently studying	2.55	0.49 - 13.19
Comorbid disease		
Hypertension	0.15	0.01 - 0.84
Dyslipidemia	2.00	0.87 - 4.62
Obesity	1.87	0.64 - 5.70
HbA1c (per 1% increase)	0.80	0.66 - 0.95
Diabetic retinopathy	3.59	0.73 - 25.96

Discussion

This retrospective cohort study's finding that SMBG frequency ≥ 3 times/day is associated with lower HbA1c. This finding aligns with a broad international evidence base. Numerous studies have demonstrated a dose-response relationship between SMBG frequency and glycemic control in T1DM. For example, analyses of large cohorts have shown that each additional blood glucose check per day is associated with an approximately 0.2% absolute reduction in HbA1c.¹⁴ Similarly, earlier pediatric diabetes studies in Europe found that patients testing glucose frequently had significantly lower HbA1c levels and fewer acute diabetes-related complications.⁶

A recent study from Indonesia found that higher SMBG frequency correlated with decreased HbA1c ($r = -0.406$) in children, and less than half of those patients achieved the recommended ≥ 4 tests per day.¹⁵ In our study, only $\sim 43\%$ of visits involved ≥ 3 SMBG checks per day (and only $\sim 14\%$ with ≥ 4 /day), which mirrors the low adherence rates reported across many countries. In fact, a global survey showed that on average only about 44% of patients with T1DM achieve the widely recommended SMBG frequency of at least 4 times daily, with pediatric adherence ranging from as low as 31% in some regions to about 69% in others.¹⁶ Current clinical guidelines continue to emphasize frequent glucose monitoring for individuals on intensive insulin regimens. The American Diabetes Association (ADA) and International Society for Pediatric and Adolescent Diabetes (ISPAD) recommend checking blood glucose at least 3–6 times up to 10 times daily for patients with T1DM on multiple injections or pump therapy.^{17,18} The improved glycemic outcomes observed in our Thai cohort with SMBG ≥ 3 times/day are consistent with these guidelines.

Our findings also mirror patterns reported in Southeast Asian populations. Glycemic control remains suboptimal for many patients with T1DM in this region, and limited SMBG is a contributing factor.⁵ A large multicenter registry study in Thailand reported a mean HbA1c of $\sim 9.3\%$ and noted that performing SMBG at least three times daily as part of intensive insulin therapy was independently associated with greater odds of achieving glycemic targets.⁵ In that nationwide cohort of 1,907 Thai patients, those who checked glucose ≥ 3 times/day had significantly better control than those monitoring less frequently.⁵ This is highly consistent with our study's result linking ≥ 3 SMBG checks/day to lower HbA1c.

Interestingly, recent DKA was reported more frequently in the frequent SMBG group. This may reflect a post-DKA behavioral change, where patients increase monitoring following an acute episode rather than indicating a causal relationship between frequent SMBG and DKA risk.

Our own study found that higher education level was a significant predictor of more frequent SMBG. Patients with a college education level may better understand the importance of self-monitoring glucose and feel more confident in diabetes self-management. This echo reports from other settings. A study of Chinese adults with diabetes, showed that having at least a high school education was associated with substantially higher odds of adhering to regular SMBG.¹⁹

Our study found that patients with hypertension monitored less frequently might reflect an older subset of T1DM patients or those with longer disease duration, who possibly have more diabetes complications or burnout. It is also possible that healthcare providers place different emphasis on glycemic monitoring in patients who already have complications or comorbidities. Regardless, these

disparities indicate that certain subgroups need extra support to engage in regular SMBG. Overall, our finding regarding education level adds to the evidence that socioeconomic factors influence self-care behavior. Interventions should consider ensuring that lower-income or less educated patients have access to diabetes education and subsidized monitoring tools, which could help bridge the gap.

Limitations

Several limitations of this study should be considered when interpreting the results. First, the sample size was small (50 patients, 102 clinic visits) and drawn from a single tertiary center, which may limit statistical power and the precision of estimates. The observational design, based on cross-sectional data from clinic visits, also precludes any conclusion about causality; we cannot determine whether frequent SMBG directly improves glycemic control or whether patients with better control, or other unmeasured characteristics such as higher motivation, are simply more likely to be tested frequently.

Selection bias and information bias are additional concerns. A substantial number of clinic visits were excluded due to missing or implausible SMBG records and the absence of recent HbA1c measurements, which may have influenced the findings. Moreover, SMBG frequency was likely self-reported or recorded from patient logs, data sources that are prone to reporting errors or deliberate overestimation. Prior research has shown that patients often over-report SMBG compared with meter downloads, which could bias results toward a stronger apparent association. Another limitation is that we did not systematically capture all factors that might confound or mediate the relationship between SMBG and outcomes—such as insulin dosing adjustments, dietary patterns, or psychosocial support—which may differ between frequent and infrequent testers.

While our findings likely generalize to many resource-constrained settings, they may not apply to settings where entirely different approaches to glucose monitoring are used. For example, in wealthier healthcare systems where the majority of T1DM patients use CGM, the paradigm for “frequency of monitoring” shifts – patients are getting continuous readings without fingersticks. In those contexts, the conversation shifts to “frequency of CGM scanning or sensor wear time” and the results from a finger-stick based study may be less relevant. However, even with growing CGM usage, SMBG remains a core component of care globally and especially in countries where CGM coverage is limited. Therefore, we believe our study addresses an issue of wide importance.

Conclusion

Regular, frequent SMBG is associated with better diabetes management and is applicable across various clinical settings. Our findings support both international and regional initiatives to enhance patient education and SMBG resources. Additionally, they contribute local evidence from Southeast Asia to the global body of research on diabetes self-management. By improving SMBG practices, we can enhance health outcomes for patients with T1DM, not only in our clinic but also in many parts of the world facing similar challenges.

Declarations

Ethical Approval and Consent to Participate

The study was approved by the Ethics Committee of Khon Kaen Hospital, Thailand (Approval No. KEXP68020). Informed consent was waived due to the study’s retrospective design.

Consent for publication

Not applicable

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing Interests

The authors declare that they have no competing interests

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Authors's contributions:

BS: Conceptualization, Data curation, Formal analysis, Investigation, Supervision, Writing – original draft, Writing – review & editing

NS: Conceptualization, Data curation, Writing – original draft, Writing – review & editing

JP: Writing – original draft, Writing – review & editing

TT: Conceptualization, Formal analysis, Investigation, Validation, Writing – original draft, Writing – review & editing

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