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ORIGINAL RESEARCH

Frequent Self-Monitoring Blood Glucose Correlated to Better Medication Adherence and Glycemic Control in Children with Type 1 Diabetes Mellitus

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Background: Type 1 diabetes mellitus (T1DM) is the most common chronic disease in children, with several severe short and long-term complications. Glycemic control is an important aspect of diabetes management with the most influential factor being compliance with self-monitoring blood glucose (SMBG). Mostly, in Indonesia, the finger stick devices as a glucose monitoring tool were frequently used. About 20% of children follow the recommendation to measure blood glucose four to six times daily.

Methods: This is a single center, cross-sectional study that was conducted between July–November 2022. The Population is children with T1DM at the Pediatric Outpatient Clinic of Dr. Soetomo Hospital, Surabaya, Indonesia. Children with T1DM aged 4–18 years were enrolled using consecutive sampling. A compliance questionnaire was used to assess SMBG. Psychosocial conditions were assessed using the Pediatric Symptom Checklist 17, and medication adherence was evaluated using the Adherence to Refills and Medications Scale for Diabetes (ARMS-D). Pearson correlation and linear regression were employed for statistical analyses using Statistical Package for Social Sciences version 21.0, with $p < 0.05$ indicating statistical significance.

Results: A total of 36 children were included in this study. SMBG frequency over 4x per day was significantly associated with increased medication adherence as measured by the ARMS-D score ($p = 0.012$). Higher SMBG frequency was also correlated with decreased HbA1c ($p = 0.014$, $r = 0.406$) and nutritional status ($p = 0.031$, $r = 0.360$). Less than 50% of the patients in Indonesia adhered to the recommended guidelines for SMBG (ie, ≥4 times per day).

Conclusion: Higher SMBG frequency was correlated with better glycemic control. This finding suggests the need for further support in conducting SMBG based on the national guideline. However, due to it being conducted in a single center, we suggest increasing the sample size or conducting multi-centre collaborations in future studies.

Originality/Value: By specifically investigating the relationship between adherence to self-monitoring of blood glucose (SMBG) and glycemic control in children with type 1 diabetes mellitus (T1DM), our study represents a novel contribution to the field of pediatric diabetes management in Indonesia. While previous research has explored similar relationships in other populations, our study focuses exclusively on the unique context of Indonesia, where rates of adherence to SMBG in pediatric patients have not been well studied and are relatively low compared to global standards.

Keywords: Diabetes mellitus type-1, medication adherence, glycemic control, HbA1c, children, self-monitoring blood glucose

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Background

T1DM is an immune-mediated disease due to pancreatic β-cell, leading to hyperglycemia as a clinical manifestation. When chronic hyperglycemia develops, individuals are at high risk of short and long-term complications.[1] Type 1 diabetes mellitus (T1DM) is the most common chronic disease in children, accounting for 1.52 million people under 20 years old living with T1DM.[2] Based on Indonesian Pediatric Society data from 2018, 1220 children had been recorded as suffering from T1DM. However, given the high rates of underdiagnosis and misdiagnosis in Indonesia due to the limitation in health facilities being covered by the government, the actual epidemiology of T1DM in children is suggested to be higher.[3]

To accomplish optimal metabolic control and prevent complications, diabetes needs to be managed thoroughly. Components of T1DM management include insulin administration, nutritional management, exercise, education, and self-monitoring (home monitoring) of blood glucose (SMBG).[3] Each child should have access to technology and tools for SMBG that would allow sufficient testing frequency to maximize diabetes care.

Two glucose meters are presently available for routine glucose monitoring: a finger stick device and a continuous glucose monitoring (CGM) device. CGM uses minimally invasive devices that are more sophisticated than those for home finger stick blood glucose monitoring given that it can detect periods of consistent hyperglycemia and periods of elevated risk for hypoglycemia.[4] CGM has been widely used globally, with several insurance companies covering some costs.[5] In contrast, Indonesia still uses finger stick devices as a glucose monitoring tool, with glucometer strips being purchased out of pocket.[3,5]

The national guidelines recommend measuring blood glucose four to six times daily. However, the American Diabetes Association and the International Society for Pediatric and Adolescent Diabetes suggest more frequent SMBG (6–10 times daily). Data from the Indonesian Pediatric Society reported that using finger stick devices as a regular glucose monitoring tool, only 20% of children follow the recommendation. This number is much lower than in Indonesia's Asian neighbor, China, where the proportion of children adhering to SMBG was 53%.[6] This number was also lower than a study conducted in Sweden, where the adherence rate was 41.3%.[7] A large international study carried out around the world in which the number of patients who adhered to the recommended SMBG ≥4 times a day was 44% in both children and adults with type 1 diabetes mellitus. The study shows adherence rates for children ranging from 31% to 69%.[8]

The treatment of diabetes as a global health issue, especially in type 1 diabetes mellitus where various complications can exist, and also due to the high discrepancy in adherence rates to SMBG globally (31% - 69%), only proves that there is an urgent need to address the factors that affect glycemic control in this population. Understanding the relationship between SMBG adherence and glycemic control is crucial for designing targeted interventions that can improve health outcomes in children with T1DM, especially in Indonesia where adherence rates are much lower. Therefore, the current study was conducted to determine the association between adherence to SMBG and glycemic control in children with T1DM. It is anticipated that increased SMBG compliance may contribute to better glycemic control by enabling early detection and intervention and facilitating tailored treatment adjustments.

Materials and Methods

This study included patients with T1DM aged ≤18 years who visited the Pediatric Endocrinology Outpatient Clinic of Dr. Soetomo General Hospital from July to November 2022. Consecutive random sampling was used for selecting participants to be included in this study. The inclusion criteria were 4 to 18-year-old children with T1DM (according to the International Society for Pediatric and Adolescent Diabetes/ISPAD guidelines). Informed consent was provided by the participant's parents or legal guardian. Patients' SMBG was measured using an invasive capillary glucometer. Patients using CGM or those who were severely ill were excluded.

SMBG was assessed using a compliance questionnaire from previous research conducted by Istanti ND et al in Indonesian Language.[9] Psychosocial conditions were assessed using Pediatric Symptom Checklist 17, and the Indonesian Language version was validated by a previous study,[10] whereas medication adherence was evaluated using the Adherence to Refills and Medications Scale for Diabetes in the Indonesian Language.[11] A descriptive analysis was conducted to

describe the profile of the subjects. Pearson correlation and linear regression were employed for statistical analyses using the Statistical Package for Social Sciences version 21.0, with $p < 0.05$ indicating statistical significance.

Results

A total of 36 children were included in this study. Most patients (69.4%) checked their blood glucose levels less frequently than recommended, with only 30.6% of the children following the recommendations for blood glucose monitoring. No differences in the mean age, mean HbA1c levels, nutritional status, psychosocial factors, and quality of life between subjects performing SMBG >4 times/day and <4 times/day were observed. However, significant differences in the decrease in HbA1c levels and medication adherence were found. Table 1 shows the relationship between SMBG frequency and glycemic control and medication adherence.

Correlation analysis and linear regression revealed that the decrease in HbA1c was influenced by SMBG frequency and was correlated with the body mass index of the patients. A positive correlation was observed between SMBG frequency and the decrease in HbA1c ($p = 0.014$, $r = 0.406$; with linear regression test $p = 0.012$, $r^2 = 17.2\%$). The decrease in HbA1c was also positively correlated with nutritional status as evaluated by body mass index ($p = 0.031$, $r = 0.360$; with linear regression test $p = 0.049$, $r^2 = 10.8\%$). Correlation analysis and linear regression results for the decrease in HbA1c are shown in Tables 2 and 3, respectively.

Table 1 Analysis of the Relationship between SMBG Frequency and Glycemic Control and Medication Adherence

Characteristics	SMBG ≥ 4 times/day	SMBG < 4 times/day	p value
Total	11 (30.6%)	25 (69.4%)	
Sex			
Male	5 (31.3%)	11 (68.8%)	
Female	5 (26.3%)	14 (73.3%)	1.000[d]
Age (mean ± SD)	11.18 ± 4.44	12 ± 2.89	0.498[a]
Duration of illness (years) [median (min–max)]	4 (1–10)	3 (1–10)	0.105[c]
HbA1c 3–6 months ago (mean ± SD)	9.86 ± 2.48	10.37 ± 2.4	0.566[a]
HbA1c a year ago (mean ± SD)	12.53 ± 3.18	10.7 ± 2.64	0.082[a]
HbA1c decrease in 6 months (mean ± SD)	2.67 ± 3.15	0.344 ± 2.035	**0.041**[a]
Body mass index			
Underweight	1 (50%)	1 (50%)	0.818[b]
Normal	9 (29%)	22 (71%)	
Overweight	1 (33.3%)	2 (66.7%)	
Medication adherence (ARMS-D) [median (min–max)]	12 (11–14)	11 (11–13)	**0.012**[c]
Psychosocial problem (PSC-17 ≥ 15) [median (min–max)]	8 (4–19)	7 (0–19)	0.247[c]
History of ketoacidosis			
Yes	3 (37.5%)	5 (62.5%)	0.678[b]
No	8 (28.6%)	20 (71.4%)	

Notes: [a]Independent *t*-test; [b]Chi-square test; [c]Mann–Whitney test, [d]Fisher test. Bold shows the significant results.

Table 2 Correlation Analysis of the Decrease in HbA1c

Variables	Correlation Coefficient	p value
Frequency of SMBG	0.406	**0.014**
Sex	0.151	0.388
Age	0.183	0.286
Duration of illness (years)	0.032	0.852
Body mass index	0.360	**0.031**
Medication adherence (ARMS-D)	0.163	0.342
Psychosocial problem (PSC-17 ≥ 15)	0.030	0.864
History of ketoacidosis	0.794	–0.045

Notes: All data are analyzed by using Spearman test; bold shows significant result.

Table 3 Linear Regression Test for a Decrease in HbA1c

Variables	*p* value	r^2
Frequency of SMBG	**0.012**	17.2%
Sex	0.609	0.8%
Age	0.266	3.6%
Duration of illness (years)	0.712	0.4%
Body mass index	**0.049**	10.8%
Medication adherence (ARMS-D)	0.331	2.8%
Psychosocial problem (PSC-17 ≥ 15)	0.695	0.5%

Notes: Bold shows significant result.

Discussion

Our study showed that children who performed SMBG ≥4 times daily showed a 17.2% greater improvement in HbA1c level compared to those who did not perform frequent monitoring (p = 0.012). SMBG frequency was significantly correlated with the decrease in HbA1c levels (p = 0.012; r^2 = 17.2%). Previous studies have reported that HbA1c levels decrease by 0.2% with one additional SMBG per day after adjusting for age, sex, diabetes duration, year of treatment, insulin regimen, insulin dose, and body mass index.[12] Hypoglycemia as a complication occurs less frequently in patients with more frequent SMBG.[12] Another investigation also reported that a SMBG frequency of <3.5 times per day appeared to be a risk factor for poor glycemic control (HbA1c ≥ 8%) in patients with T1DM.[13]

Glycemic control is an important aspect of diabetes management. Accurate information regarding blood glucose levels is the only approach for regulating the patient's insulin dose, dietary behavior, and physical activity.[14] Several factors influence glycemic control in children with diabetes, including diabetes duration and insulin dose, age, caregiver involvement in blood glucose monitoring, lipodystrophic changes at injection sites, and diet quality.[14–16] However, the most influential factor has been compliance with SMBG.[17]

The current study showed that less than half of the included children (30.6%) performed blood glucose monitoring ≥4 times/day. This number is lower than that reported by previous studies, which revealed that 34% of patients with T1DM performed SMBG ≥3 times per day.[18] Another study showed that 93% of individuals with T1DM performed SMBG ≥3

times/day, whereas 62% of patients did so ≥5 times/day.[19] The main reasons why patients did not practice regular SMBG were the costs of the strips and glucometers, the fear of pain and injection, psychological frustration, lack of information, lack of motivation, and lack of a suitable location for SMBG.[20] A previous study showed that the primary barrier to SMBG was the lack of awareness and the high cost of glucometers.[17] The current study showed that SMBG was independently correlated with BMI. This means that body mass index does not influence a person's tendency to do SMBG. This finding is in contrast to a previous study which found that people with a higher BMI were less compliant with their daily SMBG.[21]

A majority of the patients included in the current study were of middle to lower socioeconomic status and relied only on government health insurance. Meanwhile, government-sponsored health insurance does not provide coverage for the equipment needed to perform independent blood sugar tests. Therefore, frequent SMBG can be considered costly for our patients. Currently, invasive finger stick blood tests have been the main method for regular glucose monitoring in Indonesia. This issue also persists in several other developing countries, such as Pakistan and Kenya.[17,22] In contrast, most developed nations presently use non-invasive tools, such as CGM.[5]

Our findings showed that SMBG frequency was correlated with medication adherence evaluated using ARMS-D scores ($p = 0.012$). Previous studies have shown a negative correlation between medication adherence and glycemic control, with improved adherence resulting in lower HbA1c levels;[23,24] however, other studies have shown no relationship between medication adherence and glycemic control.[25]

The current study showed that the frequency of SMBG was not significantly associated with psychological issues as determined by the PSC questionnaire. These findings suggest that a higher frequency of SMBG did not burden the patients, allowing them to perform SMBG at least four times per day as recommended by their doctor. Following this recommendation would certainly improve the patient's blood glucose control, preventing complications and greater psychosocial problems in the future. Previous studies have stated that adolescents between the ages of 10 and 16 who more frequently perform SMBG have fewer problems and a lower HbA1c, and thus have a significantly improved quality of life.[20,26] The right education and counseling can reduce the impact of diabetes, enhance quality of life, and help patients reach their desired glycemic (HbA1c) level.[27]

The strength of the current study is that it is the first to evaluate the frequency of SMBG in Indonesia according to national guidelines and its relationship with glycemic control. These results can be used as a reference for further studies with larger sample sizes and as a basis for formulating recommendations to maintain good glycemic control in children with T1DM in Indonesia. Some limitations of this study include its cross-sectional design, which precludes the assessment of causality, and the inclusion of patients from a single center and have a small number of participants, hence may not be adequately applicable to the entire population of children with T1DM in Indonesia. In response to this limitation, if there's an opportunity for further research, we suggest strategies to be addressed in future studies, such as increasing the sample size, using other study designs, or by conducting multi-centre collaborations to increase the robustness and reliability of the findings.

Conclusion

The current study showed that frequent SMBG was correlated with better glycemic control in children with diabetes. Therefore, SMBG needs to be performed more frequently in order to optimize the patient's glycemic control, which would reduce the risk of complications later in life. Overall, our findings highlight the need to further support SMBG based on the national guidelines.

Data Sharing Statement

The participants of this study did not give written consent for their data to be shared publicly, so due to the sensitive nature of the research supporting data is not available.

Ethical Approval

This study was approved by the Institutional Review Board of Dr. Soetomo General Hospital, Surabaya, Indonesia (0470/KEPK/VIII/2022). All participants and their parents provided informed consent, and this study was conducted in accordance with the Declaration of Helsinki.

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Disclosure

The authors report no conflicts of interest in this work.

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