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Assessment of self-monitoring of blood glucose in type 1 diabetic children and adolescents and its influence on quality of life: practice and perspective

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Abstract

Background: Self-monitoring blood glucose (SMBG) includes an assessment of the capillary glucose concentration as well as the interpretation of and responding to the readings. The purpose of this study was to assess patients' compliance to self-monitoring blood glucose (SMBG), identify factors and barriers that affect it, and to correlate performance of SMBG to blood glucose monitoring and patients' quality of life. Three hundred and thirty children and adolescents with type 1 diabetes were subjected to the following: (1) an interview pre-structured questionnaire which included personal, medical history, and details about SMBG; (2) Questionnaire about Quality of Life Index (Diabetes Version-III) by Ferrans and Powers for patients aging 10–16 years; and (3) glycated hemoglobin (HA1C) measurement.

Results: About 67% of the patients assessed their blood glucose 3 times per day, while 0.57% assessed blood glucose 7 times. The most influential factors affecting compliance of SMBG were the cost of strips and glucometers, the fear of pain and injection, psychological frustration, lack of availability of information to deal with high reading, and the absence of motivation for doing regular SMBG.
The more the frequency of SMBG daily, the better the HA1C of the patients ($p < 0.01$).
Adolescent patients aged 10–16 years who have more frequent SMBG and those with less HA1C have significant better quality of life ($p < 0.05$).

Conclusions: More frequent SMBG practice was associated with better glycemic control and better quality of life. Patients' compliance is influenced by several factors which affect their frequency of SMBG.

Keywords: Self-monitoring of blood glucose, Type 1 diabetes mellitus, Quality of life

Background

Diabetes mellitus is a group of metabolic diseases characterized by chronic hyperglycemia resulting from defects in insulin secretion, insulin action, or both [1]. Frequent and accurate blood glucose monitoring and concomitant optimal adjustment of insulin to carbohydrate intake and exercise are the basis of diabetes treatment in type 1 diabetes mellitus (T1DM) [2]. Self-monitoring blood glucose (SMBG) includes an assessment of the capillary glucose concentration (self-measurement) as well as the interpretation of and responding to the readings (self-regulation) [3]. The frequency of (SMBG) is associated with improved HbA1c levels in patients with T1DM [4]. This is thought to be due to both better insulin adjustment for food consumed, an improved ability to quickly correct out-of-target glucose values, and early detection of lower glucose values prior to symptomatic hypoglycemia, especially during and post

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exercise [5]. The number and regularity of SMBG should be individualized depending on availability of the equipment, type of insulin regimen, and ability of the patient to identify hypoglycemia. Fasting, preprandial targets, and postprandial targets for SMBG have been outlined in several guidelines [6]. Blood glucose self-monitoring is not frequently used in developing countries due to priority problems with governments, unavailability of glucose meters and/or test strips, lack of education, or cultural issues. It is not always used as prescribed, even in settings where it is available [7].

T1DM and its complications may affect adolescents' living conditions over the years and may also influence their quality of life (QOL) [8]. People with T1DM have to cope with many factors that affect everyday disease management. The study of quality of life (QOL) in these patients is somewhat different from other populations, since T1DM requires making frequent glucose monitoring, insulin injection and dose adjustment, carbohydrate estimation, planning of therapeutic adjustments to physical activity, etc. [9].

The current study aimed to assess patients' compliance to SMBG, identify factors and barriers that affect it, and to correlate performance of SMBG to blood glucose monitoring and patients' quality of life.

Methods

This cross-sectional study was carried out on 330 children and adolescents with type 1 diabetes. Patients were recruited from the outpatient diabetes specialized clinic, pediatric hospital during the period from December 2015 till December 2016. Random sample was drawn from children and adolescents attending the outpatient diabetes specialized clinic twice weekly.

Sample size

Estimation with margin of error 5%, confidence level 95%, and the response distribution 50% of 900 population size. Calculated number is 270, plus 20% for response rate of 80%; it was 324 rounded to 330.

Methods

Included both questionnaires and mean glycated hemoglobin (HA1C) measurement during the study period

Questionnaires

i. An interview pre-structured questionnaire which included the following: personal and demographic data as age, sex, parents educational degree and career, number of siblings and order of birth, assessment of anthropometric measures including weight in kilograms (Kg) and height in centimeters (cm), and plotting them according to standard deviation scores—medical history for patient and family, health services, assessment of self-monitoring blood glucose including frequency and timing, and health education during the last year
ii. Ferrans and Powers Quality of Life Index (Diabetes Version-III) Arabic version, excluding questions that are not applicable or not socially accepted among Egyptians as questions regarding the sexual practice (https://qli.org.uic.edu/questionaires/pdf/diabetesversionIII/ArabicQOL%20Diabetes.version%203.pdf).
iii. Adolescents aged 10–16 years who had been diagnosed with type 1 diabetes mellitus were subjected to quality of life interview questionnaire. Patients with verbal communication difficulties or any disease affecting their intellectual functions were excluded from answering this questionnaire [10].

Validity

Content validity of the QLI was supported by the fact that items were based both on an extensive literature review of issues related to quality of life and on the reports of patients regarding the quality of their lives [11].

Mean glycated hemoglobin (HA1C) measurement during the study period estimated from the whole blood by column chromatography technique.

Statistical analysis

Data were collected, revised, coded, and entered to the Statistical Package for Social Science (IBM SPSS) version 20. The quantitative data were presented as mean, standard deviations, and ranges when their distribution found parametric and median, (IQR) when distribution found non-parametric, while qualitative data were presented as number and percentages. The comparison between two independent groups with qualitative data was done by using chi-square test. The comparison between two independent groups with quantitative data and parametric distribution was done by using independent t test and one-way analysis of variance (F) (ANOVA) technique to compare means of numerical data. Data with non-parametric distribution was done by Mann-Whitney test. Spearman correlation coefficients were used to assess the correlation between two quantitative parameters in the same group. The confidence interval was set to 95% and the margin of error accepted was set to 5%. So, the p value was considered significant as the following: $p > 0.05$, non-significant; $p < 0.05$, significant.

Results

The study sample included 47% males and 53% females; their mean age was 10.56 ± 4.055 years, 64.8% of them live in urban areas and 35.2% in rural areas (Table 1).

Table 1 Descriptive data of studied group patients regarding personal data

			No. = 330
Sex		Male	155 (47.0%)
		Female	175 (53.0%)
Age		Mean ± SD	10.56 ± 4.055
		Range	2–16
		2– < 10	131 (39.6%)
		10–16	199 (60.4%)
No. of siblings		Mean ± SD	2.34 ± 0.95
		Range	0–5
		≤ 3	393 (88.7%)
		> 3	37 (11.2%)
The order of birth of the child		< 3	286 (86.6%)
		≥ 3	44 (13.3%)
Residence of the child		Urban	214 (64.8%)
		Rural	116 (35.2%)
Anthropometric	Weight%	< 5 (underweight)	29 (8.7%)
		5 ≤ 85 (normal weight)	255 (77.2%)
		85–< 95 (over weight)	27 (8.1%)
		> 95 (obese)	19 (5.7%)
	Height%	< 5 (stunted)	73 (22.1%)
		5–< 90 (normal)	228 (69.09%)
		≥ 90 (over height)	29 (8.7%)

The mean duration of diabetes was 3.65 ± 2.59 years. Regarding the type of insulin used, it was found that 255 patients (77.3%) were using basal–bolus analogs, while 75 patients (22.7%) were using regular insulin and NPH.

The mean HA1C in the current study was 8.8 ± 0.11%, and 25.2% (83 patients) of the studied patients were well controlled with HA1C < 7.5%, while 33.3% (110 patients) were moderately controlled with HA1C 7.5–9%, and 41.5% (137 patients) were poorly controlled with HA1C > 9%. Classification of the patients using HA1C as a predictor of glycemic control was done according to ISPAD guidelines 2014 which was the most recent guidelines at the time of the study.

It was found that 245 patients (74.2%) received health education during their visits to the clinic and 86.7% of them know how to do carbohydrate counting.

HA1C was significantly lower in patients who practice regular SMBG than those who practice irregular (less than 3 times per day) SMBG ($p < 0.01$). The more the frequency of SMBG daily, the better the HA1C of the patients ($p < 0.01$). Twenty eight percent of the patients who assess 3 times daily have HA1C < 7.5, while all patients who assess 6 and 7 times daily have HA1C < 7.5 (Table 2).

Regarding the presence of complication, it was found that 209 patients (63.3%) have no complication, 84 patients (25.5%) have neuropathy diagnosed by history of tingling and numbness, 21 patients (6.4%) have microalbuminuria and neuropathy, 3 (0.9%) patients developed hypertension and microalbuminuria, and only one patient (0.3%) has retinopathy only, while 10 (3%) patients have retinopathy and neuropathy. A significant relation was found between the frequency of SMBG and the absence of complication [median (IQR) = 3 (0–3) non-complicated patients versus 0 (0–3) in complicated patients] ($p < 0.05$).

Assessment of SMBG of T1DM children attending diabetic clinic in the current study showed that 53.0% of them were on regular SMBG practice more than 3 times per day and 47.0% were irregularly practicing SMBG method.

During assessment of frequency of SMBG in patients with regular SMBG practice, it was observed that, most of the patients assess their blood glucose 3 times per day, while minority of them assess their blood glucose 6 and 7 times per day. None of the patients was on continuous glucose monitoring method (Table 3).

Regarding the timing of SMBG done by the studied patients, it was found that all patients measure their blood glucose before breakfast and before sleeping, while 84.5% measure their blood glucose preprandial and 29% measure it postprandial. Only 4.5% measure their blood glucose at down.

When comparing patients on regular SMBG practice and those who are not on regular SMBG as regards their personal data, it was found that, patients with younger age [mean ± SD (9.97 ± 3.98) years] and their parents have high educational level, and patients who live at urban areas, patients who have fewer siblings and patients who were diagnosed from a short period of time [mean ± SD (3.18 ± 2.26) years] were significantly more compliant on SMBG practice ($p < 0.05$).

Table 2 Correlation between frequency of SMBG and HA1C

	Frequency of SMBG										Chi-square test	
	3		4		5		6		7			
	No.	%	No.	%	No.	%	No.	%	No.	%	χ^2	*p* value
HbA1C < 7.5	33	28.0%	28	80.0%	4	80.0%	16	100.0%	1	100.0%	55.707	0.000
HbA1C 7.5-9	71	60.2%	6	17.1%	0	0.0%	0	0.0%	0	0.0%		
HbA1C > 9	14	11.9%	1	2.9%	1	20.0%	0	0.0%	0	0.0%		

Table 3 Frequency of SMBG in type 1 diabetic patients

		Regular
Place at which SMBG is done (home, school, club)	Home	137 (78.3%)
	More than one place	38 (21.7%)
Frequency	Mean ± SD	3.55 ± 0.96
	Range	3–7
	3	118 (67.4%)
	4	35 (20%)
	5	5 (2.8%)
	6	16 (9.1%)
	7	1 (.57%)

During comparison of both groups regarding the factors affecting compliance of SMBG practice in our study, it was observed that all studied type 1 diabetes mellitus children attending diabetic clinic faces common barriers and factors that can affect their practice of SMBG with no significant difference between them ($p > 0.05$). However, it was found that patients with regular SMBG practice significantly disagree with the idea that using the device in public can be a stigma and that the presence of inadequate place to do SMBG could be barriers for regular SMBG practice ($p < 0.05$) (Table 4).

Regarding patients' quality of life scoring (QOL) and its relation to the frequency of SMBG and glycemic control, a total of 199 adolescents aged 10–16 years were assessed using quality of life interview questionnaire. It was found that health and functioning subscale had 48.7% of the score, while family subscale had only 6.7% of the score. Adolescent patients aged from 10 to 16 years who have less HA1C and less complications have significant better quality of life ($p < 0.05$). Adolescents who practice SMBG about 4 or 5 times have better quality of life than others who infrequently do SMBG and those who do SMBG more than 5 times per day ($p < 0.05$). No significant relation was found between QOL and frequency of admission to the hospital ($t = 0.171$, $p = 0.865$), health education regarding diabetes education and knowledge about carb counting ($t = 0.981$, $p = 0.328$), and type of insulin ($t = 0.59$, $p = 0.551$) ($p > 0.05$) (Tables 5, 6, and 7).

Multiple regression analysis revealed that HA1C level and the presence of complications are the predicting factors on the outcome of QOL total score $p < 0.001$, OR = 0.093 and $p < 0.001$, OR = 0.593 respectively.

Discussion

The mean HA1C in the current study was 8.8 ± 0.11%. These results agree with a group of studies evaluating HA1C in their patients. A cross-sectional study that included children and adolescents with T1DM visiting the pediatric diabetes clinic at the King Abdulaziz University Hospital (KAUH), Saudi Arabia, reported that glycated hemoglobin (HA1C) level was 8.8% [12]. Also, a Turkish study found that mean hemoglobin A1C level was 8.5 ± 1.6% [13]. Found in multicentered study conducted in Europe, Japan, and the USA that HA1C was 8.6 ± 1.7% (10). A French cross-sectional study which was conducted on children and adolescents with type 1 diabetes found that the mean HA1C was 8.97% [14, 15].

On the other hand, there were some studies which found higher HA1C. Aljabri and Bokhari described HA1C values in a study done in kingdom of Saudi Arabia to be 9.9 ± 2.3% in patients less than 20 years old [16], while Mortensen et al. [17] found that HA1C was 9.1% in Denmark, while another population-based study which was done in Scotland found a value of HA1C to be 9.1% [18].

The current study reported that about quarter of the studied patients were well controlled with HA1C < 7.5, while third of them were moderately controlled with HA1C 7.5–9, and 41.5% were poor controlled with HA1C > 9. Meanwhile Sayed et al. reported that only 31.2% of children and adolescents with T1DM were well controlled in retrospective study that was performed at Jeddah, western Saudi Arabia [19].

During assessment of frequency of SMBG in patients who were compliant on SMBG, it was found that 67.4% of the patients assess blood glucose 3 times per day, while 0.57% assess blood glucose 7 times. None of the patient could afford the financial expense of use of continuous glucose monitoring devices.

Regarding the opinion of the children and their parents about reasons for not achieving good glycemic control and the most influential factors affecting compliance of SMBG, the patients conceded that the cost of strips and glucometers, the fear of pain and injection, psychological frustration, lack of availability of information to deal with high reading, no motivation, and in adequate place to assess SMBG were the main reasons for not practicing regular SMBG. These results agree with a number of other studies found that lack of awareness

Table 4 Comparison between patients on regular and those on irregular SMBG regarding the opinion of the children and their parents about the most influential factors affecting compliance of SMBG

		Regular		Irregular		Chi-square test	
		No.	%	No.	%	χ^2	*p* value
Lack of efficacy to use the device	Not sure	41	23.4%	39	25.2%	2.709	0.258
	Disagree	97	55.4%	94	60.6%		
	Strongly disagree	37	21.1%	22	14.2%		
Not knowing read the result	Not sure	13	7.4%	24	15.5%	5.527	0.063
	Disagree	119	68.0%	99	63.9%		
	Strongly disagree	43	24.6%	32	20.6%		
The cost of strips	Strongly agree	174	99.4%	154	99.4%	0.007	0.931
	Agree	1	0.6%	1	0.6%		
Fear of pain and injection	Strongly agree	158	90.3%	136	87.7%	0.547	0.459
	Agree	17	9.7%	19	12.3%		
No motivation	Strongly agree	105	60.0%	93	60.0%	2.276	0.320
	Agree	69	39.4%	58	37.4%		
	Not sure	1	0.6%	4	2.6%		
Psychological frustration	Strongly agree	139	79.4%	124	80.0%	0.017	0.898
	Agree	36	20.6%	31	20.0%		
The use of SMBG to control insulin dose	Strongly agree	17	9.7%	22	14.2%	1.891	0.388
	Agree	114	65.1%	92	59.4%		
	Not sure	44	25.1%	41	26.5%		
Use the device in public is a stigma	Strongly agree	24	13.7%	18	11.6%	11.526	0.009
	Agree	24	13.7%	38	24.5%		
	Not sure	33	18.9%	40	25.8%		
	Disagree	94	53.7%	59	38.1%		
Inadequate place	Strongly agree	18	10.3%	17	11.0%	11.657	0.009
	Agree	59	33.7%	65	41.9%		
	Not sure	30	17.1%	39	25.2%		
	Disagree	68	38.9%	34	21.9%		
Non-availability of information to deal with high reading	Strongly agree	53	30.3%	41	26.5%	0.593	0.441
	Agree	122	69.7%	114	73.5%		

and cost of glucometers were reported to be the main reasons for not practicing SMBG [20]. Another study reported that specific SMBG information deficits, motivation obstacles, and behavioral skill limitations were identified in a substantial proportion of participants [21]. Non compliance practice of SMBG can be attributed to some causes as the cost of monitoring supplies, lack of diabetes self-management skills, or concerns about the reliability of blood glucose readings [22]. In the same context, Mansour assessed patient opinion for not achieving good glycemic control among a group of patients with HbA1C ≥ 7.30. Some of the patients said that they were unaware of diabetics' complications. Others reported that strips were not available or could not be used [23].

The factors that influenced SMBG were mainly related to cost, participants' emotion, and the SMBG process. The barriers identified included are as follows:

Table 5 Relation between frequency of SMBG and quality of life of adolescent patients

		Frequency of SMBG				One-way ANOVA	
		3	4	5	6	*F*	*p* value
QOL	Mean ± SD	236.30 ± 89.26	332.36 ± 68.47	358.50 ± 93.83	293.10 ± 109.63	7.390	0.000
	Range	72–430	225–421	250.5–420	164.5–420		

Table 6 Relation between HbA1C and quality of life of adolescent patients

		HA1c< 7.5	HA1c 7.5–9	HA1c > 9	One-way ANOVA	
		No. = 83	No. = 110	No. = 137	*F*	*p* value
QOL	Mean ± SD	317.91 ± 84.34	208.39 ± 70.40	131.82 ± 64.41	106.747	0.000
	Range	79.5–430	69–370	69–297		

frustration related to high blood glucose reading, perception that SMBG was only for insulin titration, stigma, fear of needles and pain, cost of test strips and needles, inconvenience, unconducive workplace, and lack of motivation, knowledge, and self-efficacy [24].

In the current study, it was observed that the more the frequency of SMBG daily, the better the HA1C of the patients ($p < 0.01$). Twenty-eight percent of the patients who assess 3 times daily have HA1C < 7.5, and all patients who assess 6 and 7 times daily have HA1C < 7.5. Our results consistently with a number of studies which found that, more frequent SMBG was significantly associated with better metabolic control. On average, a drop of HA1C of 0.20% for one additional SMBG per day ($p < 0.001$) could be observed. However, increasing the SMBG frequency above five per day did not result in further improvement of metabolic control (decrease in HA1C). Restricted to the range of 0–5 measurements per day, HA1c decreased by 0.46% per one additional measurement [25].

In another study, a multicenter randomized trial involving subjects on basal–bolus insulin, HA1C ≥ 8.0%, and poorly compliant with SMBG. HA1C levels decreased by about 0.6% in patients who became compliant with SMBG, irrespective of the glucose meter used, while no or only minor changes in HA1C levels were documented in patients who remained not compliant with SMBG during the study [26].

In this study, it was found that adolescent patients aged from 10 to 16 years who have more frequent SMBG and those with less HA1C and less complications have significant better quality of life ($p < 0.05$). Similarly, Lalić et al. reported that the use of structured SMBG combined with intensive education was associated with clinically significant reductions in HA1C, increased SMBG frequency, and improved quality of life [27]. Also, Vyas et al. reported that the appropriate education and counseling diminish impact of diabetes, improve QOL, and help to achieve desired glycemic (HA1C) level in poorly control T1D patients [28].

Table 7 Quality of life questionnaire score of adolescent patients aged from 10 to 16 years

Total quality of life score	2783	
Health and functioning subscale	1357.6	48.7%
1. Health	177.3	6.3%
2. Health care	181.2	6.5%
3. Energy (fatigue)	184.1	6.6%
4. Ability to take care of yourself without help	199.8	7.1%
5. Ability to control blood sugar	169.9	6.1%
6. Changes made in life because of diabetes	163.2	5.8%
11. Things for fun	282.1	10.1%
Social and economic subscale	677.6	24.3%
7. Friends	171.8	6.1%
9. Emotional support from people other than your family	182.2	6.5%
10. Education	323.6	11.6%
Psychological/spiritual subscale	560.6	20.1%
12. Faith in God	173	6.2%
13. Life satisfaction in general	187.7	6.7%
14. Personal appearance	199.9	7.1%
Family subscale	186.5	6.7%
8. Emotional support from family		

Conclusions

More frequent SMBG practice more than 3 times was associated with better glycemic control and better quality of life. Patients' compliance is influenced by several factors which affect their frequency of SMBG.

Implication

Patients' education must include encouragement of frequent SMBG to achieve proper glycemic control. Education sessions must stress on the patients' medical problems and finding a solution for these problems to increase their quality of life. Directing financial expenses for glucostrip availability will improve the practice of SMBG which can lead to decreasing the expenses required for hospital stay, treatment of diabetes complication, and the psychological support required to improve quality of life.

Abbreviations

T1DM: Type 1 diabetes mellitus; SMBG: Self-monitoring blood glucose; QOL: Quality of life; HA1C: Glycated hemoglobin

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Competing of interests

Authors declare any conflict of interest.

Authors' contributions

All authors have read and approved the manuscript. S A E: contributed to the conception, design of the work, and interpretation of data; drafted the work and revised it; approved the submitted version; and agreed to be personally accountable for author's own contributions. H S E: contributed to the conception, design of the work, and interpretation of data; approved the submitted version; and agreed to be personally accountable for author's own contributions. R A T: contributed to the conception, design of the work, interpretation of data and drafted the work and revised it. She approved the submitted version and agreed to be personally accountable for author's own contributions. A S O: contributed to the conception, interpretation of data, approved the submitted version and agreed to be personally accountable for author's own contributions.

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Availability of data and materials

All data generated or analyzed during this study are included in this published article.

Ethics approval and consent to participate

This study was approved by the local research ethical committee of Ain Shams University, Faculty of Medicine in the Declaration of Helsinki (FMASU REC). The study was approved in October 2015 by pediatric department committee. A written consent was taken from children's legal guardians. All subjects were explained about the purpose of the study and were ensured that the information collected from them would be confidential and used only for academic purpose.

Consent for publication

N/A

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