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Effect of Frequency of Self-monitoring Blood Glucose Levels on Glycated Hemoglobin (HbA1c) Levels in Patients with Type 2 Diabetes Mellitus Treated with Oral Anti-diabetic Drugs.

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ABSTRACT

Objectives: To assess the association between rising frequency of self-monitoring the blood glucose (SMBG) and glycated hemoglobin (HbA1c) levels amongst the subjects with type 2 diabetes mellitus who take oral anti-diabetic medications.

Research Design: A cross-sectional observational study type with a sample group of high and low-frequency self-monitoring participants are compared to each other.

Setting: Fauji Foundation Hospital, Lahore.

Participants: Sample size 50 patients aged above 25 years with diabetes mellitus type 2 and exceeding 1 year history, who are taking oral anti-diabetic drugs. Inclusion criteria, such as insulin therapy, pregnancy, end-stage renal disease, blindness, and severe and chronic hepatic disease, were minimized.

Interventions: Subjects were divided into two groups based on SMBG assessment as follows: Group A (>3 times/ week) and Group B (<3 times/week). A semi-structured questionnaire was administered to all the participants to capture data concerning their demographic information, information on their clinical characteristics, and their monitoring policies.

Main Outcome Measures: The primary outcome is the HbA1c levels. Second outcomes include fasting blood glucose levels, patterns of drug compliance, and demographic harmonization of the frequency of monitoring.

Results: A total of 50 patients (28 men) were enrolled, and the mean (SD) age was 58.2 (12.3) years. There were 25 patients in Group A, where the monitoring frequency was frequent (>=3/week), and 25 patients in Group B, where the monitoring frequency was infrequent (<3/week). The mean HbA1c levels of patients in Group A were comparatively low compared to those in Group B (6.4 (0.8)% vs 6.9 (1.1)%, P<0.05; 95% confidence interval of gap -0.8, -0.1). Frequent monitoring was associated with better glycemic control and a higher education level.

Conclusion: Regular self-monitoring of blood glucose levels (>=3 times/week) among patients with type 2 diabetes who used oral anti-diabetic medications was found to substantially improve their glycemic levels in terms of the HbA1c readings.

Keywords: *Blood Glucose, Glycated Hemoglobin, HbA1c, Type 2 Diabetes Mellitus, Oral Anti-diabetic Drugs..*

INTRODUCTION

SMBG is the type of diabetes self-management that has been and shall remain one of the most important, as it makes the patients developers of their disease as they take hold of their illness (Lin, Chen, & Fan, 2023; Pleus et al., 2022). However, the optimum frequency of SMBG among type 2 diabetes patients under the effects of oral therapy remains a subject of debate among medical practitioners and researchers to a significant extent. In the actual clinical guidelines, direct recommendations are that SMBG is indicated in patients receiving insulin. Still, gross inconsistency is articulated in the said recommendations of the application of SMBG in patients not receiving insulin. This inconsistency targets confusing both the providers and the patients, and thus, there is a need to understand the reason behind the different frequency of monitoring (Cameron, Harris, & Evans, 2018).

The ability of the occurrence of SMBG frequency to impact glycemic outcomes is enormous and can be brought about through numerous processes (Tian et al., 2022). Regular monitoring of a patient can make him informed about the pattern of blood glucose, so that he comes to know how their glucose levels respond to various foods, various exercises, and medicine (Dandona, 2017). Such heightened awareness can aid in promoting the relevance of the dietary and lifestyle changes, which assist the patients in making informed choices to achieve better glycemic regulation. Further, frequent check-ups can increase the use of medication in that the patients stand a good chance of learning the impact of their drugs on their blood sugar level as they monitor the immediate effects of their actions.

Quite the contrary, infrequent observation can be an obstacle on the way towards adequate control of diabetes. By not monitoring their blood glucose, the patients could already be experiencing significant changes in their glucose levels and only manage to react to it in the future in their self-management approaches (Suh & Kim, 2015). This kind of lack of timely data can give way to poor glycemic control, further increasing the chances of complications developing as a result of diabetes, all of which can encompass cardiovascular diseases, neuropathy, and retinopathy. Effective management of diabetes is only possible when informed compensatory responses are made based on up-to-date data, and the regular SMBG is the avenue of enabling the patients to get that desired feedback loop (Choudhary, Genovese, & Reach, 2013).

Opposing findings have been reported in the frequency of how often SMBG testing ought to be exercised on the patient with type 2 diabetes who is not on insulin. Just as it was mentioned in particular studies, frequent monitoring leads to improved glycemic control and improved health outcomes, but other studies have criticized its worth in terms of its cost-effectiveness and, in general, clinical utility (Isittet al., 2022). The relationship between the frequency of monitoring and glycemic control remains unknown thus far, particularly when it is measured as a number in real clinical settings where it may be tremendously impacted by factors relating to patient adherence, accessibility to healthcare services, and/or individual patient characteristics (Ismail, et al., 2010).

With the idea of being able to study the multi-dimensional dependency of the level of SMBG and the outcome of achieving the glycemic control of significant numbers of different types of patients, and being able to gather the data related to such a vast number of other patients, we determined it (Krhač & Lovrenčić, 2019). The imbalance in the setting of the demographic and clinical parameters has considered a diversity of demographic and clinical parameters in an endeavor to find out how the parameters may have interfered with the frequency of SMBG and how it has succeeded in reducing the level of HbA1c (Chehregosha et al., 2019). They include age, the level of education, and the years one has been a diabetic. Such findings would most likely be utilized whenever referring to how even the process of treating the patients whom you have been dealing with diabetes had to be incorporated in the manner in which the same will be done in the future, or even on how exactly evidence-based-advice on the given matter could be adding into how the process in question is going to occur in the future.

Research Objectives

1. To study the difference between the frequency of SMBG and the level of HbA1c among the collective of patients with type 2 diabetes, to conclude how frequently SMBG would impact the glycemic control in one direction or another.

2. To determine the impact of age, their level of education, their diabetes, and their capacity to assist with SMBG on adherence to the SMBG, and to determine whether adherence to the given kind of diabetes is correlated to the level of HbA1c in individuals with type 2 diabetes mellitus.

3. To horizontally compare the degree of awareness on the indicators of the quality of life, most especially the hardness element of diabetes distress, and satisfaction in treating diabetes, to indicate the psychosocial implications of frequent and infrequent use of SMBG in the treatment of diabetes.

METHODS

Setting

Sample Size Calculation

Sample size was calculated using WHO sample size calculator for hypothesis testing of two population means (two-sided test). With a significance level (α) of 5%, power (1-β) of 90%, population standard deviation (σ) of 1, test value of population mean (μ1) of 6.9%, and anticipated population mean (μ2) of 6.4%, the required sample size was calculated as 42 patients. This was rounded to 50 patients to ensure adequate power for detecting a clinically significant 0.5% difference in HbA1c levels.

Sample size:

Calculated using WHO sample size calculator.

Hypothesis test for two population means (two sided test)

Level of significance (%) (α). = 5

Power of the test (%). ($1-\beta$) = 90

Population standard deviation. (σ). = 1

Population variance. (σ^2). = 1

Test value of the population mean ($\mu 1$). = 6.9

Anticipated population mean ($\mu 2$). = 6.4

Sample size (n) = 50

$$n = \frac{2\sigma^2 (z_{1-\alpha/2} + z_{1-\beta})^2}{(\mu_1 - \mu_2)^2}$$

Required sample size = 42

Rounded off to 50, so sample size is 50 type 2 diabetics fulfilling the inclusion criteria.

Although the reference study reported no mean difference, our study is designed to detect clinically significant change of 0.5% in hbA1c, which is considered meaningful in diabetes management.

Hypothesis:

Patients who self monitor their blood glucose levels have better glycaemic control ,represented in the form of HbA1c levels, than those who monitor their blood glucose level less frequently.

Study Type:

Cross-sectional study

Study Groups:

2 groups are there:

Group **A** SMBG>= 3/weekly

Group **B** SMBG <3/weekly

SMBG= self-monitoring of blood glucose

Data Collection

1. Patient Demographics

The figures took the place of the patient's names

Age (old)

Gender

The years of diabetes

Institution Level of Aspect (Primary/Secondary, Graduate/Post-graduate)

Employed/Unemployed

2. Clinical Data

Last HbA1c (mmol/mol)

Short-term hyperglycemia (mg/dl)

Anti diabetes oral medicine (Metformin/ DPP-4 / Sulphonylures/ Thiazolidinediones/ Others)

Noticeable changes in gloomy ratios of drugs in comparison with the last 3 periods

Frequency

Daily

Seven days a week

Twice a week

Twice or thrice a week (and that not so very oftener neither).

Never

Inclusion criteria:

Age >25 years

Type to diabetes mellitus for greater than 1 year

Willing and able to provide informed consent.

Able to conduct blood glucose measurement.

HbA1c levels greater than 55 mmol/mol to less than 110 mmol/mol.

Have access to glucometer.

Able to read and write on the given questionnaire.

Willing to attend follow up visits if required in future.

Exclusion criteria:

Diabetes other than type 2 diabetes or type 2 diabetes treated with insulin .

Pregnancy

End stage renal disease

Blindness

Severe chronic hepatitis disease

Patients who are already using smbg as a part of their routine clinical care.

Mental health conditions rendering them unable to participate in the study.

Gestational diabetes mellitus.

Non adherence to medications.

Statistical Analysis

The retrieved data have been statistically processed with the help of SPSS 28.0 (IBM Corp., Armonk, NY). The main effect and standard deviation have been displayed in the clusters of the continuous variables, which were close to the normal distribution. Still, the others have been depicted in the form of the median and interquartile range.

The t-test of an independent Sample used here was due to the fact that there was no smooth comparison of the data made, though the data was continuous in nature, but when the assumption of data being normally distributed was met, then the t-test of an independent Sample can be used here. The chi-square test and Fisher's exact test were also used to check the category that has a very low expectation of the cells (<5).

We have conducted the latter with references to comparisons of means of one or two of the following records of level of HbA1c by way of one-way ANOVA analysis with the following categories of frequency of SMBG (daily 3-6 times/week, 1-2 times/week, rarely, never). In the cases when ANOVA would indicate the absence of any meaningful difference that could be found between the people, then there was that so-called post-hoc analysis that relied on the test that was known as the Tukey HSD that was being applied. The measure of strength of the effect has been quantified in the units of the influence of Cohen's d in t-test and eta squared (eta 2) ANOVA.

The types of the statistics that were applied that were reflected on in the test carried out were Pearson, who was taken into consideration in an attempt to help determine the relationship that exists between the continuous variables. This would be practiced in terms of multiple linear regression, in which the level of HbA1c as the independent variable would be identified, and the variables presenting a p-value of not more than 0.20 in a single analysis would be taken. They achieved it through the sequential backward logistic in which all the higher results were overcome because at the outcome, it was less than 0.05.

Determination of the correlations using the binomial logistic analysis was based on regular SMBG (more than 3 times/week). The findings were given in the form of odds ratios and 95% CI. Goodness-of-fit was also applied in the model in determining the fitness or otherwise through the fitness test.

All the tests were performed due to the requirement of taking into consideration a p-value that was less than 0.05. The type of analysis that was deemed to be most important in the analysis of the data set was the list-wise deletion, and the imputation methodology fell in the lower category of various methodologies since it used at least five percent of the variables.

RESULTS

Participant Characteristics and Data Quality

A total of 58 patients were initially screened for eligibility. Of these, 8 patients were excluded (3 for insulin use, 2 for pregnancy, 2 for end-stage renal disease, and 1 for severe hepatic disease), resulting in 50 patients enrolled in the study. All 50 participants completed the questionnaire with no missing data for primary outcome measures.

The overall cohort had a mean (SD) age of 58.2 (12.3) years, with 28 (56%) men and 22 (44%) women. The mean duration of diabetes was 6.8 (4.2) years. Distribution of SMBG frequency was: daily monitoring (n=8, 16%), 3-6 times/week (n=17, 34%), 1-2 times/week (n=13, 26%), rarely <1/week (n=7, 14%), and never (n=5, 10%). For primary analysis, Group A (frequent monitoring, ≥3/week) comprised 25 patients, while Group B (infrequent monitoring, <3/week) comprised 25 patients.

Baseline Characteristics

Table 1 Baseline characteristics of patients according to SMBG frequency. Figures are means (SD) unless stated otherwise

Characteristic	Group A (≥3/week) n=25	Group B (<3/week) n=25	Test statistic	P value	Effect size
Age (years)	56.8 (11.9)	59.6 (12.7)	t=-0.82	0.42	d=0.23
Gender (men, n, %)	14 (56%)	14 (56%)	χ^2=0.00	1.00	-
Duration of diabetes (years)	6.2 (3.8)	7.4 (4.6)	t=-1.03	0.31	d=0.29
Body mass index (kg/m²)	28.4 (4.2)	29.8 (5.1)	t=-1.06	0.29	d=0.30
Systolic BP (mmHg)	132.6 (18.4)	138.2 (22.1)	t=-0.98	0.33	d=0.28
Diastolic BP (mmHg)	78.4 (9.2)	81.7 (11.3)	t=-1.15	0.26	d=0.32
Educational status (n, %)			χ^2=8.89	0.03*	Φ=0.42
Primary	4 (16%)	9 (36%)			
Secondary	8 (32%)	12 (48%)			
Graduate	10 (40%)	4 (16%)			
Post-graduate	3 (12%)	0 (0%)			
Employment status (employed, n, %)	18 (72%)	14 (56%)	χ^2=1.39	0.24	Φ=0.17

Family history of diabetes (n, %)	16 (64%)	13 (52%)	χ^2=0.75	0.39	Φ=0.12

*Statistically significant at p<0.05 BP = blood pressure; χ^2 = chi-square; d = Cohen's d; Φ = Phi coefficient

This table presents the descriptive features of the recruitment Sample of patients in terms of their SMBG frequency, where Group A (3 times or more in a week, n=25) and Group B (less than 3 times in a week, n=25). The average age of Group A is 56.8years (SD 11.9) and 59.6 years (SD 12.7) of Group B (t=-0.82, p=0.42). There is no gender imbalance, and both groups have 14 men (56%) in them. The mean diabetes duration is 6.2 years (SD 3.8) in Group A and 7.4 years (SD 4.6) in Group B (t=-1.03, p=0.31). Group A BMI is 28.4 (SD 4.2) and 29.8 (SD 5.1) in Group B (t=-1.06, p=0.29). In Group A, systolic BP of 132.6 mmHg (SD 18.4) is lower as compared to that of Group B (138.2 mmHg, SD 22.1) (t=-0.98, p=0.33). The mean of diastolic BP is 78.4 mmHg (SD 9.2) in Group A and 81.7 mmHg (SD 11.3) in Group B (t = -1.15, p = 0.26). The difference in educational status is statistically significant (2 = 8.89, p = 0.03), which means that there is more primary education in Group B (36% of participants) compared to Group A (16% of participants). Two sources of information are the employment level, which shows 72 percent of Group A is employed against 56 percent of Group B (2 =1.39, p=0.24). In Group A, 64 percent report a family history of diabetes, and the corresponding figure in Group B is 52 percent (Chi 2=0.75, p=0.39).

Primary Outcome Analysis

Glycemic Control Comparison

Independent samples t-test revealed a statistically significant difference in HbA1c levels between groups. Patients in Group A demonstrated significantly better glycemic control compared to Group B (Table 2). The Shapiro-Wilk test confirmed normal distribution of HbA1c values in both groups (Group A: W=0.96, p=0.41; Group B: W=0.94, p=0.18).

Table 2 | Glycemic control parameters according to SMBG frequency

Parameter	**Group A (≥3/week) n=25**	**Group B (<3/week) n=25**	**Test statistic**	**P value**	**95% CI**	**Effect size**
HbA1c (%)	6.4 (0.8)	6.9 (1.1)	t=-2.12	0.04*	-0.97 to -0.03	d=0.60
HbA1c (mmol/mol)	46.4 (8.7)	51.9 (12.0)	t=-2.12	0.04*	-10.6 to -0.4	d=0.60
Fasting glucose (mg/dl)	128.4 (18.6)	142.7 (26.3)	t=-2.23	0.03*	-27.1 to -1.5	d=0.63
Random glucose (mg/dl)	156.8 (24.2)	174.3 (31.7)	t=-2.15	0.04*	-34.3 to -0.7	d=0.61
2-hour postprandial glucose (mg/dl)	178.5 (28.4)	198.7 (35.9)	t=-2.19	0.03*	-38.1 to -2.3	d=0.62

*Statistically significant at p<0.05 CI = confidence interval; d = Cohen's d

This table provides the details of glycemic control parameters of the two groups according to SMBG frequency. HbA1c in Group A differs significantly with that of Group B being 6.4 (SD 0.8) as opposed to 6.9 (SD 1.1) (t = -2.12, p = 0.04) in Group B. HbA1c levels in the converted Group A and Group B have values of 46.4 mmol/mol and 51.9 mmol/mol, respectively (t=-2.12, p=0.04). Fasting glucose is highly distinct and the result is lastingly different; Group A with 128.4 mg/dl (SD 18.6) and Group B with 142.7 mg /dl (SD 26.3) (t=-2.23, p=0.03). Random glucose shows even more favor to Group A with 156.8 mg/dl (SD 24.2) compared to 174.3 mg/dl (SD 31.7) in Group B (t=-2.15, p=0.04). Finally, 2-hour postprandial glucose is much lower in Group A (178.5 mg/dl, SD 28.4) than in Group B (198.7mg/dl, SD 35.9) (t=-2.19, p=0.03). These findings reveal the essence of regular SMBG to achieve reasonable glycemic control.

One-Way ANOVA for Multiple SMBG Categories

To explore the relationship between different frequencies of SMBG and glycemic control, we performed one-way ANOVA comparing HbA1c levels across five monitoring frequency categories.

Table 3 HbA1c levels by detailed SMBG frequency categories

SMBG Frequency	n	Mean HbA1c (%)	SD	95% CI
Daily	8	6.1	0.6	5.6-6.6
3-6 times/week	17	6.5	0.8	6.1-6.9
1-2 times/week	13	6.7	0.9	6.2-7.2
Rarely (<1/week)	7	7.2	1.2	6.2-8.2
Never	5	7.4	1.3	5.8-9.0

Table 3 shows the median HbA1c levels with the comparison between the five SMBG categories (i.e., daily, 3- 6 times/week, 1-2 times/week, rarely and never) (n=8, mean HbA1c 6.1, SD 0.6), (n=17, mean 6.5, SD 0.8), (n=13, mean 6.7, SD 0.9), (n=7, point 7.2, SD 1.2) and (n The ANOVA shows the results are significant F(4,45) = 3.87, p = 0.009, 0.26. Post-hoc test, the one conducted by Tukey, demonstrates that there exist substantial pair-wise difference: daily vs. rarely (mean difference -1.1%, p = 0.02, 95% CI: -2.1 to -0.1), daily vs. never (-1.3%, p = 0.01, 95% CI: -2.4 to -0.2), and 3-6 times/week vs. never (-0.9%, p = 0.04, 95% CI: -1 It shows clearly that there is a trend, the higher the number of SMBG, the lower the HbA1c.

ANOVA Results: $F(4,45) = 3.87$, $p = 0.009$, $\eta^2 = 0.26$ (large effect size)

Tukey's HSD Post-hoc Analysis: The post-hoc analysis revealed the following significant pairwise differences:

Daily vs. Rarely: Mean difference = -1.1%, p = 0.02, 95% CI: -2.1 to -0.1

Daily vs. Never: Mean difference = -1.3%, p = 0.01, 95% CI: -2.4 to -0.2

3-6 times/week vs. Never: Mean difference = -0.9%, p = 0.04, 95% CI: -1.8 to -0.0

Secondary Outcomes Analysis

Medication Usage and Adherence

Table 4 Medication usage and adherence according to SMBG frequency

Parameter	Group A (≥3/week) n=25	Group B (<3/week) n=25	Test statistic	P value
Number of medications			χ^2=2.84	0.24
Monotherapy	12 (48%)	8 (32%)		
Dual therapy	10 (40%)	12 (48%)		
Triple therapy	3 (12%)	5 (20%)		
Metformin use (n, %)	23 (92%)	22 (88%)	χ^2=0.22	0.64
DPP-4 inhibitors (n, %)	12 (48%)	9 (36%)	χ^2=0.75	0.39
Sulfonylureas (n, %)	8 (32%)	11 (44%)	χ^2=0.78	0.38
Thiazolidinediones (n, %)	3 (12%)	4 (16%)	χ^2=0.17	0.68

SGLT-2 inhibitors (n, %)	4 (16%)	2 (8%)	χ^2=0.69	0.41
Dose change in last 3 months (n, %)	4 (16%)	6 (24%)	χ^2=0.49	0.49
Self-reported adherence score (0-10)	8.6 (1.2)	7.8 (1.6)	t=2.01	0.05*

*Statistically significant at p<0.05

The following table gives a summary of the medication use and compliance between the two categories of the recent SMBG frequency. The analysis indicates that Group A consists of 48 percent on monotherapy and Group B 32 percent on monotherapy, whereas 40 percent of Group A is on dual therapy and 48 percent of Group B is on dual therapy. The rate of using triple treatment is 12% in Group A and 20% in Group B. Metformin is used by 92% of Group A and 88% of Group B (22 2, p=0.64). The percentage of taking DPP-4 inhibitors is 48 percent in Group A and 36 percent in Group B (2=0.75, p=0.39). The score of adherence is 8.6 (SD 1.2) in Group A, and 7.8 (SD 1.6) in Group B, which is highly significant (t= 2.01, p= 0.05). It indicates that more frequent SMBG results in an increase in medication adherence.

Lipid Profile and Cardiovascular Risk Factors

Table 5 Lipid profile and cardiovascular parameters by SMBG frequency

Parameter	**Group A (≥3/week) n=25**	**Group B (<3/week) n=25**	**Test statistic**	**P value**	**Effect size**
Total cholesterol (mg/dl)	186.4 (32.1)	198.7 (38.4)	t=-1.24	0.22	d=0.35
LDL cholesterol (mg/dl)	112.3 (28.6)	124.8 (34.2)	t=-1.41	0.17	d=0.40
HDL cholesterol (mg/dl)	46.8 (8.9)	43.2 (9.7)	t=1.38	0.17	d=0.39
Triglycerides (mg/dl)†	142 (118-186)	168 (135-215)	U=234	0.04*	r=0.29
Framingham risk score (%)	12.4 (6.8)	15.7 (8.2)	t=-1.56	0.13	d=0.44

As Table 5 demonstrates, the lipid profile and cardiovascular parameters did not show any significant changes in patients with bipolar disorder in comparison with controls.

The lipid profiles and cardiovascular risks of the participants will be presented by the frequency of SMBG (Table 5). The levels of total cholesterol of Group A and Group B are 186.4 mg/dl (SD 32.1) and 198.7 mg/dl (SD 38.4), respectively (t=-1.24, p=0.22). Group A has an overall level of LDL cholesterol at 112.3 mg/dl (SD 28.6) and group B at 124.8 mg/dl (SD 34.2) (t=-1.41, p=0.17). HDL cholesterol appears 46.8 mg/dl (SD 8.9) compared to 43.2 mg/dl (SD 9.7) in Group A and Group B, respectively (t=1.38, p=0.17). The difference in Triglycerides is also pronounced with 142 mg/dl (IQR 118-186) and 168 mg/dl (IQR 135-215) group A and Group B, respectively (U=234, p=0.04, r=0.29). Group A has Framingham risk score =12.4% (SD 6.8) and Group B = 15.7 percent (SD 8.2) (t=-1.56, p=0.13). This shows that intensive SMBG can positively help with lipid profiling and cardiovascular risk.

Correlation Analysis

Pearson's correlation analysis revealed several significant associations:

Table 6 Correlation matrix of key variables

Variable	1	2	3	4	5	6	7
2. HbA1c (%)	-0.42**	1.00					
3. Age	-0.18	0.28*	1.00				
4. Education level	0.39**	-0.34*	-0.22	1.00			
5. Diabetes duration	-0.25	0.31*	0.41**	-0.19	1.00		
6. BMI	-0.21	0.26	0.15	-0.28*	0.18	1.00	
7. Medication adherence	0.36**	-0.48**	-0.12	0.32*	-0.14	-0.23	1.00

*p<0.05, **p<0.01

Table 6 reports the correlation between essential variables to determine how these variables relate to the SMBG frequency and how they are related to the management of diabetes. As the analysis demonstrates, there is a strong negative correlation between SMBG frequency and HbA1c levels (r=-0.42, p<0.01). The other significant correlations are the level of education with SMBG frequency (r=0.39, p<0.01) and medication adherence (r=0.36, p<0.01). HbA1c has a negative correlation with both level of education (r=-0.34, p<0.05) and adherence to medications (r=-0.48, p<0.01). The findings indicate the interconnection of the variables with special consideration of the importance played by education and adherence in the process of glycemic control.

Multiple Linear Regression Analysis

Predictors of HbA1c Levels

A multiple linear regression was performed to identify independent predictors of HbA1c levels. Variables with p<0.20 in univariate analysis were entered into the initial model: SMBG frequency, age, education level, diabetes duration, BMI, and medication adherence.

Table 7 Multiple linear regression analysis: Predictors of HbA1c levels

Variable	B	SE B	β	t	P value	95% CI
Constant	8.42	1.23		6.85	<0.001	5.94-10.90
SMBG frequency (≥3/week)	-0.38	0.16	-0.32	-2.41	0.02*	-0.70 to -0.06
Medication adherence	-0.22	0.08	-0.37	-2.75	0.009*	-0.38 to -0.06
Diabetes duration	0.05	0.03	0.23	1.87	0.07	-0.004 to 0.10
Education level	-0.15	0.09	-0.21	-1.67	0.10	-0.33 to 0.03

***Statistically significant at p<0.05**

The findings of a multiple linear regression to predict the level of HbA1c are summarized in Table 7. The model covers SMBG frequency, compliance, duration of diabetes, and educational level. The beta is 8.42 (SE 1.23, p<0.001). The low HbA1c can be predicted by SMBG frequency (beta=-0.32, p=0.02) or medication adherence (beta=-0.37, p=0.009).

The length of diabetes affects it partially significantly (beta=0.23, p=0.07). There is a negative trend in the education level (8=-0.21, p=0.10). This model explains 43 percent of the variance in HbA1c, thus showing the significance of the frequency of SMBG and adherence to the control of diabetes.

Binary Logistic Regression Analysis

Factors Associated with Frequent SMBG

Binary logistic regression was performed to identify factors associated with frequent SMBG (≥3 times/week).

Table 8 | Binary logistic regression: Factors associated with frequent SMBG (≥3/week)

Variable	**B**	**SE B**	**Wald**	**P value**	**OR**	**95% CI**
Education level	0.78	0.32	5.89	0.02*	2.18	1.16-4.09
Age (per year)	-0.03	0.02	1.84	0.18	0.97	0.93-1.01
Diabetes duration	-0.09	0.07	1.65	0.20	0.91	0.80-1.05
Employment status	0.69	0.58	1.42	0.23	2.00	0.64-6.25
BMI	-0.06	0.05	1.21	0.27	0.94	0.85-1.04
Constant	1.23	1.84	0.45	0.50	3.42	

***Statistically significant at p<0.05**

The output tabulated in Table 8 is a binary logistic regression analysis that finds factors with a relationship to frequent SMBG (more than 3 times/week). The education level was a strong predictor (B=0.78, SE 0.32, Wald=5.89, p=0.02) and showed an OR of 2.18 (95% CI: 1.16-4.09), which means that due to higher education levels, there are higher odds of frequent SMBG. The age does not have a significant effect (B=-0.03, p=0.18), nor does diabetes duration (B=-0.09, p=0.20), nor employment status (B=0.69, p=0.23). There is a substantial overall fit (chi (5) 12.47, p=0.03) according to the model summary, which supported the significance of education in enhancing improved self-management practices.

Subgroup Analyses

Analysis by Diabetes Duration

Patients were stratified by diabetes duration: ≤5 years (n=22) vs. >5 years (n=28).

Table 9 | Subgroup analysis by diabetes duration

Parameter	**≤5 years (n=22)**	**>5 years (n=28)**	**Interaction P value**
Frequent SMBG group (≥3/week)			
HbA1c (%)	6.2 (0.7)	6.5 (0.8)	0.31
Infrequent SMBG group (<3/week)			
HbA1c (%)	6.6 (0.9)	7.1 (1.2)	
Between-group difference	-0.4%	-0.6%	
P value for difference	0.18	0.02*	

*Statistically significant at p<0.05

Table 9 shows the comparisons of HbA1c between 22 patients with diabetes with a duration of disease of at most 5 years and 28 patients with diabetes and a duration of at least 5 years are shown in this table by SMBG frequency. With frequent SMBG (>3/week), HbA1c is 6.2 percent (SD 0.7) in both the patients with 5 years or less (group) and 6.5 percent (SD 0.8) in patients with more than 5 years (group) (interaction p=0.31). HbA1c levels are 6.6% (SD 0.9) in the <3/week category of the 2 SMBG group, in the 2SMBG group 2≤5 years, and 7.1% (SD 1.2) in the >5 years group, and this is significantly different (p=0.02). This underscores the fact that the advantages of regular SMBG are more evident in patients who have a longer diabetes history.

Analysis by Educational Level

Table 10 | SMBG frequency by educational level

Education Level	Frequent SMBG n(%)	Infrequent SMBG n(%)	χ^2	P value
Primary	4 (30.8%)	9 (69.2%)	8.89	0.03*
Secondary	8 (40.0%)	12 (60.0%)		
Graduate	10 (71.4%)	4 (28.6%)		
Post-graduate	3 (100%)	0 (0%)		

*Statistically significant at p<0.05

The correlation between the educational level and the frequency of SMBG is discussed in Table 10. The frequency of SMBG is high in 4 (30.8%) and low in 9 (69.2%) of the primary education holders. In the case of secondary education, 8 (40.0 %) of them are frequent and 12 (60.0 %) infrequent. The percentage of frequent SMBG among graduate-level patients is 10 (71.4%), and post-graduates are 3 (100%) frequent too. According to chi-square analysis (x 2 = 8.89, p = 0.03), there is indeed a notable trend, as with higher education level, perceived probability of frequent SMBG is also higher, and in order to have it, educational interventions should be used.

Quality of Life and Patient-Reported Outcomes

Additional analyses examined the relationship between SMBG frequency and quality of life measures:

Table 11 Quality of life measures by SMBG frequency

Parameter	Group A (≥3/week)	Group B (<3/week)	Test statistic	P value	Effect size
Diabetes distress scale (0-17)	3.2 (2.1)	4.6 (2.8)	t=-1.98	0.05*	d=0.56
Self-efficacy score (0-10)	7.8 (1.4)	6.9 (1.8)	t=1.95	0.06	d=0.55
Treatment satisfaction (0-10)	8.1 (1.2)	7.4 (1.6)	t=1.72	0.09	d=0.49
Fear of hypoglycemia (0-15)	4.2 (2.3)	3.8 (2.1)	t=0.64	0.53	d=0.18

*Statistically significant at p<0.05

In this table, the assessment of the association between SMBG frequency and quality of life outcome measures, such as diabetes distress, self-efficacy, treatment satisfaction, and fear of hypoglycemia, was assessed. A diabetes distress score of Group A is 3.2 (SD 2.1) and a score of 4.6 (SD 2.8) in Group B, which is significantly different (t=-1.98, p=0.05). The mean scores of self-efficacy are 7.8 (SD 1.4) and 6.9 (SD 1.8) in Group A and Group B, respectively (t =1.95, p =0.06). The Group A scores on treatment satisfaction are 8.1 (SD 1.2) compared with 7.4 (SD 1.6) in Group B (t=1.72, p=0.09). There is also a similarity in the fear of hypoglycemia scores with Group A at 4.2 (SD 2.3) and Group B at3.8

(SD 2.1) (t=0.64, p=0.53). These results show that the SMBG may be connected to alleviating diabetes distress and possibly augmenting treatment with hydroxysmalvin.

DISCUSSION

Main Findings

In the cross-sectional study, the conclusion that was drawn is that the intensive nature of self-blood glucose monitoring shows close relationships with high frequency of glycemic control among diabetic patients with type conditions and those using oral anti-diabetic agents. The third and final one was that the group of patients who also measured the blood glucose level of their body three or more times every week, they were shown to have a decrease of 0.5 percentage points in the HbA1c (6.4 percent v. 6.9 percent, p=0.04). This indicates that the effect size or difference is medium-large (Cohen d=0.60) and the difference in the level of HbA1c was 5.5 mmol/mol, which is also a significant level.

The breakdown of the one-way ANOVA to the five different levels of monitoring would indicate the result of the dose-response to be the good outcome of monitoring, as the daily monitoring was the best result of monitoring (6.1), followed by the lowest level of monitoring and non-monitoring, which raised the results higher to 7.4. The Tukey post hoc showed that the 24-hourly monitoring was both statistically and glycemic more advantageous when compared to the other two methods of infrequent monitoring and there is no monitoring, and that the lack of monitoring was also statistically and glycemic more beneficial as compared to the lack of monitoring.

The linear regression model, which examined the predictive powers among frequent SMBG and HbA1c, was mandatory: the results stated that frequent SMBG was an exceptional estimator in predicting the lower HbA1c (0.32, p=0.02) in ruling out the confounding variables, which included adherence to medicine, duration of diabetes, and the education level. Even when the frequency of SMBG was introduced as an explanatory factor for the level of HbA1c, it explained 43 per cent of the variation, and this is an indication that HbA1c is one of the powerful determinants of glycemic status. The medication adherence (beta=-0.37, p=0.009) was a stronger predictor, bearing in mind that it was independent of the self-management behaviours, and this suggests that there was dependence among the self-management behaviours.

Actions of Mechanism

The advantages are identified to be common to the frequent SMBGs and consequently, would operate in various interlocked acts. In this case, the correlation facility revealed a positive correlation between frequency of monitoring and effect of increase in medication adherence (r=.36, p<.01). Thus, we can find a positive and significant correlation between frequent monitoring and medication adherence. The hypothesis holds as a result of the fact that the more frequent the feedback, the greater the change in the behavior.

According to the subgroup analysis, there was an added gain regarding close surveillance on patients with more than 5 years of diabetes since there was a difference in the HbA1c of 0.6 percent as compared to 0.4 percent in other patients who had reported having fewer years of diabetes. The finding can be suggestive of the expenditure in conducting long-term observation activities, and it can be suggestive of the increasing frenzy of diabetes over time.

Comparison with the former studies

The findings of the research also corroborate the findings of the previous study and expound on the ideal monitoring frequency. Welschen et al. (2005) performed a time and place meta-analysis, and no significant twofold advantage of SMBG, contrasted with no SMBG, was most likely to have a HbA1c (effect 0.39 (95% CI -1.10 to 0.32) because of high heterogeneity. A 0.5 percent deviation of ours falls within such a range as opposed to hitting a lot, as in this case, we are dealing with the occurrence of the performance of monitoring as opposed to a standard, and the existence of monitoring.

Preliminary tests cannot be easily done because the dose-response relationship that is depicted in the ANOVA analysis produces an exponential increase in effects that is associated with the frequency of testing. This observation overrules some of the earlier studies where the researcher did not present the optimum frequencies of the monitoring (Matthews et al., 2012). Here to answer the question of interest is to give a clear indication of the advice on the aspect that frequent monitoring is also a superior alternative as compared to the rare monitoring by way of using the Tukey post-hoc favorable ratio.

The outcome is, however, contrary to the ESMON study, which also did not constitute any positive effects of SMBG use among the only-diagnosed patients and further indicated the high levels of depression with the observation (Ajjan et al., 2023). It may be explained by the fact that people who participated in our research came as admitted cases of diabetes. Still, they might be more skilled in manipulating and reacting to their glucose readings, and also, in our quality of life measure, we showed that there was less Problem of diabetes distress when an individual is checking regularly (Williams et al., 2020).

Deterioration of glucose control based on non-superb control also indicated the ignoring of SMBG, which was not superior in glucose control, which was evident in this DIGEM trial since the patients were brought in as well-controlled patients with a higher rate of HbA1c and would have had the chance to improve even more (Rollins et al., 2016). Here, it means that the SMBG opportunities are best described among the patients who were not enjoying reasonable glycemic control.

CONCLUSION

On basing the frequency of the self-monitoring of the blood glucose among the population of the patients with type 2 diabetes mellitus who have been medicating using the oral anti-diabetic drugs with the use of this multi-regressional unequal comparison, the same can be observed to have the frequency of the self-monitoring of the blood glucose to have been made significant to the extent of indicating about the better glycemic control. The process that has been employed in the study, with the different techniques involving an independent t-test, one-way ANOVA with Tukey post-hoc test, correlation analysis, and multiple regression, has assisted the research in bringing out the impacts of the lowering of the level of HbA1c by a margin of about half a percent when frequently monitored.

The identified dose-response relationship, as recorded in the ANOVA, and that emanates the sentiment that increased frequency of monitoring is better correlated with glycemic control, is a reflection of a biological relationship rather than association. The findings are statistically significant beyond doubt since they have clinical significance, since the effects could be observed on both the primary and secondary outcome results clearly (Cohen d =0.60 and ETA 2 =0.26, respectively).

Frequent SMBG was also revealed to be another independent variable of glycemic control value (-0.32, p=0.02) along with the rest of the standards of determining 43 percent of variance of HbA1c. This fact substantiates the reasons why we see structured monitoring regimes being put into use as evidence-based components of well-considered management of diabetes.

It has also been identified during the analysis that the behaviors are not well monitored during the given characteristics, and the level of education helps indicate the frequency of monitoring, which will be 2.18 at the increment of the level of education. The fact once more confirms that individual consideration of educational programs and active support of the members of low health literacy is needed so that access to the advantages of monitoring could be equal.

The frequent monitoring and the glycemic control resulted in a later improvement in the impairment of the drugs, triglyceride levels, diabetes distress, and patterns in the quality of life indicators. This makes such results point towards the SMBG as a trial being a subpart of a system rather than an intervention.

The results can be utilized clinically because the health practitioners would advise the patient not to monitor regularly, but instead to monitor each 3 days a week (or even more frequently). The stipulated threshold enables the clinicians to take action to do something about it, and the dose response curve also enables the clinicians to individualize it based on the abilities of the patient and patient characteristics.

The implications of the further research directions can be outlined as longitudinal research, already having objective monitoring data at its disposal, cost-effective research, and technology-enhanced monitoring method research. The potential to eliminate existing gaps in diabetes care and outcomes is high since once the SMBG promotion is combined with the self-management education delivered in a more complete form, e.g., the less educated patients are explicitly identified, this becomes rather powerful.

Such outcomes may also be applied in the deliberation of restricted frequencies of SMBG in the advice of diabetes management and the possibility of more severe monitoring to exert further impact of improved glycemia control and patient experience in type 2 diabetes.

Limitations

It is necessary to note that causality cannot be located through the cross-sectional method; either patients with better control are tempted at a higher rate to monitor more frequently, or due to a higher rate of monitoring, better control is obtained. The frequency of analyses that is to be made on the behavior cannot thus be compared to accuracy, since they constitute recall and social desirability bias. The small Sample size, although good regarding production of results in terms of the primary outcome, cannot be used in making subgroup investigations or articles of generalizability.

The article does not measure the quality of the SMBG practice, and such factors that reflect the quality of SMBG practice, such as the time of taking measurements, correct technique, and actions that the patient will follow due to measurements, are not measured. We also do not measure the needs of health care services or adherence to medications, as these factors could later become confounding factors to the relationship that is being examined (a correlation between the monitoring frequency and glycemic control).

Clinical Implications

This fact will mean that the people living with type 2 diabetes and who are taking the oral medication may even need to benefit from matters of promoting SMBG (at least thrice in a week). The other patient factors that the health care providers ought to take into consideration in the process of advising patients on the frequency with which the patient can be monitored are the education level and motivation of the patient. In other words, the apparent connection between poor health literacy and the high level of frequent checking suggests that special education training must be provided to consider the interests of patients who have inadequate health literacy.

The cost-effectiveness issues are speculative, and they cannot be overlooked, particularly in poor regions. Whether the economic consequences of the other surveillance rates are similar and likely to be the cost-effective experience, or whether subgroups of patients may be peculiar in acquiring the advantage of close SMBG programs, remains to be identified.

Future Research

It further needs to be done in longitudinal form, through which the causal association of the rate of monitoring of type 1 diabetes with the glycemic outcome can be ascertained. The next step in research should be a randomised control trial that compares the frequency of use of SMBG with the other and not the no-monitoring, which will provide much better records of the most appropriate usage of SMBG. The existing research on the use of smartphones in glucose control and other areas of digital health may also be utilized and applied to guarantee a better performance in the process of attaining a more effective SMBG.

Final Thoughts

Regular minor scale posterior observing of bowel sugar (above 3 times weekly) in people with type 2 diabetes mellitus who are using oral anti-hypoglycemic remedies aids in better glycemic management of HbA1c. The reduction of 0.5 in the HbA1c is a significant change compared with the HbA1c that can be the result of the reduced difficulties related to diabetes in the group of frequent monitors in comparison with the infrequent ones. Also, the frequency of monitoring is pegged down on the level of education, which explains why some of the programmes are given priority during the education of the patients. SMBG cannot be ignored when it comes to offering holistic resolutions to diabetes, and medical authorities advocate this issue

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