

Adherence to self-monitoring of blood glucose in Chinese patients with type 2 diabetes: current status and influential factors based on electronic questionnaires

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Background and purpose: Self-monitoring of blood glucose (SMBG) is important to the management of diabetes mellitus, yet most patients with type 2 diabetes mellitus (T2DM) do not perform SMBG as recommended. The current status and influential factors of SMBG in China have not been well investigated. This study aimed to describe the present status of SMBG adherence in China and investigate the influential factors based on electronic questionnaires.

Patients and methods: A cross-sectional study was conducted from June to July of 2017 at hospitals in Changsha, China. Seven hundred and twenty-one patients with T2DM completed the information-motivation-behavioral (IMB) skills questionnaire and other electronic questionnaires composed of demographic and clinical characteristics as well as diabetes-related and psychological scales. Univariate comparisons and multivariate logistic regression were used to explore the relationships among SMBG adherence and related factors.

Results: Seven hundred and twenty-one patients with valid questionnaires were included. Only 27.5% (198/721) of the patients with T2DM were SMBG adherent based on the guideline of the Chinese Diabetes Society (CDS) in 2017. Among all groups of treatment regimens, the rate of SMBG adherence was highest at 36.6% (82/224) in patients on oral hypoglycaemic drugs (OHAs). In multivariable analysis, the treatment of OHAs (OR =3.731, CI 2.162–6.437) and diet/exercise (OR =3.534, CI 1.841–6.783), the patient having their own blood glucose meter (OR =6.916, CI 4.054–11.800) and a higher education level (OR =3.780, CI 1.688–8.466) were significantly associated with SMBG adherence.

Conclusion: Most Chinese patients with T2DM did not perform SMBG as recommended. The treatment of OHAs and diet/exercise, the patient having their own blood glucose meter, a higher education level and other factors were correlates of SMBG adherence. There is clearly a need for prospective, multicenter, large-scale studies to explore the reasons for patients' failure to practice SMBG adherence.

Keywords: type 2 diabetes mellitus, self-monitoring of blood glucose, adherence, glycemic control, China

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Introduction

Diabetes mellitus (DM) is one of the most common chronic diseases and has become a major health issue globally.¹ According to the International Diabetes Federation, 1 in 11 adults in the world between the ages of 20 and 79 had suffered from diabetes by the year 2015, with the estimated number of patients with DM reaching 415 million people

worldwide by the same year.² The type 2 diabetes mellitus (T2DM) accounted for more than 90% of patients with diabetes and was the sixth leading cause of disability in the same year.³ The estimated number of patients with T2DM is expected to increase and would reach nearly 600 million by 2040.⁴ Like the rest of the world, the prevalence rate of DM keeps increasing in China, and the estimated prevalence of DM was 10.9% in 2013 due to rapid urbanization and the aging of the Chinese population,^{5,6} which was just below the unadjusted prevalence of total diabetes (12.3%) in the population of the United States from 2011 to 2012.⁷

As a disease of glucose metabolism dysfunction, T2DM poses a great threat to multi-organ systems and may lead to a series of related complications.^{8,9} The comprehensive treatment and control of T2DM in China are mainly composed of dietary restrictions, exercise, drugs and insulin therapy, diabetes education and blood glucose monitoring.⁶ The self-monitoring of blood glucose (SMBG) has become an effective tool in the management of diabetes as through this practice, patients can receive their real-time blood glucose level and then adjust their diet/exercise and treatment dose. Numerous studies have demonstrated that SMBG can improve glucose control and facilitate treatment promptly in patients with type 1 diabetes or T2DM.^{10,11} However, in both developed countries and developing countries, previous studies have indicated that the rate of SMBG adherence has not reached an optimal level, reporting the rate of adherence as 52% in America, 38.5% in Latin America, 49.8% in United Kingdom, 59% in Jordan, 22.6% in Cameroon and 18.98% in China.^{12–17} Several studies have shown that some factors were related to SMBG adherence, such as gender, age, education level, income, treatment regimen, the frequency of clinic visits, the duration of the diseases and the provision of glucose testing strips.^{12,13,18–21} Some studies have suggested that a higher level of education might lead to better SMBG adherence.²² And several psychological factors, such as self-efficacy, outcome expectations, physical influence, environmental barriers and social support, have also been included to explore their association with adherence to SMBG.¹⁷ High level of motivation was reported to enable patients with T2DM to maintain diet and perform SMBG.²³ And the information of diabetes also attaches importance to the management of this chronic disease.^{24,25}

As there are various differences in society and culture among China and other countries, it is uncertain whether influential factors from foreign countries apply to China. In addition, the current status and influential factors of SMBG in China have not been well investigated as SMBG has been

introduced into China just in recent years. The number of relevant studies was limited,¹² and there has been no study concerning the psychological factors of SMBG adherence. Understanding the current status and the association of factors with SMBG in China may help determine the solutions to achieving better glycemic control and decrease the burdens of chronic diseases in the future. Based on the Self- and Family Management Framework,²⁶ the management of chronic diseases is related to many factors, including facilitators and barriers, processes, proximal outcomes and distal outcomes, which have instructive significance for the design and process of relevant studies. Electronic questionnaires are convenient and efficient with high response rates. Therefore, using electronic questionnaires, we aimed to explore the present status of SMBG adherence in China. Additionally, this study focused on the influential factors of SMBG based on demographic and clinical characteristics and psychological factors.

Materials and methods

Study design and patients

A cross-sectional study was carried out between June and July 2017 at secondary and tertiary hospitals in Changsha, China. Hospitals in Changsha were divided into 84 secondary hospitals and 20 tertiary hospitals according to the hospital scale. And 11 public tertiary hospitals and 4 public secondary hospitals own the independent endocrinology wards. Simple random sampling by random numbers was conducted using Statistical Package for the Social Sciences (SPSS).²⁷ The starting point of random number were set at random via this software. Then the corresponding random numbers of 15 public hospitals were generated and then listed in an ascending sort order. The top two the random numbers were noted, and the corresponding hospitals including one secondary hospital and one tertiary hospital were selected. Three departments in each of these two hospitals were selected using the same sampling method. Patients within the three selected departments and one endocrinology ward of each of these two hospitals were included according to the following inclusive criteria: (1) the patients had been diagnosed with T2DM according to the standard World Health Organization (WHO) definition of the disease for over three months;²⁸ (2) the patients were over the age of 18 and were capable of understanding and communicating; and (3) the patients had voluntarily joined this study with informed consent. The exclusion criteria included patients with some related

complications, such as severe diabetic nephropathy, retinopathy and other diseases like low intelligence that prevented them from participating in this study.

The theoretical population of this study was calculated on the basis of local patient demographics and expert opinions, using the Krejcie and Morgan formula:²⁹

$$N = u^2_{\alpha/2} P(1 - P) \div P^2, \alpha = 0.05$$

As α is set to 0.05, u is equal to 1.96. P -value is the anticipated rate of patients with SMBG adherence (36.4% in this research), and d is admissible error (0.1P in this research). The theoretical population in this study totaled 671 based on the relevant parameters. Considering the possibility of dropouts during the survey, a larger sample size was designed to meet the aims of this study. Finally, 730 patients with T2DM were recruited to participate in this study and a total of 721 questionnaires were collected with a response rate of 98.8%.

Measurements

Background information

A general information sheet was used to collect demographic and health-related information, including age, gender (female/male), weight, height, marital status, education levels, occupation, personal monthly income, health insurance, smoking and drinking status, the family history of diabetes, the treatment regimen, the complications or comorbidities of diabetes and the frequency of hospitalization and physician consultation in the last year.

SMBG adherence

Adherence to SMBG was defined based on the frequency recommended in the official guideline on the prevention and control of T2DM in China, which was drafted by the Chinese Diabetes Society (CDS) in 2017.⁶ According to this guideline, patients with diabetes who are undergoing lifestyle intervention are supposed to perform SMBG at least once during a certain interval of time, so as to promote lifestyle modification. Patients taking oral hypoglycaemic drugs should perform SMBG at least twice a week. Patients with T2DM requiring insulin injection ought to perform SMBG at least once per day. Patients reported the actual number of times that they performed SMBG per day and per week on the electronic questionnaires accordingly. Based on the frequency recommendations referenced above and the actual frequency reflected on the questionnaires, the patients were

divided into two groups: the adherence group and the non-adherence group.

Diabetes-related and psychological scales IMB-SMBG questionnaire

The patients' information-motivation-behavioral skills (IMB) were assessed in this study to evaluate SMBG.^{30,31} The Chinese version of the IMB-SMBG questionnaire was composed of three subscales concerning SMBG information, motivation and behavioral skills.³² This questionnaire covered a total of 76 items, including 30 items in the information part, 25 items in the motivation part and 21 items in the behavioral part. Each item was scored from 1 to 5. A higher score represented better diabetes self-management. In the initial test, the IMB-SMBG questionnaire proved to have good reliability over 0.8 in the whole scale (0.92), and the content validity suggested a strong correlation between the items ($r > 0.50$ for 70% of the items, $P < 0.001$) after retesting and examining the correlations.³² The Cronbach's α of the total IMB-SMBG questionnaire was 0.931 in this study and the Cronbach's α of the information, motivation and behavioral parts were 0.859, 0.888 and 0.878, respectively.

The center for epidemiologic studies depression scale (CES-D)

Depressive symptoms were defined using the Center for Epidemiologic Studies Depression (CES-D) Scale.³³ There were a total of 20 questions on the scale. Each question was scored from 0 to 3, and a score of 16 or above indicated the presence of depressive symptoms. A cut-off score ≥ 21 was set in this study based on the optimum balance between sensitivity and specificity for Chinese patients with T2DM.³⁴ The Cronbach's α of CES-D in this study was 0.892.

General self-efficacy scale

In assessing the self-efficacy of patients with T2DM, the General Self-Efficacy Scale (GSES) was used. This scale was developed by Schwarzer et al.³⁵ There are 10 items on the GSES. The scale options were scored from 1 (totally wrong) to 4 (entirely correct). Higher scores demonstrated higher competence in dealing with the daily issues. The Cronbach's α of GSES in this study was 0.932.

Simplified coping style questionnaire

The Simplified Coping Style Questionnaire (SCSQ) developed by Yaning Xie is composed of 20 questions.³⁶ The questionnaire is divided into two parts, including 12 questions on the positive part and 8 questions on the negative part. Each item is rated on a 4-point scale, with the score level indicating the

frequency of the related coping style. The Cronbach's α of the positive parts of the SCSQ in this study was 0.918, while that of the negative parts of the SCSQ was 0.826. The Cronbach's α s of these scales ranged from 0.826 to 0.932, which indicated the relatively high reliability of the scales used in this study.

Pain caused by SMBG and body mass index

In addition to the SMBG and body mass index (BMI), the level of pain the patients experienced in performing SMBG was evaluated by the numerical rating scale (NRS).³⁷ The options provided on this scale were scored between 0 and 10, with the lowest score meaning no pain and the highest score signifying the greatest possible pain. The patients' BMIs, defined as the body weight divided by the square of the body height, were calculated based on the body heights and weights given in the questionnaires. The CDS defined being overweight as having a BMI ≥ 24 and obesity as a BMI ≥ 28 .³⁸

Ethical consideration and data collection

This study was approved by the ethics committee of Xiangya Nursing School, Central South University (No. 2018012). The Declaration of Helsinki on medical protocol and ethics were followed. The investigators received grants from school administrators to collect data. The patients were aware of the objectives involved in this study and gave written informed consent before the survey. Permission to use the scales was obtained from the copyright holders by email if permission was required.

All study investigators and assistants were trained to follow the rules of the study, including for the objectives of the study, the ethical issues, the process used for the electronic questionnaires and the meaning of the items in the questionnaires. The questionnaire was uploaded to the online questionnaire website (wjx, <https://www.wjx.cn/>). After signing the informed consents, the patients filled out the electronic questionnaires via the online questionnaire website by using their mobile phones. During the questionnaire process, the patients were given detailed explanations by the study investigators and assistants, who were standing by the side of the room when the patients filled out the questionnaires.

Statistical analysis

The raw data collected via the online questionnaire website were first transformed into Excel files. Then the data in the Excel files were analyzed using the SPSS, version 24.0 for Windows (IBM, Armonk, New York, USA). The continuous variables were presented as the mean and standard deviation (SD), and the categorical variables were presented as the

frequency and percentage. Three-phase analysis was conducted to analyze the relationship among SMBG adherence and the related factors. First, descriptive statistics on the background information and the scores on the scales were formulated to present demographic and other characteristics. Second, the univariate analyses were used to evaluate the associations between the two groups. The differences between the continuous variables were detected by an independent *t*-test or the Mann-Whitney U test. Comparisons of the categorical variables were analyzed by the Chi-squared test (for binomial variables) or the Cochran-Armitage trend test (for ordinal variables). Variables that were statistically significant ($P < 0.05$) in the univariate comparisons were entered into the multivariate logistic regression. In order to decrease the probability of type I error, the Bonferroni method was introduced.^{39,40} Variables with $P < 0.05/n$ (n is the number of subgroups of this variable) in multiple comparison is considered statistically significant. Third, a multivariate logistic regression was conducted to analyze the effects of the potential variables on SMBG adherence. Logistic regression analyses were presented as odds ratios (ORs) and corresponding 95% confidence intervals (CIs). The receiver Operating Characteristic (ROC) curve was further developed to assess the potential of the final multivariable logistic regression model. Corresponding area under curve (AUC) and 95%CI were also calculated. 1,000 bootstrap samples of the whole cohort were performed to validate the final multivariable logistic regression model. Statistical significance was set at a *P*-value of < 0.05 .

Results

Characteristics of the samples

A total of 721 patients with valid questionnaires were included in this study. The process of filling out the questionnaire took up to 18.89 mins (range 3–77, SD = 12.20) on average. The age of the patients ranged from 20 to 96 years (mean = 56.94, SD = 15.48). Female patients made up 54.6% of the total samples. The average BMI was 23.44 (SD = 3.376) and 34.67% (250/721) of the patients were overweight (BMI ≥ 24), while 9.02% (65/721) of them were obese (BMI ≥ 28). The medical fee payment methods in this study were rendered through rural cooperative medical insurance (45.4%, 327/721), followed by urban medical insurance (32.9%, 237/721), government/business subsidies (15.0%, 108/721) and self-payments (6.8%, 49/721). More than half of the patients (55.3%, 399/721) reported at least one diabetes complication and 23.4% (169/721) of them visited community clinics more than twice a year.

SMBG adherence

This study covered all standard treatment regimens: 34.5% of the patients (249/721) were on diet or exercise regimens, 31.1% (224/721) were on prescription oral hypoglycemic agents and 34.4% (248/721) were on insulin with/without hypoglycaemic drugs. The mean frequency of SMBG per week in patients on diet or exercise was 1.47 (range 0–30, SD =4.93) and that of patients treated with OHAs and insulin was 2.52 (range 0–40, SD =5.99) and 9.33 (range 0–94, SD =16.86), respectively (Table 2). Only 18.2% (131/721) of the patients performed SMBG more than once per day, while only 22.3% (161/721) of them performed it at least once a week. According to the frequency recommended by the CDS in 2017, the rate of SMBG adherence was the highest at 36.6% (82/224) in patients on OHAs, while the rate of SMBG adherence in patients on diet or exercise and insulin was 20.5% (51/249) and 26.2% (65/248), respectively. Only 27.5% (198/721) of all patients were SMBG adherent.

Clinical and demographic characteristics based on SMBG adherence

In order to explore the factors associated with adherence to SMBG, a univariate analysis of clinical and demographic characteristics was conducted based on SMBG adherence. As shown in Table 1, demographic characteristics, including gender, occupation, medical payment method and drinking status, were significantly associated with SMBG adherence. In the subgroups of BMI, education level and per capita monthly income, multiple comparisons indicated that these three variables did not reach statistical significance. Disease-related factors, including a family history of T2DM, diabetes-related complications, the frequency of visits to community clinics per year, the frequency of hospitalization per year, the treatment regimen, whether the patient had his or her own blood glucose meter and knowledge of the recommendation on the frequency of SMBG, were also significantly associated with SMBG adherence.

Associations among SMBG adherence and psychological scales

Table 3 provides descriptions of the diabetes-related and psychological scales, including the IMB-SMBG, CES-D, GSES, SCSQ and NRS, based on SMBG adherence. Among all the dimensions of the IMB-SMBG scale, the score of patients with SMBG adherence was much higher than that of patients with SMBG non-adherence and the results reached statistical significance, including the

information part of the IMB-SMBG ($t=-6.033$, $P<0.001$), the motivation part of the IMB-SMBG ($t=-6.252$, $P<0.001$), the behavior part of the IMB-SMBG ($t=-4.506$, $P<0.001$) and the total score of the IMB-SMBG ($t=-6.947$, $P<0.001$). The average score on the CES-D was 21.55 (range 0–49, SD =7.76). According to the cut-off point mentioned above, nearly 51% (368/721) of the patients had depressive symptoms at different degrees. There was no statistical significance in the scores of the other scales.

Multivariate logistic regression analysis of factors associated with SMBG adherence

Multivariate logistic regression was conducted to explore the factors associated with SMBG adherence. The covariates of the logistic regression were included based on the univariate comparisons and other variable including education level according to previous medical literature.²²

After adjusting for the covariates, the following factors remained significantly associated with better SMBG adherence: male gender (OR =2.338, CI 1.367–3.998), patients with university and postgraduate education (OR =3.780, CI 1.688–8.466), urban medical insurance (OR =2.349, CI 1.237–4.461), government/business subsidies (OR =2.615, CI 1.243–5.502), patients visiting community clinics greater than or equal to 3 times per year (OR =1.804, CI 1.069–3.042) and patients hospitalized greater than or equal to 3 times per year (OR =2.185, CI 1.107–4.314) (Table 4). Patients with T2DM who were current drinkers (OR =0.412, CI 0.207–0.820) had poor SMBG adherence.

On the psychological scales, higher scores in the information part (OR =1.069, CI 1.028–1.113) and the motivation part (OR =1.071, CI 1.029–1.115) of the IMB-SMBG were associated with better SMBG adherence. As for the SMBG-related factors, patients who had own their blood glucose meter (OR =6.916, CI 4.054–11.800) and knew the recommendation on SMBG frequency from doctors (OR =10.625, CI 5.530–20.413) tended to have better SMBG adherence. Compared with insulin injection, SMBG adherence was easier to achieve if the patients were on diet or exercise regimens (OR =3.534, CI 1.841–6.783) and on OHA prescriptions (OR =3.731, CI 2.162–6.437). ROC curve was developed to assess the potential of the final multivariable logistic regression model (Figure 1). The ROC curve indicated optimal predictive capability (AUC =0.864, CI 0.836–0.893). The final multivariable logistic model was validated via 1,000 bootstrap samples (Table S1).

Table 1 Clinical and demographic data on the studied population

Variable	Participants, n (%)		χ^2	P-values
	SMBG adherence	SMBG non-adherence		
Gender (F/M), n	86/112	308/215	13.845	<0.001
Age (years)			2.895	0.235
Young adulthood (18–44)	38 (24.4%)	118 (75.6%)		
Middle age (45–60)	59 (25.2%)	175 (74.8%)		
Old age (>60)	101 (30.5%)	230 (69.5%)		
Marital status			2.917	0.233
Single	5 (14.7%)	29 (85.3%)		
Married	176 (28.1%)	451 (71.9%)		
Divorced/widowed	17 (28.3%)	43 (71.7%)		
Education level			7.068	0.029
Primary school and below	53 (22.5%)	183 (77.5%)		
Secondary school	94 (27.7%)	245 (72.3%)		
University and postgraduate	51 (34.9%)	95 (65.91%)		
Occupation			27.018	<0.001
Farmers	39 (17.8%)	180 (82.2%)		
Workmen/clerks	53 (43.8%)	68 (56.2%)		
Self-employed/freelancers	28 (25.2%)	83 (74.8%)		
Retired/unemployed	78 (28.9%)	192 (71.1%)		
Per capita monthly income (CNY)			7.597	0.022
≤1500	60 (21.9%)	214 (78.1%)		
1501–4500	86 (29.6%)	205 (70.4%)		
≥4501	52 (33.3%)	104 (66.7%)		
Medical fee payment method			14.537	0.002
Rural cooperative medical insurance	66 (27.8%)	171 (72.2%)		
Urban medical insurance	75 (22.9%)	252 (77.1%)		
Self-payment	12 (24.5%)	37 (75.5%)		
Government/business subsidy	45 (41.7%)	63 (58.5%)		
Smoking status			1.135	0.567
Never smoked	138 (26.4%)	385 (73.6%)		
Previous smoker	21 (29.6%)	50 (70.4%)		
Current smoker	39 (30.7%)	88 (69.3%)		
Drinking status			8.908	0.012
Never drinks	147 (26.1%)	417 (73.9%)		
Previous drinker	26 (44.1%)	33 (55.9%)		
Current drinker	25 (25.5%)	73 (74.5%)		
BMI			8.289	0.040
BMI <18.5	12 (26.1%)	34 (73.9%)		
18.5 ≤ BMI <24.0	111 (30.8%)	249 (69.2%)		
24.0 ≤ BMI <28.0	66 (26.4%)	184 (73.6%)		
BMI ≥28.0	9 (13.8%)	56 (86.2%)		
Family history of T2DM			12.669	0.002
Yes	67 (35.4%)	122 (64.6%)		
No	107 (27.0%)	289 (73.0%)		
Unknown	24 (17.6%)	112 (82.4%)		

(Continued)

Table 1 (Continued).

Variable	Participants, n (%)		χ^2	P-values
	SMBG adherence	SMBG non-adherence		
Diabetes-related complications			9.718	0.002
Yes	91 (22.8%)	308 (77.2%)		
No	107 (33.2%)	215 (66.8%)		
Frequency of visiting to community clinics per year			19.466	<0.001
≤ 2 (including none)	130 (23.6%)	422 (76.4%)		
≥ 3	68 (40.2%)	101 (59.8%)		
Frequency of hospitalizations per year			16.717	<0.001
≤ 2 (including none)	161 (25.1%)	481 (74.9%)		
≥ 3	37 (46.8%)	42 (53.2%)		
Treatment regimen			15.69	<0.001
Diet/exercise (no drugs)	51 (20.5%)	198 (79.5%)		
Oral hypoglycemic agents (OHAs)	82 (36.6%)	142 (63.4%)		
Insulin (with/without OHAs)	65 (26.2%)	183 (73.8%)		
Having own blood glucose meter			101.066	<0.001
Yes	158 (44.4%)	198 (55.6%)		
No	40 (11.0%)	325 (89.0%)		
Knowing the recommendation on frequency of SMBG			111.688	<0.001
Yes	184 (41.3%)	262 (58.7%)		
No	14 (5.1%)	261 (94.9%)		

Note: Clinical and demographic characteristics were listed and compared between population with and without SMBG adherence.

Abbreviations: SMBG, self-monitoring of blood glucose; BMI, body mass index; T2DM, type 2 diabetes mellitus.

Table 2 SMBG frequency by diabetic treatment regimen

Treatment regimen	SMBG frequency per week (mean \pm SD)	F-values	P-values
Diet/exercise (no drugs)	1.47 \pm 4.93	38.117	<0.0001
Oral hypoglycemic agents (OHAs)	2.52 \pm 5.99		
Insulin (with/without OHAs)	9.33 \pm 16.86		

Note: The frequency of SMBG per week in patients with different diabetic treatment regimen was presented as mean \pm SD.

Abbreviations: SMBG, self-monitoring of blood glucose; SD, standard deviation.

Discussion

SMBG is critical for the systematic management of diabetes, though the proportion of patients with SMBG adherence was relatively low. In this cross-sectional analysis, the total proportion of SMBG adherence was 27.5% (198/721) and this proportion was consistent with the results of two previous Chinese studies.^{12,41} The rate of SMBG adherence in Western countries seems comparatively higher than that in China. The cross-sectional survey concerning SMBG in the United Kingdom in 2008 suggested that 49.8% (276/554) of patients followed the physician's advice.¹⁵ And for a study on SMBG practice conducted in the United States in 2007,⁴² the daily SMBG rate was about 63.4% in the patients with diabetes and close to

86.7% for patients with T2DM on insulin treatment. The difference in rate may derive from the various definitions of SMBG adherence, but there is actually an obvious gap with the developed countries in terms of achieving the recommended frequency of SMBG.

The rate of SMBG adherence varied under different treatment methods. The rate of patients on diet or exercise regimens who performed SMBG according to the recommendation was the lowest in this study, compared with patients receiving other types of treatment. Patients treated by diet or exercise were usually at an early stage of diabetes and these patients just needed to perform SMBG at least once during a certain interval of time, so as to

Table 3 The description of IMB-SMBG, CES-D, GSES, SCSQ and NRS

Variable	Scores (mean \pm SD)		χ^2	t-values	P-values
	SMBG adherence	SMBG non-adherence			
IMB-SMBG scale (information part)	109.72 \pm 12.35	103.42 \pm 12.56	1.342	-6.033	<0.001
IMB-SMBG scale (motivation part)	85.16 \pm 11.89	78.97 \pm 11.86		-6.252	<0.001
IMB-SMBG scale (behavior part)	70.46 \pm 11.14	66.42 \pm 10.60		-4.506	<0.001
IMB-SMBG scale (total)	265.34 \pm 28.10	248.81 \pm 28.67		-6.947	<0.001
CES-D	22.27 \pm 7.60	21.28 \pm 7.80		-1.529	0.127
No depressive symptoms (\leq 21)*	90 (25.5%)	263 (74.5%)			0.247
Depressive symptoms ($>$ 21)*	108 (29.3%)	260 (70.7%)			
GSES	2.37 \pm 0.58	2.40 \pm 0.60		0.738	0.461
SCSQ (positive part)	1.54 \pm 0.56	1.60 \pm 0.58		1.379	0.168
SCSQ (negative part)	1.23 \pm 0.49	1.25 \pm 0.58		0.538	0.591
Numerical Pain Rating Scale	2.99 \pm 2.25	2.91 \pm 2.08	-0.500	0.618	

Note: *The description of patients with and without depressive symptoms was presented with the number (%). The scores of diabetes-related and psychological scales were listed and compared between population with and without SMBG adherence.

Abbreviations: IMB, information-motivation-behavioral; SMBG, self-monitoring of blood glucose; CES-D, the center for epidemiologic studies depression scale; GSES, general self-efficacy scale; SCSQ, simplified coping style questionnaire; SD, standard deviation.

Table 4 Final adjusted multivariable logistic regression with adherence to SMBG

Variables	Number (%)	β	OR	95% CI	P-values
Gender					
Male	327 (45.4%)	0.849	2.338	1.367–3.998	0.002
Education level					
Primary school and below	236 (22.5%)	-	1.000	-	Reference
Secondary school	339 (27.7%)	0.410	1.507	0.865–2.628	0.148
University and postgraduate	146 (34.9%)	1.330	3.780	1.688–8.466	0.001
Medical fee payment method					
Rural cooperative medical insurance	237 (27.8%)	-	1.000	-	Reference
Urban medical insurance	327 (22.9%)	0.854	2.349	1.237–4.461	0.009
Self-payment	49 (24.5%)	0.835	2.305	0.873–6.081	0.092
Government/business subsidy	108 (41.7%)	0.961	2.615	1.243–5.502	0.011
Drinking status					
Never drinks	564 (26.1%)	-	1.000	-	Reference
Previous drinker	59 (44.1%)	0.087	1.091	0.507–2.349	0.824
Current drinker	98 (25.5%)	-0.886	0.412	0.207–0.820	0.012
Frequency of visiting community clinics per year					
\geq 3	552/169	0.590	1.804	1.069–3.042	0.027
Frequency of hospitalization per year					
\geq 3	642/79	0.782	2.185	1.107–4.314	0.024
Treatment regimen					
Diet/exercise (no drugs)	249 (20.5%)	1.262	3.534	1.841–6.783	<0.001
Oral hypoglycemic agents (OHAs)	224 (36.6%)	1.317	3.731	2.162–6.437	<0.001
Insulin (with/without OHAs)	248 (26.2%)	-	1.000	-	Reference
Having own blood glucose meter					
Yes	356/365	1.934	6.916	4.054–11.800	<0.001

(Continued)

Table 4 (Continued).

Variables	Number (%)	β	OR	95% CI	P-values
Knowing the recommendation on frequency of SMBG Yes	446/275	2.363	10.625	5.530–20.413	<0.001
IMB-SMBG scale (information part)	-	0.067	1.069	1.028–1.113	0.001
IMB-SMBG scale (motivation part)	-	0.069	1.071	1.029–1.115	0.001

Note: Factors significantly associated with better SMBG adherence were listed in the final multivariable logistic regression model.

Abbreviations: IMB, information-motivation-behavioral; SMBG, self-monitoring of blood glucose; OR, odds ratio; CI, confidence interval.

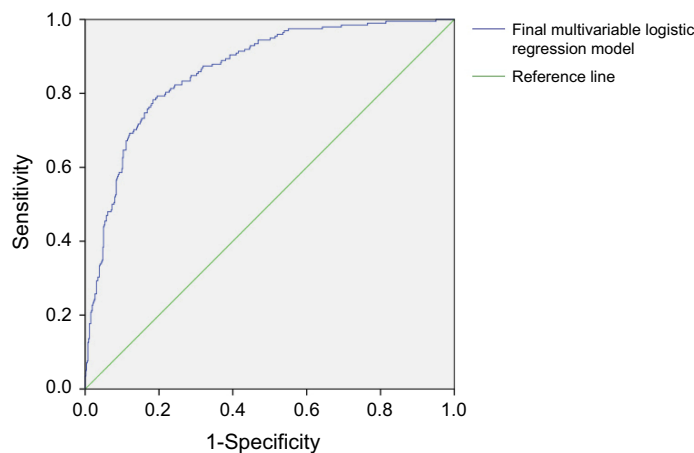


Figure 1 ROC curve of the final multivariable logistic regression model. The blue curve, the final multivariable logistic regression model including gender, education level, medical fee payment method, drinking status, frequency of visiting community clinics per year, frequency of hospitalization per year, treatment regimen, having own blood glucose meter, knowing the recommendation on frequency of SMBG and the score of information and motivation part in IMB-SMBG scale. AUC =0.864 (95% CI, 0.836–0.893).

promote lifestyle modification.⁶ There is relatively less attention devoted to the diabetic condition of these patients,⁴³ thus accounting for the low rates of adherence in these patients. In this study, the rate of SMBG adherence in patients on OHAs was much higher than that of patients on insulin injection. However, the association between OHAs and SMBG adherence seems to be opposite in one Chinese study, in which patients under OHAs tended to be poor SMBG adherence.¹⁸ One reason between the difference might be the different definitions of SMBG adherence. In the previous study, SMBG adherence was defined as the mean SMBG frequency in one week over 3-month period according to one guideline released in 2015,⁴⁴ while there was notable difference of the exact recommended SMBG frequency between this guideline and the latest one. Besides, the SMBG frequency was collect via a portable glucose monitoring device. The use of this device might be hard for older patients with low level education, thus leading to possible selection bias at the beginning of the previous study. The frequency of

SMBG of patients with T2DM in this study, by contrast, was significantly higher in the patients treated with insulin. Previous studies have indicated the frequency of SMBG was significantly correlated with treatment regimen and the purposes of performing it, and the frequency of SMBG was much higher in patients using insulin.^{13,15,41} Plenty of patients on insulin need to inject insulin repeatedly each day, so performing SMBG daily or before each meal could help them determine their blood-glucose level and then adjust the insulin dose accordingly. The paradox between the frequency of SMBG and the rate of SMBG adherence could be explained by the official guidelines on the prevention and control of T2DM in China provided by the CDS in 2017.⁶ The high frequency of SMBG recommended by the CDS underlines the importance of SMBG for patients on insulin injection.

The suboptimal adherence of SMBG also reflected low awareness of self-management in patients with T2DM. In our study, the patients who were familiar with the recommendation on SMBG frequency showed better compliance,

and patients with T2DM on insulin injection are supposed to perform more SMBG to meet the frequency criterion and their medical workers need to conduct health education on SMBG. In addition, previous studies showed that after obtaining their results, most patients with T2DM tended to take no action because of a lack of health education.⁴⁵ It is the responsibility of health workers in clinics and hospitals to help patients with DM improve their ability to interpret the results after SMBG. We also found that the patients who owned a blood glucose meter tended to be SMBG adherent because owning a blood-testing device may allow patients to perform SMBG easily.

Our study indicated that better adherence to SMBG was associated with the male gender, a higher education level, urban medical insurance, government/business subsidies and the frequency of clinic visits and hospitalization. Current drinkers were associated with poor SMBG adherence. The relationship between gender and SMBG adherence is contrast to one previous study.¹² The ratio of female versus male was 1.2 in this study while that was 0.84 in that study. Besides, the ratio of gender in this study is much closer to that in one authoritative research.⁵ Therefore, the difference may partly come from the selection bias. Further researches concerning the gender effect on SMBG adherence are needed to confirm this result. A previous study confirmed that education level was associated with the self-management of patients with diabetes.⁴⁶ Patients with a higher education level are more receptive to a doctor's recommendation and good health behavior, thus leading them to perform SMBG regularly. A study including 798 patients with T2DM conducted in Southeast China revealed that higher education was related to better glycemic control,²² which suggested a possible correlation between SMBG and glucose control. Moreover, better adherence to SMBG was related to a higher frequency of clinic visits and hospitalization. Patients who often visited clinics paid more attention to their health issues and they could obtain the latest recommendations from the physicians that could be used in self-management later, which created a virtuous cycle. As for the patients who were often hospitalized, frequent hospitalization may push them to perform SMBG more frequently. Previous studies have indicated that occupation was significantly related to diabetes and changing psychological work conditions could decrease the risk factors of diabetes.^{47,48} Drinking alcohol was a risk factor for diabetes based on the studies conducted in Asian populations,^{49,50} and there was a negative correlation between self-efficacy and drinking behavior.⁵¹ Current

drinkers usually have a low level of self-efficacy,⁵² and they tend to perform less SMBG than previous drinkers and patients who never drink. In addition, the empirical evidence has shown a positive correlation between alcohol consumption and BMI,⁵³ and an increased BMI may lead to worse glycemic control.

In this study, the IMB-SMBG questionnaire for patients with T2DM was proven to present the current status of SMBG based on the scores. Patients with SMBG adherence tended to have higher scores in the parts on information, motivation and behavior, which suggested that this questionnaire could be applied to a comprehensive assessment of SMBG in future studies. The information and motivation part play important roles in SMBG adherence, as SMBG adherence may improve significantly with the increase of scores on these two parts. Thus, health workers should probably focus on how to increase the awareness of diabetes-related information in the population with DM and enhance their motivation.

In this analysis, the CES-D was introduced to evaluate the depressive symptoms of patients with T2DM and the cut-off point was set to 21 due to achieve a better balance.³⁴ Nearly 51% of patients had depressive symptoms at different degrees in our study, while merely 34% of patients had similar symptoms within a study undertaken in Germany.⁵⁴ In another study conducted among elderly patients with DM in Vietnam,⁵⁵ almost 79.4% of patients had depressive symptoms as assessed by the scales. Patients with diabetes are at greater risk of diabetes-related complications compared with people without diabetes,^{8,9} thus it's more likely for them to develop depressive symptoms. The clinical definition of depression and the assessment tools vary from country to country, and patients' depressive symptoms don't mean that they have actually developed clinical depression. However, the relationship between SMBG adherence and depressive symptoms is still largely unclear. While the GSES and SCSQ have been proven to evaluate self-efficacy and coping style concerning the management of chronic diseases,^{56,57} the scores on the GSES and SCSQ didn't suggest a significant difference between patients with SMBG adherence and SMBG non-adherence. The long-term and repeated process of treatment and monitoring may pose negative effects upon the whole state of psychology, thus impairing self-efficacy and coping style, but the correlation between self-efficacy and the progression of diabetes remains unknown. Further study could delve deeper into the states of self-efficacy and coping styles in different stages of diabetes.

Medical questionnaires have been widely used in various fields and studies in medicine. For the self-management of chronic diseases, special medical questionnaires could assess the demographic and clinical characteristics, treatment outcome, quality of life and other aspects of diseases, which would provide further guidance on future self-management. With the rapid development of information and software technology, the use of smart phones and other portable mobile devices has increased dramatically in recent years. Electronic questionnaires, based on portable mobile devices and mobile applications accessed via the internet, have been proven to improve the response rate, clinical efficiency and doctor-patient communication.^{58,59} In our study, the self-designed questionnaire was uploaded to the online questionnaire website and could be filled out on smart phones via the internet. The background workstation of the website recorded and stored the questionnaire results, and then automatically calculated the scores of some items, which significantly improved their efficiency and accuracy. The range of time of filling out electronic questionnaires was relatively wide in this study. Some elders may have low-level ability of understanding, thus leading to relatively long time of filling out questionnaires. But with the help of assistants nearby, the questionnaires could be filled out truthfully. Therefore, the electronic questionnaires have extensive prospects in the assessment of chronic diseases.

Strengths and limitations

To the best of our knowledge, this is the first study conducted with electronic questionnaires concerning the current status and influential factors of SMBG adherence in Chinese patients with T2DM. This study provided up-to-date and accurate data on the present status of SMBG adherence in China and identified important influential factors that could be applied and explored for further study.

However, this study had some limitations that must be mentioned. First, because of the cross-sectional design, we could not draw absolute conclusions about the causal relationships of the demographic and clinical characteristics of SMBG adherence. But the results of this study do provide some evidence and suggestions for the future study of the influential factors of SMBG. Second, most patients included in this study lived in the provincial capital, so patients in the remote areas may not have been adequately considered. Third, the data collection was self-reported, thus the data might be influenced by

potential recall bias. In addition, regarding intimate issues in daily life, like income, some patients might not have answered truthfully. The sample size of this study was relatively limited and further subgroup analysis based on the treatment type need to be conducted. This study did not include an index of blood sugar, like fasting blood glucose or glycosylated hemoglobin (HbA1c), to assess glycemic control, and a future study could focus on the association between SMBG adherence and glycemic control.

Conclusions and recommendations

In summary, most of the Chinese patients with T2DM did not adhere to the SMBG frequency recommended by the CDS. In addition, this study suggested that several factors, including gender, medical fee payment methods, drinking status, the frequency of clinic visits and hospitalization, the treatment regimen, owning a blood glucose meter and knowing the recommended frequency of SMBG were associated with SMBG adherence. Our study also highlights the importance of health education, especially for patients on insulin, who often need to know their blood-glucose level and adjust their insulin dose accordingly. Based on the practical factors, patients with T2DM are encouraged to learn the recommended frequency of SMBG and use own blood glucose meter to perform SMBG. Manufacturers producing the blood glucose meter should make the device more portable and the man-machine interface friendlier. Furthermore, some applications and programs of the device need to be developed to record and analyze the blood glucose level, which is helpful to assess the history and adjust the dose of insulin.

There is clearly a need for prospective, multicenter, large-scale trials to explore the reasons for patients' failure to meet the recommended frequency of SMBG. Further studies should establish a scientific and standardized system to train investigators, collect data and analyze the results, so as to increase the efficacy and accuracy of the program.

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Disclosure

The authors report no conflicts of interest in this work.

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Supplementary material

Table SI Bootstrap OR estimates versus initial OR estimates for the final model

Variable at baseline	Initial estimates		Bootstrap estimates	
	OR	95% CI	OR	95% CI
Male	2.338	1.367–3.998	2.338	1.365–3.999
University and postgraduate	3.78	1.688–8.466	3.782	1.684–8.462
Urban medical insurance	2.349	1.237–4.461	2.351	1.234–4.468
Government/business subsidy	2.615	1.243–5.502	2.614	1.241–5.501
Current drinker	0.412	0.207–0.820	0.412	0.205–0.821
Frequency of visiting community clinics per year ≥ 3	1.804	1.069–3.042	1.802	1.068–3.041
Frequency of hospitalization per year ≥ 3	2.185	1.107–4.314	2.185	1.112–4.311
Diet/exercise (no drugs)	3.534	1.841–6.783	3.533	1.838–6.779
Oral hypoglycemic agents (OHAs)	3.731	2.162–6.437	3.731	2.162–6.437
Having own blood glucose meter	6.916	4.054–11.800	6.917	4.042–11.901
Knowing the recommendation on frequency of SMBG	10.625	5.530–20.413	10.625	5.535–20.407
IMB-SMBG scale (information part)	1.069	1.028–1.113	1.069	1.027–1.113
IMB-SMBG scale (motivation part)	1.071	1.029–1.115	1.071	1.025–1.118

Note: 1,000 bootstrap samples of the 721 patients with T2DM were performed to validate the final multivariable logistic regression model.

Abbreviations: IMB, information-motivation-behavioral; SMBG, self-monitoring of blood glucose; OR, odds ratio; CI, confidence interval.

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