# Use of smartphone-based self-monitoring blood glucose application in type 2 diabetes mellitus patients in Indonesia: A pre and post-test study

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## ABSTRACT

**Background:** The utilization of technology in diabetes management, especially self-monitoring blood glucose (SMBG), is growing rapidly. However, the effectiveness of SMBG applications on the smartphone is not yet known. This study aims to assess the effectiveness of using a smartphone-based SMBG application in type 2 diabetes mellitus (T2DM) patients in the Indonesian population.

**Methods:** This is a quasi-experimental (before and after) study conducted at three tertiary hospitals in Jakarta and Malang, Indonesia. Inclusion criteria were T2DM patients aged 18 years and above who have been familiar with performing SMBG and manually record the results. All subjects were asked to use a smartphone-based SMBG application named *Teman Diabetes* application for six months, and patients' SMBG performance was assessed at the end of the study Bivariate analysis using T-test or with the Mann Whitney U test performed. Chi-square test is used to analyze the categorical with Risk Ratio (RR) and 95% Confidence Interval (CI). The p-value <0.05 (two-tailed) is considered statically meaningful.

**Results:** From 100 patients enrolled in the study, 78 patients completed the follow-up. We found that the use of the SMBG application helped the subject overcome the difficulty in remembering to perform SMBG (p=0.004), helped change the subject's perception of the benefits of SMBG (p=0.049), improved the subject's diet pattern (p=0.006), and decreased the number of subjects who stopped performing SMBG due to self-perception of lack of benefit SMBG activity (p=0.049).

**Conclusions:** The study found that using the SMBG application helps manage diabetes in T2DM patients.

**Keywords:** diabetes, technology, self-monitoring blood glucose.
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## INTRODUCTION

Diabetes mellitus is a global health problem. It increases the morbidity and mortality burden due to its complications and the economic burden due to people's non-productivity with diabetes (PWD) and the cost to treat the conditions.[1] The incidence of diabetes has increased rapidly, especially in developing countries.[2] Based on 2018 Indonesia basic health research (RISKESDAS) data, the prevalence of diabetes in Indonesia has increased from 6.9% in 2013 to 10.9% in 2018.[3]

Self-monitoring blood glucose (SMBG) is one of the pillars in diabetes management. SMBG can empower PWD in managing their disease by providing patients with accurate feedback on how their behavior and medications affect their immediate blood glucose levels.[4] However, studies reveal many PWD do not perform SMBG according to the number of tests agreed upon with their doctor.[5-7] The subject's perceptions of the goal of SMBG in diabetes monitoring, the complexity of doing SMBG, pain due to needle sticking, SMBG-related costs, and personal and family motivation are known as barriers in carrying out SMBG.[4]

Currently, many technologies have been developed to assist PWD in managing their diabetes.[8] The use of technology in diabetes management is beneficial in improving diabetes outcomes. Today's technology offers various solutions to overcome the barriers encountered in PWD and empower PWD to pay more attention to their health.[9] One of the technologies currently available is a smartphone-based SMBG application. As previously known, SMBG has been known to play an essential role in reducing complications due to diabetes.[10] However, the effectiveness of using a smartphone-based blood glucose monitoring application on SMBG performance in type 2 diabetes mellitus (T2DM) patients is not known yet. In Indonesia, locally developed SMBG applications are limited. This study aims to assess the effectiveness of using
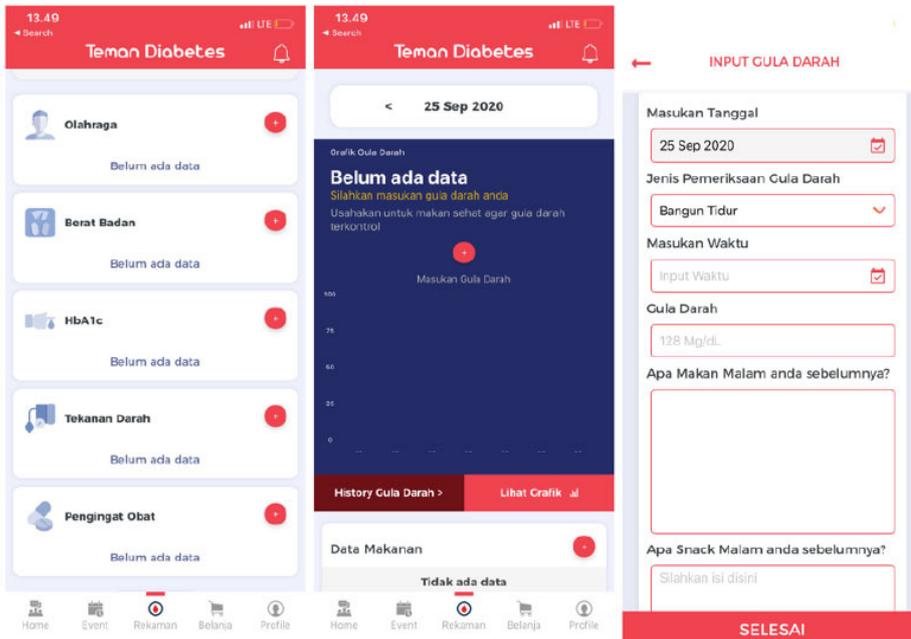
**Figure 1.** Display SMBG in *Teman Diabetes* application *on the smartphone*



**Figure 2.** Display of graphic of blood glucose over several days SMBG in *Teman Diabetes application*

smartphone-based SMBG applications on the performance of SMBG in PWD in Indonesia.

## METHODS

### Study Design
This study is quasi-experimental with a pre and post-test study. All subject's performance in conducting SMBG was assessed before and six months after using

smartphone-based SMBG application.

### Study Subjects
This study was conducted at three referral hospitals (Fatmawati General Hospital, Lavalette General Hospital, and JEC@ Kedoya Eye Hospital) from December 2019 to May 2020. Inclusion criteria were T2DM patients, aged 18 years and above, have previously been

familiar with performing SMBG and have SMBG pattern from their previous doctors, and smartphone users who can independently use their smartphone or is in the care of someone who can use the SMBG application. Exclusion criteria were patients with a history of dementia, Alzheimer's and blood disorders from medical records. A minimum sample size of 78 people is needed to achieve 80% study power and 95% confidence.

### Intervention
In this study, all subjects were asked to use the *Teman Diabetes* application on their smartphones. The *Teman Diabetes* application tracks self-recorded blood glucose levels that will only be stored if food, beverages, and activities that may affect blood glucose results are recorded. Other features of the application include educational articles, reminders of drug consumption, and health profiles developed in Indonesia and the Indonesian language (Figure 1). Subjects were asked to perform SMBG using their glucose meter and record the results into the application. Blood glucose data can be filled in manually or automatically if the subjects use a specific glucose meter available in the market. The frequency of SMBG done was agreed upon by both patients and doctors. Subjects were also asked to open the application at least three times a week, including SMBG recording. We also provided push notifications three times a week to help remind the subject to open the SMBG application. Patients can email their SMBG results to their doctor from the application or bring their smartphone during their monthly visit to the doctor and discuss the results as needed (Figure 2 and 3). The intervention was carried out for six months, subjects' SMBG performance was assessed at the start of the study (B0) and the end of the 6th month (M6). The lost-to-follow-up criteria in this study were subjects who could not be contacted at the end of the study period.

### Outcome
This study's primary outcome was the subjects' SMBG performance, assessed using an SMBG questionnaire formed by two endocrinologists tested for its validity

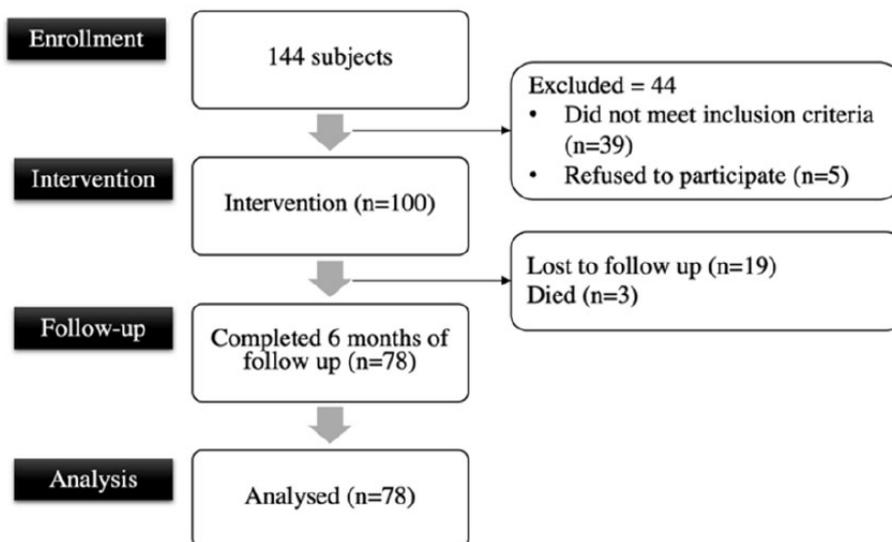**Figure 3.** Display of table of blood glucose over several days SMBG in *Teman Diabetes* application



**Figure 4.** Participants' flow diagram

and reliability (Cronbach's alpha: 0.7). The SMBG questionnaire assesses the patients' SMBG performance from a global perspective, memory, and perspective on SMBG as a whole.

This study's secondary outcome was to assess self-care activities in diabetic patients assessed using a self-diabetes self-care activities (SDSCA) questionnaire to assess six domains of self-care diabetes; global diet, specific diet, physical activity, blood glucose check, and foot examination. The questionnaire has been converted to the Indonesian language following translation and adaptation for

instruments proceeded by the World Health Organization and tested for validity and reliability (Cronbach's alpha: 0.7-0.9 per domain). Both outcomes were assessed at the start of the study (B0) and the end of the 6-month (M6) study.

### Analysis

The results of the study were presented using numerical data and categorical data. Numerical data is provided in the form of mean and standard deviation (SD) when distributed normally or median and interquartile range (IQR) when distributed abnormally. Categorical data are presented

in the form of frequency and percentage. Bivariate analysis is performed using T test for normally distributed numerical data or the Mann-Whitney U test for abnormally distributed data. Chi-square test is used to analyze the categorical with Risk Ratio (RR) and 95% Confidence Interval (CI). The p-value <0.05 (two-tailed) is considered statistically meaningful. This research has been approved by the Faculty of Medicine's ethics committee, Universitas Islam Negeri Syarif Hidayatullah, with the clinical trial protocol number 3674022P111472019091200003. All subjects have given consent before this study.

### RESULTS

At the beginning of the study, 144 subjects were checked for their eligibility, 44 subjects were excluded because 39 subjects could not operate the application independently, and five subjects did not consent. During the follow-up period of 6 months, three subjects passed away, and 19 subjects dropped out because they could not be contacted (19%). At the end of the study, a total of 78 subjects were analyzed (Figure 4). The subjects' characteristics in this study can be seen in Table 1, 48.72% of the subjects in this study were elderly subjects, and most were subjects with higher education (89.74%). Judging by its clinical characteristics, 48.72% of subjects diagnosed with diabetes over ten years and 62.82% of subjects received insulin therapy with a median SMBG per month performed six times (Table 2). When compared with subjects who experienced lost-to-follow-up, subjects that experience lost-to-follow-up are subjects with lower incomes (p=0.023), while in other variables, there is no statistically meaningful difference.

### Effect of using Teman Diabetes application on subjects' SMBG performance

Using the *Teman Diabetes* application on the subjects' SMBG performance can be seen in Table 3. Significantly, the use of SMBG for six months lowered the difficulty of the subject to remember doing SMBG, and this can be seen from the median value that drops from 3 to 2 to question how often you have difficulty remembering to

## Table 1. Demographic Characteristics of Research Subjects

| Variable – n(%) | Total N = 97 | Included N = 78 | Lost to follow up N = 19 | p-value |
|---|---|---|---|---|
| **Age** | | | | |
| ≥ 60 | 47 (48.5) | 38 (48.72) | 9 (47.37) | 0.916 |
| < 60 | 50 (51.6) | 40 (51.82) | 10 (52.63) | |
| **Sex** | | | | |
| Male | 37 (38.1) | 28 (35.90) | 9 (47.37) | 0.356 |
| Female | 60 (61.9) | 50 (64.10) | 10 (52.63) | |
| **Marriage** | | | | |
| Married | 70 (72.2) | 59 (75.64) | 11 (57.89) | 0.122 |
| Not/ ever married | 27 (27.8) | 19 (24.36) | 8 (42.11) | |
| **Smoking** | | | | |
| Yes | 6 (6.2) | 4 (5.13) | 2 (10.53) | 0.489 |
| No | 91 (93.8) | 74 (90.91) | 17 (89.47) | |
| **Work status** | | | | |
| Unemployed | 47 (48.5) | 40 (51.28) | 9 (47.37) | 0.916 |
| Employed | 50 (51.55) | 38 (48.72) | 10 (52.63) | |
| **Educational attainment** | | | | |
| Low | 11 (11.34) | 8 (10.26) | 3 (15.79) | 0.495 |
| High | 86 (88.7) | 70 (89.74) | 16 (84.21) | |
| **Income** | | | | |
| Low | 39 (40.2) | 27 (34.62) | 12 (63.16) | 0.023* |
| Middle to High | 58 (59.8) | 51 (65.38) | 7 (36.84) | |
| **Insurance** | | | | |
| National health insurance | 90 (92.8) | 73 (93.59) | 17 (89.47) | 0.534 |
| Other insurance/self-paid | 7 (7.2) | 5 (6.41) | 2 (10.53) | |

*statistically significant (p<0.05)*

## Table 2. Clinical Characteristics of Subjects

| Variable – n (%) | Total N = 97 | Included N = 78 | Lost to follow up N = 19 | p-value |
|---|---|---|---|---|
| **Diabetes duration – median (IQR), yr** | | | | |
| ≥ 10 yr | 47 (48.45) | 38 (48.72) | 9 (47.37) | 0.916 |
| < 10 yr | 50 (51.55) | 40 (51.82) | 10 (52.63) | |
| **Diabetes treatment** | | | | |
| No treatment | 1 (1.03) | 1 (1.28) | 0 (0) | 0.794 |
| Oral anti diabetics | 36 (37.11) | 28 (35.90) | 8 (42.11) | |
| Insulin | 60 (61.86) | 49 (62.82) | 11 (57.89) | |
| **Family history of diabetes** | | | | |
| Present | 63 (64.95) | 51 (65.38) | 12 (63.16) | 0.855 |
| Not present | 34 (35.05) | 27 (34.62) | 7 (36.84) | |
| **Frequency of SMBG in months – median (IQR) times** | 6 (4) | 6 (4) | 5.9 (7) | 0.2603 |
| **Obese** | | | | |
| Yes | 60 (61.86) | 47 (60.26) | 13 (68.42) | 0.511 |
| No | 37 (38.14) | 31 (39.74) | 6 (31.58) | |
| **A1C** | | | | |
| ≥ 7 | 93 (95.88) | 75 (96.15) | 18 (94.74) | 0.781 |
| < 7 | 4 (4.12) | 3 (3.85) | 1 (5.26) | |

*IQR = Interquartile range; SMBG= Self-monitoring blood glucose; yr= year; A1C= glycated hemoglobin A1C*

do SMBG with the frequency according to the doctor's recommendation (p= 0.004). The number of subjects who stopped or reduced performing SMBG for reasons that did not help their diabetes condition also decreased from 21.79% to 10.26%.

### Effect of using Teman Diabetes application on self-care activities

After six months of intervention, there was no change in the subjects' self-care activities (P = 0.200). At the beginning of the study, 52.56% of subjects were classified as having poor diabetes self-care activities with the SDSCA mean score of 19.56 (SD=5.55). Meanwhile, after six months of intervention, 42.31% of subjects were still classified as poor in doing diabetes self-care activities with the SDSCA mean score of 20.72 (SD=5.26) (p = 0.182). However, when viewed per domain, there was a change in the subject's diet globally. At the beginning of the study, the global diet domain's median value was 5 (IQR=3.5), and this value increased to 6.75 (IQR=1) at the end of the study (p = 0.006).

## DISCUSSION

*Teman Diabetes* is the only smartphone-based SMBG application available in Indonesia. This study is the first study in Indonesia that assesses smartphone-based SMBG applications' effectiveness for SMBG performance in diabetic patients. There are some limitations in this study, subject's behavior and adherence in using the SMBG application were not controlled. However, this study aims to assess the effectiveness of SMBG applications in real-life situations. Thus, this study has considered the effectiveness of blood glucose-monitoring applications, including users who are not used to technology applications.

In this study, we found a decrease in subjects' difficulty level remembering performing SMBG as recommended by the doctor. That means that the SMBG application can help patients remember when to do SMBG as recommended by the doctor. The smartphone-based SMBG application used in this study can be filled in manually or automatically if the subjects use a specific glucose meter available on the market. Patients can record any blood glucose data (BG) levels (before meals,

**Table 3.** The effect of using *Teman Diabetes* application on the performance of the subjects' SMBG

| Question | B0 | M6 | p-value |
|---|---|---|---|
| Do you check your blood glucose independently with the frequency that has been taught by your doctor? | | | |
| • Yes | 73 (93.59) | 71 (91.03) | 0.548 |
| • No | 5 (6.41) | 7 (8.97) | |
| Do you sometimes forget to do SMBG with the frequency recommended by the doctor? | | | |
| • Yes | 46 (58.97) | 38 (48.72) | 0.199 |
| • No | 32 (41.03) | 40 (51.28) | |
| When you travel or leave home, do you sometimes forget to bring your glucometer? | | | |
| • Yes | 34 (43.59) | 26 (33.33) | 0.188 |
| • No | 44 (56.41) | 52 (66.67) | |
| How often do you have difficulties in remembering the frequency of SMBG as recommended by your doctor?? ¥ | 3 (1-5) | 2 (1-5) | 0.004* |
| Have you ever stopped doing or reduced the frequency of SMBG because you felt that SMBG activity did not help your diabetes condition? | | | |
| • Yes, I have | 17 (21.79) | 8 (10.26) | 0.049* |
| • No, I have never | 61 (78.21) | 70 (89.74) | |
| When you feel your blood glucose level is stable do you sometimes stop checking your blood glucose independently? | | | |
| • Yes | 20 (25.97) | 18 (23.08) | 0.709 |
| • No | 57 (74.03) | 60 (76.92) | |
| Do you feel disturbed by SMBG activities according to the frequency recommended by your doctor? | | | |
| • Yes | 8 (10.39) | 4 (5.13) | 0.229 |
| • No | 69 (89.61) | 74 (94.87) | |
| What do you think regarding the costs involved in doing SMBG? | | | |
| • Expensive | 27 (35.06) | 24 (30.77) | 0.609 |
| • Cheap | 50 (64.94) | 54 (69.23) | |

B0= Baseline; M6= 6 months follow up
¥data in median (min-max) for answers 1=never, 2 = rarely, 3 = sometimes, 4 = usually, 5 = always
*statistically significant (p<0.05)

**Table 4.** The Summary of Diabetes Self-Care Activities Measure (SDSCA)

| Domain | B0 Mean/median (SD/IQR) | M6 Mean/median (SD/IQR) | p-value |
|---|---|---|---|
| Global diet - median (IQR) | 5 (3.5) | 6.75 (1) | 0.006* |
| Specific diet - median (IQR) | 5.5 (2) | 5.5 (1.5) | 0.833 |
| Physical activity - median (IQR) | 2.5 (3.5) | 2.25 (3) | 0.854 |
| Blood glucose testing - median (IQR) | 2.5 (1) | 3 (1) | 0.670 |
| Foot care - median (IQR) | 3.5 (6) | 3.75 (6) | 0.403 |
| Total mean SDSCA Score - mean (SD) | 19.56 (5.55) | 20.72 (5.26) | 0.182 |
| Poor - n(%) | 41 (52.56) | 33 (42.31) | 0.200 |
| Good - n(%) | 37 (47.44) | 45 (57.69) | |

B0= Baseline; IQR= Interquartile range; M6= 6 months follow up

after meals and bedtime). These data will only be stored if food, beverages, and if needed, activities that may affect blood glucose results are also recorded.

Besides helping subjects record their SMBG activity, the use of smartphone-based SMBG helps patients recognize or realize the benefits of the SMBG. Our study also showed decreased subjects who stopped using SMBG because SMBG activity did not help their diabetes condition (Figure 2). SMBG can help patients and clinicians to understand the profile and dynamics of patient's blood glucose against changes in dietary patterns, physical activity, use of anti-hyperglycemia drugs along with insulin and certain clinical conditions.[11]

There have been statistically significant improvements in the global diet domain six months post intervention in terms of

diet. This condition shows the benefits of using the SMBG application to improve diet patterns. When the subject records their daily blood glucose levels in the application, they must also record the food and beverages eaten earlier and, if needed, activities that may affect blood glucose levels. That may affect the subject's diet patterns as the subject becomes more alert to dietary patterns and their impact on blood glucose levels. Similar results found by McAndrew et al., SMBG can improve self-management in diabetics, especially in regulating diet patterns.[12] SMBG activity can provide direct feedback to patients on how dietary behavior can affect blood glucose levels and make patients more aware of what they eat.

Of the 78 subjects in our study, 40.92% of subjects were low-income, and 35.06% felt that SMBG was expensive. We found that the SMBG application's use did not change the subjects' perception of the costs required to do SMBG from expensive to cheap (p = 0.609). Currently, in Indonesia, both strips and glucose meter devices are not covered by national health insurance. Given the importance and usefulness of SMBG in diabetes management, further research on the benefits of smartphone-based SMBG in terms of outcome and cost-effectiveness, especially in Indonesia, needs to be done. Apart from price, several barriers to using technology for diabetes management are adherence and the learning process of using technology.[8] Judging from the subjects' characteristics in our study, we included almost 90% of higher education subjects. According to a study by Adams et al., one of the barriers to doing SMBG is the low socioeconomic level.[13] Another study by Zeng et al. also shows that low education affects SMBG behavior and blood glucose control.[12] Given these conditions, our study should be generalized to the population with a good education level.

## CONCLUSION

SMBG application helps the subject overcome the difficulty of remembering performing SMBG, helps change the subject's perception of SMBG benefits, and improves their dietary pattern. The use of technology is proven to be able to provide benefits in diabetes management. Further studies are needed to assess the benefits of using SMBG applications viewed from the clinical outcome and cost-effectiveness with more appropriate research methods, e.g., randomized clinical trials.

## DATA AVAILABILITY

The data are available from the corresponding author upon reasonable request

## CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this paper

## AUTHOR CONTRIBUTION

IAK, MIM, RR, ME and JN contributed to the research design and implementation, NM contributed to the analysis, results and worked on the manuscript. All authors discussed the results and commented on the manuscript.

## REFERENCES

1. World Health Organization. Global Report on Diabetes. *World Health Organization.* 2016.
2. Saeedi P, Petersohn I, Salpea P, et al. Global and regional diabetes prevalence estimates for 2019 and projections for 2030 and 2045: Results from the International Diabetes Federation Diabetes Atlas, 9(th) edition. *Diabetes Res Clin Pract.* 2019;157:107843.
3. Kesehatan BPDPKK. Hasil Utama Riskesdas 2018. *Kementerian Kesehatan Republik Indonesia.* 2018.
4. Ong WM, Chua SS, Ng CJ. Barriers and facilitators to self-monitoring of blood glucose in people with type 2 diabetes using insulin: a qualitative study. *Patient Prefer Adherence.* 2014;8:237-246.
5. Vidal Flor M, Jansa Morato M, Galindo Rubio M, Penalba Martinez M. Factors associated to adherence to blood glucose self-monitoring in patients with diabetes treated with insulin. The dapa study. *Endocrinol Diabetes Nutr.* 2018;65(2):99-106.
6. Peyrot M, Rubin RR, Lauritzen T, Snoek FJ, Matthews DR, Skovlund SE. Psychosocial problems and barriers to improved diabetes management: results of the Cross-National Diabetes Attitudes, Wishes and Needs (DAWN) Study. *Diabet Med.* 2005;22(10):1379-1385.
7. Harris MI, National H, Nutrition Examination S. Frequency of blood glucose monitoring in relation to glycemic control in patients with type 2 diabetes. *Diabetes Care.* 2001;24(6):979-982.
8. Alcantara-Aragon V. Improving patient self-care using diabetes technologies. *Ther Adv Endocrinol Metab.* 2019;10:2042018818824215.
9. Majeed W, Thabit H. Closed-loop insulin delivery: current status of diabetes technologies and future prospects. *Expert Rev Med Devices.* 2018;15(8):579-590.
10. Patton SR. Adherence to glycemic monitoring in diabetes. *J Diabetes Sci Technol.* 2015;9(3):668-675.
11. Karter AJ. Role of self-monitoring of blood glucose in glycemic control. *Endocr Pract.* 2006;12 Suppl 1:110-117.
12. Zeng Y, Wu J, Han Y, et al. Educational disparities in the associations between self-monitoring of blood glucose and glycemic control in type 2 diabetes patients in Xiamen, China. *Journal of Diabetes.* 2018.
13. Adams AS, Mah C, Soumerai SB, Zhang F, Barton MB, Ross-Degnan D. Barriers to self-monitoring of blood glucose among adults with diabetes in an HMO: a cross sectional study. *BMC Health Serv Res.* 2003;3(1):6.