Contents available at ScienceDirect

Diabetes Research and Clinical Practice

journal homepage: www.elsevier.com/locate/diabres

International Diabetes Federation

# The impact of provision of self-monitoring of blood glucose supplies on self-care activities among patients with uncontrolled Type 2 diabetes mellitus: A prospective study

*Yingqi Xu* [a], *Judith Han Lim* [a], *Henry Ramaya* [b], *Yu-chia Joyce Lee* [a,*]

[a] *Department of Pharmacy, Faculty of Science, National University of Singapore, Singapore*
[b] *National University Polyclinics, Singapore*

ARTICLE INFO

*Article history:*
Received 4 July 2019
Received in revised form
23 September 2019
Accepted 30 September 2019
Available online 8 October 2019

*Keywords:*
Self-monitoring of blood glucose
Self-care
Type 2 diabetes
Insulin
Non-insulin

ABSTRACT

*Aims:* Self-monitoring of blood glucose (SMBG) is an important self-care activity for patients with Type 2 diabetes mellitus (T2DM) to achieve glycaemic control. The aim of this study was to evaluate the impact of providing SMBG supplies on self-care among patients with uncontrolled T2DM.

*Methods:* This was a six-month, prospective study conducted in two primary care institutions. Patients ≥21 years old with uncontrolled T2DM (HbA1c > 7.0%) and polypharmacy (≥5 chronic medications) were included. All participants were given a free blood glucometer, test strips, and lancets, and were invited to consult pharmacists to learn about SMBG. The Summary of Diabetes Self-Care Activities questionnaire was administered at baseline and at six months.

*Results:* A total of 167 patients were recruited and 150 (89.8%) completed the study. At six months, significant improvements from baseline were observed for overall self-care (+0.58, $p = 0.008$), glycemic control (−0.41%, $p < 0.001$) and all specific self-care activities. The mean change in the SMBG score in all the participants was found to have a strong positive correlation with the mean change in the overall self-care score ($r_s = 0.580$, $p = 0.01$).

*Conclusions:* Provision of SMBG supplies was effective in improving self-care among patients with uncontrolled T2DM, including non-insulin-treated patients.



## 1. Introduction

Self-care is a cornerstone in the treatment of diabetes mellitus, a chronic and complex disease requiring multi-pronged approaches to ensure long-lasting control [1]. For patients with diabetes, self-care involves several key activities including healthy eating, regular exercise, self-monitoring of blood glucose (SMBG), medication adherence, foot care, and smoking cessation [2,3]. These activities are associated with greater and continuous glycaemic control, reduction of complications, and improved quality of life [4]. Despite the importance and benefits of self-care activities, the practice of self-care

* Corresponding author at: Department of Pharmacy, Faculty of Science, National University of Singapore, Block S4A, Level 3, 18 Science Drive 4, Singapore 117543, Singapore.
E-mail address: phalycj@nus.edu.sg (Y.-c. J. Lee).
https://doi.org/10.1016/j.diabres.2019.107873
0168-8227/

remains low among patients with Type 2 diabetes mellitus (T2DM) due to some challenges such as patients' lack of motivation and difficulties in changing habits [5,6].

Among the aforementioned self-care activities, SMBG has important implications for patients as well as their healthcare teams. SMBG readings provide real-time feedback on blood glucose levels, which can help patients understand the impact of specific dietary choices and physical activities on their blood glucose [7,8]. With the SMBG readings, patients can adjust their self-care activities subsequently. For patients who are using insulin in particular, SMBG is recommended to monitor and prevent hypoglycaemic episodes [3,9]. For healthcare professionals, SMBG readings can be utilised to assess therapy effectiveness, perform dose adjustments, and even teach patients to self-titrate their medications [10,11].

Although SMBG has shown to be directly associated with empowerment in managing diabetes [12], SMBG is often underutilised among patients with T2DM. In Asia, for example, with only an estimated 29.7% of Asian patients reporting regular SMBG usage [7,13]. Patients who actively engage themselves in the utilization of SMBG are more likely to achieve targeted HbA1c levels. For example, in a randomized controlled study of 137 subjects with Type 2 diabetes, an average HbA1c change of $-0.25 \pm 0.21\%$ and $+0.30 \pm 0.08\%$ were reported in the SMBG group and non-SMBG group, respectively ($p < 0.05$) [14]. Furthermore, a systematic review consisting of 15 randomised control studies has also concluded that better glucose control was achieved in patients using SMBG vs those who did not ($-0.33$ vs $-0.22$; $p < 0.001$) [15]. However, a recent study has reported lack of glucometers as one of the major barriers to the performance of diabetic self-care [6]. High cost of SMBG supplies is also a major barrier to the low SMBG utilitization [7,16–18]. Even in countries such as the United States where SMBG supplies are subsidised, patients still perceived them to be expensive [19]. Household income was found to be positively associated with the frequency of SMBG performance [20]. Several patients also reflected that they would perform SMBG more regularly if the supplies were free [21].

However, the reimbursement of SMBG supplies are still very much restricted in many countries especially in Asia [22,23], preventing patients with diabetes to attain the maximum benefits from the use of SMBG. The provision of SMBG supplies was thus included in this study design to overcome the major barriers to the performance of SMBG. Although the benefits of SMBG on self-care have largely been captured via qualitative or cross-sectional studies to date, quantitative studies are limited. Therefore, the primary objective of this study was to determine the impact of providing SMBG supplies on self-care activities and glycated hemoglobin (HbA1c) among patients with uncontrolled T2DM. The secondary objectives were to assess the impact of this intervention on self-care activities among insulin-treated and non-insulin-treated individuals and the association between SMBG and other self-care activities. The study outcome from this study may help the policy makers and insurance companies to gain new insights on the benefits of SMBG beyond glucose regulation and allow wider coverage and access by the patients with diabetes.

## 2. Methods

### 2.1. Study design and setting

This was a six-month prospective, multicentre study conducted at two outpatient primary health institutions in Singapore. The study was approved by the National Healthcare Group Domain Specific Review Board (2017/01191) and was conducted in accordance to the Declaration of Helsinki.

### 2.2. Study participants

A sample size calculation was performed based on an estimated 0.63 difference (Appendix A) in the overall self-care score between baseline and six months [24]. After accounting for an attrition rate of 20%, at least of 22 participants were needed for the study (two-sided, $\alpha = 0.05$, power = 0.80). Patients aged $\geq$21 years with uncontrolled T2DM (defined as HbA1c > 7.0%) and polypharmacy (defined as being prescribed $\geq$ 5 chronic medications) were included in this study. Patients with Type 1 diabetes and those who were unable to independently communicate in English, Mandarin, or Bahasa Melayu were excluded.

### 2.3. Study procedures

Patients were approached and screened at the study sites by research assistants. Eligible patients were invited to participate upon signing of informed consent. All participants were given a free capillary whole blood glucose meter and a set of 50 test strips and 50 lancets to perform SMBG in addition to their routine care. At three months, participants were given another set of 50 test strips and 50 lancets. The blood glucometers given in this study were certified ISO15197:2003 compliant and had the following features: blood glucose measurements in mmol/L, sensitive for blood volumes of 0.5 μL, storage of 500 measurements with date and time, five seconds test time, and operated on user-changeable batteries, which were as same as other marketed devices. Independently conducted studies show that over 80% of glucometers in the market meet the high system accuracy requirements of ISO 15197:2003; and all of them show acceptable measurement reproducibility [25]. Participants were invited to consult a pharmacist at a clinic or pharmacy counter to learn how to use the blood glucose meter and interpret the readings. Healthcare professionals who provided routine care for the participants, including physicians, pharmacists, nurses, and dieticians, were informed of their participation in the study. At baseline and six months, the Summary of Diabetes Self-Care Activities (SDSCA) questionnaire was administered to all participants. The English, Mandarin, and Bahasa Melayu versions of the SDSCA were used and research assistants were trained to administer them. Permission to use the SDSCA was obtained from the original authors (http://www.ori.org/sdsca).

### 2.4. Clinical survey

The SDSCA is a widely used, validated, and reliable tool that measures self-care levels [26]. The Malay version has

been previously translated and validated [27]. The internal consistency of the Chinese version was adequate for the all the domains: diet ($\alpha = 0.71$), exercise ($\alpha = 0.88$), blood sugar testing ($\alpha = 0.83$) and foot care ($\alpha = 0.93$) [28]. The Revised Version of the SDSCA was employed in this study, comprised of 11 core items that cover five main domains of self-care: diet, physical activity, SMBG, foot care, and smoking habits [29]. Apart from the items on smoking, the score for each item was the number of days that the activity was practised in the past week. The scores therefore ranged from zero to seven, with higher scores indicating higher frequencies at which the self-care activity was practised. The score for item four was reversed as it captures a negative self-care practice. The mean score of all the items in each domain gave the domain score. The mean of the four domain scores was then calculated and reported as the overall self-care score.

### 2.5. *Data collection and outcome measures*

The primary outcome of this study was the mean change in patient-reported self-care activities at six months across all participants, measured using the SDSCA. The secondary outcome was the mean change in patient-reported self-care activities at six months for both insulin-treated and non-insulin-treated participants. Participants' sociodemographic characteristics, including age, gender, ethnicity, education level, smoking status marital status, employment status and diabetes duration were collected from a 19-item demographic questionnaire at baseline. Patients' medical history were obtained from the institutions' electronic databases.

### 2.6. *Statistical analysis*

All analyses were performed based on intention to treat. Differences in self-care domains and mean HbA1c between

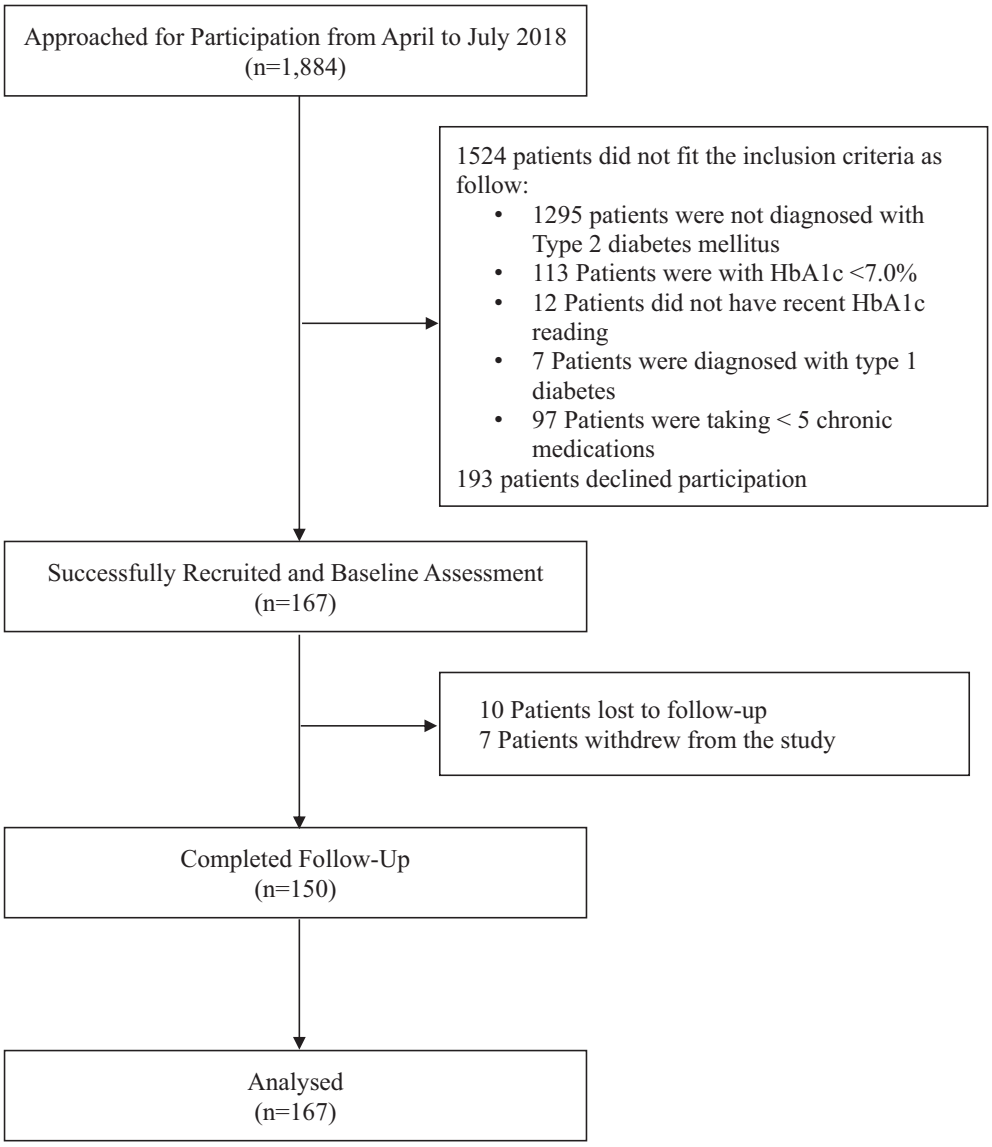



**Fig. 1 – Recruitment, follow-up, and analysis of study participants.**

baseline and six months were detected using a linear fixed-effects model, adjusted for age [30], education level [31] and income [32]. The following variables were assessed individually again the overall self-care scores across time points: age, ethnicity, education level, income, working status, diabetes duration, baseline body mass index (BMI), baseline HbA1c, baseline SMBG usage, number of comorbidities and number of medications. Using P-value < 0.20 as selection criteria [33–35], the following variables with statistically significant associations with change of overall self-care scores were included in the final model: duration of diabetes (P = 0.141) and number of medications (P = 0.151). Differences in smoking status between baseline and six months were detected using the paired samples t-test. Sensitivity analyses were conducted to compare unadjusted results and adjusted results. An ad hoc analysis between self-care domains was also performed to further investigate possible associations of the mean change in SMBG and the overall self-care score using Pearson or Spearman correlations. A two-tailed p-value of <0.05 was considered statistically significant. All analyses were conducted using IBM SPSS Statistics version 25.0.

## 3. Results

### 3.1. Study participants

A total of 1884 patients were approached to participate in this study, of whom 1524 did not fit the inclusion criteria and 193 declined participation. Common reasons for declining included lack of interest and time. The remaining 167 patients were successfully recruited into the study and completed the baseline questionnaire. Over the six-month period, 10 (6.0%) participants were lost to follow-up as they were either uncontactable or had defaulted on their appointments at the institutions. Seven (4.2%) patients also withdrew from the study due to feelings of inconvenience or a loss of interest in the study. Overall, 150 (89.8%) participants completed the study and the results of all 167 participants were analysed (Fig. 1).

The mean age was 59.4 ± 6.9 years and more than half of the participants were male (62.3%), Chinese (61.1%) and employed (64.1%). Majority of the participants were married (88.6%), received at least secondary school education (74.2%), and did not smoke (86.8%) (Table 1). Demographics of insulin-users and non-insulin users are summarized in Table S1 (Appendix 2). Among those employed, the average monthly income was S$3240 ± 2659. A total of 57 (34.1%) participants were receiving insulin treatment and 66 (39.5%) participants were existing SMBG users. The mean baseline HbA1c was 8.39%±0.97% and the mean duration of diabetes was 12.39 ± 8.58 years. Participants had an average of five comorbidities and were taking an average of seven chronic medications, of which an average of two medications were for diabetes.

### 3.2. Changes in self-care activities and HbA1c levels over six months

The baseline overall self-care mean score was 2.66 ± 1.37. Mean scores for diet, exercise, SMBG, and foot care were 3.24 ± 1.70, 2.69 ± 2.36, 1.23 ± 2.23 and 2.82 ± 2.46, respectively (Table 2). At six months, participants had significantly higher mean scores for the overall self-care score (p = 0.008), with an increase of 0.58. Among the domains, SMBG had the lowest baseline mean score but the greatest mean change in score (+0.91 ± 2.76, p < 0.001), followed by exercise (+0.61 ± 2.77, p = 0.220), foot care (+0.49 ± 2.78, p = 0.350), and diet (+0.44 ± 1.84, p = 0.018). The percentage of participants who smoked significantly decreased after six months (−6.0%, p < 0.001). A significant increase in the percentage of participants who performed SMBG from 39.5% to 60.5% was also observed by the end of the study (p < 0.001) (Fig. 2). The mean HbA1c levels was decreased from 8.39 ± 0.97% to 7.95 ± 1.07 (-0.41, p < 0.001).

**Table 1 – Baseline sociodemographics and medical history.**

| Sociodemographics and Medical History (n = 167) | n (%) |
|---|---|
| Age in years (Mean ± SD) | 59.4 ± 6.9 |
| Gender | |
| Male | 104 (62.3) |
| Female | 63 (37.7) |
| Ethnicity | |
| Chinese | 102 (61.1) |
| Malay | 41 (24.6) |
| Indian | 20 (12.0) |
| Others | 4 (2.4) |
| Marital Status | |
| Single | 5 (3.0) |
| Married | 148 (88.6) |
| Divorced or Separated | 7 (4.2) |
| Widowed | 7 (4.2) |
| Employment Status | |
| Employed | 107 (64.1) |
| Retired | 37 (22.2) |
| Housewife | 21 (12.6) |
| Others | 2 (1.2) |
| Education Level | |
| No Formal Education | 8 (4.8) |
| Primary School | 35 (21.0) |
| Secondary School | 75 (44.9) |
| College, Polytechnic, or ITE | 31 (18.6) |
| University | 18 (10.8) |
| Smoking Status | |
| Smoker | 22 (13.2) |
| Non-Smoker | 145 (86.8) |
| Insulin Treatment | |
| Insulin-Treated | 57 (34.1) |
| Non-Insulin-Treated | 110 (65.9) |
| Baseline SMBG Use | |
| Yes | 66 (39.5) |
| No | 101 (60.5) |
| BMI (Mean ± SD) | 28.28 ± 5.28 |
| Monthly Income in S$ (Mean ± SD) | 3271 ± 2697 |
| Baseline HbA1c in % (Mean ± SD) | 8.39 ± 0.97 |
| Number of Comorbidities (Mean ± SD) | 5.29 ± 1.91 |
| Duration of Diabetes in years (Mean ± SD) | 12.39 ± 8.58 |
| Number of Medications (Mean ± SD) | 6.89 ± 1.84 |
| Number of Diabetes Medications (Mean ± SD) | 2.53 ± 0.86 |

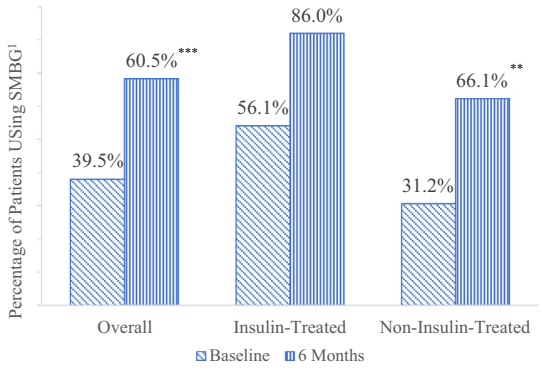
### 3.3. Changes in self-care activities among insulin- and non-insulin-treated participants

Among non-insulin-treated participants, the mean overall self-care score significantly improved from baseline (+0.70,

**Table 2 – Changes in self-care scores over six months for all participants.[1]**

| Outcome | Baseline (n = 167) | Six Months (n = 150) | Mean Change (n = 164) | P Value[2,a] | P Value[b] |
|---|---|---|---|---|---|
| Diet Score | 3.24 ± 1.70 (3.30) | 3.78 ± 1.39 (3.75) | +0.44 ± 1.84 | 0.001 | 0.018 |
| Exercise Score | 2.69 ± 2.36 (2.00) | 3.23 ± 2.37 (3.00) | +0.61 ± 2.77 | 0.013 | 0.220 |
| SMBG Score | 1.32 ± 2.23 (0.00) | 2.23 ± 2.23 (2.00) | +0.91 ± 2.76 | <0.001 | 0.025 |
| Foot Care Score | 2.82 ± 2.46 (3.50) | 3.29 ± 2.51 (3.50) | +0.49 ± 2.78 | 0.032 | 0.350 |
| Overall Score | 2.66 ± 1.37 (2.60) | 3.26 ± 1.23 (3.30) | +0.58 ± 1.41 | <0.001 | 0.008 |
| Smokers (%) | 22 (13.2) | 12 (7.2) | −6.0% | <0.001 | – |
| HbA1c | 8.39 ± 0.97 | 7.95 ± 1.07 | −0.41 ± 0.86 | <0.001 | <0.001 |

[1] Data presented as Mean ± SD (Median) or Whole Number (%) where appropriate.
[2] P-values based on linear fixed effects models and paired samples t-tests, as appropriate.
[a] Unadjusted for covariates.
[b] Estimates from mixed effects models are adjusted for age, education level, income, DM duration and number of medications.




[1] Refers to percentage of patients who performed SMBG at least once a week.
***Percentage at six months was significantly greater than baseline (p<0.001).
**Percentage at six months was significantly greater than baseline (p=0.002).

**Fig. 2 – Changes in percentage of SMBG users among insulin-treated, non-insulin-treated, and all participants.**

p = 0.014), as well as for diet, SMBG and foot care. The greatest mean change in score was observed for SMBG (+1.15, p = 0.009), followed by foot care (+0.66, p = 0.290), and exercise (+0.62, p = 0.429), and diet (+0.53, p = 0.040) (Table 3). The percentage of smokers in the non-insulin-treated group also significantly decreased by the end of the study (−8.0%, p < 0.001), while the number of non-insulin-treated participants who performed SMBG doubled to 66.1% at six months (p = 0.002) (Fig. 2).

Among insulin-treated participants, the mean overall self-care score increased by 0.35 from baseline to six months, although the improvement is not significant (p = 0.269). Between baseline and six months, the mean scores of insulin-treated participants did not change significantly for all four self-care domains (diet, physical activity, SMBG, and foot care). At six months, the percentage of insulin-treated participants who performed SMBG increased from 56.1% to 86.0% (p = 0.537) (Fig. 2).

### 3.4. *Sensitivity analyses*

Sensitivity analyses were conducted after adjusting for age, education level, income, working status, diabetes duration and number of medications. The adjusted results did not show significant difference from the unadjusted results (Tables 2 and 3).

### 3.5. *Ad hoc analysis of associations between self-care domains*

The mean change in the SMBG score was found to have a strong positive correlation with the mean change in the overall self-care score ($r_s$ = 0.580, p = 0.01) and a weak positive correlation with the mean change in the diet score ($r_s$ = 0.163, p = 0.037) (Table 4).

## 4. Discussion

This was the first study to quantitatively capture the positive impact of providing SMBG supplies on self-care levels of patients with uncontrolled T2DM. More specifically, we explored the provision of free SMBG supplies as a means of encouraging SMBG performance. This study also distinguished the changes in self-care between insulin-treated and non-insulin-treated individuals who have received free SMBG supplies. The findings from our study, therefore, complement the body of qualitative research conducted to inform the medical community about the relationship between SMBG provision and self-care [36].

The provision of SMBG supplies was successful in improving participants' overall practice of self-care (+0.58, p = 0.008) and glycemic control (−0.41, p < 0.001) within six months. The result of self-care levels was in line with a recent randomised study [37] involving SMBG interventions where an improvement in participants' overall self-care levels (+0.51) was observed. The level of HbA1c reduction was similar to another randomized control study comprising of 273 patients with HbA1c > 7% (−0.49, p < 0.001) [38]. The provision of SMBG supplies also effectively improved participants' all self-care activities. As expected, the SMBG performance was increased with the provision of free SMBG supplies, since higher socioeconomic status is a predictor for SMBG usage and the mean monthly income of the study participants was approximately S$1200 lower than that of a full-time employee in Singapore [13]. However, after adjusting for income, the levels of self-care and glycemic control were still significantly improved. The corresponding increases in dietary control and physical activity are also consistent with multiple qualitative studies

**Table 3 – Changes in self-care scores over 6 months for insulin-treated and non-insulin-treated participants.**[1]

| Outcome | Insulin-Treated Group (Mean ± SD) | | | | | Non-Insulin-Treated Group (Mean ± SD) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Baseline (n = 57) | End (n = 49) | Change (n = 49) | P value[2,a] | P value[2,b] | Baseline (n = 110) | End (n = 101) | Change (n = 101) | P value[2] | P value[2,b] |
| Diet Score | 3.25 ± 1.65 | 3.62 ± 1.34 | +0.27 ± 1.72 | 0.164 | 0.253 | 3.21 ± 1.72 | 3.83 ± 1.42 | +0.53 ± 1.90 | 0.007 | 0.040 |
| Exercise Score | 2.65 ± 2.11 | 3.21 ± 2.15 | +0.61 ± 2.58 | 0.114 | 0.223 | 2.73 ± 2.49 | 3.25 ± 2.50 | +0.62 ± 2.87 | 0.088 | 0.429 |
| SMBG Score | 2.04 ± 2.58 | 2.56 ± 2.04 | +0.44 ± 2.80 | 0.207 | 0.659 | 0.95 ± 1.93 | 2.10 ± 2.31 | +1.15 ± 2.72 | <0.001 | 0.009 |
| Foot Care Score | 3.01 ± 2.60 | 3.13 ± 2.46 | +0.14 ± 2.42 | 0.693 | 0.974 | 2.75 ± 2.39 | 3.37 ± 2.58 | +0.66 ± 2.94 | 0.044 | 0.290 |
| Overall Score | 2.84 ± 1.35 | 3.23 ± 1.13 | +0.35 ± 1.46 | 0.071 | 0.269 | 2.59 ± 1.30 | 3.27 ± 1.29 | +0.70 ± 1.38 | <0.001 | 0.014 |
| Smokers (%) | 9 (15.8%) | 6 (10.5%) | −5.3% | <0.001 | – | 14 (12.8%) | 6 (5.4%) | −8.0% | <0.001 | – |
| HbA1c | 8.63 ± 1.03 | 8.38 ± 1.11 | −0.37 ± 0.84 | 0.092 | 0.009 | 8.25 ± 0.91 | 7.80 ± 1.02 | −0.43 ± 0.87 | <0.001 | 0.012 |

[1] Data presented as Mean ± SD or Whole Number (%) where appropriate.
[2] P-value based on linear fixed effects models and paired samples t-tests, as appropriate.
[a] Unadjusted for covariates.
[b] Estimates from mixed effects models are adjusted for age, education level, income, DM duration and number of medications.

that report patients' usage of SMBG readings to make lifestyle modifications [19,39,40]. The improvement in foot care and the reduction in the percentage of smokers observed with SMBG provision are new findings amidst the vast literature on SMBG, which could be due to increased consultation to the healthcare professionals on abnormal SMBG readings [41–43].

The provision of SMBG supplies was effective in increasing both SMBG performance and the frequency at which it was performed, regardless of insulin use. Before receiving the free supplies, only 39.7% of all participants and 54.1% of insulin-treated participants were performing SMBG, with the baseline frequency of SMBG was of 1.23 ± 2.15 days per week. With the provision of SMBG supplies, the number of SMBG users nearly doubled to 68.3% and users increased their SMBG frequency to 2.20 ± 2.24 days per week, indicating greater adherence to clinical recommendations. Our findings can be explained by a study conducted in a multiethnic population, which found that individuals with financial barriers were less likely to perform SMBG at least twice a week [44]. In this study, we also found the improvement in SMBG was directly associated with the improvement in overall self-care ($p < 0.001$). These associations strengthen our earlier observation that provision of SMBG supplies facilitated improvements in overall self-care through improving the practice of multiple specific self-care activities.

This study found that the provision of SMBG facilitated a significant increase in overall self-care and specific self-care activities among non-insulin-treated participants. Since SMBG is not specifically indicated for non-insulin-treated patients [3], the significant increase in SMBG performance could have been attributed to the novelty of the experience. Non-insulin-treated patients reported an attitude of curiosity upon SMBG initiation as they desired to discover patterns in their blood glucose levels. This led them to experiment performing SMBG at different frequencies, times of the day, and after different foods, thereby adjusting their self-care activities as part of the experimental process [40]. Interestingly, no significant changes in the four core self-care activities were observed among the insulin-treated participants in this study. One possible reason is a lack of understanding on the benefits of SMBG in improving self-care. A qualitative study conducted among insulin-treated patients with T2DM in Malaysia reported a perception that SMBG is mainly used for insulin titration, which reflects an unawareness that SMBG could be employed to adjust diet and exercise regimes [21].

This study had several limitations. First, our results may have been affected by recall and social desirability biases due to the retrospective nature of the SDSCA and the face-to-face mode of administration. We attempted to minimise these biases by training all research assistants to ensure consistency in the manner of questionnaire administration and sufficiency of response time for each participant. Second, the short duration of the study prevented us from assessing the long-term impact of providing SMBG supplies on self-care. Finally, a relatively small number of insulin-treated participants were represented in our study, which could have limited us from observing the effect of SMBG supplies provision on self-care levels among them. Future studies could

**Table 4 – Associations between self-care domains.**

| Variables Correlated | | Correlation Coefficient[1] | P value |
|---|---|---|---|
| Mean Change in SMBG Score | Mean Change in Diet Score | 0.163 | 0.037 |
| | Mean Change in Exercise Score | 0.099 | 0.300 |
| | Mean Change in Foot Care Score | 0.212 | 0.025 |
| | Mean Change in Overall Self-Care Score | 0.580 | 0.01 |

[1] Spearman's Rho Correlation Coefficient ($r_s$) reported.

explore the longitudinal and long-term relationship between SMBG supplies provision and self-care levels with a greater representation of insulin-treated participants.

## 5. Conclusion

This study demonstrated that the provision of SMBG supplies had a positive impact on self-care levels and glycemic control of patients with uncontrolled T2DM. This study further demonstrated that improvements in self-care for non-insulin-treated patients are achievable with SMBG provision. The provision of SMBG supplies was also shown to be an effective method of improving the practice of self-care activities in the short-term.

## Author contributions

Study concept and design (YX, JYCL); extraction of data (JLH); data analysis and interpretation (YX, JLH); drafting of the manuscript (JLH); revision of the manuscript (YX, HR, JYCL).

## Funding

This study was supported by the Health Services Research Competitive Research Grant from the Ministry of Health, Singapore (HSRG14may006).

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.diabres.2019.107873.

## REFERENCES

[1] Aade. AADE7 self-care behaviors. Diab Educ 2008;3:445–9.
[2] Boren SA. AADE7TM self-care Behaviors: systematic reviews. Diab Educ 2007;6:866–71.
[3] Goh SY, Ang SB, Bee YM, Chen YT, Gardner DS, Ho ET, et al. Ministry of Health Clinical Practice guidelines: diabetes mellitus. Singapore Med J 2014;6:334–47.
[4] Shrivastava SR, Shrivastava PS, Ramasamy J. Role of self-care in management of diabetes mellitus. J Diab Metab Disord 2013;1:14.
[5] Tan CCL, Cheng KKF, Sum CF, Shew JSH, Holydard E, Wang W. Perceptions of diabetes self-care management among older singaporeans with type 2 diabetes: a qualitative study. J Nurs Res 2018;4:242–9.
[6] Mogre V, Johnson NA, Tzelepis F, Paul C. Barriers to diabetic self-care: a qualitative study of patients' and healthcare providers' perspectives. J Clin Nurs 2019;11–12:2296–308.
[7] Chowdhury S, Ji L, Suwanwalaikorn S, Yu NC, Tan EK. Practical approaches for self-monitoring of blood glucose: an Asia-Pacific perspective. Curr Med Res Opin 2015;3:461–76.
[8] Pugliese G, Zanuso S, Alessi E, Simonelli P, Fallucca S, Fallucca F, et al. Self glucose monitoring and physical exercise in diabetes. Diab Metab Res Rev 2009:S11–7.
[9] American Diabetes A. Standards of medical care in diabetes–2014. Diab Care 2014:S14–80.
[10] Lee JY, Tsou K, Lim J, Koh F, Ong S, Wong S. "Symptom-based insulin adjustment for glucose normalization" (SIGN) algorithm: a pilot study. Diab Technol Ther 2012;12:1145–8.
[11] Silva DD, Bosco AA. An, educational program for insulin self-adjustment associated with structured self-monitoring of blood glucose significantly improves glycemic control in patients with type 2 diabetes mellitus after 12 weeks: a randomized, controlled pilot study. Diab Metab Syndr 2015:2.
[12] Rossi MC, Lucisano G, Funnell M, Pintaudi B, Bulotta A, Gentile S, et al. Interplay among patient empowerment and clinical and person-centered outcomes in type 2 diabetes. The BENCH-D study. Patient Educ Couns 2015;9:1142–9.
[13] Chan JC, Gagliardino JJ, Baik SH, Chantelot JM, Ferreira SR, Hancu N, et al. Multifaceted determinants for achieving glycemic control: the International Diabetes Management Practice Study (IDMPS). Diab Care 2009;2:227–33.
[14] Harashima S, Fukushima T, Sasaki M, Nishi Y, Fujimoto S, Ogura M, et al. Self-monitoring of blood glucose (SMBG) improves glycaemic control in oral hypoglycaemic agent (OHA)-treated type 2 diabetes (SMBG-OHA study). Diab Metab Res Rev 2013;1:77–84.
[15] Zhu H, Zhu Y, Leung SW. Is self-monitoring of blood glucose effective in improving glycaemic control in type 2 diabetes without insulin treatment: a meta-analysis of randomised controlled trials. BMJ Open 2016;9:e010524.
[16] Tham KY, Ong JJ, Tan DK, How KY. How much do diabetic patients know about diabetes mellitus and its complications?. Ann Acad Med Singapore 2004;4:503–9.
[17] Farhan SA, Shaikh AT, Zia M, Kahara BR, Muneer R, Rehman M, et al. Prevalence and predictors of home use of glucometers in diabetic patients. Cureus 2017;6:e1330.
[18] Ismail M, Teng CL, Omar M, Ho BK, Kusiar Z, Hasim R. Usage of glucometer is associated with improved glycaemic control in type 2 diabetes mellitus patients in Malaysian public primary care clinics: an open-label, randomised controlled trial. Singapore Med J 2013;7:391–5.
[19] Hortensius J, Kars MC, Wierenga WS, Kleefstra N, Bilo HJ, van der Bijl JJ. Perspectives of patients with type 1 or insulin-

treated type 2 diabetes on self-monitoring of blood glucose: a qualitative study. BMC Public Health 2012:167.
[20] Raoufi AM, Tang X, Jing Z, Zhang X, Xu Q, Zhou C. Blood glucose monitoring and its determinants in diabetic patients: a cross-sectional study in Shandong, China. Diab Ther 2018;5:2055–66.
[21] 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 Pref Adhe 2014:237–46.
[22] Czupryniak L, Barkai L, Bolgarska S, Bronisz A, Broz J, Cypryk K, et al. Self-monitoring of blood glucose in diabetes: from evidence to clinical reality in Central and Eastern Europe–recommendations from the international Central-Eastern European expert group. Diab Technol Ther 2014;7:460–75.
[23] Jin SM, Baek JH, Suh S, Jung CH, Lee WJ, Park CY, et al. Factors associated with greater benefit of a national reimbursement policy for blood glucose test strips in adult patients with type 1 diabetes: a prospective cohort study. J Diab Investig 2018;9:549–57.
[24] Wishah RA, Al-Khawaldeh OA, Albsoul AM. Impact of pharmaceutical care interventions on glycemic control and other health-related clinical outcomes in patients with type 2 diabetes: randomized controlled trial. Diab Metab Syndr 2015;4:271–6.
[25] Freckmann G, Baumstark A, Schmid C, Pleus S, Link M, Haug C. Evaluation of 12 blood glucose monitoring systems for self-testing: system accuracy and measurement reproducibility. Diab Technol Ther 2014;2:113–22.
[26] Lu Y, Xu J, Zhao W, Han HR. Measuring self-care in persons with type 2 diabetes: a systematic review. Eval Health Prof 2016;2:131–84.
[27] Jalaludin M, Fuziah M, Hong J, Mohamad Adam B, Jamaiyah H. Reliability and validity of the revised summary of diabetes self-care activities (SDSCA) for Malaysian children and adolescents. Malays Fam Phys 2012;2–3:10–20.
[28] Cheng L, Leung DYP, Wu YN, Sit JWH, Yang MY, Li XM. Psychometric properties of the modified personal diabetes questionnaire among Chinese patients with type 2 diabetes. Eval Health Prof 2018;1:3–24.
[29] Toobert DJ, Hampson SE, Glasgow RE. The summary of diabetes self-care activities measure: results from 7 studies and a revised scale. Diab Care 2000;7:943–50.
[30] Koponen AM, Simonsen N, Suominen S. How to promote fruits, vegetables, and berries intake among patients with type 2 diabetes in primary care? A self-determination theory perspective. Health Psychol Open 2019;1. 2055102919854977.
[31] Laaksonen M, Talala K, Martelin T, Rahkonen O, Roos E, Helakorpi S, et al. Health behaviours as explanations for educational level differences in cardiovascular and all-cause mortality: a follow-up of 60 000 men and women over 23 years. Eur J Public Health 2008;1:38–43.
[32] Walker RJ, Gebregziabher M, Martin-Harris B, Egede LE. Relationship between social determinants of health and processes and outcomes in adults with type 2 diabetes: validation of a conceptual framework. BMC Endocr Disord 2014:82.
[33] Yu H, Li Q, Zhang M, Liu F, Pan J, Tu Y, et al. Decreased leptin is associated with alterations in thyroid-stimulating hormone levels after Roux-en-Y gastric bypass surgery in obese euthyroid patients with type 2 diabetes. Obes Facts 2019;3:272–80.
[34] Shanaki M, Fadaei R, Moradi N, Emamgholipour S, Poustchi H. The circulating CTRP13 in type 2 diabetes and non-alcoholic fatty liver patients. PLoS ONE 2016;12:e0168082.
[35] Fakhrzadeh H, Sharifi F, Alizadeh M, Arzaghi SM, Tajallizade-Khoob Y, Tootee A, et al. Relationship between insulin resistance and subclinical atherosclerosis in individuals with and without type 2 diabetes mellitus. J Diab Metab Disord 2015:41.
[36] Havele SA, Pfoh ER, Yan C, Misra-Hebert AD, Le P, Rothberg MB. Physicians' views of self-monitoring of blood glucose in patients with type 2 diabetes not on insulin. Ann Fam Med 2018;4:349–52.
[37] Young LA, Buse JB, Weaver MA, Vu MB, Mitchell CM, Blakeney T, et al. Glucose self-monitoring in non-insulin-treated patients with type 2 diabetes in primary care settings: a randomized trial. JAMA Intern Med 2017;7:920–9.
[38] Bonomo K, De Salve A, Fiora E, Mularoni E, Massucco P, Poy P, et al. Evaluation of a simple policy for pre- and post-prandial blood glucose self-monitoring in people with type 2 diabetes not on insulin. Diab Res Clin Pract 2010;2:246–51.
[39] Chen CM, Hung LC, Chen YL, Yeh MC. Perspectives of patients with non-insulin-treated type 2 diabetes on self-monitoring of blood glucose: a qualitative study. J Clin Nurs 2018;7–8:1673–83.
[40] Tanenbaum ML, Leventhal H, Breland JY, Yu J, Walker EA, Gonzalez JS. Successful self-management among non-insulin-treated adults with Type 2 diabetes: a self-regulation perspective. Diab Med 2015;11:1504–12.
[41] Norris SL, Lau J, Smith SJ, Schmid CH, Engelgau MM. Self-management education for adults with type 2 diabetes: a meta-analysis of the effect on glycemic control. Diab Care 2002;7:1159–71.
[42] Soprovich AL, Sharma V, Tjosvold L, Eurich DT, Johnson JA. Systematic review of community pharmacy-based and pharmacist-led foot care interventions for adults with type 2 diabetes. Can Pharm J (Ott) 2019;2:109–16.
[43] O'Kane MJ, Bunting B, Copeland M, Coates VE, Group Es. Efficacy of self monitoring of blood glucose in patients with newly diagnosed type 2 diabetes (ESMON study): randomised controlled trial. BMJ 2008;7654:1174–7.
[44] Zgibor JC, Simmons D. Barriers to blood glucose monitoring in a multiethnic community. Diab Care 2002;10:1772–7.