

Facilitating access to glucometer reagents increases blood glucose self-monitoring frequency and improves glycaemic control: a prospective study in insulin-treated diabetic patients

B. L. G. Nyomba, L. Berard and L. J. Murphy

Diabetes Research group, Department of Internal Medicine, University of Manitoba, Canada

Accepted 15 May 2003

Abstract

Aims To investigate whether availability of glucometer reagents increases the frequency of self-blood glucose monitoring (SBGM) and improves glycaemic control in diabetic patients.

Methods Sixty-two insulin-treated diabetic patients were randomized to two groups, matched for age, gender, education, income, type and duration of diabetes, years of insulin treatment, number of daily insulin injections, and haemoglobin (Hb)A_{1c}. All patients were given a glucometer, but one group (no cost, NC) was provided glucometer test strips free of charge. The other group (control, C) had to purchase strips as they found it necessary. Both groups of patients were followed longitudinally at 2-monthly intervals for 12 months with measurement of blood glucose and HbA_{1c}, and the frequency of SBGM was determined by downloading the glucometer memory.

Results The SBGM frequency was significantly higher in the NC group vs. the C group during the first 4 months (2.0 ± 0.2 tests/day vs. 1.4 ± 0.1 tests/day, $P < 0.025$). Mean HbA_{1c} remained stable over the 12 months in the NC group, whereas an increase with time was observed in the C group. The difference in HbA_{1c} between the two groups was significant ($P < 0.002$) after 6 months. Random blood glucose measured at each visit and average glucose recorded by the glucometer were also lower in the NC group vs. the C group ($P < 0.005$). There was a negative correlation between HbA_{1c} and SBGM frequency, and HbA_{1c} in patients testing at least twice a day was lower than in those testing less than twice a day ($8.8 \pm 0.2\%$ vs. $9.6 \pm 0.2\%$, $P < 0.001$).

Conclusions In this prospective study, having easy access to glucometer strips provided free of charge to patients increased SBGM frequency. The relationship between HbA_{1c} and SBGM frequency supports the view that SBGM is an essential tool in diabetes management.

Diabet. Med. 21, 129–135 (2004)

Keywords blood glucose self-monitoring, diabetes mellitus, haemoglobin A_{1c}, patient compliance, socioeconomic factors

Abbreviations C, control; DEC, diabetes Education Centre; ES, effect size; HbA_{1c}, haemoglobin A_{1c}; NC, no cost; NS, not statistically significant; SBGM, self-blood glucose monitoring; SEM, standard error of the mean

Introduction

Maintenance of near-normal glycaemia through intensive diabetes treatment can delay or prevent microvascular complications [1,2]. Recently, diabetes associations throughout the world have set blood glucose and haemoglobin (Hb) A_{1c} targets to assist care providers and patients with goal setting for diabetes management and control [3,4]. The achievement of these goals requires patient participation in the management of their diabetes, and patients need thorough diabetes education to acquire disease management skills, problem-solving interventions, and goal setting for life-style changes. HbA_{1c} is considered to be the most relevant physiologic outcome target because it integrates overall glucose control and is a proven risk predictor for diabetic microvascular complications [1,2]. For day-to-day management decisions, however, HbA_{1c} cannot be used and there is a need for a dynamic parameter that follows fluctuations in blood glucose. SBGM is considered to be one of the most important skills in diabetes self-management and is the only method currently available that allows adjustments in insulin dosage and timing to match meal plans and variation in daily exercise routines. In addition to enabling patients to make decisions in adjusting insulin or oral hypoglycaemic medications to fluctuations in diet and physical activity, it may alert them to impending hyperglycaemic or hypoglycaemic emergencies [5].

There is no consensus on the effectiveness of SBGM in patients with Type 2 diabetes, but limited data in patients with Type 1 diabetes supports the concept that it is useful [6,7]. Patients on insulin, including those with Type 2 diabetes, are commonly instructed in the technique of SBGM and taught to adjust their insulin dosage after glucose self-monitoring [8]. Patient's motivation towards SBGM depends on several ill-defined factors. The objectives of the current study were to define patient-related barriers to SBGM and to determine whether SBGM frequency is associated with glycaemic control. In particular, we wished to determine whether the cost of SBGM was an important limiting factor in the patient's use of this tool for achieving glycaemic control and whether free access to glucose monitoring reagents would increase SBGM frequency.

Patients and methods

Patients and study design

This study was undertaken from July 1998 to June 2000. It was a single-blinded control-matched longitudinal study in which patients with Type 1 and Type 2 diabetes mellitus were asked to participate in a study of a new glucometer. The patients were required to have been receiving at least two insulin injections per day for at least 1 year, have a HbA_{1c} \geq 120% of upper limit of normal, be willing to discontinue the use of their current glucometer for the duration of the study and have the ability to understand the use of the new glucometer and perform SBGM. Patients were excluded if they had poor vision or technical

skills, a concurrent illness likely to hinder participation in the study, or a special reason (e.g. pregnancy, habitual strenuous exercise) that would prompt an increase in the frequency of SBGM. Insulin-treated patients were chosen because they were expected to be more compliant with self-care, as insulin use has been shown to increase the frequency of SBGM [9,10]. The patients were required to have had recent basic diabetes education at the Diabetes Education Centre (DEC), affiliated with the Health Sciences Centre, Winnipeg, Manitoba, prior to entering the study. Methods for achieving glucose goals were discussed with them at the DEC in reference to the guidelines of the North American Diabetes Associations [3,4]. The patients were told that SBGM is an important means to achieving good glycaemic control and that ideally SBGM should take place daily at a frequency of three to four times a day.

Sixty-two patients were eligible for the study. They gave an informed written consent to participate in the study, and the protocol was approved by the Research Ethics Board of the University of Manitoba. The patients were initially interviewed and asked to complete an entry questionnaire addressing their habitual frequency of SBGM, the perceived advantages and disadvantages of SBGM and barriers to SBGM. They were also asked to report their place of employment (if any), their monthly income, and any private health insurance plans (to verify coverage for glucometer reagents). Patients were then instructed by our research nurse in the use of the glucometer DEX (Bayer, Etobicoke, Ont., Canada), but the research nurse did not voluntarily give them any information on how frequently they should self-monitor their blood glucose. Rather, the patients were told by the nurse to perform SBGM as previously advised at the DEC. Thus, attempts were made to minimize an increase in SBGM frequency that could be due to study enrolment itself.

The patients were stratified in three categories of income (i) < \$15 000, (ii) \$15–40 000, and (iii) > \$40 000 and they were randomly assigned in a patient-blinded fashion to two groups of 31 patients each. A glucometer DEX and a one-time single package of reagent strips (50 strips) were supplied to one group of patients (control, C group). The patients in this group were instructed to purchase additional reagent strips as needed. The second group of 31 patients were given a glucometer together with a supply of reagent strips, 100 strips per month (no-cost, NC group). Each patient was asked to participate in the study over a period of 12 months with second monthly visits to the research nurse. The frequency of visits to their physician was not altered. Rather, the patients were instructed to see their primary care physician and/or endocrinologist at the same frequency as before enrolment into the study. Initially, and at each subsequent visit, random blood glucose and HbA_{1c} were measured, and the research nurse checked the patient's familiarity with the glucose-testing procedure and downloaded the glucometer memory using a computer software (WinGlucofacts, Bayer Inc.). The research nurse did not provide any feedback to the patient concerning glucometer readings, random blood glucose readings or HbA_{1c} determinations. The nurse logged the results by patient number and no analysis of the data occurred until all the patients had completed the study. As knowledge of glycaemic level has been shown to alter patient behaviour and diabetes control [11], we felt that it was important that the patients should be blind to this information during the study, although they may have been aware of the HbA_{1c}

determinations performed by the primary care provider and would be able to review their own blood sugar determinations from the glucometer memory. At the exit from the study, the patients were asked to complete a questionnaire addressing their frequency of SBGM, the perceived advantages and disadvantages of SBGM and the reasons limiting self-monitoring.

The endpoints that were measured at each visit included the frequency of SBGM (mean number of tests per day) determined by downloading the glucometer memory, the average daily blood glucose over the past 2 months, and the HbA_{1c}. Glucose was measured with a YSI2300 glucose analyser (YSI Inc., Yellow Springs, OH, USA) and HbA_{1c} was measured using the DCA 2000 Analyser (Ames, Elkhart, IN, USA).

Sample size estimate

SBGM frequency and HbA_{1c} were used as parameters of interest in the computation of the required sample size (n). We employed the 'effect size' (ES) approach according to the equations: (i) $ES = \delta/\sigma$, where δ is the difference between group means, and σ is the standard deviation; (ii) $n = 1 + 15.7/ES^2$. A group difference of 1 (with a σ of 1.3) in the daily SBGM frequency corresponds to a monthly difference of 30 tests or 10 test-days, for a SBGM frequency of three times a day. An HbA_{1c} δ of 1.5% (with a σ of 2.0) is in the order of magnitude of the effect of diabetes education on glycaemic control [12]. To detect these δ s with an α -error < 0.05 and a power of 0.8 (2-tailed test), the calculated sample size is 27.5 and 27.9 per group, respectively, i.e. close to $n = 30$ per group. We initially enrolled 80 patients into the study, anticipating 10–15% dropout or withdrawal. However, only 62 patients started the study and there was a bigger dropout rate than we anticipated (see Results).

Statistical analysis

The SPSS for Windows software (SPSS Inc., Chicago, IL, USA) was used for statistical analysis. Baseline characteristics were compared between groups using Fisher's exact test for discrete variables and t -test for continuous variables. The two groups were compared using the univariate General Linear Model program with baseline values and time as co-variables. This model included a group effect, a time effect, and group-time interaction. Efficacy data from the intention-to-treat population, using the last observation carried forward, were analysed by General Linear Model with baseline values as co-variate. In subjects that completed the entire duration of the study, a repeated measure analysis of variance was also used. Spearman's rank or Pearson's correlation coefficients were computed, as applicable. Answers to questionnaires were analysed using the multiple response statistic. Results are expressed as the mean \pm SEM, unless stated otherwise.

Results

Subjects

As shown in Table 1, the two groups were well matched for age, gender, type of diabetes, duration of diabetes, number of

Table 1 Characteristics of subjects on enrolment into the study

Group	No cost	Control
Age (year)	49.1 \pm 3.1	50.8 \pm 3.3
Men : women	18 : 13	17 : 14
Years of education	12.9 \pm 0.5	12.5 \pm 0.5
Income rank	1.7 \pm 0.1	1.7 \pm 0.1
Health insurance, yes : no	13 : 18	13 : 18
Diabetes type 1 : 2	17 : 14	18 : 13
Years since diagnosis	19.8 \pm 2.2	17.0 \pm 1.9
Years on insulin	16.3 \pm 2.2	13.5 \pm 2.0
Weekly SBGM frequency	8.4 \pm 1.1	8.5 \pm 1.1
Daily insulin dose (IU)	52.5 \pm 3.0	58.5 \pm 6.9
Daily insulin injections	2.6 \pm 0.1	2.4 \pm 0.1
HbA _{1c} (%)	9.1 \pm 0.3	9.2 \pm 0.2
Random glucose (mmol/l)	11.7 \pm 0.8	12.6 \pm 0.9

Plus-minus values are means \pm SE. Health insurance refers to additional health insurance not sponsored by federal or provincial governments.

years on insulin treatment, education, habitual frequency of SBGM, random blood glucose, HbA_{1c}, and number of daily insulin injections. Insulin dose was slightly higher in the C group ($P = \text{NS}$). One patient in the NC group and two patients in the C group declined to discuss their income. Yearly income and private health insurance were comparable between groups.

The baseline characteristics remained similar between the NC and C groups throughout the study period. At 6 months into the study, with 26 patients remaining in the NC group and 21 in the C group, the daily number of insulin injections (2.9 ± 0.2 vs. 2.6 ± 0.2), the distribution of Type 1 : Type 2 diabetes (14 : 12 vs. 10 : 11), and the percentage of individuals with partial private insurance (46 vs. 48%) were similar between the two groups. At the end of the study, there were 25 patients remaining in the NC group and 16 patients in the C group, i.e. a dropout rate of 19% in the NC group and 48% in the C group. Because of this dropout rate, the power of the study using self-tests/day and HbA_{1c} as variables of interest fell to 0.64, but the power was 0.99 when insulin dose was used (see below). The daily number of insulin injections (2.7 ± 0.2 vs. 2.5 ± 0.2), the distribution of patients with Type 1 : Type 2 diabetes (13 : 12 vs. 6 : 10), and the percentage of individuals with partial private insurance (52 vs. 38%) were not statistically different between the two groups.

Initially, patients indicated that they were not self-monitoring more often because (i) testing was not convenient (47%), (ii) the test strips were too expensive (31%), (iii) they could feel their own blood sugar without testing (21%), (iv) testing was too painful (14%), (v) testing did not help (10%). At the exit, patients that completed the study ranked somewhat differently the reasons for not self-monitoring, indicating that they were not testing more often because (i) testing was not convenient, (29%), (ii) they could feel their own blood sugar without testing (20%), (iii) testing was too painful (17%), (iv) the test strips were too expensive (10%), (v) testing did not help (7%). The stated reasons for not self-monitoring were not statistically different between the two groups.

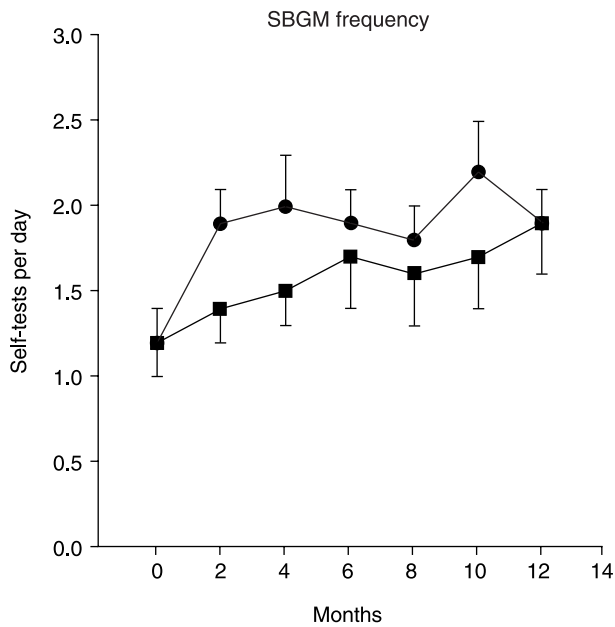


Figure 1 SBGM frequency downloaded from the glucometer in the NC (●) vs. C groups (■). SBGM at time zero was the one stated by the patients on enrolment. $P < 0.05$ for the effect of cost of strips according to the General Linear Model.

Glucose monitoring and diabetes control

The stated SBGM frequency at entry was similar between the two groups. The SBGM frequency recorded by the glucometer increased progressively with time in the study and was higher in the NC group vs. the C group (Fig. 1). The SBGM frequency during the first 4 months was 2.0 ± 0.2 tests/day in the NC group and 1.4 ± 0.1 tests/day in the C group ($P < 0.025$). Insulin dose did not change significantly in the NC group, but it increased by 1.5-fold in the C group during the course of the study (Fig. 2). HbA_{1c} decreased in both groups during the first 2 months, then it remained stable in the NC group, while increasing in the C group (Fig. 2). Overall, HbA_{1c} was significantly lower in the NC group vs. the C group ($P < 0.002$). This difference was most apparent at the 6th month of the study.

Random blood glucose measured at each visit and the average blood glucose recorded by the glucometer (Fig. 2) were also lower in the NC group vs. the C group ($P < 0.005$). As shown in Fig. 3, there was a negative correlation between HbA_{1c} and the number of tests per day, with two clusters of HbA_{1c} values demarcated by a testing frequency of 2/day. HbA_{1c} in patients testing at least twice a day was lower than in those testing less than twice a day ($8.8 \pm 0.2\%$ vs. $9.6 \pm 0.2\%$, $P < 0.001$).

Discussion

We have examined factors limiting SBGM and the effects of SBGM on diabetes control in insulin-treated diabetic individuals. Because SBGM is generally recommended for diabetic

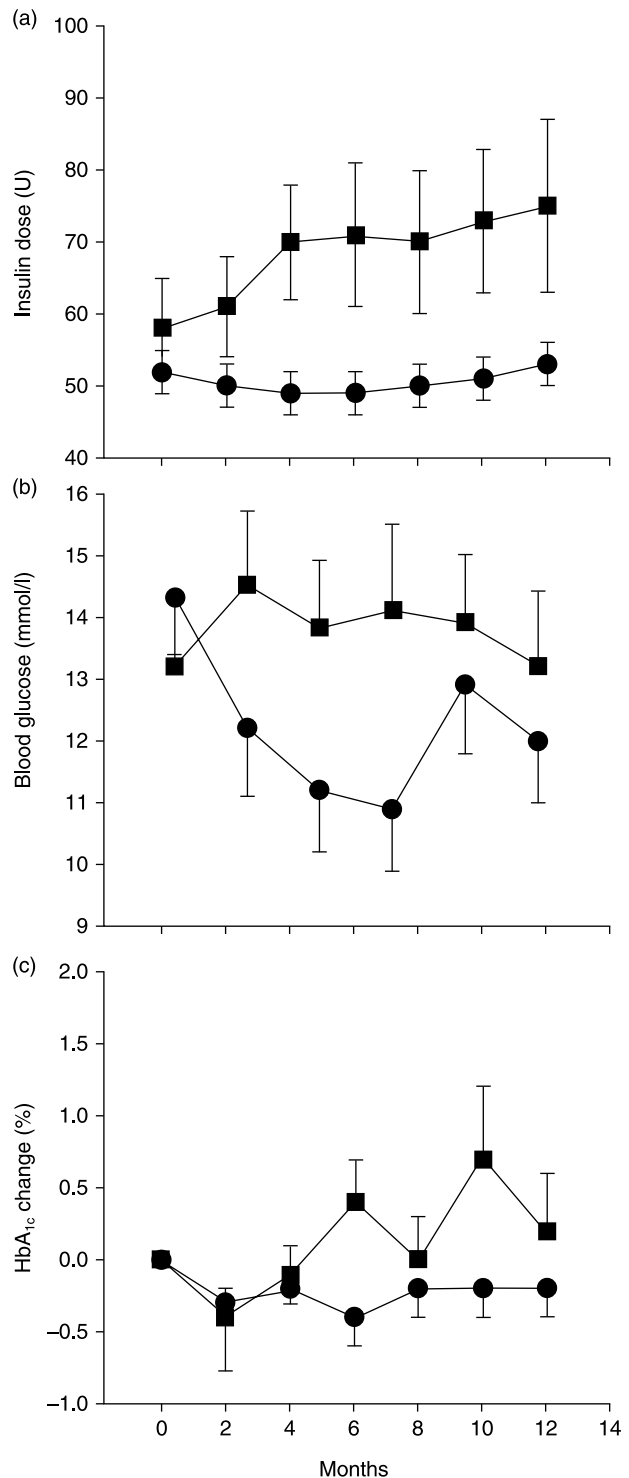


Figure 2 (a) Daily insulin dose, and (b) glucometer-recorded blood glucose, and (c) change in HbA_{1c} in the NC (●) vs. the C (■) groups. $P < 0.005$ are for the effect of cost of strips according to the General Linear Model.

patients on insulin and the use of insulin has been shown to increase SBGM frequency [9,10], we chose insulin-treated patients irrespective of whether they had Type 1 or Type 2 diabetes. These subjects were told that they would participate in

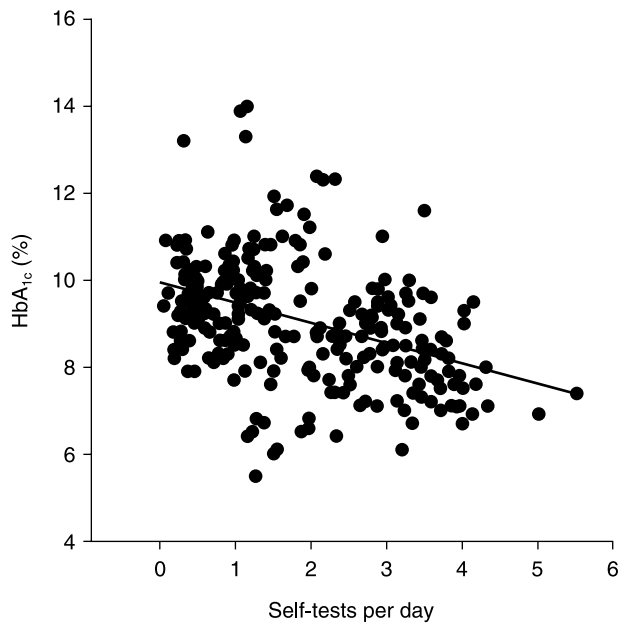


Figure 3 Relationship between HbA_{1c} and daily SBGM frequency. This relationship was best fit by the linear regression equation $HbA_{1c} = 9.883 - 0.447 \times \text{tests/day}$, $F = 46.15$, $r = 0.388$, $P < 0.0001$.

a study of a new glucometer, but they were not instructed to change their self-monitoring habits. In accordance with good clinical practice guidelines, the patients had all attended diabetes education where the importance of SBGM had been emphasized. As knowledge of glycaemic level can alter patients' behaviour and diabetes control [11], we felt that it was important that the patients should be blind to the primary objective of the study. Thus, although they may have been aware of their own blood glucose results and the HbA_{1c} determinations performed by their primary care physician or endocrinologist, no additional information was provided by the research nurse.

At entry into the study, approximately 50% of patients indicated that they refrained from self-monitoring due to inconvenience (a word used by patients to describe the uneasiness of using this technique in social situations, meaning cumbersome, distasteful, embarrassing, constraining, etc.) and about 30% of patients found glucose testing reagents to be too expensive. At exit, inconvenience was still ranked at the top of the list of barriers to self-monitoring, but cost was relegated towards the end of the list. The fact that cost was cited less often at exit than at entry suggests that it was less relevant for those patients remaining in the study. In the NC group where glucometer reagent strips were provided, the cost of the reagents was unlikely to be foremost in the patient's mind when asked to state why they do not do more frequent SBGM, whereas patients in the C group who found the cost of the reagent strips to be problematic may well have dropped out of the study, thus accounting for the decline in the reported significance of this factor at the exit. Thus, although the main reason for not testing was inconvenience, a high percentage of patients found SBGM to

be too costly, in agreement with previous reports [13–15]. The importance of the cost of SBGM is also underscored by the higher dropout rate (~50%) among patients not given free glucometer strips as compared with those given the reagents. The fact that the latter group had a still significant dropout rate (~20%), however, suggests that, while cost of reagent strips is an important factor, other factors also play an important role in the willingness of patients to self-monitor their blood glucose. The number of glucometer strips provided free of charge was only sufficient for performing 3.3 tests/day, which is somewhat short of the maximum 4 tests/day advised at the DEC, and may have limited the testing frequency. However, patients were not precluded from purchasing additional test-strips if they so wished or needed, and the simple strategy of supplying free reagent strips to cover most (if not all) of their testing needs increased compliance with SBGM and diabetes self-management, and improved diabetes control. It is also remarkable that the dropout rate in the C group was of the same magnitude as the proportion of patients who indicated that they refrained from self-monitoring at the beginning of the study.

Patient-related factors limiting SBGM have been investigated before [10–16]. Diabetes type and therapy, age, gender, education, diabetes education, more frequent visits to the physician, increasing income and having health insurance were, to variable degrees, found to influence SBGM frequency. The current study carefully matched the two groups of patients for such background and demographic factors to avoid selection bias. HbA_{1c} in both groups displayed a similar initial decrease during the time all the patients had a supply of glucometer strips, possibly also reflecting the effect of study enrolment and recent attendance at diabetes education. Overall, however, diabetic patients who had access to adequate supplies of glucometer reagents provided free of charge had better glycaemic control with lower HbA_{1c}, average blood glucose and insulin doses compared with those who were required to purchase these supplies. The worsening of glycaemic control in patients who were not given free strips may have caused ill-timed upward insulin dose adjustments by the patients themselves or by their care providers.

There was a negative (although not strong) correlation between SBGM frequency and HbA_{1c}. These results are in line with the previously reported observations that patients who self-monitor have better glycaemic control and are less likely to develop diabetic complications [1,2,11]. We cannot exclude the possibility that patients with intrinsically poorer glycaemic control became discouraged and therefore did less testing or dropped out of the study altogether. However, this seems unlikely as the dropout rate was similar to the proportion of patients who indicated they found testing inconvenient. The association between an increased SBGM frequency and a fall in HbA_{1c} has been reported mostly in patients with Type 1 diabetes [6,7,17,18]. In contrast, the importance of self-monitoring in Type 2 diabetes has been less certain. In general, no association has been found between HbA_{1c} and self-monitoring

frequency in Type 2 patients, whether on insulin or on oral hypoglycaemic agents, questioning the efficacy of SBGM in patients with Type 2 diabetes, even when treated with insulin [7,13,19–21]. It is possible that patients with Type 1 diabetes benefit more from SBGM because they, and their care-providers, are more likely to consider this tool important and as a consequence have learned to use it more effectively. This view is in line with interventions that have shown benefits of SBGM in patients with Type 2 diabetes [16,22]. Because of the small number of patients and the similar representation of the two diabetes types in both groups, our data were not analysed separately for Type 1 and Type 2 diabetes.

In a large observational study of ~23 500 patients where the frequency of SBGM was determined through pharmacy refills of prescribed glucometer strips [23], the importance of SBGM was suggested in both Type 1 and Type 2 diabetic patients. Karter *et al.* [23] found that more frequent SBGM was associated with better glycaemic control regardless of diabetes type or therapy. SBGM among patients with Type 1 diabetes (≥ 3 times daily) and pharmacologically treated Type 2 diabetes (at least once daily) was associated with 1.0 and 0.6% lower HbA_{1c}, respectively. Although our study design differs from that of Karter *et al.* [23], in that patients were followed prospectively and that glucose readings and SBGM frequency were extracted from the glucometer memory, similar results were obtained. We estimated that self-monitoring at least twice daily was associated with lower HbA_{1c} by ~0.8% in our combination of Type 1 and Type 2 insulin-treated diabetic patients.

While our study was limited by the small number of subjects, especially after dropout, we provide evidence that the simple measure of provision of glucometer reagent strips without any other intervention increases the frequency of SBGM and improves glycaemic control. This effect on glycaemic control showed no attenuation over the 12-month study period. However, longer-term follow-up would be required to examine the durability of this improvement and to determine whether it has a meaningful impact on diabetic complications and outcomes. The small number of patients in our study did not allow for meaningful analysis of the data separately for Type 1 and Type 2 diabetes. Furthermore, the study included only insulin-requiring diabetics and therefore it is unclear whether similar benefits would accrue to those treated with oral agents.

Nevertheless, in insulin-treated patients, after the inconvenience of self-monitoring, the cost of glucometer strips was the major barrier to SBGM. Providing glucometer reagents free of charge increases the frequency of SBGM and improves glycaemic control. Health care providers should consider providing free glucometer strips to this group.

Acknowledgements

We thank Linda Tang and Tracy Sadowy for assistance with volunteers' recruitment. This work was supported in part by

Bayer Inc., Etobicoke, Ontario, Canada and supported in part by a grant from the Canadian Diabetes Association.

References

- 1 Diabetes Control and Complications Trial. The effect of intensive treatment of diabetes on the development and progression of long-term complications in insulin-dependent diabetes mellitus. *N Engl J Med* 1993; **329**: 977–986.
- 2 UK Prospective Diabetes Study Group. Intensive blood-glucose control with sulphonylureas or insulin compared with conventional treatment and risk of complications in patients with type 2 diabetes (UKPDS 33). *Lancet* 1998; **352**: 837–853.
- 3 American Diabetes Association. Clinical practice recommendations. 1998; *Diabetes Care* 1998; **21**: S23–S31.
- 4 Meltzer S, Leiter L, Daneman D, Gerstein HC, Lau D, Ludwig S *et al.* Clinical practice guidelines for the management of diabetes mellitus in Canada. *Can Diabetes Assoc CMAJ* 1998; **159**: S1–S29.
- 5 American Diabetes Association. Consensus statement on self-monitoring of blood glucose. *Diabetes Care* 1987; **10**: 95–97.
- 6 Strowig SM, Raskin P. Improved glycaemic control in intensively treated type 1 diabetic patients using blood glucose meters with storage capability and computer-assisted analyses. *Diabetes Care* 1998; **21**: 1694–1698.
- 7 Evans JMM, Newton RW, Ruta DA, MacDonald TM, Stevenson RJ, Morris AD. Frequency of blood glucose monitoring in relation to glycaemic control: observational study with diabetes. *Br Med J* 1999; **319**: 83–86.
- 8 Tuttleman M, Lipsett L, Harris MI. Attitudes and behaviors of primary care physicians regarding tight control of blood glucose in IDDM patients. *Diabetes Care* 1993; **16**: 765–772.
- 9 Graber AL, Davidson P, Brown AW, McRae JR, Woolridge K. Dropout and relapse during diabetes care. *Diabetes Care* 1992; **15**: 1477–1483.
- 10 Harris MI, Cowie CC, Howie LJ. Self-monitoring of blood glucose by adults with diabetes in the US population. *Diabetes Care* 1993; **16**: 1116–1123.
- 11 Gonder-Frederick LA, Julian DM, Cox DJ, Clarke WL, Carter WR. Self-measurement of blood glucose: accuracy of self-reported data and adherence to recommended regimen. *Diabetes Care* 1988; **11**: 579–585.
- 12 Pieber TR, Brunner GA, Schnedl WJ, Schattenberg S, Kaufmann P, Krejs GJ. Evaluation of a structured outpatient group education program for intensive insulin therapy. *Diabetes Care* 1995; **18**: 625–630.
- 13 Oki JC, Flora DL, Isley WL. Frequency and impact of SMBG on glycaemic control in patients with NIDDM in an urban teaching hospital clinic. *Diabetes Educ* 1997; **23**: 419–424.
- 14 Jones PM, Remley C, Engberg RA. Development and testing of the barriers to self-monitoring blood glucose scale. *Diabetes Educ* 1996; **22**: 609–616.
- 15 Karter AJ, Ferrara A, Darbinian JA, Ackerson LM, Selby JV. Self-monitoring of blood glucose: language and financial barriers in a managed care population with diabetes. *Diabetes Care* 2000; **23**: 477–483.
- 16 Dudl RJ, Biby C, Fordon S. A cost-beneficial control program with glucose self-monitoring. *Diabetes Care* 1982; **5**: 649–650.
- 17 Levine BS, Anderson BJ, Butler DA, Antisdell JE, Brackett J, Laffel LM. Predictors of glycaemic control and short-term adverse outcomes in youth with type 1 diabetes. *J Pediatr* 2001; **139**: 197–203.
- 18 Larsen ML, Horder M, Mogensen EF. Effect of long-term monitoring of glycosylated hemoglobin levels in insulin-dependent diabetes mellitus. *N Engl J Med* 1990; **323**: 1021–1025.

- 19 Faas A, Schellevis FG, Van Eijk JT. The efficacy of self-monitoring of blood glucose in NIDDM subjects: a criteria-based literature review. *Diabetes Care* 1997; **20**: 1482–1486.
- 20 Gallichan M. Self monitoring of glucose by people with diabetes: evidence based practice. *BMJ* 1997; **314**: 964–967.
- 21 Harris MI. Frequency of blood glucose monitoring in relation to glycemic control in patients with type 2 diabetes. *Diabetes Care* 2001; **24**: 979–982.
- 22 Schiel R, Muller UA, Rauchfub J, Sprott H, Muller R. Blood glucose self-monitoring in insulin treated type 2 diabetes mellitus: a cross-sectional study with an intervention group. *Diabetes Metab* 1999; **25**: 334–340.
- 23 Karter AJ, Ackerson LM, Darbinian JA, D'Agostino RB Jr, Ferrara A, Liu J *et al*. Self-monitoring of blood glucose levels and glycemic control: the Northern California Kaiser Permanente Diabetes Registry. *Am J Med* 2001; **111**: 1–9.