Blood glucose self-monitoring in type 2 diabetes: a randomised controlled trial


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Blood glucose self-monitoring in type 2 diabetes: a randomised controlled trial

AJ Farmer,1* AN Wade,2 DP French,3 J Simon,4 P Yudkin,1 A Gray,4 A Craven,1 L Goyder,5 RR Holman,6 D Mant,1 A-L Kinmonth7 and HAW Neil,8 on behalf of the DiGEM Trial Group

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The research reported in this issue of the journal was commissioned by the HTA Programme as project number 01/38/05. The contractual start date was in October 2002. The draft report began editorial review in August 2007 and was accepted for publication in September 2008. As the funder, by devising a commissioning brief, the HTA Programme specified the research question and study design. The authors have been wholly responsible for all data collection, analysis and interpretation, and for writing up their work. The HTA editors and publisher have tried to ensure the accuracy of the authors’ report and would like to thank the referees for their constructive comments on the draft document. However, they do not accept liability for damages or losses arising from material published in this report.

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Abstract

Blood glucose self-monitoring in type 2 diabetes: a randomised controlled trial

AJ Farmer,1* AN Wade,2 DP French,3 J Simon,4 P Yudkin,1 A Gray,4 A Craven,1 L Goyder,5 RR Holman,6 D Mant,1 A-L Kinmonth7 and HAW Neil,8 on behalf of the DiGEM Trial Group

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Objectives: To determine whether self-monitoring of blood glucose (SMBG), either alone or with additional instruction in incorporating the results into self-care, is more effective than usual care in improving glycaemic control in non-insulin-treated diabetes.

Design: An open, parallel group randomised controlled trial.

Setting: 24 general practices in Oxfordshire and 24 in South Yorkshire, UK.

Participants: Patients with non-insulin-treated type 2 diabetes, aged ≥25 years and with glycosylated haemoglobin (HbA1c) ≥6.2%.

Interventions: A total of 453 patients were individually randomised to one of: (1) standardised usual care with 3-monthly HbA1c (control, n = 152); (2) blood glucose self-testing with patient training focused on clinician interpretation of results in addition to usual care (less intensive self-monitoring, n = 150); (3) SMBG with additional training of patients in interpretation and application of the results to enhance motivation and maintain adherence to a healthy lifestyle (more intensive self-monitoring, n = 151).

Main outcome measures: The primary outcome was HbA1c at 12 months, and an intention-to-treat analysis, including all patients, was undertaken. Blood pressure, lipids, episodes of hypoglycaemia and quality of life, measured with the EuroQol 5 dimensions (EQ-5D), were secondary measures. An economic analysis was also carried out, and questionnaires were used to measure well-being, beliefs about use of SMBG and self-reports of medication taking, dietary and physical activities, and health-care resource use.

Results: The differences in 12-month HbA1c between the three groups (adjusted for baseline HbA1c) were not statistically significant (p = 0.12). The difference in unadjusted mean change in HbA1c from baseline to 12 months between the control and less intensive self-monitoring groups was −0.14% [95% confidence interval (CI) −0.35 to 0.07] and between the control and more intensive self-monitoring groups was −0.17% (95% CI −0.37 to 0.03). There was no evidence of a significantly different impact of self-monitoring on glycaemic control when comparing subgroups of patients defined by duration of diabetes, therapy, diabetes-related complications and EQ-5D score. The economic analysis suggested that SMBG resulted in extra health-care costs and was unlikely to be cost-effective if used routinely. There appeared to be an initial negative impact of SMBG on quality of life measured on the EQ-5D, and the potential additional lifetime gains in quality-adjusted life-years, resulting from the lower levels of risk factors achieved at the end of trial follow-up, were outweighed by these initial impacts for both SMBG groups compared with control. Some patients felt that SMBG was helpful, and there was evidence that those using more intensive self-monitoring perceived diabetes as having more serious consequences. Patients using SMBG were often not clear about the relationship...
Abstract

between their behaviour and the test results.

**Conclusions:** While the data do not exclude the possibility of a clinically important benefit for specific subgroups of patients in initiating good glycaemic control, SMBG by non-insulin-treated patients, with or without instruction in incorporating findings into self-care, did not lead to a significant improvement in glycaemic control compared with usual care monitored by HbA1c levels. There was no convincing evidence to support a recommendation for routine self-monitoring of all patients and no evidence of improved glycaemic control in predefined subgroups of patients.

**Trial registration:** Current Controlled Trials ISRCTN47464659.
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Supplementary material, the DiGEM Training Manual for Research Nurses and the DiGEM diaries used by participants, is available to download at www.hta.ac.uk/1330.
List of abbreviations

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<td>CI</td>
<td>confidence interval</td>
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<td>CSM</td>
<td>Common Sense Model</td>
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<td>DiGEM</td>
<td>Diabetes Glycaemic Education and Monitoring (trial)</td>
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<td>EQ-5D</td>
<td>EuroQol 5 dimensions</td>
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<td>HbA1c</td>
<td>glycosylated haemoglobin</td>
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<td>HDL</td>
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<td>ICER</td>
<td>incremental cost-effectiveness ratios</td>
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<td>QALY</td>
<td>quality-adjusted life-year</td>
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<td>SDSCA</td>
<td>summary of diabetes self-care activity</td>
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<tr>
<td>SMBG</td>
<td>self-monitoring of blood glucose</td>
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All abbreviations that have been used in this report are listed here unless the abbreviation is well known (e.g. NHS), or it has been used only once, or it is a non-standard abbreviation used only in figures/tables/appendices, in which case the abbreviation is defined in the figure legend or in the notes at the end of the table.
Executive summary

Introduction

Self-monitoring of blood glucose (SMBG) is a technology that is frequently incorporated into self-management interventions of diabetes, but has been separately evaluated in only a limited number of trials. Despite this lack of evidence, guidance is given to both support and discourage its use. Self-monitoring was used to guide insulin dose adjustment among individuals with type 1 diabetes in the Diabetes Control and Complications Trial (Epidemiology of Diabetes Interventions and Complications Study Research Group 2005). This trial demonstrated conclusively that tight glycaemic control reduced the risk of long-term complications. However, among non-insulin-treated patients with type 2 diabetes it is unclear whether self-monitoring is useful in providing personal feedback about the impact of changes in eating patterns and physical activity to support self-management. Self-monitoring of blood glucose is now widely accepted as part of the management of people with type 2 diabetes (European Diabetes Policy Group 1999, Blonde et al. 2002). The use of self-monitoring in this group of patients and the cost to health systems of the consumable test strips has become a major and increasing proportion of health-care budgets (Farmer and Neil 2004, Davidson 2005). We therefore set out to establish the benefit and cost-effectiveness of SMBG in the Diabetes Glycaemic Education and Monitoring (DiGEM) study.

Objectives

We report here the results of the DiGEM study – a trial designed to test whether self-monitoring of blood glucose, used with or without instruction in incorporating findings into self-management, can improve glycaemic control in non-insulin-treated diabetes compared with standardised usual care.

Methods

The DiGEM study was an open, parallel group randomised trial with an economic analysis, examination of impact on beliefs and self-reported behaviour, and a qualitative study to explore patient experiences. Participants were recruited from 48 general practices in Oxfordshire and South Yorkshire and were eligible if they had type 2 diabetes managed with diet or oral hypoglycaemic agents alone, were aged ≥25 years and had a glycosylated haemoglobin (HbA1c) ≥6.2%. Patients were randomised to (1) standardised usual care with 3-monthly HbA1c (control); (2) SMBG with patient training focused on clinician interpretation of results in addition to usual care (less intensive self-monitoring); and (3) SMBG with additional training of patients in interpretation and application of the results, to enhance motivation and maintain adherence to a healthy lifestyle (more intensive self-monitoring).

An intention-to-treat analysis was performed with the primary outcome of HbA1c at 12 months. Blood pressure, lipids, episodes of hypoglycaemia and quality of life measured with the EuroQol 5 dimensions (EQ-5D) were secondary measures. Further questionnaires were used to measure well-being, beliefs about use of SMBG and self-reports of medication taking, dietary and physical activities, and health-care resource use.

Results

Four hundred and fifty-three patients were randomised, with mean (standard deviation) HbA1c 7.5% (1.1). The differences in 12-month HbA1c between the three groups (adjusted for baseline HbA1c) were not statistically significant (p = 0.12). The difference in unadjusted mean change in HbA1c from baseline to 12 months between the control and less intensive self-monitoring groups was −0.14% [95% confidence interval (CI) −0.35 to 0.07] and between the control and more intensive self-monitoring groups was −0.17% (95% CI −0.37 to 0.03). No evidence was found of a significantly different impact of self-monitoring on glycaemic control when comparing subgroups of patients defined by duration of diabetes, therapy, diabetes-related complications and EQ-5D score.
Self-monitoring of blood glucose was found to be significantly more expensive than standardised usual care, by £92 and £84 for the less intensive SMBG and the more intensive SMBG groups respectively. There appears to be an initial negative impact of SMBG on quality of life measured on the EQ-5D. The potential additional lifetime gains in quality-adjusted life-years, resulting from the lower levels of risk factors achieved at the end of trial follow-up, were outweighed by the initial negative impacts for both SMBG groups compared with standardised usual care. Results of the extrapolation also suggest that the incremental lifetime savings in diabetes complications did not offset the additional intervention costs. The cost-utility analysis showed that it is unlikely that either investigated form of SMBG is cost-effective compared with standardised usual care.

In-depth interviews identified groups of patients who used SMBG to monitor impact of different lifestyle choices and motivate adherence to these choices. However, there were also patients who were not clear about the relationship between behaviour and test results or who experienced no improvement in test results after changing behaviour. Questionnaires about health-related beliefs did not identify an increase in perceived control over diabetes, but did find an increase in perceived seriousness of diabetes in the group carrying out more intensive self-monitoring.

Conclusions

We have found no convincing evidence to recommend routine use of SMBG by reasonably well-controlled, non-insulin-treated patients with type 2 diabetes. The specific advantages of monitoring identified by patients need to be placed in the context of a decline in compliance in the more intensive monitoring group and, at best, a small reduction in HbA1c. Neither the within-trial economic analysis nor the long-term modelling supports SMBG as a cost-effective intervention for all non-insulin-treated patients with type 2 diabetes. However, a clinically important benefit for specific subgroups of patients in initiating good glycaemic control cannot be excluded without further research.

Implications for practice

1. This trial does not provide convincing evidence to support the routine use of SMBG for non-insulin-treated patients with type 2 diabetes. However, our trial does not negate the established benefits of SMBG in insulin-treated patients, although further work is required to optimise its use.

2. Our in-depth interviews suggest that some individuals may benefit from SMBG use. However, with our present knowledge, we cannot clearly identify these patients, and clinical judgement is required to make this assessment in discussion with patients.

3. Our trial cannot exclude the possibility that SMBG may be helpful in non-insulin-treated type 2 diabetes patients with symptoms of hypoglycaemia; in those motivated to make alterations to behaviour that lead to consistent changes in blood glucose; and where there is strong patient preference.

4. If support for self-management training is available within usual care, then 3-monthly HbA1c management may be the optimum strategy. However, if HbA1c remains above 8%, then self-monitoring may provide motivation for medication adherence and lifestyle measures, as insulin therapy may be required in this group.

Research priorities

We have identified the following research priorities:

1. The qualitative element of the trial identifies a group of patients who consider that use of SMBG provides them with motivation to adopt and maintain behaviours that lead to better diabetes control. Further work is required to characterise those who gain most benefit in terms of glycaemic control and to determine whether this is related to use of the procedure.

2. Our results suggest that routine use of SMBG may not be appropriate for reasonably well-controlled patients; however, its role in the management of patients with less well-controlled diabetes is not clear. A pragmatic strategy of self-management education with HbA1c monitoring and intensifying drug therapy may be appropriate in the first instance. If glycaemic control is not then achieved, SMBG may be appropriate, first to explore any potential motivating effect, and second because insulin treatment is likely to be required. Exploration of the utility of this strategy may be useful.

3. There is an increased rate of hypoglycaemia reported among self-monitoring individuals.
Further exploration of the data is needed to establish whether these differences are likely to result from biochemical differences or greater awareness of hypoglycaemia as a cause of symptoms.

**Trial registration**

This trial is registered as ISRCTN47464659.
Chapter 1
Introduction

Background

The clinical problem

Diabetes is now a major public health problem. It is estimated that the number of people with diabetes will reach 330 million by 2030. The disease brings with it a considerable burden: people with diabetes have a two- to fourfold increased risk of stroke and heart disease compared with the general population, along with an appreciable risk of retinopathy, peripheral nerve damage and renal problems. There is now strong evidence for the effectiveness of tight glycaemic control in reducing complications among people with diabetes. However, support for self-management of diabetes to improve blood glucose levels has shown limited and transient success in improving glycosylated haemoglobin (HbA1c) levels.

The technology

Self-monitoring of blood glucose (SMBG) is a procedure used as the basis for insulin dose adjustment in the Diabetes Control and Complications Trial among people with type 1 diabetes, which clearly demonstrated the efficacy of tight glycaemic control in reducing diabetic complications. Self-monitoring for insulin-treated patients with type 2 diabetes is also generally accepted practice, although in both cases the frequency of testing and the algorithms for insulin adjustment need further evaluation. However, neither the rationale for SMBG nor its efficacy or effectiveness among non-insulin-treated patients with type 2 diabetes is clear. Yet SMBG is now widely accepted as a part of the management of patients with non-insulin-treated type 2 diabetes. The use of self-monitoring in this group of patients and the cost to health systems of the consumable test strips has become a major and increasing proportion of health-care budgets.

The majority of previous trials have used reflectance meters rather than biosensor technology. The older meters required larger quantities of blood and took longer to produce a reading than do current systems. Although, when used correctly, the older meters provided reliable results, in practice their accuracy and usability and thus potential impact were limited and may have formed a barrier to their effectiveness without high levels of motivation.

Target population

The majority of patients with diabetes treated in primary care who are not treated with insulin are within 5–10 years of diagnosis, have an average age of around 65 years, and are managed on a range of medications and lifestyle advice. Most have type 2 diabetes and are at risk from a range of macrovascular and microvascular diabetic complications. Large trials have confirmed the effectiveness of intensive glycaemic control in reducing these complications. Tight glycaemic control can be achieved by means of lifestyle changes and medications.

Comparators

It is now increasingly possible to monitor glycaemia by measurement of HbA1c using standardised assays with appropriate quality assurance. HbA1c measurements provide clinical standards for glycaemic control. For patients with non-insulin-requiring type 2 diabetes, initiation and titration of medication can be managed using HbA1c measurement. Recent consensus guidelines have therefore based recommendations for SMBG on its theoretical potential benefits for improving motivation for self-care activities through greater understanding of diabetes.

Limitations of previous research

Observational studies have been carried out in an attempt to explore the relationship between use of SMBG and diabetes outcomes, but results were inconsistent and, despite attempts to control for differences between groups, the possibility of confounding between attitudes to self-care and use of SMBG cannot be excluded.

Three systematic reviews have provided no evidence that self-monitoring is more effective in improving glycaemic control for people with type 2 diabetes than urine testing or measurement of HbA1c. The majority of trials identified in
these reviews have been carried out in small groups of patients. Participants were not recruited from representative populations in the community and the strategies for use of the results from SMBG were not clearly defined. Two more recent trials, set both in hospitals and in a family practice setting, have adopted a more structured approach to relating blood glucose measurements to subsequent management decisions, but in one of these trials over 30% of those randomised were lost to follow-up, and in a second trial standardised counselling supporting lifestyle modification was provided only to the self-monitoring group19 adhering to use of SMBG.19,20

Research on mediators of effect not investigated in trials

There are a small number of studies that offer some insight into how SMBG might improve blood glucose control in type 2 diabetes. Such monitoring may be helpful in titrating therapy by patients, practitioners or both. Evidence from qualitative studies suggests that awareness of fluctuations in blood glucose levels may promote adherence to self-care behaviours, medication taking, dietary advice and recommendations for physical activity in selected patients.21,22

There is accumulating research on diabetes self-management that uses psychological theory to guide intervention and measurement of the processes of behaviour change. One approach, the Common Sense Model (CSM),23 proposes that how people understand threats to their health is central in determining efforts to minimise these health threats. For instance, if people with type 2 diabetes do not believe that physical activity affects their blood glucose levels, they have little incentive to be more actively involved in managing their condition. Beliefs about illness can be categorised in terms of whether they relate to symptoms/identity, cause, consequences, time lines, and control and cure.23 In support of the CSM, previous research has shown that beliefs about the consequences and controllability of diabetes, and the perceived effectiveness of treatment,24–26 predict patient adherence to lifestyle advice. Furthermore, an intervention with myocardial infarction patients based on the CSM successfully managed to alter unhelpful beliefs, and led to a faster return to work and fewer symptoms in the intervention group.27 Further research using this approach to guide intervention and measures with people with type 2 diabetes may inform understanding of the potential mechanisms through which SMBG may improve health. However, it remains unclear whether regular monitoring is more effective than periodic measurement of HbA1c.

Our trial to establish the effectiveness of blood glucose monitoring offered the opportunity to incorporate measures of process based on the areas identified by the CSM as potential mediators of effect. The trial intervention was delivered so that beliefs about diabetes were elicited using a standard approach to help patients understand how diabetes might present a threat to their health.23 The roles of diet, physical activity and medication were discussed within the framework of the CSM of illness representation,23 in which we set out to optimise the use of glycaemic feedback to facilitate behaviour change by influencing beliefs. Selection of the behaviour change techniques was based on evidence for effectiveness, and included goal setting and review of physical activity and eating patterns to help patients with lifestyle change.28,29

In addition, a health economic analysis was included to ensure that cost-effectiveness could be evaluated. Finally, a qualitative study was included to allow identification of the range of responses to the interventions and to provide further information about the potential mechanisms through which the intervention might work.

Objectives

We report here the results of a trial designed to test whether SMBG, used with or without instruction in incorporating findings into self-care, can improve glycaemic control in non-insulin-treated diabetes compared with standardised usual care.
Chapter 2

Methods

Study design and patients

The Diabetes Glycaemic Education and Monitoring (DiGEM) study was a 4-year open, randomised, three-arm, parallel group trial with sequential recruitment from general practices in Oxfordshire and South Yorkshire. The trial was managed from the co-ordinating centre at the Department of Primary Health Care, University of Oxford following NHS R&D Health Technology Assessment Programme guidelines. The protocol was approved by the Oxfordshire B Research Ethics Committee, and registered with the International Standard Randomised Controlled Trial Number Register (ISRCTN47464659).

Our primary objective was to determine whether HbA1c at 12 months was significantly different between patients with non-insulin-treated type 2 diabetes receiving one of three allocated interventions: (1) standardised usual care with 3-monthly measurement of HbA1c by health professionals (control group); (2) use of a meter with training focused on clinician interpretation of results (less intensive self-monitoring); and (3) use of a meter with training in self-interpretation and application of the results to diet, physical activity and medication adherence (more intensive self-monitoring).

Between January 2003 and December 2005, 453 patients from 48 practices were randomised (see Figure 1) to receive standardised usual care \((n = 152)\), less intensive self-monitoring \((n = 150)\) or more intensive self-monitoring \((n = 151)\). The mean number of patients per practice recruited in 24 Oxfordshire practices and 24 South Yorkshire practices was 10.2 and 8.3 respectively.

Patients

Patients were eligible for randomisation if they had type 2 diabetes, were aged 25 years or more at diagnosis and were managed with diet or oral hypoglycaemic agents alone, if their HbA1c at the assessment visit was \(\geq 6.2\%\) and they were independent in activities of daily living. Exclusion criteria were: the use of a blood glucose monitor twice a week or more often over the previous 3 months; serious disease or limited life expectancy that would make intensive glycaemic control inappropriate; or inability to follow trial procedures.

Measures

The primary outcome was HbA1c at the 12-month visit. Secondary outcomes were blood pressure, weight, total cholesterol, total/high-density lipoprotein (HDL) cholesterol ratio and body mass index. HbA1c was measured using a Variant II Hemoglobin Testing System (Bio-Rad Laboratories, Hercules, CA, USA) certified by the US National Glycohemoglobin Standardization Program and comparable to the Diabetes Control and Complications Trial Standard with an inter-assay co-efficient of variation (CV) across the range of the assay of \(<2\%\). Cholesterol was assayed in local laboratories and results were aligned with the results of a sample of paired specimens analysed with an Olympus AU400 (Olympus, Tokyo, Japan) automated chemistry analyser, with an inter-assay CV across the range of \(<2\%\). Blood pressure was measured twice in the right arm, with the subject seated, using a UA-779 electronic blood pressure monitor (A&D Instruments Ltd, Abingdon, UK), and the mean of these values was analysed.

Frequency of blood glucose testing and episodes of hypoglycaemia were transcribed from patient-held diaries. Episodes of hypoglycaemia were categorised as grade 2 (mild symptoms requiring minor intervention), grade 3 (moderate symptoms requiring immediate third-party intervention) or grade 4 (unconscious). Increases in hypoglycaemic medication collected from practice computer systems were defined as an increase in the dose or frequency prescribed, progression from use of a single oral agent to combination oral therapy, or addition of insulin to the treatment regimen.

Additional demographic and clinical data on duration of diabetes, diabetes-related complications and EuroQol 5 dimensions (EQ-5D) score were collected to characterise the groups and to identify subgroups for predefined analysis.
Methods

Additional data collection for health economic, quality of life, and qualitative analyses will be detailed separately.

Randomisation

We used computerised randomisation incorporating a partial minimisation procedure to adjust the randomisation probabilities between groups to balance three important covariates collected at baseline: duration of diabetes, HbA1c and current treatment (diet, oral monotherapy or oral combination therapy). The minimisation procedure to assign patients to their allocated intervention was conducted independently of recruitment and research nurses. The allocation was concealed from laboratory staff.

Procedures

Patients suitable for trial inclusion were identified from lists held on computer by their general practitioners (GPs). Those eligible were sent an invitation to participate signed by their GP, accompanied by an information sheet and a reply-paid envelope to facilitate response. One further letter was sent if no response was received within 1 month.

Eligibility for the trial and willingness to be randomised to blood glucose self-testing were confirmed with a pre-assessment telephone call and at the assessment visit. At the assessment visit, following informed consent, beliefs about diabetes were elicited using a standard approach to help patients understand how diabetes might present a threat to their health. The roles of diet, physical activity and medication were discussed. Behaviour change techniques were selected on evidence for effectiveness, and included goal setting and review to help patients with lifestyle change. The goal-setting and review approach was continued in subsequent visits. Baseline blood tests and clinical measurements were taken and questionnaires completed at the assessment visit.

Interventions

Following the assessment visit and confirmation of eligibility, patients were allocated to receive one of the three interventions. Their rationale is described in more detail in a previous paper. The intervention was initiated at the first visit following randomisation and continued at the scheduled 1-, 3-, 6-, and 9-month visits. Each of the three interventions included a series of standardised components.

Patients allocated to the control (standardised usual care) intervention received further information about use of goal setting and review as a means of monitoring health-related behaviours, such as eating and physical activity. They were asked not to use a blood glucose meter unless their GP considered it essential for their clinical management. They were told that information about the success of the strategies used to keep blood glucose levels under control would be provided in the form of feedback on 3-monthly HbA1c test results. A diary was used to record self-care goals and strategies for achieving them.

Patients allocated to the less intensive self-monitoring intervention continued to use the goal-setting and review techniques introduced at the assessment visit. In addition, they were given a blood glucose meter. They were asked to record three values a day on 2 days during the week, one of which should be fasting, and the other two pre-meal or 2 hours post meal, and to aim for fasting and pre-meal glucose levels glucose of 4–6 mmol/l, and 2-hour post meal levels of 6–8 mmol/l. The nurses gave advice about the need to consider contacting their clinician if readings were consistently high (> 15 mmol/l) or low (< 4 mmol/l). They were not given information about how to interpret their blood glucose readings. Separate diaries were used to record identified goals and activity, and blood glucose results.

Patients allocated to the more intensive self-monitoring intervention continued to use goal setting and review and were also given a meter. In addition, they were given training and support in timing, interpreting and using the results of their blood glucose test results to enhance motivation and maintain adherence to diet, physical activity and medication regimens. They were encouraged to experiment with monitoring to explore the effect of specific activities such as exercise on their blood glucose, and to reflect on abnormal values in an attempt to identify what might have contributed to them. A single diary was used to record goals, activities and blood glucose results.

Follow-up visits differed in content according to the allocated intervention, in line with usual practice. Patients allocated to the control intervention had a blood test for HbA1c measurement 2 weeks before
their scheduled visit, which was then fed back to them as an indication of the impact of their self-care activities on their glycaemic control. HbA1c measurements were taken at the scheduled visit for those allocated to use of self-monitoring, but SMBG results were used to provide glycaemic feedback. Therefore, patients in each arm of the trial received feedback on glycaemic control, which was used to explore success of goals and set new ones. The patient’s GP was notified of all HbA1c results and asked to consider changes in medication in line with the National Institute for Clinical Excellence diabetes guidelines for all patients. The GP was also notified if blood glucose readings were consistently above 15 mmol/l.

Blood glucose meters were calibrated to provide plasma-equivalent results (Optium, Abbott Diabetes Care, Maidenhead, UK). Calibration of meters was checked by the research nurses using a test aliquot at baseline and 6 months.

Data on adverse reactions or complications were collected at each study visit, along with information about use of medication.

**Intervention delivery**

Training and support for the research nurses delivering the intervention were designed to ensure adherence to the study protocol. Research nurses were taught psychological theory, and were trained in behaviour change techniques and skills in delivering the intervention (6 days case-based training spread over 5 weeks). Intervention protocols included scripts of the topics to be covered to guide the nurses when talking to patients. Additional measures to ensure adherence to the intervention protocols included self-review of taped consultations by the research nurses and external review by a sociologist. Prompts were also built into the patient diaries to help patients adhere to their allocated intervention.

**Statistical analysis**

**Power calculations**

We aimed to detect a difference of 0.5% in HbA1c. We estimated a standard deviation (SD) of HbA1c of 1.5 based on a previous trial of patients with type 2 diabetes and a two-sided α of 0.05, took into account a loss to follow-up of 10% and planned a trial of 630 patients with 90% power. We revised the estimate of HbA1c SD to 1.25% after recruitment of the first 235 patients, when it became clear that it had been overestimated. We retained a 10% dropout and 90% power and revised the recruitment target to 450 patients.

**Analysis**

We conducted a single analysis of main trial end points at the end of the study. An intention-to-treat analysis using analysis of covariance was carried out to compare mean levels of HbA1c at 12-month follow-up between the three allocated groups, with baseline HbA1c as a covariate. If no follow-up data were available, we imputed values by carrying forward the last available measurement. We specified that, in the event of a statistically significant overall result, comparisons of the two self-monitoring groups independently with the control group would be conducted using t-tests. Levels of HbA1c over the course of the trial were compared between groups using a repeated measures analysis of variance.

We also estimated whether the intervention effect differed in subgroups defined at baseline: duration of diabetes (above or below median), current management (oral hypoglycaemic drugs or dietary management only), health status (above or below median EQ-5D score) and presence or absence of diabetes-related complications. Again, we used analysis of covariance with baseline HbA1c as a covariate. In addition, subgroup was included as a main effect in the model, and effect modification was assessed by the significance of the interaction term: subgroup × treatment.

A Kaplan–Meier plot was used to explore adherence to a minimal level of self-monitoring, defined as at least 26 tests over 3 months (equivalent to two tests each week); significance was assessed with a log-rank test. The mean number of tests performed by those carrying out at least 26 tests in each quarter was also reported, with differences between the less and more intensive self-monitoring groups compared using a repeated measures analysis of variance.

**Role of the funding source**

The trial was funded by grants from the NHS and the National Institute for Health Research (NIHR) Health Technology Assessment Programme, which nominated an independent chair of the trial steering committee, but had no role in data collection, analysis, interpretation or decision to
publish. As principal investigator, AJ Farmer had full access to the data and takes final responsibility for the data as presented in the manuscript. The views and opinions expressed in this report are not necessarily those of the Department of Health.
Chapter 3
Clinical outcomes

Principal results

Baseline demographic and clinical characteristics were well balanced between the groups (Table 1). The median (interquartile range) duration of diabetes was 3.0 (1.8–6.4) years, mean (SD) age was 65.7 (10.2) years and mean (SD) HbA1c was 7.5% (1.1). Only 57 (12.6%) patients were lost to follow-up and this did not differ between groups (Figure 1). HDL cholesterol measurements were not obtained for 39 patients at baseline. At follow-up, HbA1c measurements were not collected for two patients, blood pressure measurements were not obtained for five patients, cholesterol measurements were not obtained for 10 patients and HDL cholesterol measurements were not obtained for 15 patients.

Primary results

The main results are shown in Table 2. At 12 months, there was no difference in HbA1c between the groups adjusted for baseline (p = 0.12). The mean difference in HbA1c from baseline to 12 months between the control and less intensive self-monitoring groups (not adjusted for baseline) was −0.14% [95% confidence interval (CI) −0.35 to 0.07], and between the control and more intensive self-monitoring groups was −0.17% (95% CI −0.37 to 0.03). Figure 2 shows the change in HbA1c over the 12-month period of follow-up, with no evidence of differences in HbA1c between groups over the period of follow-up (p = 0.38).

Secondary outcomes

There was a significant difference in the change in total cholesterol between the three groups (p = 0.010). The mean difference in total cholesterol from baseline to 12 months between the control and less intensive self-monitoring groups (not adjusted for baseline) was −0.06 mmol/l (95% CI −0.26 to 0.14), and between the control and more intensive self-monitoring groups was −0.23 (95% CI −0.43 to −0.04). There were no differences in the other secondary outcome measures (see Table 2). Within the pre-specified subgroups there were no significant interactions with the allocated group (Table 3).

Hypoglycaemia

Over the duration of the trial, 14 patients in the control group, 33 patients in the less intensive group and 43 patients in the more intensive group experienced one or more grade 2 hypoglycaemic episodes (χ² = 18.3, p < 0.001). Only one patient in the control group experienced a grade 3 hypoglycaemic episode.

Use of meter

Patients allocated to less intensive self-monitoring were significantly more likely to persist with use of the meter than those allocated to more intensive monitoring. Ninety-nine (66.0%) of those receiving the less intensive intervention and 79 (52.3%) of those receiving the more intensive intervention continued to use the meter at least twice a week for the full 12 months (p = 0.012) (Figure 3). Among those who continued to use a meter, the mean number of readings over the period of the trial was significantly higher among patients receiving the more intensive intervention than among those receiving the less intensive intervention (p = 0.022) (Figure 4). In the control group, eight patients initiated SMBG.

Increases in hypoglycaemic and lipid-lowering medication

There were no between-group differences in the proportion of patients who were prescribed increased hypoglycaemic medication between baseline and 12 months. Medication was increased in 45 (29.6%) patients in the control group, 43 (28.7%) patients in the less intensive group and 48 (31.8%) patients in the more intensive group. One patient in the control group, four patients in the less intensive monitoring group and five patients in the more intensive monitoring group were using insulin therapy by 12 months.

There were no differences between groups in the proportion of patients in whom hydroxymethylglutaryl-coenzyme A (HMG-CoA) reductase inhibitor (statin) treatment was increased or added to therapy. The number of patients not taking a statin at baseline, but who were taking one by 12 months were 17 (11.2%) in the control
TABLE 1  Demographic and pre-intervention baseline characteristics by randomisation group [numbers are n (%) unless stated otherwise]

<table>
<thead>
<tr>
<th></th>
<th>No meter</th>
<th>Use of meter</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control group (n = 152)</td>
<td>Less intensive self-monitoring (n = 150)</td>
<td>More intensive self-monitoring (n = 151)</td>
<td></td>
</tr>
<tr>
<td><strong>Demographic characteristics</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age (years)</td>
<td>Mean (SD)</td>
<td>66.3 (10.2)</td>
<td>65.2 (10.6)</td>
<td>65.5 (9.9)</td>
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<tr>
<td>Gender</td>
<td>Male</td>
<td>85 (55.9)</td>
<td>88 (58.7)</td>
<td>87 (57.6)</td>
</tr>
<tr>
<td>Occupational group</td>
<td>Professional, managerial and clerical</td>
<td>80 (52.6)</td>
<td>81 (54.0)</td>
<td>84 (55.6)</td>
</tr>
<tr>
<td></td>
<td>Skilled manual/manual</td>
<td>69 (45.4)</td>
<td>68 (45.3)</td>
<td>66 (43.7)</td>
</tr>
<tr>
<td></td>
<td>No occupation stated</td>
<td>3 (2.0)</td>
<td>1 (0.7)</td>
<td>1 (0.7)</td>
</tr>
<tr>
<td>Age on leaving full-time education (years)</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>&lt; 17</td>
<td>109 (71.7)</td>
<td>114 (76.0)</td>
<td>121 (80.1)</td>
<td></td>
</tr>
<tr>
<td>17–18</td>
<td>20 (13.2)</td>
<td>14 (9.3)</td>
<td>13 (8.6)</td>
<td></td>
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<tr>
<td>&gt; 18</td>
<td>23 (15.1)</td>
<td>22 (14.7)</td>
<td>17 (11.3)</td>
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<td>Cigarette-smoking status</td>
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<td></td>
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<tr>
<td>Never smoked</td>
<td>58 (38.2)</td>
<td>54 (36.2)</td>
<td>54 (35.8)</td>
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<tr>
<td>Ex-smoker</td>
<td>80 (52.6)</td>
<td>74 (49.7)</td>
<td>77 (51.0)</td>
<td></td>
</tr>
<tr>
<td>Current smoker</td>
<td>14 (9.2)</td>
<td>21 (14.1)</td>
<td>20 (13.2)</td>
<td></td>
</tr>
<tr>
<td><strong>Diabetes duration and treatment</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Duration of diabetes (months)</td>
<td>Median (Q1, Q3)</td>
<td>36 (24, 72)</td>
<td>36 (18, 84)</td>
<td>36 (19, 72)</td>
</tr>
<tr>
<td>Therapy</td>
<td>Diet only</td>
<td>44 (28.9)</td>
<td>39 (26.0)</td>
<td>41 (27.2)</td>
</tr>
<tr>
<td></td>
<td>Monotherapy</td>
<td>57 (37.5)</td>
<td>58 (38.7)</td>
<td>58 (38.4)</td>
</tr>
<tr>
<td></td>
<td>Combined oral therapy</td>
<td>51 (33.6)</td>
<td>53 (35.3)</td>
<td>52 (34.4)</td>
</tr>
<tr>
<td>Diabetes-related complications</td>
<td>Present</td>
<td>32 (21.1)</td>
<td>32 (21.3)</td>
<td>39 (25.8)</td>
</tr>
<tr>
<td>Use of blood glucose meter</td>
<td>Not using</td>
<td>104 (68.4)</td>
<td>110 (73.3)</td>
<td>102 (67.5)</td>
</tr>
<tr>
<td></td>
<td>Using ≤ once per week</td>
<td>48 (31.6)</td>
<td>40 (26.7)</td>
<td>49 (32.5)</td>
</tr>
<tr>
<td><strong>Physical and laboratory findings</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HbA1c (%)</td>
<td>Mean (SD)</td>
<td>7.49 (1.09)</td>
<td>7.41 (1.02)</td>
<td>7.53 (1.12)</td>
</tr>
<tr>
<td>Total cholesterol (mmol/l)</td>
<td>Mean (SD)</td>
<td>4.7 (1.1)</td>
<td>4.6 (1.1)</td>
<td>4.7 (1.1)</td>
</tr>
<tr>
<td>Blood pressure (mmHg)</td>
<td>Systolic, mean (SD)</td>
<td>140.0 (18.1)</td>
<td>140.7 (17.0)</td>
<td>137.4 (18.3)</td>
</tr>
<tr>
<td></td>
<td>Diastolic, mean (SD)</td>
<td>79.6 (10.1)</td>
<td>79.9 (10.1)</td>
<td>77.9 (9.9)</td>
</tr>
<tr>
<td>Body mass index (kg/m)</td>
<td>Mean (SD)</td>
<td>30.9 (6.1)</td>
<td>31.9 (6.2)</td>
<td>31.0 (5.3)</td>
</tr>
</tbody>
</table>
group, 11 (7.3%) in the less intensive group and 19 (12.6%) in the more intensive group.

**Loss to follow-up and deaths**

Losses to follow-up are identified in Figure 1. The number of patients who withdrew consent was eight in the control group, eight in the less intensive monitoring group and 16 in the more intensive monitoring group. Reasons given were similar in each category, including ‘unable to comply with protocol’, ‘does not like using the meter’, ‘withdrawn due to family commitments’ and ‘too busy to continue with study’. We were unable to contact eight patients in the control group, two in the less intensive group and four in the more intensive group. One patient in each group was too ill to continue participating. One patient died in the control group (B-cell lymphoma), three died in the less intensive group (chest infection, biliary duct carcinoma and acute myocardial infarction), and four died in the more intensive group (multiple organ failure, hypertensive heart disease, ischaemic heart disease and chest infection).
**TABLE 2** Changes in HbA1c, blood pressure, weight, cholesterol and body mass index between baseline and 1 year [numbers are mean (SD)]

<table>
<thead>
<tr>
<th></th>
<th>No meter</th>
<th>Use of meter</th>
<th>Use of meter</th>
<th>p-value for difference between groups&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control group (n = 152)</td>
<td>Less intensive self-monitoring (n = 150)</td>
<td>More intensive self-monitoring (n = 151)</td>
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<tr>
<td>HbA1c (%)</td>
<td>Baseline 7.49 (1.09)</td>
<td>7.41 (1.02)</td>
<td>7.53 (1.12)</td>
<td>0.12</td>
</tr>
<tr>
<td></td>
<td>Follow-up 7.49 (1.20)</td>
<td>7.28 (0.88)</td>
<td>7.36 (1.05)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Change -0.00 (1.02)</td>
<td>-0.14 (0.82)</td>
<td>-0.17 (0.73)</td>
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</tr>
<tr>
<td>Systolic blood pressure (mmHg)</td>
<td>Baseline 140.0 (18.1)</td>
<td>140.7 (17.0)</td>
<td>137.4 (18.3)</td>
<td>0.77</td>
</tr>
<tr>
<td></td>
<td>Follow-up 136.2 (17.8)</td>
<td>137.3 (16.8)</td>
<td>134.1 (17.2)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Change -3.8 (14.0)</td>
<td>-3.4 (15.6)</td>
<td>-3.3 (13.6)</td>
<td></td>
</tr>
<tr>
<td>Diastolic blood pressure (mmHg)</td>
<td>Baseline 79.6 (10.1)</td>
<td>79.9 (10.1)</td>
<td>77.9 (9.9)</td>
<td>0.67</td>
</tr>
<tr>
<td></td>
<td>Follow-up 77.1 (9.7)</td>
<td>77.8 (9.6)</td>
<td>75.8 (9.5)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Change -2.5 (8.5)</td>
<td>-2.1 (8.8)</td>
<td>-2.1 (7.5)</td>
<td></td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>Baseline 86.7 (18.9)</td>
<td>90.4 (18.9)</td>
<td>86.9 (16.4)</td>
<td>0.37</td>
</tr>
<tr>
<td></td>
<td>Follow-up 86.4 (19.4)</td>
<td>89.9 (19.0)</td>
<td>86.1 (15.7)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Change -0.3 (2.7)</td>
<td>-0.5 (2.6)</td>
<td>-0.8 (3.3)</td>
<td></td>
</tr>
<tr>
<td>Total cholesterol (mmol/l)</td>
<td>Baseline 4.73 (1.02)</td>
<td>4.64 (1.11)</td>
<td>4.67 (1.07)</td>
<td>0.010</td>
</tr>
<tr>
<td></td>
<td>Follow-up 4.56 (1.03)</td>
<td>4.42 (0.95)</td>
<td>4.28 (0.84)</td>
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</tr>
<tr>
<td></td>
<td>Change -0.16 (0.84)</td>
<td>-0.22 (0.93)</td>
<td>-0.40 (0.90)</td>
<td></td>
</tr>
<tr>
<td>Total/HDL cholesterol ratio&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Baseline 4.33 (1.12)</td>
<td>4.40 (1.33)</td>
<td>4.48 (1.35)</td>
<td>0.013</td>
</tr>
<tr>
<td></td>
<td>Follow-up 4.18 (1.12)</td>
<td>4.11 (1.17)</td>
<td>4.02 (1.17)</td>
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</tr>
<tr>
<td></td>
<td>Change -0.15 (0.72)</td>
<td>-0.29 (0.86)</td>
<td>-0.46 (0.91)</td>
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</tr>
<tr>
<td>Body mass index (kg/m&lt;sup&gt;2&lt;/sup&gt;)</td>
<td>Baseline 30.9 (6.1)</td>
<td>31.9 (6.2)</td>
<td>31.0 (5.3)</td>
<td>0.41</td>
</tr>
<tr>
<td></td>
<td>Follow-up 30.8 (6.3)</td>
<td>31.8 (6.3)</td>
<td>30.7 (5.0)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Change -0.1 (1.0)</td>
<td>-0.2 (0.9)</td>
<td>-0.3 (1.2)</td>
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</table>

HDL, high-density lipoprotein.

<sup>a</sup> p-value for difference after adjustment for baseline.

<sup>b</sup> Based on 414 participants with paired values (137/152, 136/150, 141/151).

Change is measured as 1-year follow-up minus baseline.
FIGURE 2 Change in HbA1c over the duration of the trial.

FIGURE 3 Adherence to a minimal level of self-monitoring.

FIGURE 4 Frequency of self-monitoring by randomisation group.
### TABLE 3  Changes in HbA1c (%) between baseline and 1 year by subgroup [numbers are mean (SD)]

<table>
<thead>
<tr>
<th>Number at baseline</th>
<th>No meter</th>
<th>Use of meter</th>
<th></th>
<th></th>
<th>p-value for interactiona</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control group</td>
<td>152</td>
<td>150</td>
<td>151</td>
<td>0.82</td>
<td></td>
</tr>
<tr>
<td><strong>Duration of diabetes</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤ Medianb</td>
<td>Baseline</td>
<td>7.29 (1.02)</td>
<td>7.35 (1.02)</td>
<td>7.41 (1.03)</td>
<td>0.82</td>
</tr>
<tr>
<td></td>
<td>Follow-up</td>
<td>7.30 (1.24)</td>
<td>7.23 (0.93)</td>
<td>7.25 (1.01)</td>
<td>0.01 (0.03)</td>
</tr>
<tr>
<td>&gt; Median</td>
<td>Baseline</td>
<td>7.70 (1.13)</td>
<td>7.48 (1.02)</td>
<td>7.67 (1.20)</td>
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<tr>
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<td>Follow-up</td>
<td>7.70 (1.11)</td>
<td>7.33 (0.84)</td>
<td>7.49 (1.08)</td>
<td>0.01 (1.01)</td>
</tr>
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<td><strong>Baseline therapy</strong></td>
<td></td>
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<tr>
<td>Diet only</td>
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<td>7.18 (0.98)</td>
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<td>7.09 (0.94)</td>
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<tr>
<td>Oral drug therapy</td>
<td>Baseline</td>
<td>7.61 (1.11)</td>
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<td>7.66 (1.10)</td>
<td>0.01 (1.01)</td>
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<td></td>
<td>Follow-up</td>
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<td>7.46 (1.07)</td>
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</tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>&gt; Median</td>
<td>Baseline</td>
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<td>7.22 (0.76)</td>
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<td>0.07 (0.99)</td>
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<tr>
<td>≤ Median</td>
<td>Baseline</td>
<td>7.54 (1.16)</td>
<td>7.50 (1.09)</td>
<td>7.34 (0.80)</td>
<td>0.01 (1.14)</td>
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<td>7.37 (1.04)</td>
<td>7.14 (0.78)</td>
<td>0.01 (1.14)</td>
</tr>
<tr>
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</tr>
<tr>
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<td>Baseline</td>
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<td>7.51 (1.09)</td>
<td>7.71 (1.19)</td>
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<td>7.32 (0.92)</td>
<td>7.43 (1.13)</td>
<td>0.05 (1.02)</td>
</tr>
<tr>
<td>Yes</td>
<td>Baseline</td>
<td>7.32 (1.02)</td>
<td>7.07 (0.63)</td>
<td>7.00 (0.64)</td>
<td>0.20 (1.02)</td>
</tr>
<tr>
<td></td>
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<td>7.12 (0.73)</td>
<td>7.16 (0.73)</td>
<td>0.20 (1.02)</td>
</tr>
</tbody>
</table>

EQ-5D, EuroQol 5 dimensions.
a p-value for interaction after adjustment for baseline.
b Median value duration of diabetes 36 months.
c Median EQ-5D score 0.814. Paired data for EQ-5D score available for 384 patients; this section based only on these patients.
Chapter 4
Economic analysis

Methods

A cost–utility analysis was undertaken from a health-care perspective. The within-trial analysis estimated the total health-care costs and quality-adjusted life-years (QALYs) per patient for the 12-month trial period in each of the three groups: (1) standardised usual care, (2) less intensive SMBG and (3) more intensive SMBG; and then calculated the incremental total health-care costs and QALYs gained per patient of (1) less intensive SMBG compared with standardised usual care and (2) more intensive SMBG compared with standardised usual care. The effects of the changes in the main risk factors observed in the 12-month trial period on life expectancy, quality-adjusted life expectancy and diabetes complication costs were extrapolated to a lifetime horizon using the UK Prospective Diabetes Study (UKPDS) Outcomes Model.36

Resource use

Data were collected on relevant health-care resource use during the 12-month period prior to study baseline at the recruitment visit (C2). The intervention was delivered at a visit 2 weeks later (C3) and reviewed at a visit 1 month later (C4). Further resource data were collected at subsequent follow-up visits at 3 months (C5), 6 months (C6), 9 months (C7) and 12 months (C8) during the trial period. Information was obtained on SMBG, nurse visits, medications and other health-care resource use including primary care, hospital care, and auxiliary (such as podiatry, optician and dietician services) and private health care, by means of a specific health service use questionnaire, patients' blood glucose monitoring diaries and nurse notes. The recorded lengths of nurse visits were adjusted to exclude resource use elements that were strictly trial related, such as trial administration and blood taking. Questionnaire information was supplemented by data from the patients' medical records where available. Measurement of the length of nurse contacts was carried out on a subset of patients which varied between 64% and 68% of all attended visits and was balanced between the groups. For missing information on SMBG and medication use, the last known value was carried forward. Randomly missing data in other resource use categories were computed in STATA 937 by multiple imputation conditional on randomisation group, age, gender, duration of diabetes and comorbidity. Imputation of unavailable data on the length of nurse contacts was based on the adjusted values and was conditional on the type of contact and the randomisation group.

Costs

Costs were calculated by multiplying the product of each resource use category by its associated UK national level unit cost in 2005–6 prices (Table 4). Average costs were estimated in each arm of the study for the 12-month period prior to study baseline and the 12-month follow-up period of the trial. Each resource use item was then categorised as contributor to the cost of intervention (including nurse intervention and SMBG), the cost of medication or the cost of 'other health-care resource use' (including primary care, hospital care or auxiliary health care) (see Table 4). Mean intervention and medication costs were calculated across all patients in each arm of the study. Mean costs of 'other health-care use' were censored for patients who were lost to follow-up.

Changes in mean costs between baseline and 12-month follow-up were calculated for each treatment group. For the incremental analysis between the treatment groups, follow-up costs were adjusted for baseline variations by regression analysis. For censored cost items, the difference in changes between the pre-baseline and follow-up periods was used for this purpose.

Outcomes

The impact of SMBG on quality of life was estimated using the EQ-5D at baseline and at 12 months.38 The distribution of EQ-5D responses across the different levels of each dimension was calculated for complete cases, and differences between treatment groups were analysed using a categorical chi-squared test. Mean utility values were derived using the UK 'tariff'38 both for complete cases and for a full data set, where missing values were replaced by conditional multiple imputation in STATA 9.37 Changes in
### TABLE 4 Resource use categories measured and their unit costs (2005–6 prices)

<table>
<thead>
<tr>
<th>Unit</th>
<th>Cost</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Intervention</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nurse per hour of client contact</td>
<td>26</td>
<td>Curtis and Netten 2006^9</td>
</tr>
<tr>
<td>Meter</td>
<td>17.50</td>
<td>British Medical Association 2006^40</td>
</tr>
<tr>
<td>Lancets (100)</td>
<td>3.40</td>
<td>British Medical Association 2006^40</td>
</tr>
<tr>
<td>Test strips (50)</td>
<td>17.50</td>
<td>British Medical Association 2006^40</td>
</tr>
<tr>
<td><strong>Medication</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oral medication per prescription</td>
<td>See source</td>
<td>Department of Health 2007^41</td>
</tr>
<tr>
<td>Insulin per unit</td>
<td>See source</td>
<td>British Medical Association 2006^40</td>
</tr>
<tr>
<td>Dispensing fee</td>
<td>1.54^a</td>
<td>Department of Health 2007^41</td>
</tr>
<tr>
<td><strong>Other health care</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Primary care</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GP per visit: surgery</td>
<td>21</td>
<td>Curtis and Netten 2006^9</td>
</tr>
<tr>
<td>GP per visit: home</td>
<td>60</td>
<td>Curtis and Netten 2006^9</td>
</tr>
<tr>
<td>Nurse per visit: surgery</td>
<td>8</td>
<td>Curtis and Netten 2006^9</td>
</tr>
<tr>
<td>Nurse per visit: home</td>
<td>11</td>
<td>Curtis and Netten 2006^9</td>
</tr>
<tr>
<td><strong>Hospital care</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A&amp;E care per episode</td>
<td>85^a</td>
<td>National Health Service 2007^42</td>
</tr>
<tr>
<td>Outpatient care per episode</td>
<td>96^a</td>
<td>Netten and Curtis 2002^45</td>
</tr>
<tr>
<td>Day hospital care per episode</td>
<td>100^a</td>
<td>Netten and Curtis 2002^43</td>
</tr>
<tr>
<td>Inpatient care per day: medical</td>
<td>269^a</td>
<td>National Health Service 2007^42</td>
</tr>
<tr>
<td>Inpatient care per day: surgical</td>
<td>496^a</td>
<td>National Health Service 2007^42</td>
</tr>
<tr>
<td>Inpatient care per day: other</td>
<td>288^a</td>
<td>National Health Service 2007^42</td>
</tr>
<tr>
<td><strong>Auxiliary health care</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dietician per session</td>
<td>35</td>
<td>Department of Health 2007^44</td>
</tr>
<tr>
<td>Optician per session</td>
<td>18.39</td>
<td>Department of Health 2004^10</td>
</tr>
<tr>
<td>Podiatrist per session: NHS</td>
<td>31</td>
<td>Department of Health 2007^44</td>
</tr>
<tr>
<td>Podiatrist per session: private</td>
<td>50</td>
<td>Department of Health 2007^44</td>
</tr>
<tr>
<td>Private/allied health-care professional per session</td>
<td>49^b</td>
<td>Obtained from relevant agencies</td>
</tr>
</tbody>
</table>

A&E, accident and emergency.  
^a Inflated to year 2005–6 from the published cost using the Department of Health’s Pay and Price Inflation Indices^9  
^b Average of unit costs.

Mean utility values between baseline and 12-month follow-up and baseline-adjusted 12-month utility differences between treatment groups were calculated and analysed using standard parametric techniques.

For the economic analysis, within-trial survival times were weighted by the average change in quality of life between baseline and end-of-trial utility values to estimate QALYs gained for each patient during the study period.45

**Lifetime extrapolation**

Lifetime extrapolation of the clinical results was carried out using the UKPDS Outcomes Model.56 The Outcomes Model is a computer simulation model for forecasting quality-adjusted life
Expectancy and other outcomes of people with type 2 diabetes. It involves probabilistic discrete-time computer simulation and is based on an integrated system of parametric proportional hazards risk equations developed using patient-level data from the large UKPDS trial. The equations estimate the probability of occurrence of different complications given risk factors such as patient’s age, sex, duration of diabetes, systolic blood pressure, HbA1c, lipid levels and smoking status. Costs and utility decrements associated with these complications are also summed within the model. The model was used to assess the long-term impact of the disease on morbidity and mortality, and to estimate health-care costs associated with the disease with or without the interventions for patients in each treatment group of the DiGEM trial. For this, both costs and outcomes were discounted at a 3.5% annual rate.

Cost-effectiveness

The long-term cost and QALY projections were added to the within-trial results to estimate the overall lifetime effects of the interventions. The differences in mean costs were then divided by the differences in mean QALYs between the two SMBG groups and the standardised usual care group to calculate the incremental cost-effectiveness ratios (ICERs).

Uncertainty

Within-trial results are reported as means, together with their SDs or standard errors, and as changes/differences, together with their 95% CIs to address uncertainty. These summary statistics were calculated and analysed using standard parametric techniques, except for censored cost items where non-parametric bootstrapping was used. For the extrapolation, Monte Carlo uncertainty was eliminated by performing 10,000 repeated simulations in the model.

Non-parametric bootstrapping was used to demonstrate the uncertainty around the point estimate of the ICERs. The probability that SMBG is cost-effective compared with standardised usual care is illustrated by cost-effectiveness acceptability curves.

Results

Resource use and costs

The mean length of nurse visits differed significantly between the three interventions to which patients were allocated (Table 5). Visits C3 and C4 were shorter for the standardised usual care group than for the SMBG groups, and C2 and C5 were longer for the more intensive SMBG group than for the other two groups.

Costs

Intervention and medication costs

The intervention and medication cost results are summarised in Table 6. The 12-month cost of SMBG is similar (£96 versus £89) in both self-monitoring groups. Nurse time spent on standardised patient care is significantly greater in both SMBG groups than in the control group. The additional cost per patient over 1 year (including 10% opportunity cost for non-attended visits), however, is minor: £6 (95% CI 1–11) in the less intensive SMBG group and £5 (95% CI 0–10) in the more intensive SMBG group. The differences in overall intervention costs were statistically significant: £92 (95% CI 80–103) between less intensive SMBG and standard usual care and £84 (95% CI 73–96) between more intensive SMBG and standard usual care.

A substantial increase in overall medication costs (£70–98) compared with baseline is evident in all three groups. Although there is some indication that more patients started on insulin in the more and less intensive SMBG groups than in the control group (5, 4 and 1 patients respectively), no significant differences were found in the overall cost of diabetes medications between patients using SMBG and those receiving standardised usual care.

Other health-care costs

Table 7 summarises details of ‘other health-care costs’ by resource use items based on the available data. Nine patients (2%) had at least one ‘other health-care resource use’ item missing for the pre-baseline period and 76 patients (17%) had incomplete data over the 12-month follow-up. Table 8 presents the results of the ‘other health-care costs’ analysis after imputing randomly missing data and censoring for patients who were lost to follow-up, together with the total health-care cost estimates, which include the intervention and medication costs.
TABLE 5  Mean length of attended nurse visits (SD) per patient

<table>
<thead>
<tr>
<th>Visit</th>
<th>Available data Unadjusted for trial related-factors</th>
<th>Available data Adjusted for trial-related factors</th>
<th>Imputed full data set Adjusted for trial-related factors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Minutes n</td>
<td></td>
<td>Minutes n</td>
</tr>
<tr>
<td>Control group</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C2</td>
<td>53 (13) 104</td>
<td>29 (7) 104</td>
<td>28 (6) 152</td>
</tr>
<tr>
<td>C3</td>
<td>42 (14) 96</td>
<td>39 (13) 96</td>
<td>41 (11) 145</td>
</tr>
<tr>
<td>C4</td>
<td>32 (14) 92</td>
<td>33 (15) 92</td>
<td>35 (13) 138</td>
</tr>
<tr>
<td>C5</td>
<td>35 (11) 96</td>
<td>30 (10) 96</td>
<td>30 (8) 133</td>
</tr>
<tr>
<td>C6</td>
<td>37 (12) 85</td>
<td>32 (10) 84</td>
<td>33 (8) 129</td>
</tr>
<tr>
<td>C7</td>
<td>39 (13) 80</td>
<td>34 (11) 79</td>
<td>33 (9) 124</td>
</tr>
<tr>
<td>Less intensive self-monitoring</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C2</td>
<td>51 (12) 104</td>
<td>27 (6) 104</td>
<td>26 (5) 150</td>
</tr>
<tr>
<td>C3</td>
<td>52 (13) 105</td>
<td>48 (12) 101</td>
<td>50 (11) 140</td>
</tr>
<tr>
<td>C4</td>
<td>42 (14) 91</td>
<td>39 (13) 90</td>
<td>38 (10) 138</td>
</tr>
<tr>
<td>C5</td>
<td>46 (14) 90</td>
<td>32 (10) 90</td>
<td>32 (8) 139</td>
</tr>
<tr>
<td>C6</td>
<td>49 (13) 88</td>
<td>32 (9) 88</td>
<td>32 (7) 131</td>
</tr>
<tr>
<td>C7</td>
<td>46 (13) 86</td>
<td>32 (9) 86</td>
<td>33 (8) 122</td>
</tr>
<tr>
<td>More intensive self-monitoring</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C2</td>
<td>54 (13) 94</td>
<td>30 (7) 94</td>
<td>29 (6) 151</td>
</tr>
<tr>
<td>C3</td>
<td>56 (17) 98</td>
<td>52 (16) 94</td>
<td>51 (13) 140</td>
</tr>
<tr>
<td>C4</td>
<td>43 (17) 82</td>
<td>40 (16) 82</td>
<td>40 (13) 125</td>
</tr>
<tr>
<td>C5</td>
<td>49 (14) 86</td>
<td>35 (10) 86</td>
<td>35 (8) 128</td>
</tr>
<tr>
<td>C6</td>
<td>53 (14) 70</td>
<td>36 (9) 70</td>
<td>34 (8) 118</td>
</tr>
<tr>
<td>C7</td>
<td>49 (13) 74</td>
<td>35 (9) 74</td>
<td>33 (8) 113</td>
</tr>
</tbody>
</table>

C2, assessment visit; C3, initial intervention delivery; C4, 1-month follow-up; C5, 3-month follow-up; C6, 6-month follow-up; C7, 9-month follow-up.

Trial-related factors include trial administration and blood taking unrelated to patient care and the 12-month follow-up visit (C8) which is not reported here.

There was a non-significant increase in the ‘other health-care costs’ between the pre-baseline and the follow-up periods, averaging approximately £100–150 per patient in each group, which was attributable mainly to additional hospitalisation.

Total mean health-care costs per patient (see Table 8), including medications, intervention costs and other health-care costs, averaged £1042 for standardised usual care, £1048 for less intensive SMBG and £1145 for more intensive SMBG over the 12-month period prior to baseline. They increased by about £300–400 over the trial period to £1371, £1434 and £1482 respectively. There were no statistically significant differences between the groups.

In summary, only the intervention costs differed significantly between the control group and the two SMBG groups. All other cost changes during the trial follow-up compared with the 12-month period prior to baseline were similar between the groups.

Outcomes

Within-trial outcomes

Table 9 summarises the results of both the complete case-based and the imputed full data set-based EQ-5D utility analyses. Three hundred and thirteen patients (69%) completed the whole EQ-5D questionnaire both at baseline and at 12-month follow-up. There was no significant change during the trial in the mean utility per patient for the standardised usual care group. In contrast, both SMBG groups showed a reduction in their quality of life, and this reached statistical significance for the more intensive monitoring group. As there was some imbalance between the groups at baseline, follow-up results were adjusted for this variation using standard parametric techniques for
<table>
<thead>
<tr>
<th></th>
<th>1 Control group (n = 152)</th>
<th>2 Less intensive self-monitoring (n = 150)</th>
<th>3 More intensive self-monitoring (n = 151)</th>
<th>Difference</th>
</tr>
</thead>
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<td>12 months pre-baseline</td>
<td>12-month follow-up Change</td>
<td>12 months pre-baseline</td>
<td>12-month follow-up Change</td>
</tr>
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<td>Insulin</td>
<td>0 (0)</td>
<td>0.3 (4.0)</td>
<td>0.3 [−0.3 to 1.0]</td>
<td>0 (0)</td>
</tr>
</tbody>
</table>

a. p < 0.05.
TABLE 7  Mean 'other health-care' costs (SD) per patient (£, 2005–6 prices): available cases

<table>
<thead>
<tr>
<th>Control group (n = 152)</th>
<th>Less intensive self-monitoring (n = 150)</th>
<th>More intensive self-monitoring (n = 151)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12 months pre-baseline</td>
<td>12-month follow-up</td>
<td>12 months pre-baseline</td>
</tr>
<tr>
<td></td>
<td>12-month follow-up</td>
<td>12-month follow-up</td>
</tr>
<tr>
<td></td>
<td>12-month follow-up</td>
<td>12-month follow-up</td>
</tr>
<tr>
<td>n</td>
<td>Cost</td>
<td>n</td>
</tr>
<tr>
<td>148</td>
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<td>148</td>
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<td>129</td>
<td>774 (1612)</td>
<td>131</td>
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<tr>
<td>Other health care</td>
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<td>148</td>
</tr>
<tr>
<td>GP surgery</td>
<td>152 111 (87)</td>
<td>150 110 (93)</td>
</tr>
<tr>
<td>GP home</td>
<td>135 8 (34)</td>
<td>139 8 (25)</td>
</tr>
<tr>
<td>Nurse surgery</td>
<td>134 98 (84)</td>
<td>139 8 (30)</td>
</tr>
<tr>
<td>Nurse home</td>
<td>152 8 (33)</td>
<td>139 8 (25)</td>
</tr>
<tr>
<td>Hospital care</td>
<td></td>
<td>150 8 (93)</td>
</tr>
<tr>
<td>A&amp;E</td>
<td>152 10 (31)</td>
<td>138 9 (31)</td>
</tr>
<tr>
<td>Outpatient</td>
<td>152 133 (243)</td>
<td>138 16 (41)</td>
</tr>
<tr>
<td>Day hospital</td>
<td>152 9 (31)</td>
<td>151 32 (23)</td>
</tr>
<tr>
<td>Inpatient</td>
<td>152 172 (674)</td>
<td>137 14 (46)</td>
</tr>
<tr>
<td>Auxiliary health care</td>
<td></td>
<td>152 269 (1020)</td>
</tr>
<tr>
<td>Dietician</td>
<td>151 5 (18)</td>
<td>137 3 (16)</td>
</tr>
<tr>
<td>Optician</td>
<td>151 17 (10)</td>
<td>151 9 (37)</td>
</tr>
<tr>
<td>Podiatrist: NHS</td>
<td>149 34 (55)</td>
<td>151 17 (7)</td>
</tr>
<tr>
<td>Podiatrist: private</td>
<td>152 43 (132)</td>
<td>151 43 (90)</td>
</tr>
<tr>
<td>Private health care</td>
<td>152 19 (71)</td>
<td>151 26 (97)</td>
</tr>
</tbody>
</table>

A&E, accident and emergency.
### TABLE 8  Mean 'other health-care' costs (SE) and cost differences [95% CI] per patient (£, 2005–6 prices)

<table>
<thead>
<tr>
<th></th>
<th>1 Control group (n = 152)</th>
<th>2 Less intensive self-monitoring (n = 150)</th>
<th>3 More intensive self-monitoring (n = 151)</th>
<th>Difference 2 vs 1</th>
<th>Difference 3 vs 1</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Other health care</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12 months pre-baseline</td>
<td>596 (66)</td>
<td>567 (74)</td>
<td>693 (120)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12-month follow-up</td>
<td>747 (130)</td>
<td>676 (77)</td>
<td>786 (145)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Change</td>
<td>151 [−77 to 431]</td>
<td>[−93 to 297]</td>
<td>93 [−173 to 347]</td>
<td>−41 [−396 to 257]</td>
<td>−57 [−447 to 288]</td>
</tr>
<tr>
<td><strong>Primary care</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GP surgery</td>
<td>111 (7)</td>
<td>110 (7)</td>
<td>89 (5)</td>
<td>3 [−9 to 16]</td>
<td>−9 [−32 to 11]</td>
</tr>
<tr>
<td></td>
<td>100 (7)</td>
<td>90 (6)</td>
<td>93 (6)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GP home</td>
<td>8 (3)</td>
<td>8 (2)</td>
<td>5 (2)</td>
<td>0 [−5 to 6]</td>
<td>−1 [−4 to 5]</td>
</tr>
<tr>
<td></td>
<td>9 (3)</td>
<td>8 (3)</td>
<td>5 (2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nurse surgery</td>
<td>33 (3)</td>
<td>36 (3)</td>
<td>28 (2)</td>
<td>3 [−15 to 0]</td>
<td>−7 [−17 to 2]</td>
</tr>
<tr>
<td></td>
<td>35 (2)</td>
<td>30 (2)</td>
<td>32 (3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nurse home</td>
<td>0.4 (0.3)</td>
<td>0.8 (0.4)</td>
<td>3.2 (1.9)</td>
<td>−2.1 [−6 to 1]</td>
<td>−1.8 [−4.8 to 0.2]</td>
</tr>
<tr>
<td></td>
<td>1.9 (1.2)</td>
<td>0.5 (0.3)</td>
<td>1.1 (0.7)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.5 [−0.4 to 4.4]</td>
<td>[−1.3 to 0.5]</td>
<td>[−6 to 1]</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Hospital care</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A&amp;E</td>
<td>10 (3)</td>
<td>11 (2)</td>
<td>16 (3)</td>
<td>−3 [−9 to 4]</td>
<td>−5 [−11 to 6]</td>
</tr>
<tr>
<td>Outpatient</td>
<td>133 (19)</td>
<td>125 (16)</td>
<td>132 (18)</td>
<td>−3 [−12 to 102]</td>
<td>−5 [−24 to 87]</td>
</tr>
<tr>
<td>Day hospital</td>
<td>9 (2)</td>
<td>11 (3)</td>
<td>5 (2)</td>
<td>4 [−6 to 12]</td>
<td>−4 [−13 to 10]</td>
</tr>
<tr>
<td>Inpatient</td>
<td>172 (54)</td>
<td>143 (66)</td>
<td>309 (111)</td>
<td>−24 [−61 to 304]</td>
<td>−30 [−385 to 245]</td>
</tr>
<tr>
<td></td>
<td>327 (121)</td>
<td>267 (67)</td>
<td>383 (137)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>155 [−55 to 410]</td>
<td>[−61 to 304]</td>
<td>[−172 to 314]</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*continued*
TABLE 8 Mean ‘other health-care’ costs (SE) and cost differences [95% CI] per patient (£, 2005–6 prices) (continued)

<table>
<thead>
<tr>
<th></th>
<th>1 Control group (n = 152)</th>
<th>2 Less intensive self-monitoring (n = 150)</th>
<th>3 More intensive self-monitoring (n = 151)</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>12 months pre-baseline</td>
<td>12-month follow-up</td>
<td>Change</td>
<td></td>
</tr>
<tr>
<td>Auxiliary health care</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dietician</td>
<td>5 (1)</td>
<td>3 (1)</td>
<td>−2</td>
<td>−5</td>
</tr>
<tr>
<td></td>
<td>[−4 to 2]</td>
<td>[−5 to 2]</td>
<td></td>
<td>[−11 to 0]</td>
</tr>
<tr>
<td>Optician</td>
<td>17 (1)</td>
<td>18 (1)</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>[−1 to 4]</td>
<td>[−2 to 2]</td>
<td></td>
<td>[−6 to 3]</td>
</tr>
<tr>
<td>Podiatrist: NHS</td>
<td>34 (4)</td>
<td>44 (5)</td>
<td>−2</td>
<td>−8</td>
</tr>
<tr>
<td></td>
<td>[−8 to 13]</td>
<td>[−12 to 6]</td>
<td></td>
<td>[−18 to 0]</td>
</tr>
<tr>
<td>Podiatrist: private</td>
<td>43 (11)</td>
<td>29 (8)</td>
<td>−2</td>
<td>−8</td>
</tr>
<tr>
<td></td>
<td>[−34 to −1]</td>
<td>[−22 to 5]</td>
<td></td>
<td>[−18 to 0]</td>
</tr>
<tr>
<td>Private health care</td>
<td>19 (6)</td>
<td>27 (7)</td>
<td>−13</td>
<td>−10</td>
</tr>
<tr>
<td></td>
<td>[−8 to 22]</td>
<td>[−27 to 1]</td>
<td></td>
<td>[−20 to −2]</td>
</tr>
<tr>
<td>Total health care^2</td>
<td>1042 (70)</td>
<td>1048 (82)</td>
<td>387^a</td>
<td>1145 (127)</td>
</tr>
<tr>
<td></td>
<td>[103–625]</td>
<td>[188–573]</td>
<td></td>
<td>[77–588]</td>
</tr>
</tbody>
</table>

A&E, accident and emergency.

a $p < 0.05$.

b Includes intervention and medication costs.
the incremental comparison. The full case-based analysis suggests that the negative impact of the more intensive SMBG results in significantly lower quality of life (−0.072 (95% CI −0.127 to −0.017)) compared with the control group. Sensitivity analysis based only on patients alive at the end of the trial showed very similar results (−0.062 (95% CI −0.112 to −0.012)).

Table 10 shows the distribution of responses to the EQ-5D across the different levels of each dimension. This table indicates that decrease in the quality of life among patients in the SMBG groups was due primarily to greater levels of anxiety and depression at 12-month follow-up than at baseline.

Life-time extrapolation
The extrapolated effects of the interventions compared with usual care, and the total QALYs gained and total costs incurred by the different treatment groups are given in Table 11. The mean gain in QALYs beyond the trial period was estimated to be 0.045 per patient for standardised usual care, 0.049 per patient for less intensive SMBG and 0.060 per patient for more intensive SMBG. Complication costs were reduced in the beyond-trial period, by £69, £102 and £97 respectively in the three groups, with no significant difference between groups.

Cost-effectiveness
Table 11 presents the overall differences in costs and outcomes between the SMBG groups and the control group. The mean estimates suggest that both forms of SMBG are more costly (£59 and £56) and less effective (−0.004 and −0.020 QALYs) than standardised usual care, with relatively wide CIs around the point estimates.

A formal ICER is not reported, as its calculation is meaningful only when the intervention is more costly and more effective than the comparator. Uncertainty intervals surrounding the ICER point estimates were assessed by recalculating the differences in costs and effects 1000 times using non-parametric bootstrapping with replacement. Figure 5 illustrates the distribution of the incremental cost and effect pairs between the control group and the less and more intensive SMBG groups plotted on the cost-effectiveness plane. This shows that the 95% CIs of the ICERs cannot be meaningfully defined, as they range from the interventions dominating standardised usual care to the SMBG groups being dominated by the control group (points falling into all four quadrants of the plane).

The cumulative probability that SMBG is cost-effective compared with standardised usual care...
as a function of decision makers’ maximum willingness-to-pay for an additional QALY can be illustrated by cost-effectiveness acceptability curves\(^4^8\) (Figure 6). In the UK, the current cost-effectiveness ceiling ratio is \(£20,000–30,000\) per QALY gained.\(^4^9\) The probability of the more intensive SMBG having a cost-effectiveness ratio lower than this does not reach 15%, and the

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**TABLE 10** Proportion (%) of EQ-5D answers across the dimensions: complete case analysis

<table>
<thead>
<tr>
<th></th>
<th>Mobility</th>
<th>Self-care</th>
<th>Usual activities</th>
<th>Pain</th>
<th>Anxiety</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td><strong>Baseline</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control group</td>
<td>62</td>
<td>38</td>
<td>0</td>
<td>92</td>
<td>8</td>
</tr>
<tr>
<td>Less intensive self-monitoring</td>
<td>66</td>
<td>34</td>
<td>0</td>
<td>92</td>
<td>8</td>
</tr>
<tr>
<td>More intensive self-monitoring</td>
<td>67</td>
<td>33</td>
<td>0</td>
<td>95</td>
<td>5</td>
</tr>
<tr>
<td><strong>12-month follow-up</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control group</td>
<td>66</td>
<td>34</td>
<td>0</td>
<td>90</td>
<td>10</td>
</tr>
<tr>
<td>Less intensive self-monitoring</td>
<td>61</td>
<td>39</td>
<td>0</td>
<td>90</td>
<td>10</td>
</tr>
<tr>
<td>More intensive self-monitoring</td>
<td>67</td>
<td>33</td>
<td>0</td>
<td>91</td>
<td>9</td>
</tr>
</tbody>
</table>

---

**TABLE 11** QALYs gained and costs\(^a\) [95% CI] per patient over a lifetime

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control group</td>
<td>More intensive self-monitoring</td>
<td>Less intensive self-monitoring</td>
<td>More intensive self-monitoring</td>
</tr>
<tr>
<td><strong>Trial period</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>QALYs gained</td>
<td>0.000</td>
<td>0.035</td>
<td>0.035</td>
<td>-0.008</td>
</tr>
<tr>
<td>Costs</td>
<td>[89]</td>
<td>[173–184]</td>
<td>[181]</td>
<td>[173–189]</td>
</tr>
<tr>
<td><strong>Beyond trial extrapolation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>QALYs gained</td>
<td>0.045</td>
<td>0.060</td>
<td>0.060</td>
<td>0.004</td>
</tr>
<tr>
<td>Costs</td>
<td>[−69]</td>
<td>[−158 to −37]</td>
<td>[−176 to −28]</td>
<td>[−147 to 9]</td>
</tr>
<tr>
<td><strong>Lifetime total</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>QALYs gained</td>
<td>0.045</td>
<td>0.025</td>
<td>0.025</td>
<td>0.004</td>
</tr>
<tr>
<td>Costs</td>
<td>[20]</td>
<td>[76]</td>
<td>[76]</td>
<td>[56]</td>
</tr>
</tbody>
</table>

QALY, quality-adjusted life-year.
\(a\) Costs for year, 2005–6 prices.
\(b\) \(p<0.05\).
\(c\) Compared with no intervention.
The probability of the less intensive SMBG being cost-effective remains below 40% at this threshold. Overall, the cost–utility analysis suggests that the investigated forms of SMBG are not cost-effective in comparison with standardised usual care.

**Summary**

Within the trial, SMBG was found to be significantly more expensive than standardised usual care, by £92 and £84 for the less and more intensive SMBG groups respectively. There appears to be an initial negative impact of SMBG on quality of life measured using the EQ-5D. Potential additional lifetime gains in QALYs resulting from the lower levels of risk factors achieved at the end of trial follow-up were outweighed by the initial negative impacts for both SMBG groups compared with standardised usual care. Results of the extrapolation also suggest that the incremental lifetime savings in diabetes complications did not offset the additional intervention costs. The cost–utility analysis showed that it is unlikely that either investigated form of SMBG is cost-effective compared with standardised usual care.

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**FIGURE 5** Cost–utility analysis of self-monitoring of blood glucose compared with standardised usual care on the cost-effectiveness plane.

**FIGURE 6** Cost-effectiveness acceptability curves: probability that self-monitoring of blood glucose (SMBG) is cost-effective compared with standardised usual care as a function of decision makers’ maximum willingness to pay for an additional QALY.
Chapter 5
Well-being, beliefs and self-reported behaviour

Methods

Questionnaires were included at baseline and 12 months to measure dietary intake and physical activity (the diabetes self-care activities questionnaire with five subscales), medication adherence (the medication adherence rating scale), and the scores in the diabetes treatment satisfaction questionnaire and the well-being questionnaire (12 items).

Beliefs about diabetes and its management were assessed using the revised illness perceptions questionnaire (IPQ-R) which has eight subscales. The beliefs about medicines questionnaire (BMQ) with two subscales was used to assess beliefs about medication benefits and harms; the medication adherence report schedule (MARS, one subscale) was used to report medication adherence, and a self-reported questionnaire (summary of diabetes self-care activity, SDSCA, five subscales) assessed eating and physical activity. Treatment satisfaction was assessed with the Diabetes Treatment Satisfaction Questionnaire (DTSQ, three subscales) and overall well-being with the well-being questionnaire (W-BQ12).

The response set used for the analysis presented here comprises those patients responding to questionnaires at both baseline and 12 months. All analyses are conducted using analysis of covariance (ANCOVA), adjusting for baseline values.

Mediation analysis

We set out to establish whether differences between groups in the extent to which any change over time in outcome measures (behavioural, emotional or clinical) was due to differences in beliefs about SMBG or illness perceptions by means of formal mediation analyses, conducted using the approach recommended by Baron and Kenny. This approach involves the calculation of four separate regression equations and satisfaction of the following criteria: (1) the outcome measure was significantly predicted by the belief measure; (2) the belief measure was significantly predicted by the belief measure and group in the same regression equation, with the belief variable remaining statistically significant. If the relationship between group and outcome measure is reduced in the fourth regression analysis, then we have at least partial mediation. If the effect of group is reduced by a significant amount to a level of non-significance (i.e. \( p > 0.05 \)), then there is complete mediation: the differences on the outcome measure between groups is due entirely to its effect on the belief measure. To ensure the mediation analyses reflect change in outcome measures, the outcome measure scores used in these analyses were the unstandardised residuals saved after the baseline scores were used to predict the follow-up scores.

Results

Of the 453 patients randomised in the trial, 339 (74.8%) completed questionnaires at baseline and 12 months and were included in the final analysis.

Differences between groups in belief changes over time

Group differences in mean scores on belief measures at follow-up, adjusted for baseline scores, are shown in Table 12. Changes in illness beliefs did not significantly differ between groups, with the exception of beliefs about consequences (\( p = 0.004 \)). The mean difference in change in consequence scores from baseline to 12 months between the control group and the less intensive intervention group (not adjusted for baseline) was 0.92 (95% CI −0.07 to 1.91; Cohen’s \( d = 0.19 \)), and between the control group and the more intensive intervention group was 1.59 (95% CI 0.66–2.51; \( d = 0.36 \)).

A significant difference was also found in the change in mean belief scores between the three groups for beliefs concerning feeling negative about self-testing (\( p < 0.001 \)) and the importance of self-testing (\( p < 0.001 \)). The mean difference in change in feeling negative about self-testing scale scores from baseline to 12 months between the
### TABLE 12
Comparison of changes in mean scores (SD) between groups on measures assessing beliefs about illness, self-monitoring of blood glucose and medication from baseline to 1 year

<table>
<thead>
<tr>
<th>Illness perceptions (IPQ-R)</th>
<th>Usual care: no meter (n = 113)</th>
<th>Self-testing (n = 121)</th>
<th>Self-monitoring (n = 105)</th>
<th>p-value for difference between groups</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cronbach’s α</td>
<td>Baseline</td>
<td>Follow-up</td>
<td>Baseline</td>
</tr>
<tr>
<td>Identity ¹</td>
<td>NA</td>
<td>2.2 (2.8)</td>
<td>1.7 (2.2)</td>
<td>1.7 (2.2)</td>
</tr>
<tr>
<td>Timeline: acute/ chronic²</td>
<td>α = 0.81</td>
<td>24.5 (4.1)</td>
<td>25.0 (3.6)</td>
<td>24.4 (4.0)</td>
</tr>
<tr>
<td>Timeline: cyclical³</td>
<td>α = 0.87</td>
<td>10.4 (3.3)</td>
<td>10.0 (3.1)</td>
<td>10.4 (3.0)</td>
</tr>
<tr>
<td>Consequences⁴</td>
<td>α = 0.68</td>
<td>17.3 (3.9)</td>
<td>16.8 (4.3)</td>
<td>16.9 (3.7)</td>
</tr>
<tr>
<td>Personal control⁵</td>
<td>α = 0.76</td>
<td>24.1 (3.1)</td>
<td>24.3 (2.8)</td>
<td>24.2 (2.7)</td>
</tr>
<tr>
<td>Treatment control⁶</td>
<td>α = 0.40</td>
<td>18.2 (1.9)</td>
<td>17.8 (2.0)</td>
<td>18.3 (2.0)</td>
</tr>
<tr>
<td>Illness coherence⁷</td>
<td>α = 0.88</td>
<td>16.9 (4.1)</td>
<td>17.4 (4.4)</td>
<td>16.6 (4.5)</td>
</tr>
<tr>
<td>Emotional representations⁸</td>
<td>α = 0.87</td>
<td>15.3 (4.3)</td>
<td>15.0 (4.0)</td>
<td>15.1 (4.7)</td>
</tr>
</tbody>
</table>

| Self-monitoring of blood glucose beliefs | Baseline | Follow-up | Baseline | Follow-up | Baseline | Follow-up | Baseline | Follow-up | Baseline | Follow-up | Baseline | Follow-up | Baseline | Follow-up | Baseline | Follow-up | p-value for difference between groups |
|------------------------------------------|----------|-----------|----------|-----------|----------|-----------|----------|-----------|----------|-----------|----------|-----------|----------|-----------|----------|-----------|
| Feel negative about self-testing⁹        | α = 0.65 | 5.5 (1.8) | 5.9 (1.9) | 5.5 (1.7) | 4.6 (1.4) | 5.3 (1.7) | 4.3 (1.6) | <0.001    |          |           |          |           |          |           |          |           |
| Symptoms make test unnecessary⁸          | α = 0.69 | 5.1 (1.4) | 5.2 (1.7) | 5.0 (1.6) | 5.3 (1.7) | 5.1 (1.8) | 5.2 (1.7) | 0.96      |          |           |          |           |          |           |          |           |
| Important to self-test¹¹                 | α = 0.36 | 6.4 (1.4) | 6.1 (1.3) | 6.4 (1.4) | 6.9 (1.5) | 6.5 (1.6) | 7.3 (1.6) | <0.001    |          |           |          |           |          |           |          |           |
| Checking is painful¹²                    | NA       | 2.1 (0.8) | 2.2 (0.9) | 2.3 (0.8) | 2.1 (0.9) | 2.2 (0.8) | 2.0 (0.9) | 0.21      |          |           |          |           |          |           |          |           |

| Beliefs about medication (BMQ)            |          |           |          |           |          |           |          |           |          |           |          |           |          |           |          |           |                                       |
| Necessity¹³                               | α = 0.82 | 19.1 (2.3) | 18.9 (2.4) | 18.5 (3.2) | 18.6 (2.9) | 18.7 (2.9) | 19.4 (2.8) | 0.28      |          |           |          |           |          |           |          |           |
| Concerns¹⁴                                | α = 0.77 | 13.7 (2.9) | 13.3 (3.2) | 13.6 (3.9) | 13.1 (3.5) | 13.3 (3.8) | 13.4 (3.9) | 0.75      |          |           |          |           |          |           |          |           |

IPQ-R, revised illness perceptions questionnaire; NA, not applicable.

Missing data for scales: ¹0; ²5; ²3; ²5; ²6; ²9; ²9; ³1; ⁴0; ⁴7; ⁵3; ⁶0; ⁶4; ⁷0; ⁸5; ⁹0; ¹⁰6.

BMQ scales completed only by patients taking medication at baseline.
control group and the less intensive intervention group (not adjusted for baseline) was \(-1.37 (–1.83 \text{ to } –0.91; d = 0.57)\), and between the control group and the more intensive intervention group was \(-1.52 (–2.01 \text{ to } –1.02; d = 0.63)\). The mean difference in change in the importance of self-testing scale scores from baseline to 12 months between the control group and the less intensive intervention group (not adjusted for baseline) was \(0.72 (0.24–1.19; d = 0.31)\) and between the control group and the more intensive intervention group was \(1.08 (0.55–1.61; d = 0.45)\). No differences in change between groups were found in either of the other two measures concerning beliefs about SMBG, nor were differences found in changes in beliefs about medication between groups.

**Differences between groups in outcome changes over time**

Group differences between the mean scores on behavioural and emotional measures at follow-up, adjusted for baseline scores, are shown in Table 13. There were significant differences in scale score changes on the general diet scale of the SDSCA between groups (\(p = 0.014\)), as well as the specific diet items concerning fruit and vegetables (\(p = 0.006\)) and high-fat foods (\(p = 0.022\)). The mean difference in change in SDSCA general diet scores from baseline to 12 months between the control group and the less intensive intervention group (not adjusted for baseline) was \(0.12 (–0.33 \text{ to } 0.57; d = 0.06)\) and between the control group and the more intensive intervention group was \(-0.50 (–1.00 \text{ to } 0.01; d = 0.23)\). The mean difference in change in the SDSCA fruit and vegetables item from baseline to 12 months between the control group and the less intensive intervention group (not adjusted for baseline) was \(-0.26 (–0.72 \text{ to } 0.19; d = 0.12)\) and between the control group and the more intensive intervention group was \(-0.79 (–1.30 \text{ to } –0.28; d = 0.54)\). The mean difference in change in the SDSCA high-fat foods item from baseline to 12 months between the control group and the less intensive intervention group (not adjusted for baseline) was \(-0.03 (–0.48 \text{ to } 0.40; d = 0.02)\), and between the control group and the more intensive intervention group was \(0.51 (0.01–1.00; d = 0.23)\).

No differences were found in changes in either self-reports of exercise or medication adherence between groups, nor did groups differ in terms of their changes in treatment satisfaction or well-being scores.

**Mediation analysis**

Formal mediation analyses were used to investigate the effects of the intervention groups on all outcomes that had statistically significant differences in mean change score between groups. There were such differences on four outcome measures: cholesterol (\(p = 0.010\)), general diet (\(p = 0.014\)), specific diet (fruit and vegetables, \(p = 0.006\)) and specific diet (high fat, \(p = 0.022\)). Only three belief measures were significantly different between groups: beliefs about consequences (\(p = 0.004\), feeling negative about self-testing (\(p < 0.001\)) and the belief that it is important to self-test (\(p < 0.001\)). Of the four outcome measures, only two were significantly related to any of the three belief measures: change in cholesterol was predicted by feeling negative about self-testing (\(\beta = 0.130, p = 0.016\)) and change in self-reported fruit and vegetable consumption was predicted by consequence beliefs (\(\beta = –0.125, p = 0.031\)). In a regression analysis with group and feeling negative about self-testing used to predict change in cholesterol, group remained a significant predictor (\(\beta = –0.114, p = 0.046\)), while feeling negative about testing became non-significant (\(\beta = –0.090, p = 0.113\)). Similarly, in a regression analysis with group and beliefs about consequences used to predict change in self-reported fruit and vegetable consumption, group remained a significant predictor (\(\beta = –0.168, p = 0.004\)), while beliefs about consequences were non-significant (\(\beta = –0.099, p = 0.086\)). There was no evidence of even partial mediation of the effects of the intervention on any outcome measure by the belief measures.

**Summary of findings**

Among patients allocated to use of more intensive SMBG compared with those allocated to usual care over 1 year, there was a small, but significant increase in level of beliefs about the severity of the consequences of diabetes. However, there were no differences between groups in mean changes in beliefs about personal control over diabetes and the perceived effectiveness of treatment. In addition, there was no observed effect on the mean change in well-being between groups. There was a small but significant effect on self-reported dietary behaviour, with patients allocated to usual care reporting changes towards healthier eating patterns than those allocated to more intensive monitoring. Change in beliefs about the consequences of diabetes did not mediate the self-reported changes in dietary behaviour observed between groups.
TABLE 13 Comparison of changes in mean scores (SD) between groups on behavioural and emotional outcome measures from baseline to 1 year

<table>
<thead>
<tr>
<th></th>
<th>Usual care: no meter (n = 113)</th>
<th>Self-testing (n = 121)</th>
<th>Self-monitoring (n = 105)</th>
<th>p-values for differences between groups</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cronbach's α</td>
<td>Baseline</td>
<td>Follow-up</td>
<td>Baseline</td>
</tr>
<tr>
<td><strong>Self-care behaviours (SDSCA)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>General diet</td>
<td>0.93</td>
<td>5.2 (1.8)</td>
<td>5.6 (1.5)</td>
<td>5.0 (1.8)</td>
</tr>
<tr>
<td>Specific diet</td>
<td>0.08</td>
<td>5.4 (1.2)</td>
<td>5.9 (1.1)</td>
<td>5.3 (1.2)</td>
</tr>
<tr>
<td>Specific diet: fruit and vegetables</td>
<td></td>
<td>5.2 (1.8)</td>
<td>5.7 (1.6)</td>
<td>5.1 (2.0)</td>
</tr>
<tr>
<td>Specific diet: high fat foods</td>
<td></td>
<td>2.4 (1.7)</td>
<td>1.9 (1.5)</td>
<td>2.5 (1.6)</td>
</tr>
<tr>
<td>Exercise</td>
<td>0.75</td>
<td>3.3 (2.1)</td>
<td>4.0 (2.2)</td>
<td>3.2 (2.2)</td>
</tr>
<tr>
<td>MARS</td>
<td>0.62</td>
<td>24.0 (1.6)</td>
<td>24.1 (2.0)</td>
<td>23.9 (1.6)</td>
</tr>
<tr>
<td>DTSQ</td>
<td>0.84</td>
<td>29.3 (6.8)</td>
<td>30.0 (5.3)</td>
<td>29.4 (6.5)</td>
</tr>
<tr>
<td>How often felt blood sugar unacceptably high</td>
<td></td>
<td>1.7 (1.7)</td>
<td>1.9 (1.9)</td>
<td>1.5 (1.6)</td>
</tr>
<tr>
<td>How often felt blood sugar unacceptably low</td>
<td></td>
<td>0.6 (1.2)</td>
<td>0.7 (1.3)</td>
<td>0.7 (1.3)</td>
</tr>
<tr>
<td>W-BQ12</td>
<td>0.87</td>
<td>25.1 (6.3)</td>
<td>25.9 (5.8)</td>
<td>24.3 (6.8)</td>
</tr>
</tbody>
</table>

DTSQ, diabetes treatment satisfaction questionnaire; MARS, medication adherence rating scale; SDSCA, summary of diabetes self-care activity; W-BQ12, well-being questionnaire. Missing data for scales: 1^40; 2^32; 3^28; 4^30; 5^37; 6^96; 7^92; 8^93; 9^32. MARS completed only by those taking medication at baseline. DTSQ scales completed only if some experience of SMBG.
Methods

Semi-structured interviews with patients taking part in the DiGEM trial were used to explore the experiences and perspectives of SMBG. A sample of 40 patients was recruited from participants in the clinical trial. Trial participants were contacted by post and asked if they would like to take part in a related substudy, involving a single, semi-structured interview, to discuss their experience of having diabetes and taking part in the trial. Invitations were sent to those who had been in the trial for a minimum of 3 months to ensure that patients had at least undergone their 3-month follow-up visit with the study nurse, and so would be able to discuss their views on the feedback they had received about their glycaemic control, enabling a comparison across the three intervention groups.

Interviews were conducted with the first 20 participants who replied positively to the invitation. After the first group of interviews had been conducted and the characteristics of these participants determined, we adopted a purposive sampling technique to recruit the remaining participants. Further letters of invitation were sent only to those whose characteristics had not been represented in the initial interviews with patients selected to span a range of age groups, socioeconomic classifications, both genders and the three intervention groups. Selection was also balanced to obtain an equal number of participants attending clinics with each study facilitator, as well as a range of baseline medication adherence scores (as assessed by the self-reported MARS questionnaire) and dietary and exercise behaviours (assessed by the self-reported SDSCA questionnaire). All respondents were given the option of being interviewed on a weekday or at the weekend and in a place of their choosing so that employed people and those who were not mobile would not be excluded.

Interviews were semi-structured in design to allow both open-ended questioning, which would allow respondents to speak in an undirected fashion, and inquiry about specific topics. The interview began with questions about demographics, followed by an illness narrative, in which patients were encouraged to talk at length about their experiences since being diagnosed with diabetes. In the second part of the interview, inquiry was made about specific topics, which are summarised in Box 1. The interviews lasted between 25 and 90 minutes.

BOX 1  Topics for specific inquiry in qualitative interviews

| Self-care behaviours affecting control of diabetes |
| Understanding of the randomised controlled trial (RCT) process |
| Usefulness of taking part in the RCT |
| Comparison of SMBG and clinic monitoring |
| Usefulness of knowledge of glycaemic control |
| Use of SMBG – ease, prompts, timing, relationship to behaviour |

Analysis of the interviews was conducted concurrently with data collection to facilitate exploration of emergent themes in ongoing interviews. The grounded theory approach was used, in which the analytical themes are derived from or ‘emerge’ from the data.16 The transcripts from the semi-structured interviews were imported into the NU*DIST computer program (QSR International, 2002).

Interview transcripts were read and reread in order to identify general themes. Any text relating to SMBG was highlighted and assigned a unique code under one of these general themes. These themes were determined as the transcripts were read and added to the coding structure as necessary. Items in general themes were compared with each other and coding was refined to produce subthemes based on the similarities and differences between items. Broader categories were then identified and text units reviewed to ensure all categories emerging from the data had been identified. Results were gathered into broad categories to facilitate discussion.
Results of in-depth interviews on trial participants

Participant characteristics
Forty patients were interviewed. Their characteristics are summarised in Table 14. Characteristics of patients sampled represented the range of participants included in the trial, including age, socioeconomic status and participation in each of the trial’s three allocated interventions.

Perspectives of SMBG
Interviewees’ perspectives of SMBG focused around three main themes: awareness, influence on health behaviour and empowerment. Both benefits and disadvantages associated with these themes were expressed and these are presented together to illustrate the range of patient views.

Awareness
Increased awareness of diabetes
Several patients raised an increased awareness of having diabetes as a consequence of SMBG. The presence of an elevated blood sugar on monitoring was viewed by respondents as tangible evidence of an abnormality. One interviewee, who earlier in her interview had commented that she had thought her diabetes was curable and only temporary when diagnosed, noted that SMBG had helped to demonstrate that there was a persistent abnormality:

Well, it makes it real that you’ve got it. That there, there is sugar there.

(D21, 57-year-old woman, group 3)

Although the increased awareness of diabetes was typically viewed as beneficial, two respondents considered it a disadvantage. In one instance, this was a perceived disadvantage as the respondent had never self-monitored. She controlled her illness with lifestyle changes and felt quite strongly that monitoring her blood sugar would distress her:

I would feel like an ill person. I would walk about feeling ‘I am a sick person’ and I’d hate that because I know that I’m not, I’m a healthy animal.

(D22, 71-year-old woman, group 1)

This respondent clearly placed significant emphasis on her self-image as a ‘healthy’ person which she felt would be threatened by constant reminders of illness. SMBG may have been particularly significant for her because she did not have the daily reminder of taking medication which might reinforce the presence of disease in other patients. This illustrates a potential barrier to initiating SMBG in non-pharmacologically treated patients who may not consider themselves ill, and find close monitoring unnecessary and distressing. This did not seem to be a concern once SMBG had been started; however, none of the non-pharmacologically treated patients who self-monitored during the trial expressed distress that their awareness of their diabetes had increased.

<table>
<thead>
<tr>
<th>TABLE 14 Characteristics of interview participants</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Patients interviewed (n = 40)</strong></td>
</tr>
<tr>
<td>Age, years [mean (SD)]</td>
</tr>
<tr>
<td>Socioeconomic classification [n (%)]</td>
</tr>
<tr>
<td>Managerial and professional occupations</td>
</tr>
<tr>
<td>Intermediate occupations</td>
</tr>
<tr>
<td>Small employers and own account workers</td>
</tr>
<tr>
<td>Lower supervisory and technical occupations</td>
</tr>
<tr>
<td>Semi-routine and routine occupations</td>
</tr>
<tr>
<td>Group allocation (%)</td>
</tr>
<tr>
<td>Standard care (group 1)</td>
</tr>
<tr>
<td>Less intensive self-monitoring (group 2)</td>
</tr>
<tr>
<td>More intensive self-monitoring (group 3)</td>
</tr>
</tbody>
</table>
A second respondent, who felt increased awareness of diabetes, acknowledged that she had never made a concerted effort to control her illness. She reported that SMBG was:

... a sort of reminder of the fact that you know that I've got something wrong with me...I don't like to be reminded particularly.

(D15, 67-year-old woman, group 2)

It is difficult to distinguish whether she preferred not to be reminded of her diabetes because she was not actively controlling it or whether she did not actively control it because she tended not to be conscious of it.

Increased understanding of the relationship between physical symptoms and blood sugar

Some participants noted that SMBG helped them to establish the relationship between their physical symptoms and their blood sugar. Most of the interviewees who reported this benefit checked their blood sugar to confirm suspected hypoglycaemia, rather than suspected hyperglycaemia. One participant who had a medical condition whose symptoms were similar to hypoglycaemia commented:

And as I said, whenever I have one of these bad bouts I always, now I've got the equipment, I always go and check my blood to make sure that, which one or what, which one it is that's doing the problem.

(D3, 65-year-old man, group 3)

Only those respondents who had been exposed to monitoring, either as part of the trial or previous occasional users, considered SMBG as a tool to detect hypoglycaemia. Those who had never used the technology perceived it solely as a tool for detecting hyperglycaemia, analogous to the blood tests that they had at their GP surgery. As such, several felt that SMBG was a redundant further check on glycaemic control and could lead to unnecessary worry:

I feel I get it done often enough so that quite suits me. I think very often [um] you could get worried if you keep doing it ...I'd rather just have it done there at the doctor's surgery.

(D18, 78-year-old woman, group 1).

Reassurance about health status

Awareness of blood sugar levels provided reassurance for several respondents. Some interviewees used SMBG to ensure that previously detected high readings had returned to normal, while others felt that readings within normal parameters indicated their diabetes had not worsened. This could be comforting, particularly given the time frame between visits to their health professional. For example:

So if I woke up one morning and took it on a fasting reading and it was, I don't know, 22 or 24, for example, then the alarm bells really would start to ring. But because it's, they've been contained within a, a band which doesn't seem to ever increase as dramatically as what I've indicated, then there is a crumb of comfort there, if you see what I mean.

(D8, 62-year-old man, group 2)

Reassurance was clearly associated with normal readings. Readings outside the specified parameters were associated with feelings of failure. These participants described making efforts to adhere to dietary and physical activity recommendations as part of their diabetes control strategies, and abnormally high readings may have been considered a failure of these efforts:

I think I'm disappointed because I feel, I suppose, in a way that I've failed, even though you know, I sit there afterwards and think, well no, I didn't actually, I haven't done anything I shouldn't have done, so why do I feel it, but I still do. I feel guilty and, and a bit of a failure and I don't know why.

(D33, 45-year-old woman, group 3)

Some respondents in both the comparison and the less intensive monitoring groups felt that other patients might become obsessed with checking blood sugar if they had access to a monitor. This was not a concern in the more intensive monitoring group, perhaps because the readings were being used to support behaviour change and were therefore thought necessary.

Understanding of diabetes

Two participants volunteered that SMBG helped them to understand their diabetes by illustrating the fluctuations in blood sugar. One commented:

I would have thought that was a good idea, just to give every, anybody, when they first get it a meter, and to do it for 3 months, even just for 2, 2 or 3 months, even if you take it back off them then, at least they can see what, you know, what's happening to the body and [um],...
Qualitative interviews: methods and results

and they’d understand it more.

(D25, 69-year-old man, group 2)

Respondents in both monitoring groups reported frustration when they were unable to understand why they got the SMBG values they did:

… it seems to me that the figures, other than the fasting reading, are very high some days, reasonable the next, I cannot see why this should be, because when I think I, I think ‘Ooh I’ve over-indulged a little bit my figures will be really high’, they’re not necessarily high. And other times when I’ve had a very lean day in terms of what I’ve eaten, the figures can be high. And I can’t, I cannot see a, a, a balance of why this should be as I’ve said, and that’s the only thing about taking these readings that tends to confuse me a little, because I just cannot make sense of it.

(D8, 62-year-old man, group 2)

This suggests that the benefits derived from illustrating fluctuations are related to the ability to understand the relationship between fluctuations and behaviour, rather than simply observing them.

Health behaviour
Assessing the effect of self-management behaviour
Some participants felt they had the ability to use SMBG to assess the effects of behaviour. Facilitators encouraged participants in the more intensive monitoring group to experiment with the timing of their monitoring to see, for example, how certain food affected their blood sugar. Interviewees confirmed that this was a useful strategy for SMBG:

I think you can certainly tell whether you’ve eaten the wrong things. Or whether you’ve overdone it and then you obviously need to go and correct that by doing exercise or being extremely good, you know.

(D33, 45-year-old woman, group 3)

Although participants in the less intensive monitoring group were not encouraged to use SMBG as a check on their behaviour, some reported having done so. One participant noted:

But, the thing that has, has also been extremely helpful with the exercise is that because you’re monitoring your blood sugar levels, you actually see what pushes it up and what, what doesn’t. Not only in connection with what you eat, but what you’re doing, so that you can stray

from straight and, and narrow in terms of diet provided you are active enough. Whereas you can eat the same things and if you’re not active you know it shows – immediately.

(D15, 67-year-old woman, group 2)

Promoting adherence to self-management behaviour
A related theme, promotion of adherence to self-management, also emerged as a benefit of SMBG. As noted previously, adherence to these behaviours is often less than optimal in people with diabetes. Interviewees in both the less and more intensive monitoring groups felt that SMBG was a useful tool in providing discipline and helping them to adhere, because it demonstrated what happened when they failed to do so:

I think it has, yes, that it is really important that I do take the medication. Because I’ve seen exactly what happens if I forget to take those night time pills from monitoring the blood sugar, I can see what happens and, so yes it has had an effect, yeah.

(D15, 67-year-old woman, group 2)

The previous subtheme relates to behaviour change which was prompted when specific instances of non-adherence, such as not taking medication, demonstrated elevated blood glucose. Elevated readings also prompted behaviour change even when they were not attributable to a particular behaviour:

So if I’m very, if I’m high which, by that I mean by over ten which I know that’s probably much too high by everyone else’s standards but by my standards I think ten isn’t too bad, but if I go over ten then I will take great care with my diet for two or three days till I bring it right down to about five or six.

(D4, 67-year-old man, group 3)

Respondents in both monitoring groups with a range of characteristics reported using SMBG to provide information about the general state of their diabetes, suggesting that this was a widely derived perceived benefit of SMBG. The trial intervention was based on the hypothesis that SMBG could provide two types of feedback to patients: feedback on their general diabetes control and feedback on specific behaviour which might influence glycaemic control. The data from the qualitative study suggest that both these methods of feedback were employed by some respondents in both monitoring groups.
Failure to see improvement after modifying behaviour was discouraging. Several interviewees, all of whom were in the more intensive monitoring group, commented on how little their behaviour seemed to impact on their blood sugar. For example:

But, but, even if I, even if I do everything they say, for a couple of days, I still don’t get good readings, so you know there’s nothing there to encourage me, saying oh, you know ‘I didn’t have a drink for two days, I didn’t eat a pork pie, I didn’t have a packet of crisps, I didn’t have any bacon, I didn’t fry any food and look at that, my reading is six, that is wonderful’. Oh no, it’s still seven, it’s still eight, you know, and so you don’t think to yourself that’s the way forward, because nothing’s happening. I’m just the same, it doesn’t seem to matter whether I have ten pints, I mean I don’t have ten pints, but you know, it doesn’t seem to matter if I have a lot to drink or a little to drink, my readings very, very rarely alter, they’re all between 7 and 10, depending which time of day I take them.

(D1, 60-year-old man, group 3)

Participants in the more intensive self-monitoring group were encouraged to make lifestyle changes and to keep track of them by SMBG. Although changes such as those discussed by this interviewee, if maintained, might result in longer-term improvements in glycaemic control by contributing to weight loss, the impact would not be apparent in the shorter term. The lack of immediate feedback from the monitoring may have contributed to this perspective. Other incentives might be needed to encourage maintenance of behaviour change in these patients.

Comments regarding the role of SMBG in assessing and promoting behaviour were generally made by those who had been exposed to the technology either before or during the trial. Only one SMBG-naïve respondent in the comparison group commented on this use of SMBG. Not surprisingly, she placed less emphasis on its role than those who had used the technology:

And you see you can’t, whether you, you check it at home or not it doesn’t make any difference, you have to, still have to do the right thing you see.

(D20, 73-year-old woman, group 1)

Two participants volunteered that they timed their SMBG to ensure they only got satisfactory readings. One respondent did this by testing only on days on which he felt he had adhered to his regimen, while the other strayed from her regimen only when not testing:

I have to say this now, that I be – be completely honest here, on the days I check me blood I behave meself, whereas I can come – I come in this morning lunch time, I say when I have me breakfast about, quarter past eight this morning, then I went into town, I come back, well I might have a, I might have occasionally have a treat, a cup of tea, about half ten I’ll read the paper and have a cake, but I won’t when I’m about to have the blood check, so that makes me stick to something, now I don’t know what the difference to me to have the cake because, I guess there’ll be some sugar in it so that would probably send it the wrong way really, you know.

(D11, 64-year-old man, group 2)

Empowerment

The third major theme emerging from the data was empowerment. This related to respondents’ access to a convenient method of assessing glycaemic control that allowed them more control over their health care and their ability to contribute to their physician’s evaluation of their status.

Convenience

Several participants raised the convenience of SMBG as a benefit. It allowed them to check on their glycaemic control whenever they wanted, without having to visit their surgery:

You’ve only got to press a button and it will show you your averages for the period, so it’s no problem, no difference but then you haven’t got the inconvenience of making appointments and sitting in doctor’s surgery, etc. and then going back for the results.

(D30, 53-year-old man, group 2)

These participants might be using SMBG to support their self-care activities, and therefore desire frequent feedback on their glycaemic control, which would be inconvenient to arrange at a GP surgery.

The convenience of SMBG was tempered by the physical discomfort reported by some respondents. Several previous studies identify physical
discomfort as a barrier to or disadvantage of SMBG.4,5,8,18 While interviewees in both monitoring groups reported some physical discomfort associated with use of SMBG, this was noted to be trivial:

It, it’s not particularly pleasant, but it’s not that bad.
(D12, 68-year-old man, group 3)

Fear of the discomfort associated with SMBG was not a significant deterrent to the respondents in either of the monitoring groups or the comparison group, where only one respondent raised a fear of needles as a potential barrier to the use of SMBG. The interruption of routine caused by SMBG and the expense to the NHS were also raised by respondents.

Initiation of physician visits
Respondents also noted that SMBG allowed them to initiate physician visits if they thought it was warranted, allowing them to take more responsibility for their care. One reported:

… any trend that comes up with, I don’t have to wait for a doctor to tell me the answer. I mean if I have any problems, if I find my blood sugar low, low, low, I can go straight into the doctor and say ‘Look what’s happening.’ If I have to wait for somebody else then I could be done by then.
(D3, 65-year-old man, group 3)

Initiation of physician visits was reported by patients in both monitoring groups as well as in one patient in the comparison group who had been previously exposed to monitoring, suggesting that this was a widely experienced benefit.

Informing health-care decisions
Although respondents appeared to use their SMBG results primarily to inform their own behaviour, some did report that they considered these values an important source of information and, as such, showed their values to their health-care professionals outside the setting of the trial. As described previously, trial participants received two different levels of advice and feedback from study facilitators, depending on group allocation, but adjustments to medication were done by the participant’s GP. Some participants, all of whom were in the more intensive monitoring group, felt that SMBG values were important in informing treatment. This may reflect their trial group allocation, as the potential of SMBG to evaluate and inform treatment decisions was emphasised in this group. The emphasis may also account for the confusion described by these participants when discussing the value placed by health-care professionals on their SMBG. Participants felt more emphasis was placed on HbA1c than on SMBG, especially if these elicited contrasting information. One participant who was monitoring intensively felt her physician was ignoring important information, rendering monitoring a waste of time.

Well, I think what a waste of, what a waste of effort, you know, there’s a lot of information here that that would give them more feedback than they can obviously do from one reading, once in six months.
(D40, 71-year-old woman, group 3)

Comparison of SMBG and HbA1c
Although use of SMBG may have enabled some participants to feel more in control of their diabetes, only two respondents expressed an absolute preference for SMBG over periodic clinic visits and HbA1c. One was concerned that the feedback from her health-care professional was deficient and felt her only source of feedback was SMBG. The other participant, in the less intensive monitoring group, felt that clinic assessment was unable to give an accurate measurement as it was a one-off reading:

I can keep a more up-to-date tab on it. I mean, for example, if it were every 3 months, on the occasion of that third month, I might go along when it, it could be as low as anything on here. Now, another day before or after it might be high, but I wouldn’t know that, so this is by far the better thing, in my view.
(D8, 62-year-old man, group 2)

This respondent thought that the blood tests carried out at his surgery provided the same information (i.e. his blood sugar at that point in time) as those taken at home and therefore could not detect variations. Consequently, he felt more regular monitoring to detect such variations was necessary. This reflects a misunderstanding of the nature of HbA1c tests, which was not noted in other interviews.

Some respondents, all of whom were in the comparison group, expressed a preference for clinic testing. While willing to test if their health-care professionals thought it necessary, they were somewhat reluctant to do so, commenting on the appropriateness of that level of health-care involvement and their ability to carry it out:
I don’t think it’s a good thing for people to mess about like that, unless the doctor suggests that I get something of that nature, then I would. But I would only do it, under his instruction or if he told me or showed me how to do it, or the nurse. I don’t mess about with those sort of things on my own.

(D10, 80-year-old man, group 1)

I think I might prefer possibly to, to do, stick to the 3 months, really. I mean I would do the other way if, if, if they thought it was of benefit to, to them and to me. But I think I, as I say, my, my, my memory is not the best. I, I’d forget it now and again and then that would, you know, probably upset the whole system.

(D27, 74-year-old woman, group 1)

Most of the respondents in this study reported using their SMBG values to guide their behaviour, rather than depending on interpretation by their health-care professional or study nurse. Participants who require continued significant input from health-care professionals may therefore not benefit as much from use of the technology. Anxieties about misuse of SMBG might be allayed by reassurance that SMBG was an adjunct rather than a replacement for standard care. The absence of these concerns in those actually monitoring suggests that they might be overcome with exposure to SMBG and appropriate education.

Most respondents, however, described benefits of utilising both HbA1c and SMBG. The value of HbA1c in giving a longer-term assessment of glycaemic control than SMBG gave was widely praised, as were the other services provided at clinic visits:

The nurse does checks on me feet and she does me urine, urine test and things like that, and weighs me and all that.

(D25, 69-year-old man, group 2)

The wide range of participants who reported this benefit suggests that most people recognise a role for dual monitoring strategies, with distinct objectives for each strategy.

Comparison of SMBG and urine monitoring

Perceptions about accuracy were relevant to perceptions of empowerment, with participants who felt that SMBG was inaccurate being less likely to use it or to feel that their results were relevant to their management. Concerns about the accuracy of SMBG, in comparison with urine testing, were also reported.

Three participants compared SMBG to their experience with urine monitoring. While urine monitoring was simple, all felt it was not as accurate and did not provide adequate information, supporting previously published findings:21

Well I had some little strips which you put in your urine and I think it’s, is it red is it? And they go blue, or they go a different colour anyway, and I noticed once when I’d just checked it a- and I had had some chocolate or something and it, went the wrong colour completely, and I thought ‘Well, I know that was wrong for me.’ But no, there wasn’t, it wasn’t the same as with this because it’s not very good method that really. It’s like – if it goes the wrong colour, you don’t know how bad it is really, do you?

(D11, 64-year-old man, group 2)

Although SMBG was thought to be more accurate than urine monitoring, participants expressed reservations about its accuracy when compared with HbA1c. Three participants across both monitoring groups expressed reservations about the accuracy of SMBG. Doubts about accuracy were related to the volume of blood, with one patient feeling that the blood tests done at the surgery should have been more accurate by virtue of the larger quantity of blood. Another patient obtained a lower reading after washing his hands and felt this was a reflection of the accuracy of the technique:

The nurse does checks on me feet and she does me urine, urine test and things like that, and weighs me and all that.

(D29, 75-year-old man, group 3)

In this instance, the patient attributed the difference in readings to deficiencies in the meter, rather than in his technique. Appropriate technique and informing patients about potential sources of error might reduce this and increase confidence in the accuracy of the meter.

I have my doubts sometimes, have my doubts. Like I washed my hands. I came down, where did I come from, I went somewhere. Anyway I came in, took my blood sugar and it was 11 something. And I said to my wife, I said that’s got to be wrong. She said wash your hands. So I did and it went down to 10.0. That makes a difference.

(D29, 75-year-old man, group 3)
Chapter 7
Discussion

Interpretation of results

Clinical outcomes

Our results showed no convincing evidence of improvement in glycaemic control after 12 months in patients with non-insulin-treated type 2 diabetes using SMBG, compared with those not using SMBG. There was no evidence of improved glycaemic control in predefined subgroups of patients although the data do not exclude the possibility of a clinically important benefit for specific subgroups of patients in initiating good glycaemic control. There was no evidence that monitoring plus additional training in interpretation compared with monitoring alone was effective in improving glycaemic control. Despite the lack of clinical benefit, more patients receiving the SMBG interventions recorded harm in terms of grade 2 hypoglycaemia, but this may be due to an increased awareness of the possibility of low blood glucose from using a meter.

Health economic outcomes

The economic analysis showed that SMBG was significantly more expensive than standardised usual care, by £92 and £84 for the less and the more intensive SMBG groups respectively. There appears to be an initial negative impact of SMBG on quality of life measured using the EQ-5D. The potential additional lifetime gains in QALYs resulting from the lower levels of risk factors achieved at the end of trial follow-up were outweighed by the initial negative impacts for both SMBG groups compared with standardised usual care. Results of the extrapolation also suggest that the incremental lifetime savings in diabetes complications did not offset the additional intervention costs. The cost–utility analysis showed that it is unlikely that either investigated form of SMBG is cost-effective compared with standardised usual care.

Generalisability

This was a large, rigorously designed and conducted randomised controlled trial. We successfully conducted independent randomisation, concealed allocation for measurement of the main outcome and had a low loss to follow-up. Participants were drawn from a well-defined sampling frame with reasons for exclusion recorded. The majority were taking oral hypoglycaemic medication and were not using a meter, with a minority testing no more than once a week. The demographic and clinical characteristics of the trial population at entry were similar to those seen in other trials, although with slightly lower HbA1c. These non-insulin-treated patients under good control represent the target group for current recommendations of up to twice-daily self-monitoring and testing after meals.62,63 However, it could be argued that the trial does not include sufficient patients with very poor glycaemic control to exclude a benefit of self-monitoring in this subgroup to initiate better control.

Design of trials to evaluate SMBG is difficult because of the need to include education about the use and interpretation of testing,64 while maintaining an appropriate comparison group which is also given the opportunity to improve self-care activities.65 We achieved this by providing a common structure for interventions incorporating standardised best practice in all three arms of the trial, within which nurses discussed issues of glycaemic control, assessed by either HbA1c or SMBG, and its role in setting and monitoring self-care goals.30 The stepwise approach to the interventions across the three arms of the trial allowed examination of what aspects of the intervention, if any, were responsible for improved outcomes. Recent consensus guidelines have based recommendations for SMBG on a theoretical potential to better self-manage glycaemic control.11,12 We incorporated SMBG into a framework that, based on psychological theory, should have optimised its utility. Careful specification, training and monitoring of consultations ensured that the allocated interventions were delivered as planned.66

Although our trial included only 15% of those potentially eligible, it is unlikely that the patients enrolled in our trial were less able to make best use of the procedure than those who were not enrolled. In addition, patients enrolled in our trial were able...
Discussion

to have 3-monthly HbA1c testing. Our results may not be generalisable to groups where this is not possible, although again this seems unlikely. The main limitation to generalisability is, therefore, that the relatively good control of the motivated patients who enrolled for the trial left less room for improvement of HbA1c than in those with initially poorer control who were not motivated to join the study. It remains possible that a subgroup of patients with high initial HbA1c levels, who would gain significant clinical benefit from self-monitoring in initiating better control, might be identifiable.

Comparisons with other studies

Comparisons with early trials of blood glucose monitoring are of limited relevance owing to their small size, the large quantity of blood required by older meters and the skill required for their use. However, more recent trials have been conducted with meters utilising technologies that require smaller amounts of blood and simplified procedures for testing. Our findings support those of a recent small trial using standardised counselling for both intervention and control groups. The trial reported a non-significant HbA1c reduction of 0.17% in the intervention group compared with the control group.67 However, our findings are less encouraging than the findings of two of the largest trials of SMBG to date, although CIs of differences encompass the estimated effect from recent meta-analyses.65 One of these trials reported a significant decrease in HbA1c of 0.3% in the intervention group compared with the control group.20 However, more than 30% of those randomised were lost to follow-up. Initial specific training in use of a blood glucose meter was not matched by additional training for the control group, although all patients received dietary advice regardless of randomisation. A second trial reported a reduction in HbA1c of 0.46% in the intervention group compared with the control group. However, standardised counselling supporting lifestyle modification was provided only to the self-monitoring group.19 This type of educational support for self-management in itself has been estimated as improving HbA1c by 0.26%.4

Fewer people allocated to more intensive monitoring than to less intensive monitoring continue testing. Previous studies have found that trying to understand blood glucose measurements may lead to frustration when results do not fall into a pattern, or may cease to be of interest when they are entirely predictable.21 The increased recording of hypoglycaemia in the self-monitoring arms may be due to an increased awareness of low blood glucose from using the meter rather than a true biochemical difference between groups. Although no improvement in glycaemic control was observed, there was a small but significant improvement in total cholesterol with the monitoring intervention. Although it is possible that an increased intensity of self-management might lead to this change, it is counter-intuitive that an intervention targeted at glycaemic control should not also have led to improved glycaemic outcomes. These findings may represent a statistical anomaly.

Interpretation of in-depth interviews and questionnaires about well-being, beliefs and behaviour

Changes in beliefs and self-reported behaviour

Questionnaires administered as part of the trial identified that, after 12 months, patients given the more intensive self-monitoring intervention were more likely to consider diabetes a serious condition than those not using a meter. However, there were no differences in the extent to which they felt they had greater control over their condition. The more intensive meter-using group felt less negative about self-testing and considered it more important to self-test than those not using a meter.

The trial was designed around the framework of the CSM of illness representations. The results concerning the beliefs and behaviour measures are in line with the clinical results in suggesting that the intervention failed to modify beliefs and behaviour to the extent necessary to lead to clinical changes. Our prior hypothesis, that SMBG increases patients’ perceptions of self-control over their disease, is not supported by these findings. It appears instead that SMBG may increase concerns about the consequences of diabetes.

Views of participants

Patients who perceive themselves as independently interpreting results of SMBG in the light of their self-management behaviour and using them to support improved adherence to self-management had a positive attitude towards the use of SMBG. However, there were also people who expressed a
favourable view\textsuperscript{21} of the idea of adherence to health behaviours who seemed to be demotivated if SMBG results did not reflect their efforts. Conversely, negative perspectives were expressed by those who found difficulty in understanding the relationship between their SMBG values and their behaviour, or who experienced no improvement after behaviour modification. Exposure to SMBG appeared to affect these perspectives. Anticipated disadvantages such as physical discomfort, distress from increased awareness of diabetes and undue responsibility for care, which were raised by respondents in the comparison group, were not concerns for those actually monitoring.

Interviews and questionnaires reveal important differences between patients allocated to the three trial interventions in changes in beliefs and attitudes towards diabetes and blood glucose over 12 months. However, the mediation analysis indicated that observed differences between groups of patients allocated to the different interventions in behaviour and outcomes were not explained by the observed changes in beliefs. Despite the perceived conceptual advantages of SMBG revealed though both the interviews and questionnaires, these results need to be placed in the context of the decline in compliance with the more intensive self-monitoring group and the reduction of, at best, 0.2\% in HbA1c.

**Health economic study – meaning and implications**

This is the first detailed economic evaluation of SMBG to be performed prospectively alongside a randomised trial. The economic analysis was closely related to the trial design and was designed to be conservative: the length of the interventions was 1 year and no long-term treatment effects were assumed beyond the first year for any of the groups. As the evaluation was carried out on an intention-to-treat basis, one should be careful when drawing conclusions for specific subgroups of patients (e.g. compliant patients only) from the current cost–utility estimates.

A validated simulation model was used to extrapolate the effects of the interventions beyond the trial period. The uncertainty investigated in this analysis incorporated the first-order uncertainties inherent in the trial design and the simulation model. We also examined the effects of parameter uncertainty by repeatedly running the model with different sets of bootstrapped parameters, which had the effect of increasing the width of the CIs around the base-case results without any substantial influence on the final cost-effectiveness results.

If the utility analysis had been restricted only to those patients with complete data, it would have greatly reduced the sample size and would also have resulted in biased estimates, as those included are likely to be a non-representative subset of the overall sample by being healthier and more compliant to the allocated intervention. The use of conditional multiple imputation for missing values allowed the whole data set to be analysed.

The increased costs of the enhanced support offered to all groups within the trial may overestimate the costs of implementation in practice, but the additional costs of blood glucose measurement test supplies are of a similar order to this enhanced care. The trial does not provide evidence that the use of SMBG is cost-effective, but if the technology were to be offered to patients, the fall in EQ-5D score observed over 1 year suggests that they should be reviewed regularly and that any concerns about the use of meters should be closely monitored.

**Implications for health care**

Although the trial did not provide evidence that routine use of SMBG is beneficial, the qualitative study suggests that some individuals may benefit. Our trial suggests that if support for self-management training is available along with 3-monthly HbA1c management, then titration of medication without self-monitoring may be the optimum strategy. However, if HbA1c remains above 8\% and progressively deteriorates, then self-monitoring may be necessary in this group and insulin therapy may eventually be required.

Hypoglycaemia remains an issue for some patients using sulfonylurea drugs. However, the majority of such events are associated with changes in food intake or exercise, and therefore are not predictable by SMBG. Nevertheless, use of a monitor may be helpful for people reporting frequent hypoglycaemia, in order to establish whether therapy is too intensive if HbA1c levels are equivocal.
Recommendations for research

The qualitative element of the trial identifies a group of patients who consider that use of SMBG provides them with motivation to adopt and maintain behaviours that lead to better diabetes control. Further work is required to characterise those who gain most benefit in terms of glycaemic control and whether this is related to use of the procedure.

Our results suggest that routine use of meters may not be appropriate for reasonably well-controlled patients, although their role in the management of patients with less well-controlled diabetes is not clear. However, a pragmatic strategy of self-management education with HbA1c monitoring may be appropriate in the first instance. If glycaemic control is not then achieved, SMBG may be appropriate, first to explore any potential motivating effect, and second because insulin treatment is likely to be required. Exploring the utility of this strategy may be appropriate, although the potential adverse effect on mood would need to be actively addressed.

There is an increased rate of hypoglycaemia reported among individuals using self-monitoring. Further exploration of hypoglycaemia rates during the trial, questionnaire, HbA1c measures and medication adjustment measures are needed to establish whether these differences are likely to result from biochemical differences or greater awareness of hypoglycaemia as a cause of symptoms.

Conclusions

Routine SMBG for non-insulin-treated patients with type 2 diabetes is not well accepted and appears to offer, at best, small advantages; the cost, effort and time involved in the procedures may be better directed to supporting other health-related behaviours. SMBG may be associated with a negative impact on health status, and is not associated with anticipated improvements in perceived personal control over self-management. Current guidelines for the use of SMBG require review. This trial does not provide convincing evidence to support the routine use of SMBG for non-insulin-treated patients with reasonably well-controlled type 2 diabetes.
Acknowledgements

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Oxfordshire Morland House Surgery, Wheatley; Jericho Health Centre, Oxford; 19 Beaumont Street, Oxford; West Street Surgery, Chipping Norton; Long Furlong Medical Centre, Abingdon; The Health Centre, Bicester; White House Surgery, Chipping Norton; The Health Centre, Berinsfield; Burford Surgery, Burford; The Leys Health Centre, Oxford; Nuffield Health Centre, Witney; Islip Medical Practice, Kidlington; Summertown Health Centre, Oxford; West Bar Surgery, Banbury; Exeter Surgery, Kidlington; Hollow Way Medical Centre, Oxford; Victoria House Surgery, Bicester; East Oxford Health Centre, Oxford; The Brook Surgery, Chalgrove; Didcot Health Centre, Didcot; Windrush Health Centre, Witney; Cogges Surgery, Witney; Sonning Common Health Centre, Sonning Common; The Manor Surgery, Oxford.

South Yorkshire Dovercourt Surgery, Sheffield; Woodseats Medical Centre, Sheffield; Selborne Road Medical Centre, Sheffield; Tramways Medical Centre, Sheffield; Rustlings Medical Centre, Sheffield; Darnall Health Centre, Sheffield; Gleadless Medical Centre, Sheffield; Buchanan Road Surgery, Sheffield; Bluebell Medical Centre, Sheffield; Highgate Surgery, Sheffield; The Village Surgery, Rotherham; Nethergreen Surgery, Sheffield; Woodhouse Medical Centre, Sheffield; Baslow Road/Shoreham Street Surgeries, Sheffield; Broom Lane Medical Centre, Rotherham; Rose Court Surgery, Rotherham; Thorpe Hesley Surgery, Rotherham; Jaunty Springs Surgery, Sheffield; Birley Health Centre, Sheffield; Dykes Hall Medical Centre, Sheffield; Duke Medical Centre, Sheffield; Upperthorpe Medical Centre/Ecclesall Medical Centre, Sheffield; Pitsmoor Surgery, Sheffield.

Contribution of authors

AJ Farmer, A-L Kinmonth and HAW Neil had the original idea for the study and wrote the trial protocol with P Yudkin, D French and RR Holman. D Mant contributed to the trial design. A Gray contributed the design of the health economic study. AJ Farmer, AN Wade, DP French and A-L Kinmonth developed the trial measures and intervention. AN Wade, AJ Farmer, A Craven and E Goyder managed the trial. P Yudkin was trial statistician and analysed the clinical outcomes data. J Simon conducted the health economic analysis. DP French analysed the questionnaire data. AN Wade and S Ziebland analysed the interview data. AJ Farmer, AN Wade, DP French and J Simon wrote the first draft of this report. AJ Farmer wrote the final draft. All members of the writing group contributed to interpretation of results, reviewed and commented on the final draft.

The qualitative chapter and discussion are adapted from the DPhil thesis submitted by AN Wade.

A Farmer was supported by an NHS R&D Career Development Award from 2001 to 2005. AN Wade was supported by a Rhodes Scholarship. J Simon was supported by an NHS R&D Research Scientist Award.

The DiGEM trial group


Coordinating centres  (Oxford) AN Wade (to 2005, trial coordinator), A Craven (trial manager), P Yudkin (trial statistician) J Simon (health economist) and A Fuller (data manager); (Sheffield) Vivienne Walker.

Data monitoring committee  C Baigent (Chair), J Levy and K Wheatley.


Central laboratory  K Islam.

Publications


References


Appendix 1

Patients lost to follow-up
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- **Practice number**
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  - 1 = usual care
  - 2 = less intensive monitoring
  - 3 = more intensive monitoring

**Comments**: Carcinoma of breast diagnosed; mastectomy

**Reasons for loss to follow-up**: 1 = withdrawn; 2 = uncontactable; 3 = too ill to continue; 4 = died

- **Gender**: 1 = male
- 2 = female

**Age at baseline**: 1 = 97; 2 = 87; 3 = 76; 4 = 82; 5 = 71; 6 = 80; 7 = 71; 8 = 77; 9 = 65; 10 = 63; 11 = 70; 12 = 68; 13 = 58; 14 = 73; 15 = 66; 16 = 40; 17 = 48; 18 = 48; 19 = 64; 20 = 70; 21 = 83; 22 = 54; 23 = 68; 24 = 72
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<td>Withdrawn; does not like using meter</td>
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<tr>
<td>44</td>
<td>596</td>
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<td>Unable to cope with being in the trial</td>
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<td>49</td>
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<td>Patient works long hours and could not keep regular appointments</td>
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<tr>
<td>35</td>
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<td>3</td>
<td>Patient feels she can’t cope with study requirements</td>
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<td>Patient has reconsidered the study and has decided against meter use; meter not issued</td>
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