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ORIGINAL RESEARCH

A Longitudinal Study into the New and Long-Term Use of Self-monitoring Blood Glucose Strips in the UK

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ABSTRACT

Aims: To determine the impact of self-monitoring blood glucose (SMBG) strip use in patients with type 2 diabetes in the UK. ***Methods:*** The study period was April 1, 2004 to July 31, 2005. Data from primary care was extracted from The Health Improvement Network database. Patients identified with diabetes and matching the inclusion criteria were defined as new users of SMBG, prevalent users, or non-users. Patients were also defined as treated with insulin, with oral agents (OA), or not pharmacologically treated. Change in glycosylated hemoglobin (HbA_{1c}) at baseline and after 12 months was compared. ***Results:*** 2559 patients met the inclusion criteria. For new users, HbA_{1c} fell by 0.59% (P=0.399) for those treated with insulin, 1.52% (P<0.001) for those treated with OA, and 0.51% (P<0.001) for no treatment. In prevalent users, changes were 0.31% (P<0.001), 0.34% (P<0.001), and 0.09% (P=0.456), respectively. In non-users, changes were 0.28% (P=0.618), 0.42% (P<0.001), and an increase of 0.05% (P=0.043), respectively. A significant decrease in mean HbA_{1c} was associated with increasing strip use in OA patients newly initiated on strips. ***Conclusion:*** This observational study showed a significant decrease in HbA_{1c} for new users of SMBG treated either non-pharmacologically or with OA, and for prevalent users treated with insulin or OA. Reduced HbA_{1c} with increasing strip use was observed but was only significant for OA-treated new users. This suggests that SMBG use has a role in the treatment of non-insulin treated patients with type 2 diabetes.

Keywords: blood glucose strips; self-monitoring; type 2 diabetes

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INTRODUCTION

The importance of glycemic control for patients with type 2 diabetes has been well documented.[1] Current guidance in both the UK and the US recommends the use of self-monitoring blood glucose (SMBG) for both insulin and non-insulin treated type 2 diabetes.[2,3] There is, however, continuing debate as to the role of SMBG in the management of patients with non-insulin treated type 2 diabetes.[4,5]

Data from randomized controlled trials are both confusing and contradictory, predominantly due to differences in study design and the inability to measure the impact of SMBG use in isolation to different treatment and management change algorithms.[6,7] Studies based on observational data are equally inconsistent. A report based on the Fremantle Diabetes Study described no difference in glycosylated hemoglobin (HbA_{1c}) between those using SMBG and those who were not,[8] whereas a study based in the United States showed a significant reduction in HbA_{1c} for those patients newly initiated on SMBG and those patients already using strips treated with either insulin or oral hypoglycemic agents (OA).[9] Furthermore, this study also demonstrated a significant dose response between frequency of SMBG usage and reduction in HbA_{1c}.

There is a cost to providing SMBG,[4] but this may prove cost-effective when improved management is offset by the reduction of diabetes-related complications.[10] There have also been concerns about the potential negative psychological impact upon patients of using SMBG.[11,12] However, this has been countered with claims that the use of SMBG allows for the empowerment of patients and enables them to have a greater understanding of their condition and how it is affected by medication and their lifestyle choices. Nevertheless, SMBG use requires the patient and/or carer to act appropriately on the results, otherwise no benefit will accrue.

A previous cohort study by Karter et al.[13] sought to assess the longitudinal association between SMBG and glycemic control in diabetic patients within a US health plan (Kaiser Permanente, Northern California, USA). The study reported reductions in HbA_{1c} for new users of SMBG, compared with non-users, although it was acknowledged that it did not control for dose escalation during the study period and, as such, could not isolate the impact of initiation of SMBG.

The aim of this study was to characterize patterns of SMBG use, treatment, and associated HbA_{1c} values in patients with type 2 diabetes within a UK setting, based on the findings from the Karter Study.[13]

MATERIALS AND METHODS

Data Sources

Data used in this study were provided by The Health Improvement Network[14] database, which is a longitudinal research database derived from over 350 primary care practices in the UK and has records for approximately 6 million patients.[15]

Inclusion Criteria

The study period was based on April 1, 2004 to July 31, 2005. Patients included in the study were those with a diagnosis of type 2 diabetes recorded in their medical history using the Read Code classification between 2002 and 2007, and a HbA_{1c} test result recorded in the 90 days (inclusive) before baseline and the final quarter of the study period (between 273-365 days after baseline). For patients using SMBG, baseline HbA_{1c} was defined as the date of the first prescription during the study period. For non-

strip users, baseline was defined arbitrarily as the December 1, 2004.

Only patients prescribed the same combinations and dosages of oral and/or insulin treatment in the quarter before baseline and final quarter were included. Patients were excluded if they had a history of end-stage renal failure or a test result of serum creatinine ≥200 µmol/L recorded in their patient history.

Cohort Definitions

Patients were classified by SMBG use according to the nomenclature defined by Karter et al.,[13] based upon British National Formulary codes recorded in the patient's prescription records. "Prevalent users" were those with at least one strip prescription before baseline date, and at least two separate prescriptions during the study period. "New users" were those with at least two separate prescriptions in the study period and no strips prescribed in the year before baseline. "Non-users" were those with no SMBG strips prescribed either before baseline or during the study period.

Patients were also classified according to therapy regimen based upon prescription records using the British National Formulary definitions. The "no medication" group were those patients with no prescriptions (either insulin or OA) recorded in the 90 days before baseline and the final quarter of the study. "OA" (oral agents only) were those patients prescribed at least one OA and no insulin prescription in the 90 days before baseline and the final quarter of the study. The "insulin" group were those patients prescribed at least one insulin agent, either on its own or in combination with OA at the quarter pre-baseline and the final quarter of the study period. Patients changing their total insulin dosage or OA dosage between these periods were excluded.

Statistical Analysis

Changes in mean HbA_{1c} before and 12-months post-baseline were compared using the paired *t*-test. To evaluate the change in HbA_{1c} associated with different volumes of strips use, mixed-effects multi-level models were created that allowed for the change in HbA_{1c} to be analyzed at multiple hierarchical levels, that is: strip category (<0.5/0.5-1/>1), age, sex, duration of diabetes, baseline HbA_{1c}, and primary care practice. Due to the relatively small number of patients in the insulin groups when disaggregated by strip frequency, this analysis was restricted to those patients treated either with oral agents or who were not receiving pharmacological intervention. The variables were assumed to stand behind the fixed effects, whereas random effects were put on the primary care variable.

RESULTS

From a total of 31,667 patients with type 2 diabetes, 2559 (8.1%) met the inclusion criteria as shown in Figure 1.

Demographic characteristics, duration of diabetes, baseline HbA_{1c}, and mean daily SMBG strip usage by therapy type and SMBG use is shown in Table 1. For each treatment group (no treatment, OA, and insulin), baseline HbA_{1c} was higher for patients newly initiated on SMBG compared with non-users/prevalent users, although this was only significant for the OA group ($P<0.001$). It was lowest for those patients who were non-users of SMBG. The new user groups were also younger with a shorter duration of diabetes.

SMBG was most commonly used by patients treated with insulin ($n=271$), of which 98.5% of these patients were either new or prevalent users. Conversely, it was least common in those who were receiving no medication ($n=293$ [29.8%]).

Figure 1. Derivation of study cohort and grouping by self-monitoring blood glucose usage and treatment regimen. HbA_{1c}=glycosylated hemoglobin; OA=oral agents.

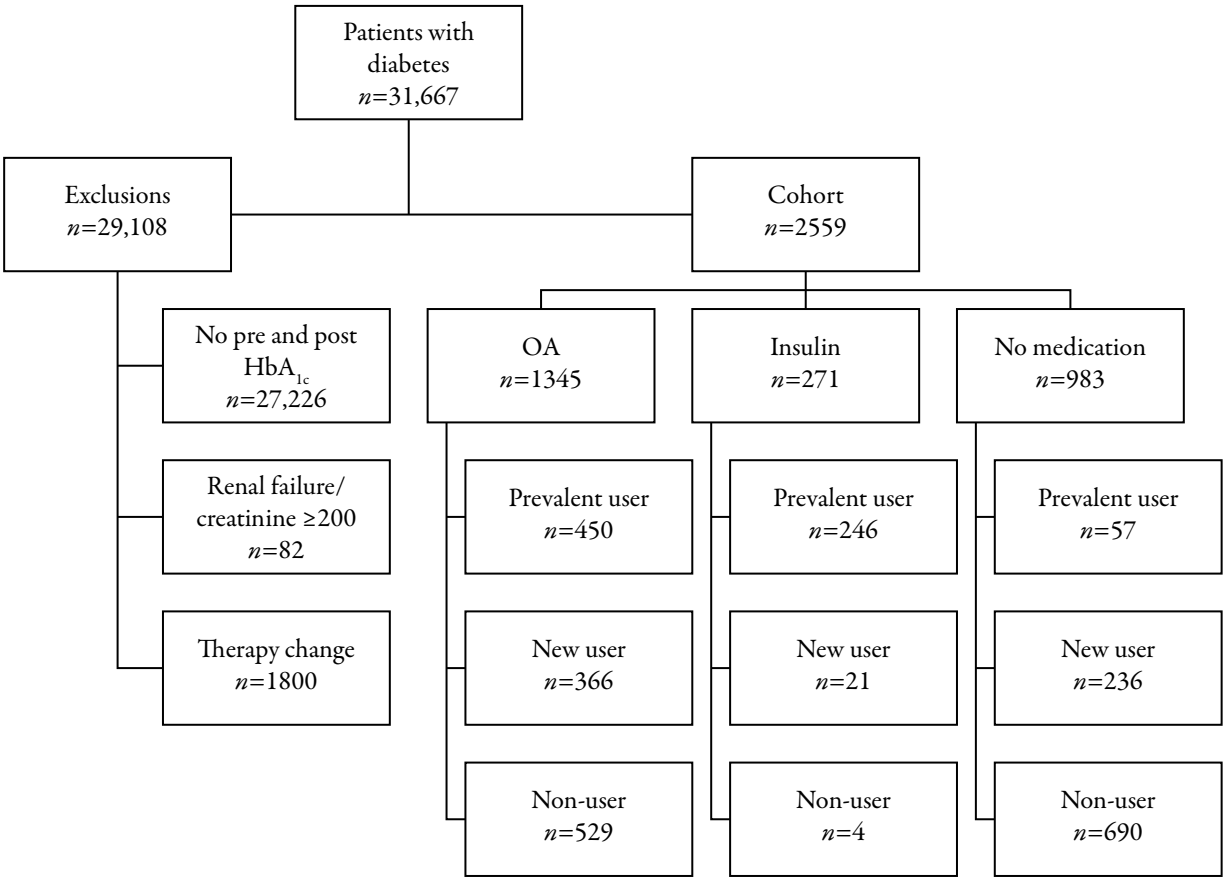


Figure 2. Change in mean baseline HbA_{1c} for patients by self-monitoring blood glucose use and treatment. *P<0.001. †P<0.05. HbA_{1c}=glycosylated hemoglobin; OA=oral agents.

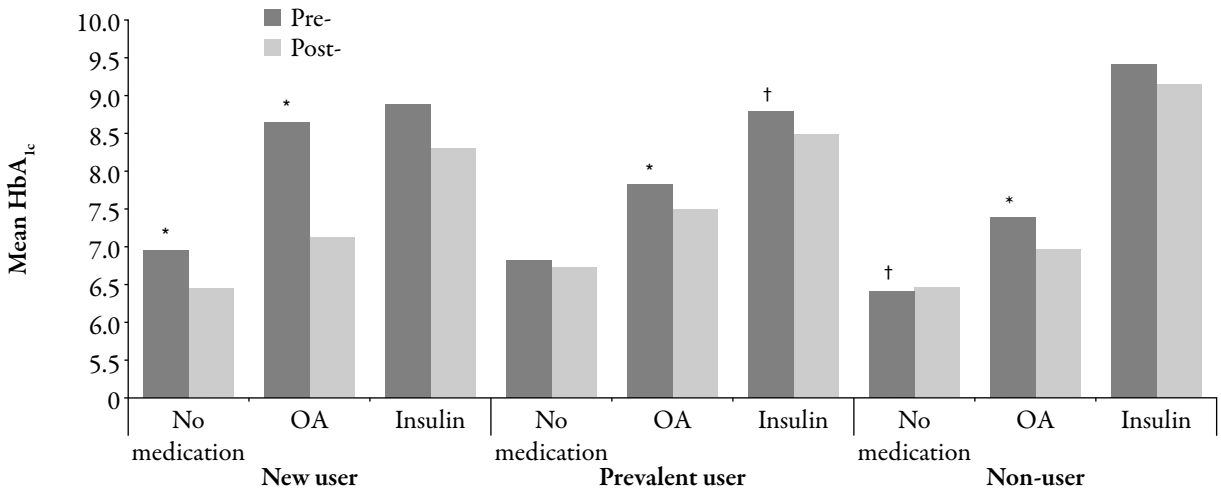


Table 1. Baseline characteristics and self-mean monitoring blood glucose (SMBG) use per day by treatment regimen and use of SMBG.

	Insulin			OA			No treatment		
	Prevalent	New	Non-user	Prevalent	New	Non-user	Prevalent	New	Non-user
n	246	21	4	450	366	529	57	236	690
Mean age, years±SD	64.5±11.1	62.6±12.8	68.5±19.7	63.8±11.5	59.6±11.9	67.0±11.9	65.1±12.2	62.3±10.8	67.1±11.4
Female, *n* (%)	127 (51.6)	6 (28.6)	1 (25.0)	211 (46.9)	148(40.4)	239 (45.2)	30 (52.6)	111 (47.0)	341 (49.4)
Diabetes duration, years±SD	10.8±6.7	8.2±9.0	8.5±6.7	5.2±4.4	1.5±3.3	3.4±4.4	2.7±3.2	0.5±2.2	1.2±2.5
Mean SMBG usage per day during year, use±SD	1.7±1.4	1.3±0.7		0.9±0.9	0.9±0.7		0.7±0.7	0.7±0.4	
Baseline HbA_{1c}, %±SD	8.8±1.6	8.9±2.4	9.4±2.1	7.8±1.4	8.7±2.1	7.4±1.5	6.8±1.1	7.0±1.3	6.4±0.7

HbA_{1c}=glycosylated hemoglobin; OA=oral agents.

Figure 3. Change in HbA_{1c} between baseline and 12 months by treatment group and daily self-monitoring blood glucose use in newly initiated patients. *P<0.05. HbA_{1c}=glycosylated hemoglobin; OA=oral agents.

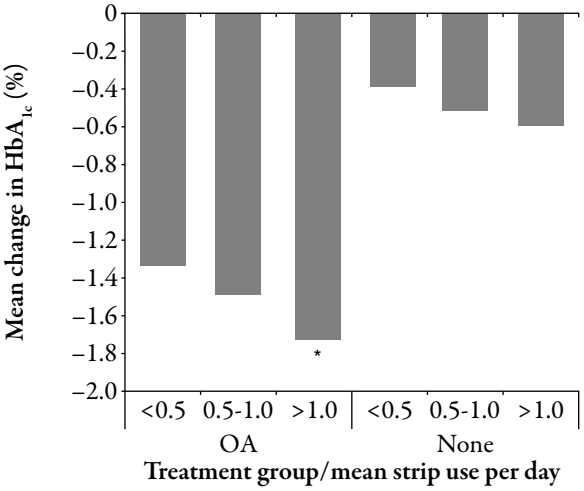
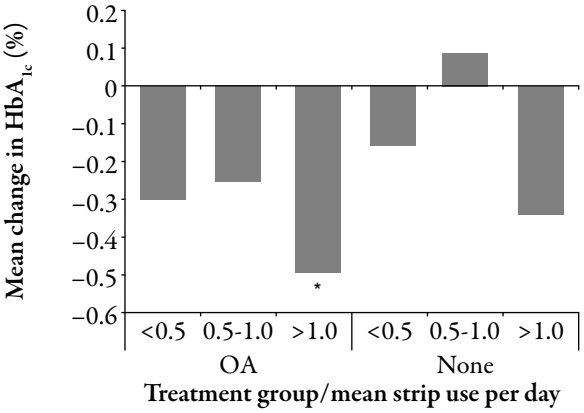


Figure 4. Change in HbA_{1c} between baseline and 12 months by treatment group and daily self-monitoring blood glucose use in prevalent patients. *P<0.05. HbA_{1c}=glycosylated hemoglobin; OA=oral agents.



Change in HbA_{1c}

Figure 2 shows the change in HbA_{1c} before and after baseline by treatment type and SMBG use. For new users, HbA_{1c} fell by 0.59% (P=0.399) for those patients treated with insulin, 1.52% (P<0.001) for those patients treated solely by OA, and 0.51% (P<0.001) for those patients receiving no treatment. In the prevalent users, HbA_{1c} fell

by 0.31% (P<0.001) for those patients treated with insulin, 0.34% (P<0.001) for those patients treated solely by OA, and by 0.09% (P=0.456) for those patients receiving no treatment.

In the non-user group, HbA_{1c} fell by 0.28% (P=0.618) for those patients treated with insulin, 0.42% (P<0.001) for those patients treated solely with OA and increased by 0.05% (P=0.043) for those patients receiving no treatment.

Change Associated with SMBG Strip Use

Mean SMBG strip use for insulin-treated patients was lower for newly initiated rather than prevalent SMBG users (1.24 versus 1.73 strips per day, P=0.010). For the OA group, mean strips used per day was 0.84 for new users, compared with 0.86 for prevalent users (P=0.689). For the non-medication group, the mean strips used per day was 0.69 for new users, compared with 0.74 for prevalent users (P=0.628).

Figures 3 and 4 show the change in HbA_{1c} associated with different volumes of strip use by treatment groups for newly initiated and prevalent strip users, respectively, for those patients receiving either oral treatment or no treatment after adjusting for age, sex, baseline HbA_{1c}, and duration of diabetes in the fixed-effects model.

There was a significant decrease in mean HbA_{1c} associated with increasing strip use in those patients newly initiated on strips, for patients in the OA group using greater than 1 strip per day. In the prevalent user groups there was a pattern of reduced HbA_{1c} associated with increased strip use for both treatment groups, but this was not significant.

DISCUSSION

This study aimed to replicate and improve upon the US study by Karter et al.,[13] which determined the impact of SMBG use upon HbA_{1c} for both newly initiated and prevalent users. Unlike this previous study, we were able to limit our analysis to those patients whose medication remained constant over the study period. As in the Karter[13] study, there was a decrease in HbA_{1c} for all new users regardless of therapy regimen following initiation of SMBG, although this was not significant for those patients prescribed insulin. For prevalent users we showed a significant decrease for those using insulin and OA, although there was a pattern of reduced HbA_{1c} with greater strip use in the non-pharmacologically treated group.

For patients not using SMBG, there was a significant decrease in HbA_{1c} only in those patients prescribed OA. For patients who did not receive pharmacological intervention, there was a significant increase in HbA_{1c}. Whilst there was a pattern of reduced HbA_{1c} with increasing strip use, this was only significant for new users on OA. It should also be noted that unlike the majority of insulin users, who will use a broadly consistent number of strips each day, patients on OA or diet and exercise may perform intermittent glucose profiling, where they would test four or more times a day for a week, and then not test for a period. The "dose response" in the OA group may therefore indicate a frequency of glucose profiling rather than an absolute number of tests per day.

This was an observational study based on treatment patterns observed in primary care. As such it offers a "real world" picture of the impact of SMBG use in everyday practice. However, we accept that as it did not have the randomization that would occur in a controlled trial there may have been differences between those patients prescribed SMBG and may have confounded our results. Such differences may include patient compliance and motivation and physician preference. However, unlike

Karter,[13] in this study we were able to compare patients who remained on the same therapy regimen before and after initiation of SMBG. Clearly, the motivation to initiate SMBG, either by the patient or physician, will be the need to maintain glycemic control and so may be accompanied by changes in therapy.

Karter et al.[13] highlighted the potential for reverse causality and we noted similar observations in our study—notably that the non-SMBG patients had lower HbA_{1c} at baseline than new users. As such, poor glycemic control may be the trigger for SMBG use with accompanying intensification of educational interventions. In both patients treated with OA and those managed by diet and exercise, new users of SMBG had higher HbA_{1c} values than the non-user groups, suggesting that prescribers had criteria (explicit or implicit) in determining when (and why) to initiate a patient on to SMBG. Furthermore, both groups also showed a significant decrease in HbA_{1c} following initiation of SMBG. One criticism of SMBG studies is that it cannot be determined to what extent initiation of strips was accompanied by educational interventions which may have been different to those received by non-users. It should, however, be acknowledged that SMBG use in itself is not a therapeutic intervention, but an insight to glucose control. In that context it makes sense that a patient that is being "educated" to improve control of their diabetes might receive SMBG as a tool to provide awareness of glucose levels and therefore seen as part of that education. This raises the issue as the extent to which the patient uses the data afforded to them from their SMBG monitoring. It could potentially be the process of testing itself which by reinforcing the presence of diabetes to the patient leads to increased awareness of the need to maintain glucose control. This question, however, cannot be addressed by this study.

The implication that poor glycemic control is one potential trigger for SMBG fits with the recent National Institute for Health and Clinical Excellence clinical guidelines[2] on the management of type 2 diabetes, where it recommends that SMBG be offered to persons newly diagnosed with type 2 diabetes only as an integral part of his or her self-management education. Furthermore, the observation that patients do not routinely start SMBG until they start to lose glycemic control may partly explain the conflicting results revealed by clinical trials investigating the impact of SMBG in non-insulin users. For example, patients in the Diabetes Glycemic Education and Monitoring (DiGEM) study,[16] with a mean HbA_{1c} at baseline of approximately 7.5%, observed no benefit from SMBG in non-insulin treated patients, compared with the Auto-Surveillance Intervention Active (ASIA) study,[17] reporting a mean baseline HbA_{1c} of around 9%, which did observe a benefit.

This study demonstrated that SMBG use was associated with lower HbA_{1c} in non-pharmacologically treated patients who were new users but not in prevalent users. This might indicate that SMBG is of benefit initially in informing the patient about his or her HbA_{1c} levels and how this can be affected by a patient's exercise and diet regimes. Over a longer time period, this may be limited either due to the reduced impact of diet and exercise to control HbA_{1c} over time or perhaps changes in patients' behavior after the initial "novelty" of monitoring and reacting to HbA_{1c} readings.

Whereas some guidelines are moving away from recommending SMBG use in patients not treated with insulin, this study, and that of Karter,[13] may indicate that SMBG use in

some subgroups of non-insulin-using patients is beneficial, at least initially, as a means of allowing a patient to understand his or her condition and the impact of behaviors upon it.

CONCLUSION

This observational study showed a significant decrease in HbA_{1c} for new users of SMBG treated either non-pharmacologically or with OA, and for prevalent users treated with insulin or OA. Reduced HbA_{1c} with increasing strip use was observed, but was only significant for OA treated new users. This suggests that SMBG use has a role in the treatment of non-insulin-treated patients with type 2 diabetes.

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