

Estimation of blood glucose levels by people with diabetes: a cross-sectional study

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ABSTRACT

Background

Recommendations suggest that all patients with diabetes who use insulin should home test their blood glucose. Recommendations for those not using insulin remain contradictory. These recommendations are in part based upon the assumption that people with diabetes cannot make an accurate estimate.

Aim

To explore whether people with diabetes can accurately estimate their blood glucose levels and to assess which factors explain variability in these estimates.

Design

A cross-sectional design.

Setting

One general practice in Oxfordshire, UK.

Participants

One hundred and fifteen consecutive patients with diabetes attending a diabetic clinic were invited to estimate their blood glucose level prior to having it routinely measured.

Results

One hundred and four patients made estimates. Of these, 45 (43.3%) underestimated their blood glucose, 18 (17.3%) overestimated, and 41 (39.4%) made guesses that fell into the range defined as accurate. Of those not using insulin ($n = 85$), 37 (43.5%) underestimated their blood glucose, 12 (14%) overestimated and 36 (42.3%) were accurate. Accuracy in the non-insulin users was associated with home testing, lower blood glucose levels, coming to the clinic in a fasting state, and reporting no symptoms when they felt that their blood glucose level was high. Overestimation was associated with having co-occurring illnesses and experiencing no symptoms when their blood glucose was low.

Conclusion

The majority of patients with diabetes in this study could not accurately estimate their blood glucose levels indicating that home testing may be a necessary part of diabetes self care. Home testing may also function as a form of biofeedback to facilitate an improved ability to estimate blood glucose levels.

Keywords

blood glucose self monitoring; diabetes mellitus, type 2; insulin.

INTRODUCTION

There is well-established advice^{1,2} that all patients with diabetes who use insulin should regularly test their blood glucose level, to ensure that they are controlling their diabetes with the correct balance of diet, exercise and medication. This is partly because insulin, unlike oral hypoglycaemic treatments for diabetes, has the immediate potential to cause dangerously low blood glucose levels ('hypos'). The advice on whether patients with diabetes who are not using insulin should test their blood is equivocal and sometimes contradictory.³⁻⁷ For example, Diabetes UK have argued that 'home monitoring is essential in the context of diabetes education for self management'⁶ and NICE have suggested it should be taught as a part of integrated self-care.⁵ In contrast, Reynolds and Strachan⁷ argue that the evidence concerning the effectiveness of testing is insufficient and that 'consensus recommendations' are not appropriate in this case. Further research has also highlighted patient's experiences of home testing and have argued that it can be seen as inconvenient, relatively painful, and can highlight a sense of failure resulting in self blame and guilt.^{8,9} The advice to home test is in part predicated on the belief that diabetics cannot accurately estimate their own blood glucose levels, since accurate guessers would have no need to undergo this expensive procedure. Research exploring patients

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with insulin-dependent diabetes has consistently shown that they cannot accurately estimate their blood glucose levels and that interventions such as feedback and blood glucose awareness training are only moderately effective at improving these estimations.¹⁰⁻¹³ To date, however, whether or not patients not using insulin can make accurate judgements about their blood glucose levels remains unknown. This is particularly relevant as research indicates that patients sometimes believe that they can perceive whether or not their blood glucose is too high or low and use these perceptions to modify their self care practices in a way that has been termed as 'flexible adherence'.¹⁴⁻¹⁶ Therefore, the present study was designed to examine how accurate patients with diabetes who do not use insulin are at guessing their own blood glucose levels in the context of a routine visit to their normal diabetic clinic. In addition, the study aimed to assess the factors that may account for variability in the accuracy of such estimates as a means to explore who may and may not benefit from home testing.

METHOD

Consecutive patients attending a general practice diabetic clinic aged over 18 years were asked to provide their consent to take part in a brief study exploring their estimations of their blood glucose. Following consent, they were asked to complete a short questionnaire before seeing the nurse when they had their blood glucose measured routinely using a 'OneTouch Ultra' blood glucose meter. Regular calibration and quality control were by means of samples sent to the local hospital biochemistry laboratory.

How this fits in

The recommendation that diabetics should home test their blood glucose levels is predicated on the assumption that they cannot make an accurate estimation. For diabetics not using insulin, rationing of home testing requires an understanding of who would most benefit from this expensive and inconvenient practice. The majority of diabetics in this study could not accurately estimate their blood glucose levels and most showed a tendency to underestimate. Those with co-occurring vascular disease, who take β -blockers, or who run higher blood glucose levels may benefit most from home testing. Home testing may not only help diabetic control but may also facilitate accurate estimation.

The questionnaire

The questionnaire asked patients to complete the following:

- To estimate their current blood glucose level;
- To describe the symptoms they experienced, if any, when they believed that blood sugar levels had been high or low. The symptoms were then classified by the researchers as: none; physical (such as headache, shaky, hot, dry tongue, thirsty); or psychological (such as aggressive, irritable, restless, confused, tired);
- To describe what information they used to make their estimation. This involved rating three statements using five point Likert scales: 'on the basis of how I feel'; 'on the basis of what I have done'; and 'I made a guess'. These were then reduced to a dichotomous scale (1/2/3 coded as 'no'; 4/5 coded as 'yes').

If unable to estimate, patients were invited to seek help from the nurse or GP in the clinic, who had a visual aid to blood glucose levels. Data was also collected regarding a range of profile, clinical, management and control factors: actual blood glucose; self reported fasting or random status; age; sex; current treatment; other significant diagnoses and treatments; how long they had had diabetes; how well it was controlled (average HbA1C over the last 2 years); and whether they tested their blood already and if so how often (estimated by prescriptions for glucose measuring strips).

Data analysis

The data were analysed to describe the participants' profile characteristics and the accuracy of their estimates using descriptive statistics. The data were then analysed separately for patients not taking insulin to explore the accuracy of their estimates and to explore differences between people who were underestimators, overestimators, and those who were accurate, using ANOVA and χ^2 tests.

RESULTS

Profile characteristics

The participants' profile characteristics are shown in Table 1.

One hundred and fifteen people with diabetes took part in the study, of whom 104 were able to make a guess about their blood glucose level. The majority of participants (55.7%) were users of tablets (that is, their diabetes was controlled by

Table 1. Profile characteristics (all subjects $n = 115$).

Age (years)	
Mean	65±11.11
Range	35–88
Sex	
Male	67 (58.3%)
Female	48 (41.7%)
Management	
Diet only	31 (27%)
Tablets	64 (55.7%)
Insulin	20 (17.4%)
Home testing	47 (40.9%)
Strips/month (users)	30.8±41.24
Time diagnosed (years)	5.87±6.01
Comorbidity	
Vascular disease	33 (28.7%)
Hypertension	41 (35.7%)
On β -blockers	32 (27.8%)
On ACE inhibitors	51 (44.3%)
On statins	53 (46.1%)
Blood glucose	
HbA1C, average 2 years (range)	7.93±1.42 (5.6–12.2)
HbA1C, last (range)	8.04±1.54 (5.8–13.2)
Fasting/random blood glucose	
Fasting	78 (67.8%)
Random	37 (32.2%)

diet and oral hypoglycaemics), and together with those controlled by diet alone these non-insulin users constituted 82.7% of the total. Two-thirds of all the participants attended the diabetic clinic in a fasting state. The results showed that patients reported using the following information to make their estimate: how they feel, $n = 37$ (45.3%); what they had done, $n = 21$ (24.7%); and just made a guess, $n = 48$ (56.5%).

Accuracy of diabetics' estimates. Accuracy of the participants' guesses was calculated by subtracting their estimated blood glucose levels from the actual blood glucose levels measured in the clinic. The mean overall difference was -1.37 mmol/l, indicating a tendency to underestimate. The average measured blood glucose (a mixture of fasting and random results) was 9.57 mmol/l.

The participants' estimates were analysed on the basis of whether they were 'accurate' (defined as being between -1.0 and $+1.0$ mmol/l of the measured result), or whether their guess was an under- or overestimate (<-1.0 or $>+1.0$ mmol/l respectively). These cuts offs were in part based upon previous work in this area¹¹ but also reflected the tendency for patients to use whole numbers and to allow some margin of error in their estimations. Forty-five participants (43.3%) underestimated their blood glucose, 18 (17.3%) overestimated, and 41 (39.4%) made guesses that fell into the range defined as accurate. For those patients not taking insulin ($n = 85$), 37 (43.5%) underestimated their blood glucose, 12 (14%) overestimated and 36 (42.3%) were accurate.

Differences between accuracy group. For non-insulin users, differences between those patients who were accurate, underestimated and overestimated in terms of profile, control, management, clinical and subjective factors are shown in Tables 2 and 3. α was set at 0.01 to account for multiple comparisons.

Profile, control and management factors

Degree of accuracy was unrelated to sex, management method, age, time since diagnosis or

Table 2. Differences in terms of level of accuracy: profile, control and management factors (patients not using insulin), $n = 85$.

	Underestimators ($n = 37$)	Accurate ($n = 36$)	Overestimators ($n = 12$)	F/χ^2	P -value
Profile					
Management					
Diet only (%)	13 (35.1)	12 (33.3)	3 (25)	4.12	0.390
Tablet (%)	24 (64.8)	24 (66.7)	9 (75)		
Age, years (CI)	66.40 (62.5 to 69.2)	64.59 (61.0 to 69.2)	62.83 (55.9 to 69.8)	0.576	0.750
Sex					
Male (%)	19 (51.3)	23 (63.8)	10 (83.3)	3.042	0.081
Female (%)	18 (54.5)	13 (36.1)	2 (16.6)	1.424	0.491
Time since diagnosis, years (CI)	4.13 (2.8 to 5.1)	5.75 (3.7 to 7.2)	5.25 (2.7 to 7.7)		
Control					
Measured glucose (CI)	11.31 (10.1 to 12.3)	7.78 (7.2 to 8.3)	8.13 (5.4 to 10.7)	29.980	0.001
HbA1C mean, last 2 years (CI)	7.95 (7.5 to 8.4)	7.36 (7.0 to 7.8)	7.56 (6.5 to 8.6)	4.145	0.126
HbA1C, most recent (CI)	7.88 (7.5 to 8.2)	7.40 (6.9 to 7.8)	7.87 (6.6 to 9.1)	3.875	0.144
Management					
Home testing (%)	12 (32.4)	14 (38.8)	2 (16.6)	16.011	0.001
Strips per month, users only (CI)	4.31(1.7 to 6.5)	8.12 (1.9 to 14.8)	0.83 (-0.65 to 2.3)	2.674	0.263
State at clinic (%)	26 (70.2)	29 (74.5)	6 (50.0)		
Random (%)	11 (29.7)	7 (19.4)	6 (50.0)	12.895	0.001

quality of control of diabetes (as measured by HbA1C levels) or the number of strips used per month. Those who were accurate, however, had lower blood glucose levels, were more likely to home test and were more likely to attend the clinic in a fasting state.

Clinical and subjective factors

Accuracy was not related to whether the patient was diagnosed with hypertension or whether they were being prescribed ACE inhibitors or statins. However, patients who overestimated were more likely to have vascular disease (ischaemic heart disease or cerebrovascular disease) and to be on β -blockers. Further, those who were accurate reported that they were more likely to experience no symptoms when their blood glucose was high, whereas more of those who overestimated said that they experienced no symptoms when their blood glucose level was low.

DISCUSSION

Summary of main findings

The results show that the majority of patients with diabetes cannot accurately estimate their blood glucose level and show a tendency for under- rather than overestimation. This pattern is also apparent when examining only those patients not using insulin. The results also showed that those who were accurate had lower blood glucose levels, were more likely to home test, were more likely to attend the clinic in a fasting state and reported feeling no symptoms when their blood glucose was high. In contrast, patients who overestimated were more likely to have vascular disease (ischaemic heart disease or cerebrovascular disease) and be on β blockers and reported experiencing no symptoms when their blood glucose was low.

Strengths and limitations of the study

There are some problems with the study that need to be addressed. First the study took place in one diabetic clinic in one general practice. This has implications for the generalisability of the results to other patients in other geographical locations. The practice used, however, consists of patients from an urban area from a middle range of social classes, the majority of whom are of a white ethnic origin. The results can therefore be said to reflect similar types of general practice patient groups. Secondly, the sample involved consecutive rather than random patients. This may mean that the patient group are in some way different to patients with diabetes as a whole. However, the clinic does not employ any imposed ordering on its patients suggesting that the patients are probably

Table 3. Differences in terms of accuracy: clinical and subjective factors (for patients not using insulin).

Factors	Underestimators (n = 37) n (%)	Accurate (n = 36) n (%)	Overestimators (n = 12) n (%)	F/ χ^2	P-value
Clinical					
Vascular disease	11 (29.7)	9 (25.0)	5 (41.7)	17.695	0.001
Hypertension	16 (43.2)	10 (27.7)	7 (58.3)	3.800	0.051
β blockers	11 (29.7)	6 (16.7)	5 (41.7)	23.253	0.001
ACE inhibitors	20 (54.1)	13 (36.1)	4 (33.3)	1.274	0.259
Statins	20 (54.1)	15 (41.7)	7 (58.3)	0.095	0.758
Subjective					
Symptoms when blood glucose is believed high					
No symptoms	21 (56.7)	29 (80.5)	7 (58.3)	57.747	0.001
Physical	11 (29.7)	5 (13.8)	4 (33.3)		
Psychological	5 (13.5)	2 (5.5)	1 (8.3)		
Symptoms when blood glucose is believed low					
No symptoms	20 (54.1)	17 (47.2)	8 (66.6)	27.874	0.001
Physical	13 (35.1)	14 (38.8)	4 (33.3)		
Psychological	4 (10.8)	5 (13.8)	0 (0)		

representative of those who turn up to diabetic clinics. Finally, the study involved only one attempt at estimation rather than gathering estimates over a period of time. It is possible, therefore, that rather than conceptualising patients as either accurate, overestimators or underestimators, their ability to estimate may vary according to a range of temporal and situational factors. Further research should explore the stability of the ability to estimate and examine the reasons behind any variability.

Comparisons with existing literature

Undetected and uncontrolled high blood glucose levels have been associated in many trials with poor outcomes including vascular complications and death.^{6,17} One solution is to require people with diabetes to estimate their blood glucose levels and adjust their behaviour and medication accordingly. Previous research has consistently shown that patients using insulin cannot accurately estimate their blood glucose levels.¹⁰⁻¹³ As a result, current advice unequivocally recommends that these patients should regularly carry out home testing.^{10,14} The present study indicates that the inability to judge blood glucose levels is also similarly apparent in patients with diabetes who are not using insulin. This suggests that patients, whether or not they use insulin, should be discouraged from relying upon their own perceptions of their blood glucose levels and that home testing, although inconvenient and costly, may be a necessary part of self-care for all patients with diabetes. As highlighted by both quantitative and qualitative

research home testing, however, this is not without its economic and psychological costs^{8,9} suggesting a role for rationing this practice. The results from the present study could be used to identify which patients would most benefit from this practice and in particular suggests that those with co-occurring illnesses and higher blood glucose levels may make less accurate estimates and may therefore gain greater benefit from home testing. It would also seem that the very process of home testing is associated with the ability to make more accurate estimates of blood glucose levels.

Implications for future research and clinical practice

The present study suggests that the majority of people with diabetes who either use or do not use insulin cannot accurately judge their blood glucose levels. This has implications for both research and practice. In terms of research, further studies are needed to explore what factors impact upon a patient's ability to judge their blood glucose levels and to assess whether estimation should be considered a state or trait variable.

In terms of practice, patients with diabetes should be discouraged from relying upon their own judgements to inform their self-care practices. This could highlight a universal role for home testing. However, such a policy would have serious costs implications and the results from the present study suggest that if home testing is to be rationed then there are some patients who may benefit more than others. Further, given that the ability to estimate accurately and home testing co-occur, perhaps home testing could be used not only as a substitute for estimation but also as a training tool to facilitate the ability to estimate. In the same way that biofeedback techniques have been shown to improve blood pressure estimates¹⁸⁻²¹ home testing for diabetics may similarly enhance an individual's ability to self monitor. Home testing may be an expensive option in the shorter term but it could lead to both improved control and also to improved estimations, which in the longer term may minimise the need for this expensive and inconvenient practice.

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Competing interests

None

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