

# Frequency of Blood Glucose Monitoring in Relation to Glycemic Control in Patients With Type 2 Diabetes

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**OBJECTIVE** — The aim of the study was to investigate the relationship between blood glucose level, measured as HbA<sub>1c</sub>, and frequency of self-monitoring in patients with type 2 diabetes. Daily self-monitoring is believed to be important for patients treated with insulin or oral agents to detect asymptomatic hypoglycemia and to guide patient and provider behavior toward reaching blood glucose goals.

**RESEARCH DESIGN AND METHODS** — A national sample of patients with type 2 diabetes was studied in the third National Health and Nutrition Examination Survey. Data on therapy for diabetes, frequency of self-monitoring of blood glucose, and HbA<sub>1c</sub> values were obtained by structured questionnaires and by clinical and laboratory assessments.

**RESULTS** — According to the data, 29% of patients treated with insulin, 65% treated with oral agents, and 80% treated with diet alone had never monitored their blood glucose or monitored it less than once per month. Self-monitoring at least once per day was practiced by 39% of those taking insulin and 5–6% of those treated with oral agents or diet alone. For all patients combined, the proportion of patients who tested their blood glucose increased with an increasing HbA<sub>1c</sub> value. However, when examined by diabetes therapy category, there was little relationship between HbA<sub>1c</sub> value and the proportion testing at least once per day or the proportion testing at least once per week.

**CONCLUSIONS** — In this cross-sectional study of patients with type 2 diabetes, the increase in frequency of self-monitoring of blood glucose with increasing HbA<sub>1c</sub> value was associated with the higher proportion of insulin-treated patients in higher HbA<sub>1c</sub> categories. Within diabetes therapy categories, the frequency of self-monitoring was not related to glycemic control, as measured by HbA<sub>1c</sub> level.

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Self-monitoring of blood glucose is believed to be a useful component of patient self-care practices. For patients with type 2 diabetes, the American Diabetes Association (ADA) position is that daily self-monitoring is especially important for those treated with insulin or oral agents to monitor for and prevent asymptomatic hypoglycemia (1). Self-monitoring is also suggested for these patients to facilitate reaching blood glucose

goals, although the role of self-monitoring in diet-treated patients with type 2 diabetes is not specified by the ADA (1). Given the two-fold objective of monitoring glucose levels at both the low and high ends of the spectrum, it might be expected that monitoring might be more frequent for those with lower and those with higher blood glucose values compared with patients in the intermediate range. We investigated the relationship between blood

glucose level, measured as HbA<sub>1c</sub>, and the frequency of self-monitoring in a nationwide sample of patients with type 2 diabetes.

## RESEARCH DESIGN AND

**METHODS** — Data were analyzed from the third National Health and Nutrition Examination Survey (NHANES III), in which questionnaire, clinical, and laboratory data were obtained for a representative sample of adults with type 2 diabetes. NHANES III was conducted from September 1988 to October 1994 and included a stratified probability sample of the civilian noninstitutionalized U.S. population (2). Participants were interviewed in their homes and were given a standardized set of examinations and laboratory measurements in a mobile examination center. There were 16,993 participants aged  $\geq 25$  years, of whom 1,608 had been diagnosed with diabetes by a physician before the survey. Women with diabetes diagnosed only during pregnancy ( $n = 105$ ) and subjects with type 1 diabetes, defined as those with age at diagnosis  $< 30$  years who had continuous insulin use since diagnosis of diabetes ( $n = 23$ ), were excluded from analysis. The remaining 1,480 subjects were considered to have type 2 diabetes.

Information was obtained by structured questionnaires on diabetes therapy and blood glucose self-monitoring. Measurement of HbA<sub>1c</sub> was made during a separate clinical examination in which 88.2% of the interviewed subjects participated (3). HbA<sub>1c</sub> was measured by a high-performance liquid chromatographic assay as used in the Diabetes Control and Complications Trial. The upper limit of normal for HbA<sub>1c</sub> in the assay system is 6.1%, defined as the mean + 2 SDs ( $5.27 + 0.86\%$ ) for the group of people with fasting plasma glucose  $< 110$  mg/dl and 2-h postchallenge glucose  $< 140$  mg/dl. This value (6.1%) is virtually identical to the upper limit of normal (6.0%) recommended by the ADA using the same assay system (1). Statistical analyses were performed using SAS (Statistical Analysis

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**Abbreviations:** ADA, American Diabetes Association; NHANES III, third National Health and Nutrition Examination Survey.

A table elsewhere in this issue shows conventional and Système International (SI) units and conversion factors for many substances.

**Table 1—HbA<sub>1c</sub> values and frequency of blood glucose self-monitoring by patients with type 2 diabetes, according to diabetes treatment**

	All patients	Insulin	Oral agents	Diet alone
Patient distribution (%)	100.0	27.3	45.5	27.2
Mean HbA <sub>1c</sub> value*	7.64	8.29	8.04	6.37
Proportion with HbA <sub>1c</sub> ≥8 (%)	37.1	51.4	42.2	14.9
Blood glucose self-monitoring (%)				
Never or <1 time per month	58.9	28.7	65.2	79.7
1–3 times per month	8.5	11.1	9.2	4.6
1–6 times per week	18.0	21.1	21.0	9.2
≥1 time per day	14.6	39.1	4.6	6.5

\*The upper limit of normal for HbA<sub>1c</sub> in the assay system is 6.1%, defined as the mean + 2 SDs (5.27 + 0.86%) for the group of people with fasting plasma glucose <110 mg/dl and 2-h postchallenge glucose <140 mg/dl.

System; Cary, NC) with appropriate survey sampling weights. Logistic regression was performed using SUDAAN (Research Triangle Institute, Research Triangle Park, NC) to assess the relationship between HbA<sub>1c</sub> and self-monitoring in those treated with insulin, oral agents, or diet alone.

**RESULTS** — The median age of the patients was 62.5 years. About 44% were male, 26% were of minority race or ethnicity, 55% had a high school education or more, 93% had health insurance, 96% had a regular source of primary medical care, and 85% had at least two physician visits in the 12 months before the survey.

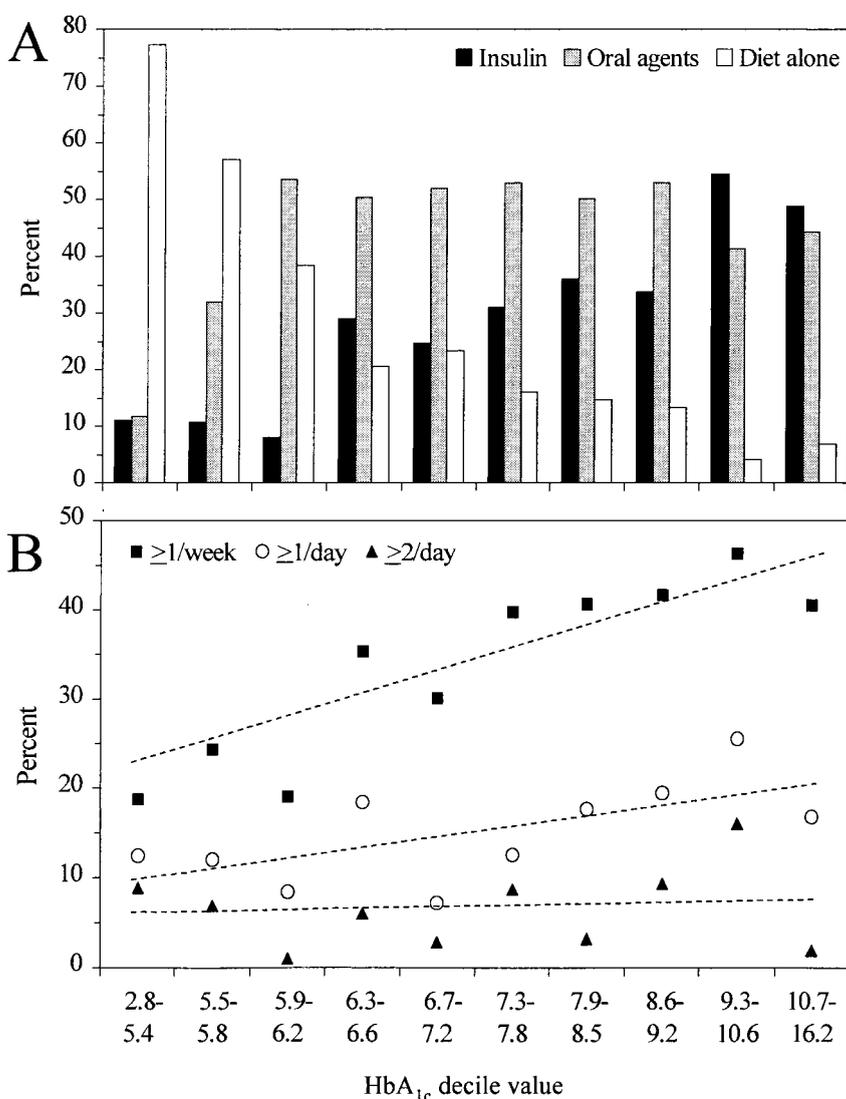
Table 1 shows HbA<sub>1c</sub> values and the frequency of blood glucose self-monitoring, according to diabetes therapy. One-fourth of patients treated with insulin and most patients treated with oral agents or diet alone had never monitored their blood glucose or monitored it less than once per month. Self-monitoring at least once per day was practiced by 39% of those taking insulin and was infrequent for those treated with oral agents or diet alone.

In Fig. 1, the patients are distributed according to deciles of HbA<sub>1c</sub>. The percentage of patients in each decile who were treated with insulin rises with increasing HbA<sub>1c</sub> value. The percentage treated with oral agents is relatively constant across deciles 3–10, and the percentage treated with diet alone declines markedly with increasing HbA<sub>1c</sub> value.

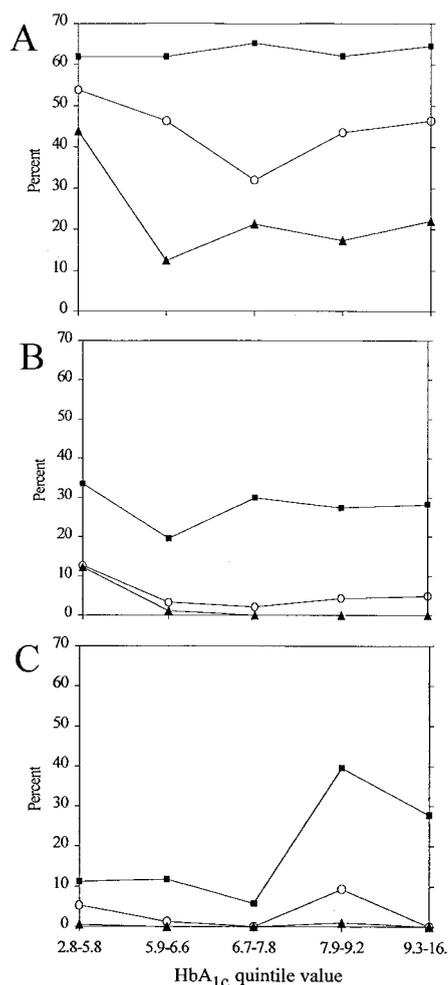
The frequency of self-monitoring by patients in each decile of the HbA<sub>1c</sub> distribution is shown in Fig. 1. The proportion of patients who tested at least once per week or who tested at least once per day increased with increasing HbA<sub>1c</sub>

value. Testing at least twice per day was uncommon and showed no relation to HbA<sub>1c</sub> value.

Figure 2 illustrates the frequency of self-monitoring by patients for those treated with insulin, oral agents, or diet alone in each quintile of the HbA<sub>1c</sub> distribution. There was little relationship between HbA<sub>1c</sub> value and the proportion testing at least once per week for those treated with insulin or oral agents, although, for those treated with diet alone, the test frequency was higher in the highest two quintiles of HbA<sub>1c</sub> (comprising 14% of diet-treated patients). The pro-



**Figure 1—Distribution of patients with type 2 diabetes according to HbA<sub>1c</sub> decile. Each decile contains 10% of the population of all patients. The mean ± SD HbA<sub>1c</sub> value for nondiabetic subjects was 5.27 ± 0.43%. A: Percentage of patients in each decile of HbA<sub>1c</sub> who were treated with insulin, oral agents, or diet alone. B: Percentage of patients in each decile of HbA<sub>1c</sub> who self-monitored their blood glucose. Dashed lines are linear regression lines. R<sup>2</sup> = 0.81, one or more tests per week; R<sup>2</sup> = 0.23, one or more tests per day; R<sup>2</sup> = 0.03, two or more tests per day.**



**Figure 2**—Percentage of patients with type 2 diabetes in quintiles of the HbA<sub>1c</sub> distribution who self-monitor their blood glucose, according to diabetes therapy. The mean  $\pm$  SD HbA<sub>1c</sub> for nondiabetic subjects is 5.27  $\pm$  0.43%. In logistic regression, there was no relationship between HbA<sub>1c</sub> value and self-monitoring in any diabetes therapy group ( $P > 0.5$ ). A: Insulin-treated patients. B: Oral agent-treated patients. C: Diet-treated patients. ■, Self-monitoring test one or more times per week; ○, self-monitoring test one or more times per day; ▲, self-monitoring test two or more times per day.

portion testing at least once per day was lower in the middle quintile for those taking insulin, but there was no relationship to HbA<sub>1c</sub> for those treated with oral agents or diet alone. The proportion testing at least twice per day was highest in the lowest quintile for those taking insulin (8% of insulin-treated patients) and was low throughout the spectrum of HbA<sub>1c</sub> for those taking oral agents or treated with diet alone.

Logistic regression models were con-

structed to further evaluate the association of self-monitoring and HbA<sub>1c</sub>. In these models, there was no relationship between the frequency of self-monitoring and HbA<sub>1c</sub> level for those treated with insulin, oral agents, or diet alone ( $P > 0.5$ ).

**CONCLUSIONS**— The data for all patients combined indicate that self-monitoring of blood glucose is more common as HbA<sub>1c</sub> increases, suggesting that patients with poorer glycemic control have a greater tendency to self-monitor. However, the increase in frequency of self-monitoring with increasing HbA<sub>1c</sub> value is related to the higher proportion of insulin-treated patients, who are more likely to self-monitor, in higher HbA<sub>1c</sub> categories. Within each diabetes therapy category there was little relationship between the frequency of testing and HbA<sub>1c</sub> value. Indeed, half of patients with HbA<sub>1c</sub>  $> 8\%$ , the ADA value at which intensification of glucose control is recommended (1), monitored less than once per week.

Prior studies have shown that self-monitoring is more common in Caucasian patients than in African-American or Mexican-American patients (3,4). Those with more education, those who have had a diabetes patient education class, and those who have frequent physician visits are more likely to practice self-monitoring (4). However, self-monitoring was not related to higher income or to having health insurance (4).

The relationship between HbA<sub>1c</sub> value and self-monitoring frequency was investigated in a study in England of 290 type 2 diabetic patients treated with insulin; no association was found (5). A study in Missouri of 61 type 2 diabetic patients who self-monitored found no difference in mean GHb values based on the frequency of testing (6). Among 115 patients treated with oral agents at a Veterans Administration Medical Center in Arizona, glucose control was independent of the number of blood glucose test strips dispensed (7). Some reports have questioned the efficacy of self-monitoring in patients with type 2 diabetes (8,9). In contrast, the importance of self-monitoring in patients with type 1 diabetes is more certain, and an increased frequency of self-monitoring is generally associated with decreased HbA<sub>1c</sub> values for these patients (5,10).

Self-monitoring is considered to be a tool to guide patient and physician action with respect to changes in diet, physical

activity, and use of antihyperglycemic medication. Both patient and physician action are needed to change diabetes management when hyperglycemia is evident. Patients with differing levels of insulin resistance and  $\beta$ -cell reserve may respond differently to self-monitoring and changes in diabetes control regimens. The true impact of self-monitoring could be assessed in a randomized clinical trial with pre-established guidelines for how glucose monitoring results would be used to facilitate achievement of glycemic targets.

Adequate co-involvement of the medical care team, the patient, and the family appears to be important in effective management of diabetes. Clinical trials have demonstrated that health care systems that utilize nurses and other nonphysician personnel as case managers and those with telephone-based contact are efficacious in improving glycemic control, blood pressure, and lipid levels (11–14). Key elements in the success of the Diabetes Control and Complications Trial were the frequent clinic visits involving nurses and dietitians and the extensive telephone access to these health care practitioners. These elements were afforded to patients in the intensive intervention group, and HbA<sub>1c</sub> remained low throughout the study (15). Availability of social support, such as that provided by nurse case-managers, appears to be a major factor that contributes to adherence by diabetic patients to such behaviors as following a diabetic diet, weight loss, taking prescribed medications, checking blood glucose, and checking feet (16). In a logistic regression analysis of the NHANES III type 2 diabetic patients, the HbA<sub>1c</sub> level was not significantly associated with having a primary source of ambulatory medical care, the number of physician visits per year, having any type of health insurance, or having private insurance (17).

The NHANES III is a cross-sectional study, and it cannot be determined from this study whether self-monitoring influenced blood glucose control. Furthermore, the study was conducted during the period when Medicare reimbursed the cost of blood glucose monitors and test strips for monitors only for patients treated with insulin. Although self-testing of blood glucose does not require monitors, it is likely that the lower frequency of testing by patients treated with oral agents and diet alone was a result, in part, of the lack of reimbursement. In 1998, this pol-

icy was changed to reimburse patients for these items, regardless of whether the patient is treated with insulin. In a survey conducted in 1997–1999, the proportion of all diabetic patients who self-monitored at least once per day was 44% (18), which was higher than that seen in NHANES III.

#### References

1. American Diabetes Association: Standards of medical care for patients with diabetes mellitus (Position Statement). *Diabetes Care* 24 (Suppl. 1):S33–S43, 2001
2. Harris MI, Flegal KM, Cowie CC, Eberhardt MS, Goldstein DE, Little RR, Wiedmeyer HM, Byrd-Holt DD: Prevalence of diabetes, impaired fasting glucose, and impaired glucose tolerance in U.S. adults: the Third National Health and Nutrition Examination Survey, 1988–94. *Diabetes Care* 21:518–524, 1998
3. Harris MI, Eastman RC, Cowie CC, Flegal KM, Eberhardt MS: Racial and ethnic differences in glycemic control of adults with type 2 diabetes. *Diabetes Care* 22:403–408, 1999
4. Harris MI, Cowie CC, Howie LJ: Self-monitoring of blood glucose by adults with diabetes in the United States population. *Diabetes Care* 16:1116–1123, 1993
5. Evans JMM, Newton RW, Ruta DA, MacDonald TM, Stevenson RJ, Morris AD: Frequency of blood glucose monitoring in relation to glycemic control: observational study with diabetes database. *Br Med J* 319:83–86, 1999
6. Oki JC, Flora DL, Isley WL: Frequency and impact of SMBG on glycemic control in patients with NIDDM in an urban teaching hospital. *Diabetes Educ* 23:419–424, 1997
7. Rindone JP, Austin M, Luchesi J: Effect of home blood glucose monitoring on the management of patients with non-insulin dependent diabetes mellitus in the primary care setting. *Am J Manag Care* 3: 1335–1338, 1997
8. Faas A, Schellevis FG, Van Eijk JT: The efficacy of self-monitoring of blood glucose in NIDDM subjects: a criteria-based literature review. *Diabetes Care* 20:1482–1486, 1997
9. Gallichan M: Self-monitoring of glucose by people with diabetes: evidence based practice. *Br Med J* 314:964–967, 1997
10. Strowig SM, Raskin P: Improved glycemic control in intensively treated type 1 diabetic patients using blood glucose meters with storage capability and computer-assisted analysis. *Diabetes Care* 21:1694–1698, 1998
11. Aubert RE, Herman WH, Waters J, Moore W, Sutton D, Peterson BL, Bailey CM, Koplan JP: Nurse case management to improve glycemic control in diabetic patients in a health maintenance organization: a randomized, controlled trial. *Ann Intern Med* 129:605–612, 1998
12. O'Connor PJ, Rush WA, Peterson J, Morben P, Cherney L, Keogh C, Lasch S: Continuous quality improvement can improve glycemic control for HMO patients with diabetes. *Arch Fam Med* 5:502–506, 1996
13. Peters AL, Davidson MB: Application of a diabetes managed care program: the feasibility of using nurses and a computer system to provide effective care. *Diabetes Care* 21:1037–1043, 1998
14. Wasson J, Gaudette C, Whaley F, Sauvigne A, Baribeau P, Welch HG: Telephone care as a substitute for routine clinic follow-up. *JAMA* 267:1788–1793, 1992
15. The Diabetes Control and Complications Trial Research Group: Resource utilization and costs of care in the Diabetes Control and Complications Trial. *Diabetes Care* 18:1468–1478, 1995
16. Sherbourne CD, Hays RD, Ordway L, DiMatteo MR, Kravitz RL: Antecedents of adherence to medical recommendations: results from the Medical Outcomes Study. *J Behav Med* 15:447–468, 1992
17. Harris MI: Health care and health status and outcomes for patients with type 2 diabetes. *Diabetes Care* 23:754–758, 2000
18. Centers for Disease Control and Prevention: Levels of diabetes-related preventive-care practices—United States, 1997–1999. *Morb Mort Weekly Report* 49:954–958, 2000