

Self-monitoring of Blood Glucose Levels and Glycemic Control: the Northern California Kaiser Permanente Diabetes Registry*

Andrew J. Karter, PhD, Lynn M. Ackerson, PhD, Jeanne A. Darbinian, MPH, Ralph B. D'Agostino, Jr, PhD, Assiamira Ferrara, MD, PhD, Jennifer Liu, MS, Joe V. Selby, MD, MPH

PURPOSE: We sought to evaluate the effectiveness of self-monitoring blood glucose levels to improve glycemic control.

SUBJECTS AND METHODS: A cohort design was used to assess the relation between self-monitoring frequency (1996 average daily glucometer strip utilization) and the first glycosylated hemoglobin (HbA_{1c}) level measured in 1997. The study sample included 24,312 adult patients with diabetes who were members of a large, group model, managed care organization. We estimated the difference between HbA_{1c} levels in patients who self-monitored at frequencies recommended by the American Diabetes Association compared with those who monitored less frequently or not at all. Models were adjusted for age, sex, race, education, occupation, income, duration of diabetes, medication refill adherence, clinic appointment "no show" rate, annual eye exam attendance, use of nonpharmacological (diet and exercise) diabetes therapy, smoking, alcohol consumption, hospitalization and emergency room visits, and the number of daily insulin injections.

RESULTS: Self-monitoring among patients with type 1 diabetes (≥ 3 times daily) and pharmacologically treated type 2 diabetes (at least daily) was associated with lower HbA_{1c} levels (1.0 percentage points lower in type 1 diabetes and 0.6 points lower in type 2 diabetes) than was less frequent monitoring ($P < 0.0001$). Although there are no specific recommendations for patients with nonpharmacologically treated type 2 diabetes, those who practiced self-monitoring (at any frequency) had a 0.4 point lower HbA_{1c} level than those not practicing at all ($P < 0.0001$).

CONCLUSION: More frequent self-monitoring of blood glucose levels was associated with clinically and statistically better glycemic control regardless of diabetes type or therapy. These findings support the clinical recommendations suggested by the American Diabetes Association. *Am J Med.* 2001;111:1-9. ©2001 by Excerpta Medica, Inc.

Although self-monitoring of blood glucose is widely recommended as a component of diabetes management, there is substantial controversy about this costly practice, especially for patients with type 2 diabetes. The American Diabetes Association's 1997 Clinical Practice Recommendations suggest monitoring at least 3 times daily for patients with type 1 diabetes and daily for pharmacologically treated (insulin or oral agents) patients with type 2 diabetes (1). No recommendations have been proposed for patients with type 2 dia-

betes who use nonpharmacological treatment (diet, exercise, or both). It has been argued that these recommendations are not supported by evidence, particularly about effectiveness in improving glycemic control (2,3). Although most of the evidence supporting the use of self-monitoring comes from a few small studies in patients with type 1 diabetes (4,5), its usefulness is still questioned for these patients (6-10), and there is even less evidence supporting its use in patients with type 2 diabetes (3,9,11-18). Consequently, the American Diabetes Association's position statement (19) about the latter group has been left vague: "Optimal frequency of self-monitoring of blood glucose for patients with type 2 diabetes is not known, but should be sufficient to facilitate reaching glucose goals." It has even been argued that self-monitoring may cause psychological harm (20).

Publication of the results of the Diabetes Control and Complications Trial (21) in 1993 has led to a greater emphasis on near-normalization of glucose level and promotion of self-monitoring (22,23). Aside from the uncertainty regarding effectiveness, self-monitoring is costly: the annual price of strips alone can exceed \$850 for the

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From the Division of Research (AJK, LMA, JAD, AF, JL, JVS), Kaiser Permanente, Oakland, California, and Public Health Sciences (RBD), Wake Forest University School of Medicine, Winston-Salem, North Carolina.

Andrew J. Karter, PhD, The Division of Research, Kaiser Permanente, 3505 Broadway, Oakland, California 94611-5714; e-mail: ajk@dor.kaiser.org

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recommended frequency in patients with type 1 diabetes. In 1998, blood glucose monitoring strips were the fourth largest outpatient pharmacy expenditure in the Kaiser Permanente Northern California Region, representing 2% of total pharmacy expenditures. Given the need to control health care costs and the efforts to practice evidence-based medicine, self-monitoring guidelines are debated in many managed care organizations.

Although a randomized controlled trial would be the best way to determine the effectiveness of monitoring, such trials may no longer be feasible, given that practice guidelines recommend universal monitoring in the U.S. We therefore studied the association between self-monitoring and glycemic control in a cohort study of 24,312 adults in the diabetes registry of Kaiser Permanente, Northern California Region, stratified by the type of diabetes and treatment, and adjusting for possible confounders.

METHODS

Sample

The Kaiser Permanente Medical Care Program of Northern California, a group model Health Maintenance Organization, provides comprehensive medical services to approximately three million members (~25% of the population in the geographical area) in Northern California through 15 hospitals and 23 outpatient clinics. The health plan maintains administrative databases that are linked to the individual member through a unique medical record number assigned at enrollment. The sample came from the Northern California Kaiser Permanente Diabetes Registry (24–27), which annually identifies prevalent and incident cases of diabetes from several sources, including pharmacies (prescriptions for diabetic medications), laboratories (glycosylated hemoglobin [HbA_{1c}] level >6.7%), and outpatient, emergency room, and hospitalization records listing a diagnosis of diabetes; it was estimated to be 96% sensitive as of January 1, 1996 (25). Only the 48,614 adults (≥19 years of age) with continuous membership from January 1, 1996, to December 31, 1997, full pharmacy benefits (to avoid under-ascertainment of strip utilization), and an HbA_{1c} level that was measured during follow-up were included. At the time of this study, there were no Kaiser Permanente practice guidelines about self-monitoring.

Measurements

The number of glucometer strips redeemed at Kaiser pharmacies during 1996 was determined (and expressed as average strips per day). Kaiser pharmacies require a prescription for glucometer strips; given the substantial cost savings for those with drug benefits (patients pay a minimal copayment rather than the full cost of the strips), this captures the vast majority of use (27).

We defined categories of self-monitoring levels based on average daily strip utilization using an algorithm that accommodated occasional missed monitoring days. Patients with type 1 diabetes were categorized as monitoring three or more times daily if their average utilization was ≥2.5 strips per day; at least once but less than three times daily if their average was <2.5 but ≥0.75 strips per day; less than daily but at least occasionally if their average was <0.75 but >0 per day; and not practicing self-monitoring if there was no recorded strip utilization for the entire year. Patients with pharmacologically treated type 2 diabetes were categorized as monitoring daily if they used an average of at least 0.75 strips per day; less than daily but at least occasionally for lesser levels of utilization; or not practicing self-monitoring. Using these categories, patients were further characterized as “adherent” or “non-adherent” to the American Diabetes Association Clinical Practice Recommendations (1,19,28). Because these recommendations did not include self-monitoring among patients with type 2 diabetes who are not treated with drugs, we specified the goal of “at least occasionally” for this group. We could not establish whether a patient was aware of or instructed about the American Diabetes Association recommendations. Thus, the terms “adherent” and “nonadherent” were used to classify levels of practice relative to those recommendations, not to imply the reasons for that practice (e.g., patient compliance vs. physician not providing guidance).

HbA_{1c} levels were recorded from Kaiser’s laboratory database for 1997, which was the year following baseline ascertainment of glucometer strip utilization. The earliest HbA_{1c} level was used if multiple tests were recorded. All assays were conducted at Kaiser’s centralized laboratory using high-performance liquid chromatography. Patients with at least one HbA_{1c} level measured during this 12-month period (66% of total patients) were included in this study.

Potential confounders were collected from several sources. Eighty-three percent (n = 77,726) of the 94,024 noninstitutionalized health plan members with suspected diabetes had responded to a self-administered questionnaire or computer-assisted telephone interview. The survey asked about daily number of insulin injections, use of exercise and diet as diabetes treatments, smoking, alcohol consumption, education, and ethnicity. Type of diabetes was based on age at diagnosis, length of time between initial diagnosis and start of insulin treatment, intervals of 3 months or longer off insulin after initiation, and obesity at diagnosis (27,29; Appendix). Those with an unclear type of diabetes (2%) were excluded. Diabetes treatment in 1996 and this algorithm were used to classify patients into mutually exclusive categories: type 1 diabetes, insulin-treated type 2 diabetes (includes combination therapy), oral agent only-treated type 2 diabetes, and “diet-controlled” type 2 diabetes. For

patients with type 2 diabetes who changed treatment during 1996, classification was based on the therapy that was used for the longest period of time in that year. Five percent of patients were classified as having type 1 diabetes, 75% had pharmacologically treated type 2 diabetes (23% insulin-treated and 53% oral agent only-treated), and 20% had diet-controlled type 2 diabetes.

Automated pharmacy records were used to calculate a medication refill adherence index (30,31). Administrative utilization files were used to assess the numbers of hospitalizations and emergency room visits, the proportion of outpatient appointments that were neither attended nor canceled (“no shows”), and the number of ophthalmology exams during the baseline period. We also characterized neighborhood-level socioeconomic status by geocoding each member’s address, which was mapped to an average annual per capita income and proportion in a working-class profession, as determined by 1990 census data.

Analysis Plan

Our analyses included the 23,412 members of the diabetes registry who had responded to the survey, in whom type (and treatment) of diabetes could be determined and in whom HbA_{1c} level had been measured in 1997. All analyses were stratified by diabetes type and treatment. Comparisons were made using the chi-squared test for categorical variables, the two-sample *t* test for normally distributed continuous variables, and the Wilcoxon rank sum test for continuous variables with skewed distributions. General linear models (SAS Proc GLM) were used to assess the relation between HbA_{1c} level and adherence and between HbA_{1c} level and ordinal self-monitoring level. Adjusted (least squares means) HbA_{1c} levels for the ordinal categories of self-monitoring, and for adherent and nonadherent patients and their differences, were estimated with 95% confidence intervals.

To determine whether the relations that we observed in the main analyses were caused by selection bias, we compared age- and sex-adjusted models for our sample to those for the 24,302 registry members who were excluded because they did not respond to the survey or did not provide sufficient data for covariate adjustment or stratification. Because type of diabetes was missing for most patients not included in the main analyses, we stratified by therapy alone for these analyses.

RESULTS

Patient Characteristics and Adherence

Adherence with the recommended frequency of self-monitoring was more common among patients with type 1 diabetes (34% [395/1159]) or insulin-treated type 2 diabetes (54% [3011/5552]) than among patients with oral agent only-treated type 2 diabetics (20% [2543/12,786],

$P = 0.001$; Table 1). The level of adherence in patients with “diet-controlled” type 2 diabetes (41% [1987/4815]) reflects the looser criterion (any monitoring) for adherence. In unadjusted analyses, HbA_{1c} levels were significantly ($P \leq 0.001$) lower among adherent patients in all 4 groups than in the nonadherent patients (Table 1). Adherent patients were usually more likely to be female and white and to have greater education and income (Table 1). There were small, albeit sometimes statistically significant, differences in mean age, time since diagnosis, and working-class status (proportion in census block group) between adherent and nonadherent patients. Self-care practices (other than self-monitoring), healthy lifestyle behaviors, and appropriate annual screenings were usually more common in adherent patients (Table 1). There were higher rates of hospitalization and emergency room visitation in adherent patients with type 2 diabetes, however.

Self-monitoring of Blood Glucose Level and Subsequent Glycemic Control

Within all four groups of patients, adherence (vs. less frequent or no monitoring) was associated with significantly ($P < 0.0001$) better glycemic control (lower HbA_{1c} levels) after adjustment for demographic, socioeconomic, behavioral, and clinical variables (Table 2). The differences between adherent and nonadherent patients ranged from 0.4 percentage points for patients with “diet-controlled” type 2 diabetes to 1.0 points for those with type 1 diabetes (Table 2).

As monitoring frequency increased, adjusted HbA_{1c} levels declined (Figure 1). In pharmacologically treated patients, the largest improvement in HbA_{1c} levels ($P < 0.0001$) was observed with monitoring at the recommended frequency (at least three times daily in patients with type 1 diabetes or at least daily in patients with type 2 diabetes), whereas lesser frequencies of monitoring conferred little benefit. In diet-controlled patients with type 2 diabetes, there were significant ($P < 0.0001$) incremental decreases in HbA_{1c} levels associated with each increase in monitoring frequency.

Assessing Selection Bias

The overall study finding was qualitatively similar when comparing those included in the main analysis with those who were excluded because of missing data, suggesting it is unlikely that responder bias explained our findings (Figure 2). Although slightly stronger effects of self-monitoring were noted in those who were included in the main study, the study conclusions remain consistent and significant for each treatment group.

CONCLUSIONS

In this large cohort study, levels of strip utilization that were consistent with American Diabetes Association rec-

Table 1. Characteristics of Subjects by Adherence to Monitoring Guidelines within Categories of Types and Treatments of Diabetes*

Characteristic	Type 1 Diabetes		Type 2 Diabetes, Insulin-treated		Type 2 Diabetes, Oral Agents Only		Type 2 Diabetes, Diet-controlled		P value
	Adherent (n = 395) Number (%) or Mean ± SD	Nonadherent (n = 764) Number (%) or Mean ± SD	Adherent (n = 3011) Number (%) or Mean ± SD	Nonadherent (n = 2541) Number (%) or Mean ± SD	Adherent (n = 2543) Number (%) or Mean ± SD	Nonadherent (n = 10,243) Number (%) or Mean ± SD	Adherent (n = 1987) Number (%) or Mean ± SD	Nonadherent (n = 2828) Number (%) or Mean ± SD	
Average strip utilization									
No utilization	0	190 (25)	0	1050 (41)	0	6192 (61)	0	2828 (100)	0.001
Some, but less than daily	0	189 (25)	0	1491 (59)	0	4051 (40)	1370 (69)	0	
At least once daily	0	385 (50)	3011 (100)	0	2543 (100)	0	617 (31)	0	
At least 3× daily	395 (100)	0	NA	NA	NA	NA	NA	NA	
HbA _{1c} (%)	7.6 ± 1.4	8.8 ± 1.9	8.2 ± 1.7	8.9 ± 2.2	8.0 ± 1.8	8.7 ± 2.3	7.6 ± 1.8	8.1 ± 2.3	0.001
Age (years)	43.2 ± 12.9	40.4 ± 12.6	62.9 ± 10.4	60.5 ± 10.8	62.4 ± 10.9	60.7 ± 11.7	59.6 ± 12.2	60.5 ± 12.4	0.01
Female sex	232 (59)	373 (49)	1600 (53)	1302 (51)	1295 (51)	4586 (45)	988 (50)	1305 (46)	0.02
Ethnicity									0.001
Non-Hispanic white	347 (88)	569 (75)	2050 (68)	1336 (53)	1705 (67)	5828 (57)	1259 (63)	1610 (57)	
African American	11 (3)	65 (9)	329 (11)	493 (19)	196 (8)	1156 (11)	195 (10)	312 (11)	
Hispanic	9 (2)	28 (4)	196 (7)	217 (9)	175 (6.9)	919 (9)	166 (8)	240 (9)	
Asian-Pacific Islander	9 (2)	36 (5)	215 (7)	266 (11)	273 (11)	1476 (14)	199 (10)	385 (14)	
Native American	0	5 (0.6)	15 (0.5)	19 (0.7)	15 (0.6)	79 (0.8)	12 (0.6)	17 (0.6)	
Other	0	1 (0.1)	7 (0.2)	5 (0.2)	8 (0.3)	29 (0.3)	8 (0.4)	12 (0.4)	
Multiethnic	19 (5)	60 (8)	199 (7)	205 (8)	171 (7)	756 (7)	148 (8)	252 (9)	0.09
Educational attainment									
Less than high school	77 (20)	222 (29)	1278 (42)	1193 (47)	1081 (43)	4552 (44)	781 (39)	1201 (43)	0.03
Some college	136 (34)	271 (36)	970 (32)	819 (32)	771 (30)	3160 (31)	660 (33)	893 (32)	
College graduate	182 (46)	271 (36)	763 (25)	529 (21)	691 (27)	2531 (25)	546 (28)	734 (26)	
Block group working-class occupation (%)	58 ± 13	61 ± 13	63 ± 13	65 ± 13	63 ± 13	64 ± 13	63 ± 13	63 ± 13	0.5
Median block group average annual income (25th and 75th percentiles)	\$18,801 (15,297, 23,721)	\$16,813 (13,602, 21,506)	\$16,559 (13,142, 21,209)	\$15,685 (12,331, 19,703)	\$16,642 (13,296, 21,186)	\$16,488 (12,903, 20,631)	\$16,541 (13,040, 20,887)	\$16,542 (13,148, 21,134)	0.9
Years since diabetes diagnosis									0.001
0–9 years	54 (14)	134 (18)	1221 (41)	1003 (40)	1879 (74)	7468 (73)	1624 (82)	2151 (76)	

Table 1. Characteristics of Subjects by Adherence to Monitoring Guidelines within Categories of Types and Treatments of Diabetes*—Continued

	Type 1 Diabetes		Type 2 Diabetes, Insulin-treated		Type 2 Diabetes, Oral Agents Only		Type 2 Diabetes, Diet-controlled		P value
	Adherent (n = 395) Number (%) or Mean ± SD	Nonadherent (n = 764) Number (%) or Mean ± SD	Adherent (n = 3011) Number (%) or Mean ± SD	Nonadherent (n = 2541) Number (%) or Mean ± SD	Adherent (n = 2543) Number (%) or Mean ± SD	Nonadherent (n = 10,243) Number (%) or Mean ± SD	Adherent (n = 1987) Number (%) or Mean ± SD	Nonadherent (n = 2828) Number (%) or Mean ± SD	
10+ years	341 (86)	630 (83)	1790 (60)	1538 (61)	664 (26)	2775 (27)	363 (18)	676 (24)	
Diabetes therapy refill adherence index (days supply/refill interval)	1.1 ± 0.5	1.0 ± 0.5	1.0 ± 0.5	0.9 ± 0.4	1.2 ± 0.4	1.1 ± 0.4	NA	NA	0.001
Insulin injections per day									
≤1/day	15 (4)	88 (12)	611 (20)	716 (28)	NA	NA	NA	NA	
2/day	119 (30)	473 (62)	1977 (66)	1658 (65)	NA	NA	NA	NA	
3/day (or insulin pump)	261 (66)	203 (27)	423 (14)	167 (7)	NA	NA	NA	NA	
Median clinic appointment “no show” rate (25th and 75th percentiles)	0.06 (0.00, 0.16)	0.07 (0.00, 0.20)	0.05 (0.00, 0.12)	0.06 (0.00, 0.15)	0.03 (0.00, 0.11)	0.00 (0.00, 0.13)	0.00 (0.00, 0.13)	0.00 (0.00, 0.14)	0.9
Annual eye exam attendance	234 (59)	419 (55)	1921 (64)	1498 (59)	1273 (50)	4348 (43)	809 (41)	1009 (36)	0.001
Use of exercise as diabetes therapy	182 (46.1)	309 (40.5)	1340 (45)	1072 (42)	1645 (65)	5751 (56)	1368 (69)	1670 (59)	0.001
Use of diet as diabetes therapy	209 (52.9)	343 (44.9)	1567 (52.0)	1236 (48.6)	1918 (75)	6774 (66)	1640 (83)	2116 (75)	0.001
Smoking status									
Current	38 (10)	118 (16)	232 (8)	303 (12)	203 (8)	1156 (11)	191 (10)	353 (13)	0.001
Former	129 (33)	169 (22)	1441 (48)	1099 (43.3)	1204 (47)	4164 (41)	861 (43)	1063 (38)	
Never	228 (58)	477 (62)	1338 (44)	1139 (45)	1136 (45)	4923 (48)	935 (47)	1412 (50)	0.08
Current alcohol consumption									
Abstain	130 (33)	242 (32)	1710 (57)	1413 (56)	1312 (52)	5067 (50)	881 (44)	1283 (45)	
<3 drinks/day	262 (66)	503 (66)	1271 (42)	1091 (43)	1194 (47)	4939 (48)	1079 (54)	1484 (53)	
3+ drinks/day	3 (0.8)	19 (3)	30 (1)	37 (2)	37 (1.4)	237 (2)	27 (1)	61 (21)	
Hospitalization during baseline year	52 (13)	126 (17)	606 (20)	428 (17)	366 (14)	1219 (12)	264 (13)	306 (11)	0.009
Emergency room visit during baseline	124 (31)	242 (32)	1056 (35)	817 (32)	676 (27)	2491 (24)	546 (28)	686 (24)	0.01

* See Methods for definitions of “adherent” and “nonadherent.”
HbA_{1c} = glycosylated hemoglobin level. NA = not applicable.

Table 2. Adjusted Glycosylated Hemoglobin (HbA_{1c}) Levels among Those Who Adhered or Did not Adhere to Recommended Self-monitoring Guidelines*

Group	Adjusted HbA _{1c} Level (95% Confidence Interval)		Difference between Groups (95% Confidence Interval)	P Value
	Adherent	Nonadherent		
Type 1 diabetes, N = 1159	7.7 (7.6, 7.9)	8.7 (8.6, 8.9)	1.0 (0.8, 1.3)	0.0001
Insulin-treated Type 2 diabetes, N = 5552	8.2 (8.2, 8.3)	8.8 (8.8, 8.9)	0.6 (0.5, 0.7)	0.0001
Oral agent only-treated, N = 12,786	8.1 (8.0, 8.2)	8.7 (8.7, 8.7)	0.6 (0.5, 0.7)	0.0001
Type 2 diabetes Diet-controlled Type 2 diabetes, N = 4815	7.7 (7.6, 7.8)	8.1 (8.0, 8.2)	0.4 (0.3, 0.6)	0.0001

* Adjusted for age, sex, ethnicity, educational attainment, block group annual income and occupation class, years since diabetes diagnosis, diabetes therapy refill adherence, number of daily insulin injections (insulin users only), clinic appointment “no show” rate, annual eye exam attendance, self-reported exercise and diet as diabetes therapy, smoking status, alcohol consumption, and hospitalization and emergency room visit during the baseline year. See Methods for definitions of “adherent” and “nonadherent.”

ommendations for self-monitoring of blood glucose levels were associated with better glycemic control (HbA_{1c} levels). This association was seen in patients with type 1 diabetes and pharmacologically treated type 2 diabetes, as well as in diet-controlled diabetes.

Evidence for the benefits of self-monitoring has been lacking for type 2 diabetes. There have been several positive anecdotal reports (2,4–6,13,32–34), but the results of most trials have been negative (14,17,35,36). A meta-analysis of randomized studies among patients with type 2 diabetes failed to find a benefit from self-monitoring on glycemic control (37). However, the authors of that analysis acknowledged several important limitations, including lack of statistical power (the largest study included 208 patients), inconsistencies in recommended monitoring frequency, lack of standardization of training and ad-

vice given on modification of therapy, insufficient duration, and substantial loss to follow-up (37). Most of the previous observational studies also had methodological shortcomings (17), including lack of controls (33), short follow-up (32), low power (sample sizes ranged from 12 to 250 patients (8), and failure to stratify patients by type of treatment (38). Lack of explicit recommendations or education to accompany the self-monitoring intervention has complicated the interpretation of other studies (3). One well-designed randomized trial (36) that failed to demonstrate effectiveness reported that the patients did not adapt the recommended behavioral changes in response to their blood glucose readings. A recent observational study (18) demonstrated better glycemic control with increased prescriptions for glucometer strips in 258 patients with type 1 diabetes (0.7 points lower HbA_{1c} level

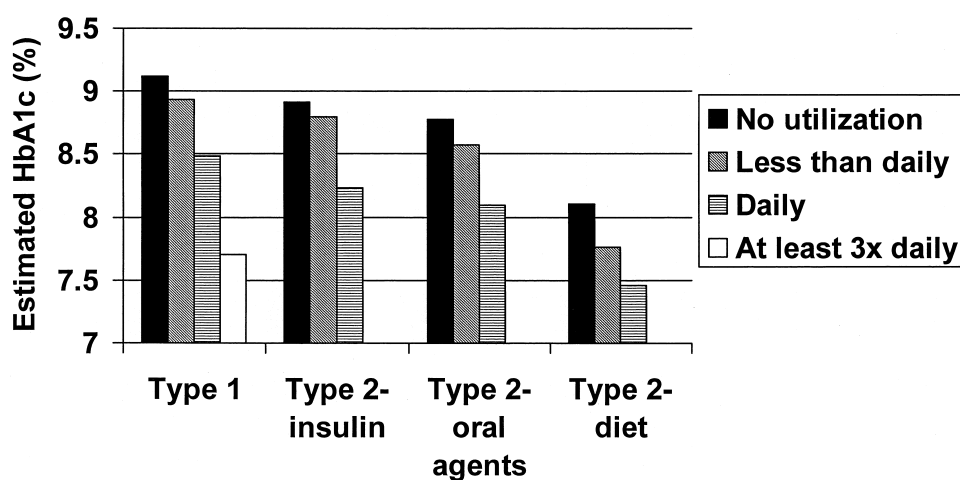


Figure 1. Adjusted glycosylated hemoglobin (HbA_{1c}) levels by categories of strip utilization (average strips per day). The category of at least three times daily was only included for patients with type 1 diabetes. Models were adjusted for age, sex, ethnicity, educational attainment, block group annual income and occupation class, years since diabetes diagnosis, diabetes therapy refill adherence, number of daily insulin injections (insulin users only), clinic appointment “no show” rate, annual eye exam attendance, self-reported exercise and diet as diabetes therapy, smoking status, alcohol consumption, and hospitalization and emergency room visit during the baseline year.

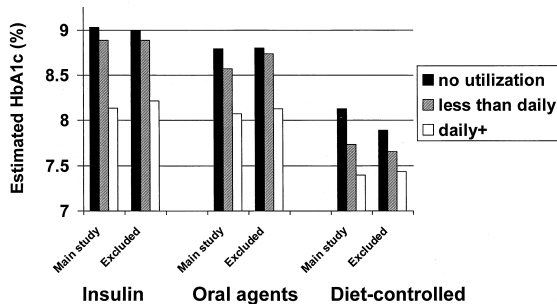


Figure 2. Adjusted (for age and sex) glycosylated hemoglobin (HbA_{1c}) levels by average daily strip utilization for those included in (n = 24,312) or excluded from (n = 24,302) the main analysis.

per strip per day) but failed to find a significant association in 290 patients with type 2 diabetes who were treated with insulin. Although we observed the largest benefit in patients with type 1 diabetes, we also found significant benefits in type 2 diabetes.

Several potential limitations of this study deserve comment. We did not include patients who did not have HbA_{1c} levels measured during the follow-up. The term “nonadherence” was used to indicate suboptimal practice according to American Diabetes Association guidelines. We were unable to establish whether the patient failed to follow recommendations or just never received these guidelines from their provider, however. We measured utilization of self-monitoring indirectly, through pharmacy refills; to the extent that this mismeasured actual utilization of monitoring, we may have underestimated the actual benefits. Most important, this was an observational study, and we cannot determine whether the association between self-monitoring and glycemic control is causal or not. For example, patients with chronically poor control may become discouraged and monitor less frequently, although we suspect that this pattern would be countered by increasing pressure from their health care providers to monitor more frequently. It is also possible that monitoring frequency is a marker for more intensive diabetes management, which more directly influences glycemic control. This study was conducted in a single health maintenance organization, however; thus the quality of diabetes care was probably more uniform than in a community sample. Moreover, analyses were adjusted for indicators of disease management, as well as key diabetes self-care practices and other adherence and lifestyle behaviors, which may be associated with monitoring frequency and with glycemic control. As an example, smoking is associated with self-monitoring as well as with poor glycemic control (39) and diabetes (40). We found, however, that adjustment for diabetes therapy refill adherence, number of daily insulin injections, appointment no show rate, annual eye exam attendance, self-reported use of exercise and diet, smoking status and alcohol consumption, and markers of disease se-

verity (hospitalization or emergency room visit during the baseline year) had only a minor effect on the benefit.

The association between self-monitoring and glycemic control may strengthen as we improve our ability to teach self-management skills, instill greater awareness of their importance, motivate patients to make behavioral changes in response to readings, and enhance their self-confidence (2,41,42). For example, well-informed patients readily modify insulin dose and timing in response to home glucose readings, and improved insulin administration is the best way to improve glycemic control (43). Because lifestyle changes such as improved diet and exercise have limited sustainability (43), patients may benefit from the feedback provided by regular monitoring. Benefits for patients treated with oral agents may also be mediated through modifications in type and dosing of medication in response to recorded home glucose readings. Although the use of self-monitoring is not well understood for “diet-controlled” patients (1), the immediate feedback about the effects of diet and exercise on glycemic control may be of value. Research is needed to confirm whether special training and enhanced patient motivation and confidence (self-efficacy) would improve the effectiveness of self-monitoring.

Our findings favor American Diabetes Association recommendations for intensive self-monitoring of blood glucose levels among patients with type 1 diabetes. They also provide supportive evidence for the benefits of this self-management practice in the larger group of patients with type 2 diabetes.

APPENDIX

Algorithm for Determining Type of Diabetes

Diabetes was classified as type 1, type 2, or unclear based on self-reported clinical characteristics measured in a diabetes survey (1994–1997). Typing criteria included age at diagnosis and presence of obesity based on body mass index >27.8 kg/m² in men, >27.3 kg/m² in women at the time of diagnosis of diabetes, and, for patients using insulin, the interval between diagnosis and the initiation of insulin treatment, and history of insulin “holidays” (intervals of 3 months or longer off insulin after initiation; 27,29). The algorithm is detailed below.

Type 2 Diabetes

Those meeting the following criteria were classified as having type 2 diabetes:

1. reported using no hypoglycemic medications, oral hypoglycemic agents, or combination of oral agents and insulin; or
2. reported using insulin monotherapy and:
 - Age of onset <20 years, initiated insulin >2 years after diagnosis, and obese; or

- Age of onset 20 to 40 years, initiated insulin <1 month after diagnosis, and obese with insulin holiday; or
- Age of onset 20 to 40 years, initiated insulin 1 month to 2 years after diagnosis, and obese; or
- Age of onset 20 to 40 years, initiated insulin >2 years after diagnosis; or
- Age of onset 40+ years, initiated insulin <1 month after diagnosis, and obese with no insulin holiday; or
- Age of onset 40+ years, initiated insulin <1 month after diagnosis with insulin holiday; or
- Age of onset 40+ years, initiated insulin <1 month after diagnosis with no insulin holiday, and lean; or
- Age of onset 40+ years, initiated insulin 1 month or more after diagnosis

Type 1 Diabetes

Those reporting using insulin monotherapy and meeting the following criteria were classified as having type 1 diabetes:

- Age of onset <20 years, initiated insulin <2 years after diagnosis with no insulin holiday; or
- Age of onset <20 years, initiated insulin <2 years after diagnosis with an insulin holiday, and lean; or
- Age of onset <20 years, initiated insulin >2 years after diagnosis, and lean; or
- Age of onset 20 to 40 years, initiated insulin <1 month after diagnosis, and lean

Unclear Type of Diabetes

Those reporting using insulin monotherapy and meeting the following criteria were classified as having unclear type of diabetes:

- Age of onset <20 years, initiated insulin <2 years after diagnosis with an insulin holiday, and obese; or
- Age of onset 20 to 40 years, initiated insulin <1 month after diagnosis with no insulin holiday, and obese; or
- Age of onset 20–40 years, initiated insulin 1 month–2 years after diagnosis, and lean

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