The Role of Diet Behaviors in Achieving Improved Glycemic Control in Intensively Treated Patients in the Diabetes Control and Complications Trial

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OBJECTIVE — To determine whether specific diet-related behaviors practiced by IDDM patients in the intensive treatment group of the Diabetes Control and Complications Trial were associated with lower HbA_{1c} values.

RESEARCH DESIGN AND METHODS — A questionnaire addressing various aspects of their dietary behavior during the previous year in the DCCT was completed by 623 DCCT intensive treatment group subjects. The association between self-reported diet behaviors and the subject's mean HbA_{1c} during the previous year was evaluated using a linear rank test for trend. The goal of intensive treatment was to achieve blood glucose and HbA_{1c} levels as close to the nondiabetic range as possible without hypoglycemia.

RESULTS — Adherence to the prescribed meal plan and adjusting food and/or insulin in response to hyperglycemia were significantly associated with lower HbA_{1c} levels. Over-treating hypoglycemia and consuming extra snacks beyond the meal plan were associated with higher HbA_{1c} levels. Adjusting insulin dose for meal size and content and consistent consumption of an evening snack were associated, albeit to a lesser degree, with lower HbA_{1c}.

CONCLUSIONS — The average HbA_{1c} among intensively managed patients who reported that they followed specific diet-related behaviors was 0.25 to 1.0 lower than among subjects who did not follow these behaviors. Health-care providers may wish to use these results to focus clinical care for intensively treated IDDM patients by emphasizing counseling on meal plans, prompt response to high blood glucose levels, appropriate treatment of hypoglycemia, and consistent snacking behaviors.

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IDDM, insulin-dependent diabetes mellitus; DCCT, Diabetes Control and Complications Trial; TAG, total available glucose; CHO, carbohydrate; HPLC, high-performance liquid chromatography; BMI, body mass index; ADA, American Diabetes Association.

Diet therapy is considered an essential component of diabetes treatment. However, few studies have examined the role of specific diet behaviors in achieving specific levels of glucose control. Because individuals with IDDM often find following their diet the most difficult part of their medical plan, which includes insulin injections, monitoring blood glucose levels, and incorporation of self-care behaviors into many aspects of their daily life (1–3), investigating the relative importance of diet in achieving stipulated glucose goals is especially important.

Our research was designed to identify diet-related behaviors used by patients attempting to achieve normal HbA_{1c} levels in the DCCT. Identifying and promoting these diet behaviors may simplify self-care routines and improve adherence and glycemic control.

RESEARCH DESIGN AND METHODS

— The DCCT was a prospective, randomized, multicenter trial designed to compare the effects of intensive therapy aimed at achieving near-normal blood glucose levels with the effects of conventional therapy on the development of long-term complications of IDDM (4). Subjects randomized to the intensive treatment group had a complex regimen that included insulin therapy via insulin pump or multiple (≥3) daily injections, blood glucose monitoring ≥4 times/day, and instruction on a diet that is 45–55% CHO, 12–20% protein, and no more than 30–35% fat. In addition, specific dietary instruction to promote normoglycemia was emphasized.

Dietitians instructed intensive treatment group subjects using various meal-planning strategies: exchange system, CHO counting, TAG, weighing and measuring foods, and estimating food portions (5–8). In many centers, dietitians taught patients a combination of dietary strategies, i.e., exchange system and CHO counting.

This research was conducted as a

Table 1—*Distribution of HbA_{1c} values and length of time on intensive therapy*

	Mean ± SD	Range	First quartile	Median	Third quartile
HbA_{1c} values*	7.15 ± 1.00	5.23–13.37	6.53	6.99	7.58
Time on intensive therapy (yr)	4.10 ± 1.70	—	2.83	3.83	5.08

The values are an average of 12 monthly readings taken during the year before questionnaire administration.

DCCT ancillary study, and all 29 clinics participated. Subjects were a subgroup (n = 687) of the intensive treatment group of the full-scale DCCT (n = 711). Eligible subjects had been in the study on intensive therapy for at least 18 mo (mean 4.1 yr). On entry into the DCCT, all subjects had IDDM for 1–15 yr, were 13–39 yr of age, and had no other major medical problems or diabetic complications. A complete description of eligibility criteria is available (4). The distribution of HbA_{1c} values and time on intensive therapy for the study subgroup is included in Table 1.

A Diet Behavior Questionnaire (unpublished, available upon request) was distributed during the sixth year of the full-scale study (1990) to all DCCT intensive treatment group patients who agreed to participate. By the end of 1991, 90% of potential participants (623 of 687) had completed the self-administered questionnaires and mailed them to the DCCT Coordinating Center in stamped preaddressed envelopes.

The 84-item questionnaire took 20–30 min to complete and asked patients to report on methods used to implement diet, adherance to meal plans, managing expected changes in food intake, treatment of reactions, consumption of concentrated sweets, and timing of insulin in relation to meals and snacking habits. This survey instrument was pretested in 1986 with 101 intensively treated subjects in the feasibility phase (9,10). At that time, analysis of the data was used to refine the survey instrument and narrow the focus of the full-scale study reported herein. The questions in Table 2 were selected for this analysis based on prior evidence (9) or beliefs about their relationship to glycemic control. Other sections of the questionnaire related to hypoglycemia and weight gain are not included in this analysis.

Table 2—*Questions from diet behavior questionnaire*

1. Over the past year I have followed my prescribed meal plan.
   - Never
   - Very infrequently (<10% of the time)
   - Infrequently (10–44% of the time)
   - About half of the time (45–55% of the time)
   - More than half the time (56–69% of the time)
   - Most of the time (71–90% of the time)
   - Almost all of the time (>90% of the time)
   - Always
2. When treating a reaction, how often do you. . .

Test your blood glucose before eating	(1)	(2)	(3)	(4)	(5)
Eat until you feel better	(1)	(2)	(3)	(4)	(5)
Eat a specified amount, wait at least 10–15 minutes, then test your blood glucose before eating again	(1)	(2)	(3)	(4)	(5)
Eat a specified amount, wait 10–15 minutes before eating more	(1)	(2)	(3)	(4)	(5)

   Never = (1)
   Less than half the time = (2)
   About half the time = (3)
   More than half the time = (4)
   Almost always = (5)
3. When my blood glucose is high. . .

I eat less food at the next meal	(1)	(2)	(3)	(4)	(5)
I eat fewer carbohydrates at the next meal	(1)	(2)	(3)	(4)	(5)
I skip a snack	(1)	(2)	(3)	(4)	(5)
I take more insulin	(1)	(2)	(3)	(4)	(5)

   Never = (1)
   Less than half the time = (2)
   About half the time = (3)
   More than half the time = (4)
   Almost always = (5)
4. How often do you have an extra snack at night? (Do not include snacks taken to treat low blood glucose)

Less than once a month	1–2 times a week	3–5 times a week	Every day

5. Do you adjust your insulin dose based on what you are going to eat for meals?

Never	Less than half the time	About half the time	More than half the time	Almost always

6. How often do you eat a snack at night?

Less than once a month	1–2 times a week	3–5 times a week	Every day

Table 3—*Association between following prescribed meal plan and mean HbA_{1c} achieved*

Followed meal plan (% of time)	n	Mean ± SD HbA_{1c}*	First quartile	Median	Third quartile
<45%	70	7.59 ± 1.43	6.69	7.34	8.12
45–55%	100	7.33 ± 0.99	6.67	7.21	7.65
56–70%	166	7.31 ± 1.03	6.70	7.15	7.72
71–90%	204	6.96 ± 0.72	6.46	6.88	7.41
>90%	69	6.73 ± 0.79	6.17	6.62	7.20
Did not respond	12	6.44 ± 0.68	5.98	6.25	6.73

*P <0.001 for differences in distribution of HbA_{1c} between categories.

Measures

Glycemic control was assessed by HbA_{1c} assays in the DCCT Central Biochemistry Lab using an HPLC method (11). The nondiabetic range is 4.0–6.05. Mean HbA_{1c} was calculated based on the mean of monthly HbA_{1c} results from the previous 12 mo.

Statistical methods

Patients were divided into groups on the basis of questionnaire responses; those who did not respond to a particular question were dropped from that comparison. When no single questionnaire item adequately captured a behavior pattern, responses to several related items were aggregated into a composite index. (For example, the highest frequency with which the patient reported responding to high blood glucose in any of four different ways was used to estimate the consistency with which the patient took prompt action to treat a high reading.) On the assumption that progressively higher (or lower) HbA_{1c} concentrations would be associated with increasing frequency of the behavior under study, contiguous categories were combined when necessary to provide relatively well-balanced sample sizes.

Wilcoxon's rank-sum test (12) was used to test for differences between two groups. Because HbA_{1c} levels were expected to vary monotonically across categories, when more than two groups were compared, we used the Jonckheere-Terpstra test for ordered alternatives (13,14). All calculations were performed in the SAS computing language (15).

RESULTS

Adherence to diet

Questions that addressed compliance to diet used rating categories corresponding with those used in the DCCT quarterly visit form. Intensive treatment group subjects who reported following their prescribed meal plans >90% of the time had an average HbA_{1c} level 0.9 lower than that of subjects who followed their meal plans <45% of the time (Table 3). These results confirmed findings from the pilot study.

Treating hypoglycemia

Overconsumption of food used to treat hypoglycemia was associated with significantly higher HbA_{1c}. A difference of 0.5 in average HbA_{1c} was found between groups who reported "never eating until you feel better," i.e., never overeating or overtreating a reaction, and those who "almost always" ate until they felt better (Table 4).

Treating hyperglycemia

Patients who reported promptly responding to high values from self-blood glucose monitoring showed a significant tendency to achieve lower HbA_{1c} levels than those who did not (Table 5). Those who almost always responded to high blood glucose levels via more insulin, less food, or less CHO had HbA_{1c} levels 0.5 lower than those who responded to high glucose levels ≤50% of the time.

Snacking behavior

Patients who reported extra nighttime snacking (beyond the meal plan) ≥3 times/wk typically had higher HbA_{1c} levels than those who consumed extra snacks ≤1 time/wk (Table 6). Patients who consumed prescribed evening snacks more consistently tended to have lower HbA_{1c} levels than those who consumed bedtime snacks ≤2 times/wk (Table 7).

Managing changes in food intake by insulin dose adjustment

When patients who "never" adjusted their insulin dose for meal size and content were compared with those who "almost always" adjusted insulin, those who "never" adjusted insulin had mean HbA_{1c} levels that were 0.5 higher than

Table 4—*Association between eating until you feel better to treat hypoglycemia and mean HbA_{1c} achieved*

	n	Mean ± SD HbA_{1c}*	First quartile	Median	Third quartile
Never	121	6.92 ± 0.80	6.33	6.83	7.42
<50% of the time	252	6.98 ± 0.90	6.39	6.82	7.38
~50% of the time	119	7.41 ± 1.79	6.60	7.20	7.80
>50% of the time	67	7.47 ± 0.78	6.88	7.45	7.85
Almost always	54	7.43 ± 1.08	6.71	7.27	7.93
Did not respond	8	7.6 ± 1.82	6.54	6.87	8.55

*P < 0.001 for differences in distribution of HbA_{1c} between categories.

Table 5—*Association between promptly responding to high blood glucose and mean HbA_{1c} achieved*

	n	Mean ± SD HbA_{1c}*	First quartile	Median	Third quartile
≤50% of the time	56	7.46 ± 1.47	6.53	7.19	7.92
>50% of the time	122	7.31 ± 0.95	6.71	7.15	7.74
Almost always	438	7.06 ± 0.89	6.45	6.91	7.51
Did not respond	5	7.81 ± 2.21	6.36	6.75	9.79

*$P < 0.005$ for differences in distribution of HbA_{1c} between categories.

those who "almost always" adjusted insulin dose for changes in food intake (Table 8). However, the pattern was not consistent across all categories.

Timing of insulin and food intake

Intensively treated patients are commonly taught to allow 30 min between injecting regular insulin and eating their next meal. Several questions in our study addressed this behavior. No relationship seemed evident between timing of insulin injection for food intake and HbA_{1c}.

Use of concentrated sweets

Although DCCT participants were taught how to adjust their insulin for meals, including concentrated sweets, only 30% of them ate candy, cake, pie, pastry, or other sweets ≥1 time/wk. Our data did not clearly indicate whether eating sweets was related to HbA_{1c} achieved. Relatively few of the intensive treatment group subjects frequently consumed sweets.

Possible confounding variables

To investigate whether differences in HbA_{1c} could be explained by differences in patient characteristics, distribution of the following covariates were also examined: age, sex, time in follow-up, diabetes duration, insulin dose, alcohol use, smoking, exercise level, body weight, and change in BMI from baseline. None of these covariates appeared to vary systematically with HbA_{1c} (data not shown).

CONCLUSIONS— This research was designed to identify diet-related behavior used by a relatively homogenous group of intensively treated IDDM patients attempting to achieve normal HbA_{1c} levels. This study identified four patient-reported diet-related behaviors that were associated with maintenance of lower HbA_{1c} levels: adherence to diet, prompt treatment of hyperglycemia, avoidance of overtreatment of hypoglycemic reactions with food, and avoidance of extra snacks. Two additional behaviors were associated albeit, to a less significant degree, with lower HbA_{1c} levels, adjusting insulin for meals and consistency of night snacks.

Frequency of adherence to specific behaviors made large differences in HbA_{1c} achieved. For instance, patients who followed their diet >90% of the time had mean HbA_{1c} levels 0.9 lower than patients who "followed their diet" <45% of the time. Patients who "followed their diet" reported instruction on multiple strategies to implement diet e.g., CHO counting and exchanges or TAG and exchanges. Determining whether 1 method of diet teaching offered advantages over another was not possible because of the nonrandom choice of strategies offered by the patient and clinic. However, it is important to note that all diet-teaching strategies provided patients with a tool to evaluate diet consistency and determine whether insulin adjustments were necessary to manage variations in food intake. Specific strategies used in the DCCT are discussed elsewhere (16,17). A 0.5 lower HbA_{1c} was achieved in patients who almost always adjusted insulin dose for changes in diet compared with patients who never adjusted insulin dose for diet changes. The association between mean HbA_{1c} and adjusting insulin dose for changes in food intake was not consistent across all categories. Subjects who had lower HbA_{1c} values and adjusted food intake <50% of the time might have been individuals whose diet adherence was good (i.e., consistent eating habits) and thus rarely needed to adjust their insulin dosages.

Although the results from this study may not be valid in populations not supported by an interactive healthcare team (dietitians, mental health professionals, nurses, and physicians), it is interesting that in this population a lower mean HbA_{1c} was achieved by patients who reported following their diets and not overtreating hypoglycemic reactions. This study emphasizes the importance of appropriate treatment of hypoglycemia and its impact on HbA_{1c} in a group of intensively managed patients who have a higher incidence of hypoglycemia than their counterparts receiving conventional insulin treatment (18).

Research on the relationship of self-care behaviors and glycemic control

Table 6—*Association between eating extra snacks at night beyond meal plan and mean HbA_{1c} achieved*

	n	Mean ± SD HbA_{1c}*	First quartile	Median	Third quartile
<1 time/wk	258	7.01 ± 0.98	6.37	6.82	7.44
1 or 2 times/wk	270	7.24 ± 0.97	6.62	7.10	7.68
≥3 times/wk	78	7.33 ± 1.12	6.59	7.28	7.78
Did not respond	15	6.87 ± 0.50	6.51	6.75	7.27

*$P < 0.001$ for differences in distribution of HbA_{1c} between categories.

Table 7—*Association between consistency of eating prescribed bedtime snack and mean HbA_{1c} achieved*

	n	Mean ± SD HbA_{1c}*	First quartile	Median	Third quartile
≤2 times/wk	83	7.28 ± 1.20	6.59	7.10	7.62
3–5 times/wk	152	7.24 ± 0.95	6.62	7.11	7.72
Every day	256	7.06 ± 0.93	6.45	6.87	7.45
Did not respond	130	7.14 ± 1.01	6.42	6.97	7.59

*P = 0.01 for differences in distribution of HbA_{1c} between categories.

in diabetes mellitus has been performed by many groups (19–21). Results to date are inconclusive and contradictory. Rubin et al. (21,22) found a positive relationship between dietary adherence and glycemic control (21,22). Glascow and Watkins did not (19,20). No group specifically focused their research on dietary behaviors as distinguished from general compliance to diet or food selection.

The ADA lists 15 topic areas that must be included in diabetes patient education programs (23). Another ADA publication *Goals for Diabetes Education* (24) references 58 behavioral objectives IDDM patients are required to master during the initial stages of diabetes education. Of these, 20 refer to nutrition.

Identifying key behaviors that relate to improved glycemic control is a challenge mandated by literature on adherence. Studies suggest that when therapeutic regimens for individuals with chronic disease are simplified, compliance improves (25). Educators faced with the task of providing time-consuming and costly services to those with IDDM may improve efficiency and outcomes of counseling sessions by focusing on these diet-related behaviors when the goal of therapy is to achieve lower levels of glycemia. Because the long-term benefits of achieving lower levels of glycemia have been clearly established by the DCCT, it is even more important to apply these findings to clinical practice. Future studies will need to explore the potential impact of combinations of these behaviors on lowering HbA_{1c} levels and whether these self-reported behaviors are associated with lower levels of HbA_{1c} in populations other than the intensively managed patients in the DCCT.

Several dietary behaviors were associated with lower HbA_{1c} levels among IDDM patients randomized to intensive therapy in the DCCT. Intensively managed patients who reported following their prescribed diet had average HbA_{1c} levels 0.9 lower than intensively treated patients who did not follow their meal plan. Patients who did adhere to other prescribed dietary behaviors had average HbA_{1c} levels 0.25–0.5 lower than those who did not. Health-care providers may wish to use these data to focus clinical care by emphasizing counseling on meal plans, prompt treatment of high blood glucose, appropriate treatment of hypoglycemia, and consistent snacking behaviors.

Table 8—*Association between adjusting insulin dose for meals and mean HbA_{1c} achieved*

	n	Mean ± SD HbA_{1c}*	First quartile	Median	Third quartile
Never	33	7.53 ± 1.57	6.41	6.91	8.36
<50% of the time	117	7.11 ± 1.11	6.47	6.87	7.46
~50% of the time	90	7.40 ± 0.94	6.76	7.37	7.81
>50% of the time	112	7.25 ± 0.87	6.63	7.12	7.72
Almost always	261	6.97 ± 0.83	6.38	6.85	7.47
Did not respond	8	7.79 ± 1.84	6.61	7.08	9.07

*P < 0.03 for differences in distribution of HbA_{1c} between categories.

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