Impact of Carbohydrate Counting on Glycemic Control in Children With Type 1 Diabetes

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OBJECTIVE — To study the association between parent carbohydrate counting knowledge and glycemic control in youth with type 1 diabetes.

RESEARCH DESIGN AND METHODS — We assessed 67 youth ages 4–12 years with type 1 diabetes (duration ≥1 year). Parents estimated carbohydrate content of children's meals in diet recalls. Ratios of parent estimates to computer analysis defined carbohydrate counting knowledge; the mean and SD of these ratios defined accuracy and precision, respectively. A1C defined glycemic control.

RESULTS — Greater accuracy and precision were associated with lower A1C in bivariate analyses ($P < 0.05$). In a multivariate analysis ($R^2 = 0.25$, $P = 0.007$) adjusting for child age, sex, and type 1 diabetes duration, precision ($P = 0.02$) and more frequent blood glucose monitoring ($P = 0.04$), but not accuracy ($P = 0.9$), were associated with lower A1C. A1C was 0.8% lower (95% CI −0.1 to −1.4) among youth whose parents demonstrated precision.

CONCLUSIONS — Precision with carbohydrate counting and increased blood glucose monitoring were associated with lower A1C in children with type 1 diabetes.

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Medical nutrition therapy in type 1 diabetes is associated with improved glycemic outcomes (1,2). Meal-planning strategies for type 1 diabetes emphasize the relationship between prandial insulin dose selection and the anticipated amount of carbohydrate to be consumed. Although no method for carbohydrate estimation has proven superior in the management of youth with type 1 diabetes, carbohydrate counting has become a principal strategy for children with type 1 diabetes (3,4). In this study, we investigated the association between parental carbohydrate counting knowledge and glycemic control in youth with type 1 diabetes.

RESEARCH DESIGN AND METHODS — Families with type 1 diabetes who were routinely attending a multidisciplinary pediatric diabetes program were invited to participate in this study. During the 3 months after the study visit, a research dietitian conducted three unannounced telephone interviews. The Committee for Clinical Investigation approved the protocol, and participants provided written informed consent/assent.

Eligible youth were aged 2–12 years with type 1 diabetes duration ≥1 year. They had a daily insulin dose ≥0.5 units/kg, used carbohydrate counting in meal planning, and were intensively treated with multiple (three or more) daily injections or insulin pump therapy. A1C (reference range 4–6%) was determined at the study visit.

During each telephone call, parents provided estimates of carbohydrate content (in grams) for each meal consumed during the previous 24-h period. The dietitian then completed a diet recall using a multiple-pass approach with Nutrition Data System for Research (NDSR) software (version 2005; the Nutrition Coordinating Center, University of Minnesota, Minneapolis, MN) (5). Household kitchen measures and two-dimensional food models assisted portion size estimation.

Carbohydrate counting knowledge was defined using the ratios of carbohydrate content estimated by parents to those calculated using NDSR. "Accuracy" was defined by the mean of meal ratios; a value of 1 defined perfect accuracy. Values <1 and >1 defined inaccuracy due to underestimation and overestimation, respectively. "Precision" (consistency) was defined by the SD of meal ratios; a value of 0 defined perfect precision. Increasing SD values defined decreasing precision.

Analyses were performed with SAS (version 9.1; SAS Institute, Cary, NC); $\alpha < 0.05$ determined significance.

RESULTS — Youths (45% female) with complete dietary data ($n = 67$) were 9.1 ± 2.5 years old (range 4–12 years) with diabetes duration of 4.1 ± 2.3 years (range 0.6–9.9 years). All were intensively treated using pump (70%), sliding scale–supported injection (27%), or basal-bolus injection (3%) therapy. Mean blood glucose monitoring frequency was 5.5 ± 0.8 checks daily, and mean A1C was 7.5 ± 0.8% (range 5.8–10.3%). Only four youth had A1C >9%.

Dietary analyses were based on 182 phone interviews (average 2.7/family). Average meal carbohydrate content was 50 g but varied across meals and ages. On average, parent estimates of carbohydrate intake were 120% of NDSR-calculated intake. Precision ranged from 0.1 to 1.6 (least precise). Neither pump use nor time since the last nutritionist visit was associated with accuracy or precision with carbohydrate counting ($P > 0.5$ for all comparisons).

For bivariate analyses, youth were grouped into quartiles (Q) of carbohydrate counting accuracy: Q1, inaccurate (underestimation); Q2–3, most accurate; and Q4, inaccurate (overestimation). Ac-

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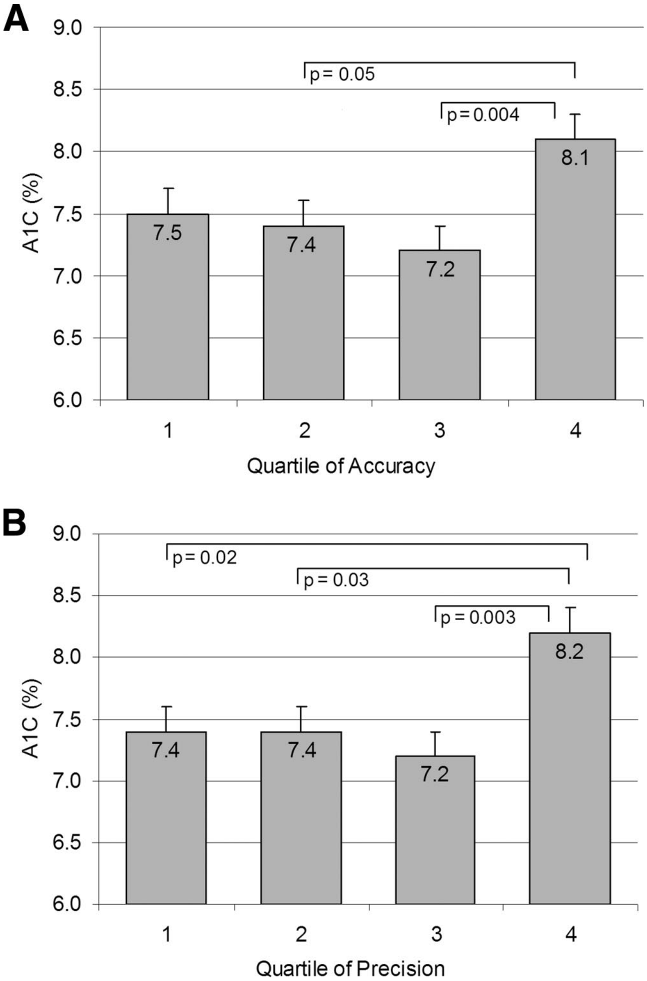

Figure 1—*Child A1C (mean ± SE) by quartiles of parent carbohydrate counting accuracy* (A) *or precision* (B). A: *The A1C of children whose parents overestimated carbohydrate content (Q4) was higher than the A1C of children whose parents were most accurate (Q2–3). The A1C of children whose parents underestimated carbohydrate content (Q1) was not significantly different from the A1C of other children.* B: *The A1C of children whose parents were the least precise (Q4) was significantly higher than the A1C of all other children (Q1–3).*

curacy was associated with lower A1C (P = 0.006) due to differences between the most accurate parents (Q2–3) and those who overestimated (Q4). Similarly, youth were grouped into quartiles of carbohydrate counting precision: Q1 (most precise) to Q4 (least precise). Greater precision was associated with lower A1C (P = 0.003); A1C was significantly higher among children whose parents' precision was above the 75th percentile (Q4) (Fig. 1).

To determine the unique contributions of carbohydrate counting accuracy and precision to glycemic control, we performed a multivariate analysis adjusting for age, sex, type 1 diabetes duration, and frequency of blood glucose monitoring. For this analysis, accuracy was defined by estimates within 20% of calculated intake and precision was defined by values less than the 75th percentile. In a significant model ($R^2 = 0.25$, $P = 0.007$), lower A1C was associated with precision ($B = -0.77$ [95% CI −0.10 to −1.44]; $P = 0.02$) and more frequent blood glucose monitoring ($B = -0.24$ [−0.01 to −0.48]; $P = 0.04$), but not accuracy ($B = -0.04$ [−0.63 to 0.55]; $P = 0.9$). Precision with carbohydrate counting explained 7% of the variance in A1C in the model.

CONCLUSIONS— Among intensively treated youth with type 1 diabetes, parental carbohydrate counting knowledge was associated with lower A1C. Although both accuracy and precision were related to A1C in bivariate analyses, only precision was associated with lower A1C when adjusting for demographic and diabetes-specific characteristics. Precision was associated with a 0.8% lower A1C. Similar to previous studies, more frequent blood glucose monitoring was also independently associated with lower A1C (6,7).

We hypothesized that carbohydrate counting knowledge would allow for proper calculation of prandial insulin doses and improve glycemic control. Our findings suggest that precise estimation may offset the negative impact of inaccurate estimation (that is, inaccurate estimation, if done consistently, may not adversely affect A1C). Furthermore, it is recognized that blood glucose monitoring facilitates the selection and adjustment of insulin doses, and its association with A1C was not unexpected.

There are caveats to this analysis. Social desirability and reliance on memory may limit the validity of diet recalls in assessing actual intake in children (8,9). For this reason, parent estimation was compared with formal analysis of recalled foods, not actual intake. Discrepancies between recalled and actual intake may affect glycemic control, but we were unable to evaluate this possibility. Furthermore, we did not assess carbohydrate quality (10), alterations in timing of insulin dosing (11,12), or glycemic excursions (13,14), which are also known to affect A1C. Our sample included children with relatively well-controlled type 1 diabetes (78% achieving American Diabetes Association age-specific A1C recommendations [15]), and parents were mostly married (88%), well-educated (73% college degree), and of higher socioeconomic status (defined by education and 90% privately insured). Our findings would be strengthened by confirmation in more diverse populations.

Consistency (precision) when estimating carbohydrate content was associated with improved glycemic control. Future studies investigating factors that promote carbohydrate counting knowledge could help optimize nutrition education for youth with type 1 diabetes and their families.

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