Randomized Nutrition Education Intervention to Improve Carbohydrate Counting in Adolescents with Type 1 Diabetes Study: Is More Intensive Education Needed?

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ABSTRACT

Background Youth with type 1 diabetes do not count carbohydrates accurately, yet it is an important strategy in blood glucose control.

Objective The study objective was to determine whether a nutrition education intervention would improve carbohydrate counting accuracy and glycemic control.

Design We conducted a randomized, controlled nutrition intervention trial that was recruited from February 2009 to February 2010.

Subjects Youth (12 to 18 years of age, n=101) with type 1 diabetes were screened to identify those with poor carbohydrate counting accuracy, using a previously developed carbohydrate counting accuracy test covering commonly consumed foods and beverage items presented in six mixed meals and two snacks. All participants (n=66, age=15±3 years, 41 male, diabetes duration=6±4 years, hemoglobin A1c [HbA1c]=8.3%±1.1%) were randomized to the control or intervention group at the baseline visit. The intervention group attended a 90-minute class with a registered dietitian/certified diabetes educator and twice kept 3-day food records, which were used to review carbohydrate counting progress.

Main outcome measures Carbohydrate counting accuracy (measured as described) and HbA1c were evaluated at baseline and 3 months to determine the effectiveness of the intervention.

Statistical analyses performed *t* Tests, Spearman correlations, and repeated measures models were used.

Results At baseline, carbohydrate content was over- and underestimated in 16 and 5 of 29 food items, respectively. When foods were presented as mixed meals, participants either significantly over- or underestimated 10 of the 9 meals and 4 snacks. After 3 months of follow-up, HbA1c decreased in both the intervention and control groups by −0.19%±0.12% (P=0.12) and −0.08%±0.11% (P=0.51), respectively; however, the overall intervention effect was not statistically significant for change in HbA1c or carbohydrate counting accuracy.

Conclusions More intensive intervention might be required to improve adolescents' carbohydrate counting accuracy and nutrition management of type 1 diabetes. Additional research is needed to translate nutrition education into improved health outcomes.
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THE PRIMARY GOAL IN MANAGEMENT OF TYPE 1 diabetes is to maintain blood glucose close to normal levels. Many patients with type 1 diabetes have hemoglobin A1c (HbA1c) values that exceed American Diabetes Association goals (<7.5% for ages 13 to 19 years old and <8% for ages 6 to 12 years old)[1] and elevated postprandial glucose levels contribute to failure to attain optimal glycemic control.[2] The total amount of carbohydrates consumed strongly predicts glycemic response; therefore, monitoring total carbohydrates by either exchanges or carbohydrate counting to appropriately dose rapid-acting insulin is critical to lower mean glycemia (HbA1c) and to reduce glucose variability.[3-7]

Few data exist on the accuracy of carbohydrate counting in youth with type 1 diabetes, yet it is a recommended part of their daily care.[5,8-13] Using continuous subcutaneous insulin infusion and multiple daily insulin injections requires patient (or parent) assessment of carbohydrate amount in order to determine proper bolus insulin dosing.[5,9] Accurate estimation of total carbohydrates to be consumed is critical to achieving glycemic control.[3,4] Carbohydrate counting in treatment of youth with type 1 diabetes is not a new approach; however, the adjustment of premeal doses based on the carbohydrate content of meals has become more standard since the introduction of rapid-acting insulin analogs, subcutaneous insulin infusion, and multiple daily insulin injections.[5]

There is very little research specifically providing evidence for the accuracy of carbohydrate counting in youth with diabetes,[8,10,13] and no standardized approach to assessing the accuracy of carbohydrate counting is available. Koontz and colleagues developed a pediatric questionnaire that evaluates knowledge about carbohydrates and insulin dosing calculations, but does not assess all aspects of carbohydrate counting.[14] Although one study found 102 children and adolescents estimated carbohydrates within 10 to 15 g of the actual amount for 73% of 17 meals and snacks,[13] this group has reported in a previous study that adolescents with type 1 diabetes do not count carbohydrates accurately and commonly either over- or underestimate carbohydrates in a given meal. Only 11 of 48 (23%) adolescents estimated daily carbohydrates within 10 g of the true amount, despite selection of common meals and only 15 (31%) estimated accurately within 20 g/day.[8] The Dose Adjustment for Normal Eating randomized controlled trial in the United Kingdom found that adult patients with type 1 diabetes who were taught how to use flexible intensive insulin treatment with carbohydrate to insulin ratios, improved HbA1c by 1% after 6 months and reported improved quality of life.[15] In addition, a recent study conducted in Italy found that adults with type 1 diabetes who attended a 4-week nutrition-education program focusing on carbohydrate counting had a significant decrease in HbA1c and fewer hypoglycemic events.[16] However, no research exists on whether a nutrition-education intervention focusing on carbohydrate counting can improve adolescents' ability to count carbohydrates and whether such an improvement translates into better glycemic control.

There are two hypotheses for this study. The first hypothesis is that carbohydrate counting is not practiced accurately among adolescents with type 1 diabetes. The second hypothesis is that a nutrition intervention conducted by a registered dietitian/certified diabetes educator (RD/CDE) and aimed at improving carbohydrate counting accuracy will result in improved carbohydrate counting accuracy and as a result improved glycemic control in the intervention group compared with the control group. Therefore, the aim of this study was to evaluate carbohydrate counting accuracy in adolescents with type 1 diabetes and to determine whether a nutrition education intervention with an RD/CDE for those who do not count carbohydrates accurately could improve carbohydrate counting accuracy and, as a result, improve glycemic control. This study reports the results of a randomized, controlled nutrition intervention trial.

METHODS

Eligibility Criteria

Adolescents ages 12 to 18 years with type 1 diabetes (defined by American Diabetes Association criteria)[17] for 1 year or more, seen at the Barbara Davis Center for Childhood Diabetes, and using insulin to carbohydrate ratios for at least one meal a day were eligible for the study. Patients with celiac disease, type 1 diabetes with <1-year duration, HbA1c >10% (at most recent clinic appointment) or non−English-speaking were excluded.

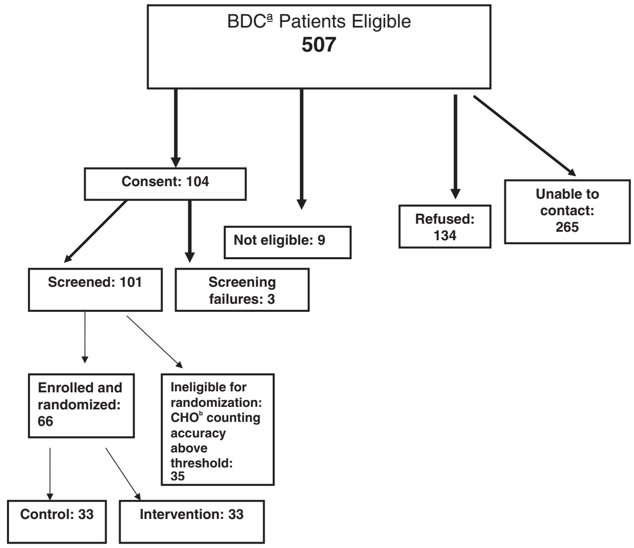

Figure 1. Flow chart of recruitment and enrollment of participants in the Carbohydrate Counting in Adolescents with Type 1 Diabetes Study: Is More Intensive Education Needed? [a]BDC=Barbara Davis Center for Childhood Diabetes. [b]CHO=carbohydrate.

Sample Selection

Patients coming to the Barbara Davis Center for Childhood Diabetes for their routine follow-up visit between February 2009 and February 2010 were contacted to see whether they would be interested in participating in the study. A carbohydrate counting accuracy test (as we will describe) was given based on a previously published method,[8] and participants were included if they counted carbohydrates inaccurately. The a priori accuracy cut point was defined as participant's carbohydrate count for a meal within 10 g carbohydrates of the true carbohydrate value for four of six meals. A total of 104 individuals provided consent (three were screening failures, four intervention participants withdrew after the baseline visit); therefore, baseline data were analyzed for 101 participants and complete data were analyzed from 97 participants (Figure 1). Screening failures included two participants who were not carbohydrate counting for at least one meal per day and one who had a developmental disorder. Sixty-six of the 101 eligible participants screened qualified for the intervention by scoring below the carbohydrate counting accuracy cut point and were randomized into the intervention or control group (33 in each group).

Informed Consent

All participants provided written informed consent and/or assent and the study was approved by the Colorado Multiple Institutional Review Board.

Study Design

At the baseline visit, 101 participants completed a carbohydrate accuracy test,[8] which involved assessing the carbohydrate content (g) for 29 food items (eg, apple [snack] and cereal with milk and banana [breakfast]) presented as typical breakfasts, lunches, dinners, and snacks (six mixed meals, two snacks) commonly consumed by youth. Participants recorded their estimate of portion size, carbohydrate content, and their frequency of consumption (from "<1/month" to "almost every day") for each individual food item presented in the six mixed meals and two snacks. The total meal carbohydrate (g) estimate of the six mixed meals was used for scoring the carbohydrate counting accuracy test at the baseline visit. In order to assess how well participants estimate carbohydrates when evaluating a whole meal rather than individual foods, they were also asked to record their estimate of total meal carbohydrates (g) for an additional three meals and two snacks. All food items were selected as common by RDs after a review of diet records at the Barbara Davis Center for Childhood Diabetes and of dietary data collected from youth with diabetes in the SEARCH for Diabetes in Youth Study.[18] Food items were presented either as food models or as real food, with some items presented as standard serving sizes and some self-portioned by the study participant. Packaged real food items were presented to participants with the food labels and participants were allowed to use these food labels in their estimations if they wanted. Study staff recorded the use of nutrition labels by participants during the study visit (for foods that were presented with a nutrition label). For self-portioned foods, the actual weight of the food served was recorded out of sight of the participant. The amount of carbohydrates in each food was determined by either the nutrition label for the real food that came in packaging, by the Nasco Food Replica Nutrition Guide (based on US Department of Agriculture Standard Reference for Nutrient Composition) for all food models, or by the Nutrient Data System for Research (version 2007, Nutrition Coordinating Center, University of Minnesota) for real foods that were self-portioned by the study participant. Participants were also given a sheet with two labels with Nutrition Facts and asked to calculate carbohydrate grams for a given serving (Figure 2).

Data Collection

At baseline, an interviewer-administered questionnaire assessed carbohydrate counting education received from an RD, duration of carbohydrate counting, family/friend support for carbohydrate counting, and pattern of carbohydrate counting (at which meals and snacks they count carbohydrates and how often). Participants also completed a self-administered questionnaire of parental support (collaborative scale) of their diabetes management.[19,20] This questionnaire was completed by the participant only, without input from the parent.

A demographic/medical history questionnaire was also completed, which included information such as date of birth, ethnicity, and routine clinical data such as height, weight, body mass index (BMI), and insulin dosing (Table 1). As part of the participant's clinical visit concurrent with the study visit (baseline and final visit), HbA1c was measured by blood sample on a Bayer DCA 2000+ (Siemens/Bayer), and BMI was calculated by a computer program after obtaining height on a wall-mounted stadiometer (Seca) and weight on a clinic electronic scale (Detecto). Height and weight were measured in duplicate to 0.1-cm and 0.1-kg increments, respectively.

At their 3- to 4-month follow-up (routine clinic visit/final visit), all participants repeated the carbohydrate counting accuracy test conducted to determine whether their accuracy had improved. The carbohydrate counting questionnaire, demographic/medical history questionnaire and parental support questionnaire were also repeated at this visit.

Usual Practice

Usual carbohydrate counting education for patients at the Barbara Davis Center for Childhood Diabetes includes meeting with an RD/CDE for 60 minutes at diagnosis, attending a 120-minute class at 1 week after diagnosis and an individual visit with an RD/CDE at 1 month after diagnosis. All pump patients also attend a 60-minute class on carbohydrate counting and complete food records for evaluation of carbohydrate counting accuracy and insulin to carbohydrate ratio dosing adjustments before pump initiation. All patients can meet with an RD at each quarterly visit if needed, but the frequency of those visits varies widely. Patients at the Barbara Davis Center for Childhood Diabetes are taught to match insulin dose to the total amount of carbohydrate grams they are eating. In addition, food records are evaluated periodically for carbohydrate counting accuracy and insulin to carbohydrate ratio dosing adjustments. All participants received this education as part of their routine care.

Randomized Controlled Trial/Nutrition Education Intervention

Participants were randomly assigned to the nutrition intervention group or the control group using a computer-generated scheme developed by our staff biostatistician.

Control

Participants randomized to the control group received a handout with the carbohydrate content of commonly eaten foods and a list of carbohydrate counting resources. RDs or a study staff member with a master's degree in nutrition briefly (5 minutes) reviewed the handouts and discussed the importance of carbohydrate counting and gave the participant the phone number of the staff RD to call with questions.

Intervention

In addition, the intervention group attended a carbohydrate counting class and completed two sets of 3-day food records as described here.

Carbohydrate Counting Class. The intervention targeted the adolescent and was designed by RDs/CDEs to improve carbohydrate counting accuracy and insulin dosing. This was an interactive 90-minute class taught by the same RD/CDE following a planned curriculum with hands-on activities and time for discussion. The class applied knowledge gained by RDs from previous studies conducted by this research group about areas of deficiency that this population encounters when estimating carbohydrate content of foods.[8] RDs adapted the current nutrition education program, used as part of standard clinical care at the Barbara Davis Center for Childhood Diabetes, to better address performance deficits in car-

Please look at the following nutrition labels and answer the questions that follow:

1) *Frosted Strawberry Toaster Pastries*

Nutrition Facts

Serving Size	1 Pastry (52g)
Servings Per Container	8
Amount Per Serving	
Calories 200	Calories from Fat 45
	% Daily Value*
Total Fat 5g	**8%**
Saturated Fat 1.5g	**8%**
Trans Fat 0g	
Cholesterol 0mg	**0%**
Sodium 170mg	**7%**
Total Carbohydrate 37g	**12%**
Dietary Fiber less than 1g	**2%**
Sugars 17g	
Protein 2g	

Vitamin A	10%	Vitamin C	0%	Calcium	0%
Iron	10%	Thiamin	10%	Riboflavin	10%
Niacin	10%	Vitamin B_6	10%	Folic Acid	10%

* Percent Daily Values are based on a 2,000 calorie diet. Your daily values may be higher or lower depending on your calorie needs:

	Calories	2,000	2,500
Total Fat	Less than	65g	80g
Sat. Fat	Less than	20g	25g
Cholesterol	Less than	300mg	300mg
Sodium	Less than	2,400mg	2,400mg
Total Carbohydrate		300g	375g
Dietary Fiber		25g	30g

Calories per gram: Fat 9 • Carbohydrate 4 • Protein 4

- If you ate **2 toaster pastries,** how many grams of carbohydrates would you eat? _______________

2) Apple Juice (15.2 oz or 450 ml size bottle)

Nutrition Facts

Serving Size 8 fl oz (240 ml)	
Servings per Container about 2	
Amount Per Serving	
Calories 110	
	% Daily Value*
Total Fat 0g	**0%**
Sodium 20mg	**1%**
Total Carbohydrates 28	**9%**
Sugars 26 g	
Protein 0g	
Vitamin C 100%	

Not a significant source of fat cal, sat fat, trans fat, cholest, fiber, vitamin A, calcium and iron.

*Percent Daily Values are based on a 2,000 calorie diet.

- If you drank the whole **bottle** of juice (15.2 fl oz or 450 ml), how many grams of carbohydrates would you drink? _______________

Figure 2. Label reading activity for participants in the Carbohydrate Counting in Adolescents with Type 1 Diabetes Study: Is more intensive education needed?

Table 1. Baseline characteristics of the participants who qualified vs those who did not qualify for the study and those in the intervention group vs control group in the Carbohydrate Counting in Adolescents with Type 1 Diabetes Study: Is more intensive education needed?

	Qualifiers (n=66)	Nonqualifiers (n=35)	*P* value[a]	Intervention (n= 33)	Control (n= 33)	*P* value[a]
	←—— *mean±SD*[b] ——→			←—— *mean±SD* ——→		
Age (y)	15.1±2.8	14.8±3.5	0.58	15.7± 3.4	14.5±1.8	0.083
Diabetes duration (y)	5.5±3.5	6.9±3.5	0.064	5.5±3.5	5.6±3.4	0.83
BMI[c]	22.1±3.8	20.7±2.6	0.057	22.3±3.7	21.9±3.8	0.63
HbA1c[d] **(%)**	8.33±1.09	8.10±0.92	0.29	8.41±1.04	8.25±1.14	0.54
Blood glucose	190.3±70.6	206.1±61.9	0.27	193.8±79.6	186.8±61.4	0.69
Insulin total	56.8±26.5	48.7±14.7	0.10	59.5±17.0	54.2±33.3	0.42
Basal %	47.2±12.8	45.1±10.1	0.43	47.4±10.9	47.1±14.5	0.93
Bolus %	52.8±12.8	54.9±10.0	0.44	52.6±10.9	52.9±14.5	0.93
No. of boluses per day	5.8±2.2	7.3±2.8	0.009	6.0±1.7	5.6±2.6	0.59
	←—— *n (%)* ——→		***P* value**[e]	←—— *n (%)* ——→		***P* value**[e]
Sex						
Female	25 (38)	18 (51)		8 (24)	17 (52)	
Male	41 (62)	17 (49)	0.21	25 (76)	16 (48)	0.041
Ethnicity						
Non-Hispanic whites	60 (91)	33 (94)		30 (91)	30 (91)	1.0
Other	6 (9)	2 (6)	0.71	3 (9)	3 (9)	
Parent education						
Associate degree and higher	51 (77)	21 (60)		22 (67)	29 (88)	
Less than associate degree	15 (23)	14 (40)	0.10	11 (33)	4 (12)	0.076
Family income (US$)						
≥50,000	46 (78)	28 (90)		20 (71)	26 (84)	
<50,000	13 (22)	3 (10)	0.25	8 (29)	5 (16)	0.35
Insulin mode						
Injections	13 (20)	5 (14)		7 (21)	6 (18)	
Pump	53 (80)	30 (86)	0.59	26 (79)	27 (82)	1.0

[a]Pooled *t* test.
[b]SD=standard deviation.
[c]BMI=body mass index.
[d]HbA1c=hemoglobin A1c.
[e]Fisher's exact two-sided test.

bohydrate counting in this patient population. Targeted review areas included calculating carbohydrates from food labels, estimating portions accurately when eating out or at home with no label available, reviewing carbohydrate content of foods that most patients eat often, determining carbohydrate content of restaurant meals, and calculating insulin doses using an insulin to carbohydrate ratio and blood glucose correction factor. To help participants estimate portions, real foods including pasta, chips, cereal, juice, and milk were used along with food models. Participants portioned out the amounts of foods that they usually eat and then used measuring cups to determine what portion size and carbohydrate content the food contained.

Participants randomized to the intervention group were scheduled for a class while at the baseline study visit, if possible. The classes were offered weekly and were attended by one to two study participants. The original intention was to have a larger group class, but because of difficulty scheduling within the protocol's time frame (1 to 2 weeks after baseline visit) and the participants' schedules, this was not possible. Family members were also offered the opportunity to attend and a total of 17 family members attended, usually being one parent with the participant. Participants were given measuring cups, a food scale, and *The Calorie King Calorie, Fat and Carbohydrate Counter* book[21] to keep for home use and to help with ease and accuracy of carbohydrate counting. Participants were instructed by the RD/CDE at the end of the class on how to complete food record forms.

Completion of Food Records and Follow-Up with RDs. As part of the intervention, participants completed the 3-day food record form at approximately 2 weeks and 8 weeks after the carbohydrate counting class for review of carbohydrate counting accuracy. The RD called all participants 1 week in advance to remind them to complete the food records. The RD followed up with the participant or parent (ie, whoever completed the forms) by phone to review the food records and gave feedback on carbohydrate counting, correcting any inaccuracies in carbohydrate content estimation and adjusting insulin doses, including insulin to carbohydrate ratios or basal insulin, based on blood glucose results taken before and 2 hours after meals and recorded in the records. Records indicating topic and problem areas discussed were kept for each phone consult. Other topics discussed included adjustments for high-fat meals using extra insulin or extended boluses, bolusing before eating, checking blood glucose more frequently, restaurant eating, treatment of hypoglycemia, and whether participants weighed and measured foods for the records.

Statistical Analysis

Frequencies, means, and standard deviations were calculated as descriptive statistics. nQuery Advisor (version 4.0, 2000, Statistical Solutions, Los Angeles, CA) was used to calculate power for the difference in mean differences in carbohydrate estimates vs actual and HbA1c. A total of 29 participants in each arm provided 80% power to detect a 0.75 difference in HbA1c between the intervention and control groups, assuming a standard deviation of 1%. Sixty-six participants were recruited to account for potential dropouts. Accuracy of carbohydrate counting was determined as a difference between actual and participant-estimated carbohydrate content (in grams) for each food and meal. *t* Tests were used to assess the significance of over- or underestimation of carbohydrate content. The effect of the intervention on the outcome variable was assessed by fitting the repeated measurements model using SAS MIXED procedure. Spearman rank correlation was used to test the associations when the normality assumption was violated. All analyses were performed using SAS (version 9.2, 2010, SAS Institute Inc). A P value <0.05 was considered statistically significant.

RESULTS

Table 1 describes the baseline characteristics of the 101 adolescents screened for this study and the 66 who were randomized into the control and intervention groups. There were significantly more boys (n=25) than girls (n=8) who were randomized to the intervention group ($P=0.041$) (Table 1). Those who did not qualify were similar to those who qualified in most characteristics including age and HbA1c, except that nonqualifiers on pumps bolused significantly more frequently ($P=0.009$) had diabetes for a slightly longer duration (not significant, $P=0.064$), and had a slightly lower BMI (not significant, $P=0.057$). Participants who were below the carbohydrate counting accuracy cut point (n=66) at baseline significantly overestimated carbohydrate amounts in many individual foods, including milk, syrup, orange juice, chips, peanut butter, jelly, carrots, broccoli, chicken nuggets, cheese, hamburger, spaghetti, Goldfish crackers (Pepperidge Farm), and waffles (Table 2). They underestimated carbohydrate amounts in some individual foods as well, including cereal, banana, fries, barbecue sauce, and regular soda. When evaluating accuracy when foods were presented as meals, participants significantly under- or overestimated carbohydrate amounts in 10 of the 9 meals and 4 snacks (Table 3).

There was no association between previous reported carbohydrate education, receiving help while counting carbohydrate, duration of carbohydrate counting, and carbohydrate counting accuracy. Mean length of time that participants reported they had been carbohydrate counting was 45±28 months (6 to 108 months) with no significant difference between the groups. At baseline, 40 of the participants reported not having received carbohydrate counting education from an RD for more than 1 year with no significant difference between groups. Fifty-five of 66 participants reported receiving help with carbohydrate counting from their mother, with dinner being the most frequent meal for which they reported receiving help. There was no significant difference between groups in these areas and the distribution of parents helping across the groups was similar. There was a statistically significant negative correlation between HbA1c and the collaborative scale, such that adolescents who collaborated more with their parents had lower HbA1c ($r=-0.264$, $P=0.008$). There was also a negative correlation between frequency of eating a food and accurate estimates of carbohydrates in milk, string cheese, waffles, and apple. When evaluating use of labels and its correlation with accuracy of carbohydrate estimates, accuracy was significantly better for some foods when using labels (eg, crackers, nuggets, fries, diet iced tea), but not for others.

HbA1c for the intervention and control groups were similar at baseline (8.41%±0.19%, 8.25%±0.19%, respectively). After 3 months of follow-up, HbA1c decreased to 8.22%±0.18% (−0.19%±0.12%; $P=0.12$) in the intervention group and to 8.17%±0.18% (−0.08%±0.11%; $P=0.51$) for the control group, and overall intervention effect was not statistically significant ($P=0.49$).

At the 3-month follow-up visit, 29 of the 33 control participants and 26 of the 29 intervention participants continued to be below the carbohydrate counting accuracy cut point. There were limited statistically significant improvements in carbohydrate counting accuracy on the carbohydrate counting test from baseline to final visit in the intervention or control group (Tables 2 and 3).

DISCUSSION

The findings in this study demonstrate that adolescents with type 1 diabetes do not accurately count carbohydrates and commonly either over- or underestimate carbohydrate grams in a given meal. A previous study conducted at the Barbara Davis Center found similar results to the current study in the same age group.[8] Smart and colleagues assessed carbohydrate counting accuracy in 8- to 18-year-olds in Australia and the United Kingdom and found that for 73% of the meals, youth estimated carbohydrates within 10 to 15 g of the actual carbohydrates and concluded that they count carbohydrates reasonably accurately.[13] By the accuracy definition used in this study, many of those participants would not be considered accurate. Another study evaluating carbohydrate counting accuracy and precision in youth looked at parents of 4- to 12-year-olds using diet recalls

Table 2. Carbohydrate counting accuracy at baseline and follow-up, by individual foods for control and intervention participants in the Carbohydrate Counting in Adolescents with Type 1 Diabetes Study: Is more intensive education needed?

Food	Mean CHO (g)	Qualifiers group	CHO[a] Estimate Accuracy[b] (g)			
			Baseline	Follow-up	*P* value[c]	*P* value[d]
Cereal[e]	41.6	Control	−3.7	−3.7	1.00	0.90
		Intervention	−6.0	−5.5	0.86	
Milk (with cereal)[e]	7.9	Control	5.7	6.0	0.71	0.19
		Intervention	4.9	3.4	0.15	
Banana	27.0	Control	−4.4	−2.6	0.22	0.41
		Intervention	−8.3	−4.6	0.023	
Macaroni and cheese	45.7	Control	0.7	1.3	0.82	0.98
		Intervention	−9.4	−8.7	0.80	
Carrots	4.9	Control	4.1	3.6	0.71	0.28
		Intervention	3.3	4.8	0.25	
Snack milk[e]	11.4	Control	5.0	4.3	0.65	0.38
		Intervention	3.1	4.4	0.44	
Cookies[e]	30.0	Control	0.6	1.1	0.81	0.58
		Intervention	0.4	−0.7	0.58	
Chicken nuggets[e]	16.0	Control	5.3	5.4	0.95	0.77
		Intervention	3.8	3.2	0.74	
Fries[e]	48.0	Control	−2.9	−4.4	0.49	0.11
		Intervention	−6.3	−2.7	0.11	
Barbeque sauce	12.0	Control	−1.6	−2.6	0.41	0.19
		Intervention	−3.4	−2.1	0.31	
Soda	86.0	Control	−11.2	−8.6	0.60	0.47
		Intervention	−12.8	−15.2	0.62	
Goldfish crackers[ef]	20.5	Control	3.1	−1.1	0.032	0.45
		Intervention	3.2	1.1	0.29	
String cheese	0.0	Control	5.3	4.1	0.15	0.64
		Intervention	4.7	3.0	0.042	
Waffles	27.0	Control	8.1	5.4	0.24	0.29
		Intervention	6.7	7.5	0.74	
Syrup[e]	12.6	Control	12.4	12.7	0.93	0.62
		Intervention	13.6	12.2	0.55	
Orange juice[e]	23.8	Control	5.2	3.4	0.41	0.60
		Intervention	3.1	2.9	0.94	
Burger	0.0	Control	2.7	3.1	0.59	0.040
		Intervention	4.3	2.8	0.021	
Bun	26.1	Control	−0.7	−3.4	0.085	0.75
		Intervention	−0.7	−2.7	0.21	
Chips[e]	16.1	Control	6.8	6.0	0.63	0.29
		Intervention	4.7	6.4	0.32	

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Table 2. Carbohydrate counting accuracy at baseline and follow-up, by individual foods for control and intervention participants in the Carbohydrate Counting in Adolescents with Type 1 Diabetes Study: Is more intensive education needed? *(continued)*

Food	Mean CHO (g)	Qualifiers group	CHO[a] Estimate Accuracy[b] (g)		*P* value[c]	*P* value[d]
			Baseline	Follow-up		
Milk[e]	11.9	Control	3.8	3.0	0.54	0.96
		Intervention	2.2	1.5	0.61	
Spaghetti	35.8	Control	9.1	12.5	0.32	0.54
		Intervention	3.3	9.8	0.075	
Marinara sauce	11.7	Control	1.6	1.5	0.95	0.68
		Intervention	−1.9	−1.0	0.61	
Broccoli	2.9	Control	4.1	3.4	0.37	0.014
		Intervention	2.9	5.0	0.011	
Diet iced tea[e]	2.0	Control	0.9	0.9	0.99	0.79
		Intervention	0.1	−0.2	0.70	
Bread	30.0	Control	−0.9	−2.0	0.38	0.40
		Intervention	−3.1	−2.7	0.76	
Peanut butter	7.0	Control	4.0	3.7	0.83	0.31
		Intervention	2.0	3.3	0.23	
Jelly	13.0	Control	4.2	4.3	0.94	0.77
		Intervention	3.8	4.6	0.63	
Apple	21.8	Control	0.2	1.2	0.36	0.81
		Intervention	−1.4	−0.8	0.59	
Brownie[e]	40.0	Control	4.8	2.3	0.39	0.11
		Intervention	−0.9	3.4	0.17	

[a]CHO=carbohydrate.
[b]Accuracy was defined as a difference between actual and estimated CHO.
[c]Significance of change between baseline and follow-up accuracy within the group, adjusted for age, sex, and diabetes duration.
[d]Significance of the overall intervention effect.
[e]Foods presented with nutrition labels in study visit.
[f]Pepperidge Farm.

and found that, on average, parent estimates of carbohydrate intake were 120% of nutrition database calculation and greater precision (consistency), but not accuracy was associated with lower HbA1c.[10] Perhaps this indicates that if patients consistently overestimate or underestimate the carbohydrate content of foods, their insulin dose is adjusted accordingly and this type of inaccuracy does not affect blood glucose control adversely as expected. A limitation of this study may be that accuracy was assessed on 24-hour dietary recalls of parents rather than actual intake over several days.

Although it was expected that participants' carbohydrate estimates for foods eaten more frequently would be more accurate, that was not the case for all foods. A possible explanation is that some foods are easier to memorize or are more standard than others. Smart and colleagues found that foods in labeled packages were estimated most accurately.[13] But in this study, participants who used labels to estimate carbohydrates were not more accurate than those who did not use labels for many of the foods, and that might point to the difficulty that adolescents have in estimating portion size. Therefore, RDs need to continually focus on helping adolescents estimate portions using real food and food models and encourage them to check the serving sizes of foods they are eating by measuring portions regularly. This study found that there was no association between duration of carbohydrate counting and accuracy, while Smart and colleagues found that adolescents who were carbohydrate counting for the longest duration were the least accurate.[13] The assumption in clinical care is that the longer patients count carbohydrates, the more accurate they would be. Because this does not appear to be the case, RDs need to meet with patients regularly for re-education. Parental support as measured on the collaborative scale was associated with better HbA1c, supporting the idea that adolescents do better when their parents continue to be involved in their diabetes care and this needs to be encouraged in the clinical setting.

Intervention studies conducted on patients with type 1 diabetes have included adults only and were comprised of four

Table 3. Carbohydrate counting accuracy at baseline and follow-up, by meals for control and intervention participants in the Carbohydrate Counting in Adolescents with Type 1 Diabetes Study: Is more intensive education needed?

	Meal	Mean CHO (g)	Qualifiers group	CHO[a] Estimate Accuracy[b] (g)		*P* value[c]	*P* value[d]
				Baseline	Follow-up		
Day 1	Breakfast	52.3	Control	−8.1	−6.2	0.39	0.91
			Intervention	−12.3	−10.7	0.50	
	Lunch	83.4	Control	−14.9	−15.5	0.86	0.29
			Intervention	−18.5	−13.8	0.19	
	Dinner	48.9	Control	9.2	7.9	0.70	0.036
			Intervention	1.8	10.7	0.012	
	Snack	66.0	Control	7.7	6.3	0.65	0.32
			Intervention	2.2	5.1	0.35	
Day 2	Breakfast	76.6	Control	−2.4	−0.3	0.54	0.92
			Intervention	−9.2	−6.5	0.46	
	Lunch	92.0	Control	10.2	10.3	0.99	0.71
			Intervention	−2.4	0.2	0.59	
	Dinner	162.0	Control	−10.5	−10.7	0.97	0.82
			Intervention	−18.2	−16.5	0.78	
	Snack	20.5	Control	8.3	3.0	0.014	0.62
			Intervention	8.1	4.3	0.085	
Day 3	Breakfast	63.4	Control	25.7	21.5	0.35	0.60
			Intervention	23.3	22.4	0.85	
	Lunch	54.0	Control	12.6	8.5	0.15	0.67
			Intervention	10.6	8.2	0.43	
	Dinner	52.4	Control	15.6	18.3	0.52	0.29
			Intervention	4.3	13.5	0.040	
	Snack	71.8	Control	7.4	7.3	0.97	0.51
			Intervention	1.3	4.1	0.38	

[a]CHO=carbohydrate.
[b]Accuracy was defined as a difference between actual and estimated CHO.
[c]Significance of change between baseline and follow-up accuracy within the group, adjusted for age, sex, and diabetes duration.
[d]Significance of the overall intervention effect.

to five sessions of education that resulted in reductions in HbA1c.[15,16] But those participants had no experience with carbohydrate counting or adjusting insulin for carbohydrates before the study. The participants in this study were already adjusting insulin for carbohydrates and had previous education on carbohydrate counting. Baseline HbA1c levels (Table 1) for both the control and intervention groups were higher than the American Diabetes Association goal of <7.5%[11] for this age group, confirming that some type of intervention was needed to help optimize their control. A limitation of this study was the lack of an evidence-based model to inform development of an intervention for this specific population.

Comparing the intervention and control groups, there was no statistically significant difference in carbohydrate counting accuracy or HbA1c after 3 months of intervention and follow-up. These negative outcomes might be due to several reasons, including limitations in the study. First, perhaps a one-time class with phone feedback on two sets of 3-day food records from an RD/CDE is not intensive enough education to improve knowledge, carbohydrate estimation, and accuracy skills. Second, participants might not have measured portions as directed when completing food records and, for some participants, parents were completing the records and still doing much of the carbohydrate counting, so the child might not have learned as much. Third, the carbohydrate counting test used might not have reflected the actual foods that the participants eat frequently and their true ability to estimate carbohydrates at home. In addition, although this method has been used previously to evaluate carbohydrate counting skills,[8] it might lack sufficient resolution to capture changes. Fourth, many variables affect HbA1c and glycemic control, including illness, puberty, change in activity levels, and stress. These factors could not be controlled and were not measured in this study. Although carbohydrate counting is the most commonly used method for determining the insulin bolus dose for meals and snacks, other methodologies have been proposed that also account for fat and protein.[22,23] However, these methods add complexity to the bolus dose decision and might prove to be too complex for some families. Additional data on these methods is required to determine their effect on glycemic control. Missed meal or snack boluses and timing of meal doses are also important factors affecting postprandial hyperglycemia and HbA1c. Missed or late boluses commonly occur in adolescents and might also explain some of the challenge in affecting change in glycemic control in this group compared with adults.[24] Although these factors were not tracked in this study, it would not be expected that missed doses or late bolusing would have occurred disproportionately in the two groups. It is also possible that continuous glucose monitoring might have detected differences in postprandial glycemia, but any such possible differences were insufficient to have a substantial effect on HbA1c between the two groups. Finally, there were several intervention participants who did not follow recommendations given by the RD/CDE to adjust insulin doses. Of the 101 participants screened for the randomized study, 70% of the boys qualified compared with 58% of the girls, and more boys than girls were allocated to the intervention arm. Also, although a larger study population might have resulted in a statistically significant difference between the two groups, the magnitude of the difference in HbA1c at 3 months (0.11%±0.16%) would not be considered clinically important because a decrease of 0.3% to 0.5% would need to be achieved to have been clinically meaningful.

CONCLUSIONS

Bolusing rapid-acting insulin for meals (carbohydrates) is a cornerstone of current management of type 1 diabetes; however, this study demonstrates that adolescents do not count carbohydrates accurately. Few data exist on how health-care providers can optimize advice on this important aspect of diabetes care performed multiple times daily, and educating adolescents with type 1 diabetes on carbohydrate counting is a stepping stone to improving glycemic control. In addition, educating adolescents and helping them make changes in their diabetes care has its unique challenges as compared with adults. This study found that improvements in carbohydrate counting accuracy are difficult to achieve with one class and phone feedback on two sets of 3-day food records by an RD/CDE. Parental support was found to be associated with better HbA1c; therefore, clinicians need to assess this aspect of diabetes care and encourage more involvement in their care and education, if found to be inadequate. Also, continued emphasis by RDs on estimating portions and measuring foods can be helpful. Additional research is needed to identify cost-effective approaches to improve this skill, which might include multiple classes, including parents in the intervention more actively, and using media. Until full development of a closed-loop artificial pancreas, insulin-dosing decisions will continue to be an everyday challenge for patients with type 1 diabetes and their parents. Therefore, these data can serve to inform future studies designed to improve dietary management of type 1 diabetes.

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STATEMENT OF POTENTIAL CONFLICT OF INTEREST

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