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Original article

Carbohydrate intake in relation to BMI, HbA1c and lipid profile in children and adolescents with type 1 diabetes

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SUMMARY

Background & aims: To compare reported and recommended carbohydrate intake in children and adolescents with type 1 diabetes (T1D) and to explore associations with BMI, HbA1c and lipid profile.
Methods: A cross-sectional observational study of reported carbohydrate intake in 46,010 patients with T1D aged 1–18 years from 332 diabetes centres in Germany and Austria in comparison to age-matched healthy children and adolescents.
Results: The median reported carbohydrate intake in T1D patients was markedly lower than in healthy children. It varied between 56% and 90% of recommended amounts across the paediatric age range with younger patients showing levels closer to recommend. Lower carbohydrate intake was associated with higher BMI-SDS ($p < 0.001$), particularly during adolescence, higher total cholesterol ($p < 0.001$), higher LDL-cholesterol ($p = 0.005$) and lower HbA1c ($p < 0.001$).
Conclusions: The methodologically simple measure of reported carbohydrate intake may be a valuable addition to the information gathered on paediatric patients with T1D in an outpatient setting. Children and adolescents with T1D appear to restrict their consumption of carbohydrates, which may have adverse effects on BMI and the lipid profile, particularly if there is a compensatory increased fat intake. Health care providers should therefore advise patients and parents of the recommended age-dependent levels of carbohydrate intake.

1. Introduction

In the past, patients with T1D adjusted their diet to meet the requirements of an inflexible insulin treatment regimen. The advent of self-monitoring of blood glucose levels and use of multiple, flexible insulin injections have allowed even paediatric patients to change insulin doses according to their dietary intake, which may aid efforts to achieve good glycaemic control.[1] There is a debate about the putative benefit of a day-to-day consistency in the timing and amount of food intake and its association with better blood glucose control.[2] Moreover, the estimation of the amount of carbohydrate in a meal, which is commonly used to calculate the insulin dose, can have an error rate of up to 50%.[3] In addition, the amount of injected insulin that is absorbed may be highly variable even within individual patients.[4]

The deliberate reduction of carbohydrate intake and therefore insulin doses has been used as a means to limit post-prandial glucose excursions and fluctuations as well as to reduce the risk of hypoglycaemia, but it tends to be met with non-compliance.[5–7] Adherence to any dietary guidelines appears to be particularly poor in children and adolescents with T1D.[8] Compared to healthy children, paediatric patients with T1D had lower intakes of carbohydrate but ate more saturated fat,[9–11] which may be contributing to their atherogenic risk profile.[12,13] This is at odds with

Abbreviations: BMI, body mass index; CU, carbohydrate unit (1 unit = 10–12 g carbohydrate); DPV, Diabetes Patienten-Verlaufsdokumentation (diabetes patients observational study); HbA1c, glycated haemoglobin A1c; HDL-cholesterol, high-density lipoprotein-cholesterol; LDL-cholesterol, low-density lipoprotein-cholesterol; SDS, standard deviation score; T1D, type 1 diabetes.

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recommendations for all children and adolescents[14,15]; carbohydrates are advised to constitute at least 50% of total daily energy intake.[15] The importance of trying to eat sufficient amounts of carbohydrate has been highlighted through small studies that showed associations between lower carbohydrate intake and worse glycaemic control, lipid profile, higher BMI and body fat percentage.[16–20]

These changes are of concern and we therefore set out to determine whether the easily accessible information on average daily carbohydrate intake reported by patients with T1D and their families is associated with these adverse outcomes. To this end, we compared cross-sectional data of patients aged 1–18 years with nutritional reference values and levels from healthy peers. We then explored associations between carbohydrate intake and BMI, lipid profile and glycaemic control with the hypothesis that lower carbohydrate intake will adversely affect these three parameters.

2. Materials and methods

Patients were selected from the DPV database from all patients registered between January 1995 and September 2011 according to the following criteria: age 1–18 years and carbohydrate intake reported at least once. Software based on the Visual FoxPro 9.2 compiler was used for standardised prospective documentation.[21] The documentation of anonymised data was approved by the local ethics committee at the University of Ulm, Germany.

Standard care in Germany and Austria includes teaching patients with T1D and their parents how to estimate CUs, where one CU corresponds to 10–12 g carbohydrate. For this study, 1 CU equalled 11 g carbohydrate. Patients and/or parents reported average carbohydrate intake per day, which was put in relation to the recommended 50% carbohydrate of total daily energy intake based on age-dependent reference values of the German, Austrian and Swiss Nutrition Societies.[15,22] This is similar to the population-based Dietary Reference Intake ranges for carbohydrates of the Institute of Medicine (45–65% of total daily energy intake), the European Food Safety Authority (45–60% of total daily energy intake) and the American Academy of Pediatrics guideline for diabetes management (ca. 50% of total daily energy intake).[23–25] For comparison with the general population, we used data on carbohydrate intake in 2506 healthy children aged 6–17 years of the EsKiMo-study, the nutrition module of the German Health Interview and Examination Survey for Children and Adolescents.[26] HbA1c was mathematically adjusted to the Diabetes Control and Complication Trial reference range (4.05–6.05%) using the multiple of the mean method.

2.1. Statistics

The SAS 9.2 statistical software package (SAS Institute Inc., Cary, USA) was used. $p < 0.05$ was considered statistically significant. Patients were divided into quartiles of adherence to nutritional recommendations. The associations between carbohydrate intake and BMI, lipid profile and HbA1c were evaluated using a hierarchical mixed linear regression model (SAS proc glimmix) with age group, duration of diabetes and sex as fixed effects, and treatment centre as a random effect (covariance structure: Cholesky). Adjusted means (least squares means) were calculated based on observed marginal frequencies and p-values were adjusted for multiple comparisons according to Tukey–Kramer.

3. Results

The study included 46,010 children and adolescents with T1D between 1 and 18 years of age from 332 clinical centres in Germany and Austria. 51.8% of patients were male. Median age was 11.9 years and mean duration of diabetes was 4.3 years. Insulin replacement therapy was provided by conventional therapy (35%), intensive conventional insulin therapy (50%) or continuous subcutaneous insulin infusion (15%).

The reported carbohydrate intake increased with age in boys, but plateaued in girls after the age of 10 years (Fig. 1a). This gender difference disappeared after adjustment for recommended carbohydrate intake. Nevertheless, carbohydrate intake still fell short of recommended values in an age-dependent manner in both boys and girls (Fig. 1b). 15- to 18-year-old boys and girls had the lowest carbohydrate intake (57% and 56% of the recommended value; Fig. 1b). These differences persisted after adjustment for treatment centre and in comparison to healthy children: children and adolescents with T1D had an average carbohydrate intake 55–75% of healthy peers. This discrepancy also increased with age.

Following stratification of T1D patients into quartiles (Q1–Q4) of reported vs. recommended carbohydrate intake (Q1: $45.6 \pm 5.3\%$; Q2: $57.1 \pm 2.6\%$; Q3: $66.5 \pm 3.1\%$; Q4: $81.7 \pm 7.2\%$), there was an inverse association between carbohydrate intake and BMI-SDS in boys and girls ($p < 0.001$ and $p < 0.001$; Fig. 2, Table 1). Lower reported carbohydrate intake was associated with lower HbA1c in boys and girls ($p < 0.001$ and $p < 0.001$; Fig. 2, Table 1). Average HbA1c was 0.2% lower in Q1 than in Q4 for the whole cohort (Fig. 2). This difference increased to 0.25% in adolescents.

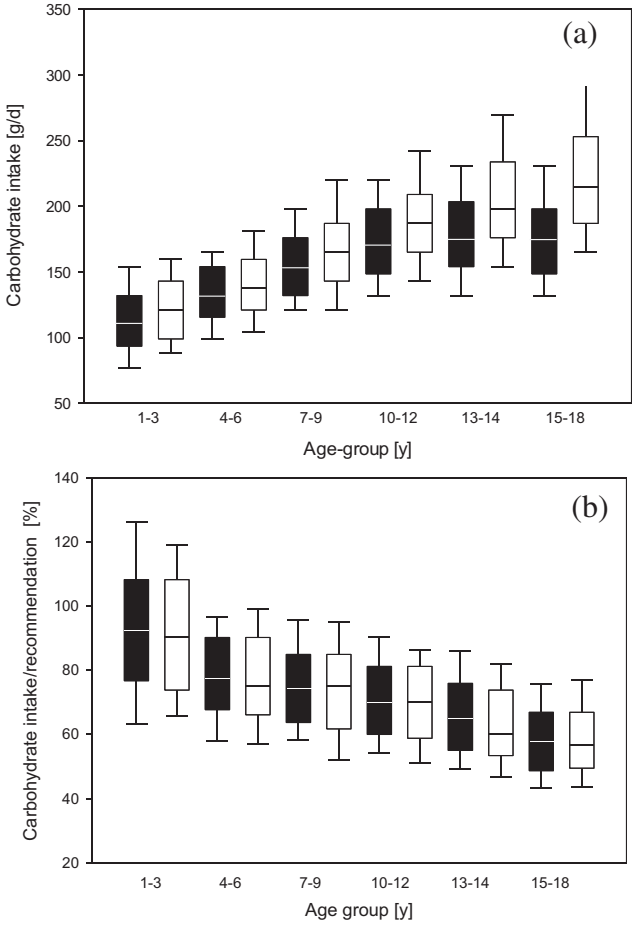

Fig. 1. (a) Reported carbohydrate intake in girls (black) and boys (white) with T1D by age-group. Data are medians, quartiles, 10th and 90th percentiles. (b) Reported carbohydrate intake in girls (black) and boys (white) with T1D relative to age and sex-dependent recommended carbohydrate intake. Data are medians, quartiles, 10th and 90th percentiles.