Published in final edited form as:

Nutr Res. 2014 May ; 34(5): 428–435. doi:10.1016/j.nutres.2014.04.008.

Intensively-Managed Young Children with Type 1 Diabetes Consume High-Fat, Low-Fiber Diets Similar to Age-Matched Controls

Sanjeev N. Mehta¹, Lisa K. Volkening¹, Nicolle Quinn², and Lori M.B. Laffel¹

¹Pediatric, Adolescent, and Young Adult Section, Joslin Diabetes Center, 1 Joslin Place, Boston, MA, 02215, USA

²Clinical Translation Study Unit, Boston Children's Hospital, 300 Longwood Avenue, Boston, MA, 02115, USA

Abstract

Despite significant emphasis on nutrition, older children with diabetes demonstrate poor dietary quality. We tested the hypothesis that dietary quality in young children with type 1 diabetes (T1D) would be better than age-matched children in the US population. Dietary data from children with T1D ($n=67$), ages 2–12 years, attending a pediatric diabetes clinic were compared to a nationally representative, age-matched sample from the National Health and Nutrition Examination Survey (NHANES, $n=1691$). Multiple 24-hour dietary recalls were used. Recommended intakes were based on national guidelines, and dietary quality was assessed using the Healthy Eating Index-2005 (HEI-2005). More children with T1D were overweight or obese compared to children participating in NHANES (42% vs. 30%, $p=0.04$). Greater proportions of children with T1D met daily recommendations for vegetables (22% vs. 13%, $p=0.03$), whole grains (12% vs. 5%, $p=0.005$), and dairy (55% vs. 36%, $p=0.001$) compared to NHANES children while similar proportions met daily fruit recommendations (40% vs. 33%, $p=0.2$). Less than one-third of all children limited total fat to recommended levels; children with T1D consumed more saturated fat than NHANES children (14% vs. 12% total energy intake, $p=0.0009$). Fiber intakes were very low in both groups. Compared to NHANES children, children with T1D had higher HEI-2005 scores (59.6 vs. 49.7, $p=0.0006$) primarily due to lower intakes of added sugars. The nutritional intake of young children with T1D remains suboptimal in the contemporary era of diabetes management. Despite focused nutrition management, young children with T1D consume high-fat, low-fiber diets comparable to youth in the general population.

© 2014 Elsevier Inc. All rights reserved.

CORRESPONDING AUTHOR: Sanjeev N. Mehta, MD, MPH, Pediatric, Adolescent, & Young Adult Section, Joslin Diabetes Center, One Joslin Place, Boston, MA 02215, Phone: 617-732-2603, Fax: 617-732-2447, sanjeev.mehta@joslin.harvard.edu.

Publisher's Disclaimer: This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final citable form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

Keywords

Diabetes mellitus; type 1; nutrition; pediatrics; childhood obesity; cross-sectional analysis

1. INTRODUCTION

The management of type 1 diabetes (T1D) requires meticulous attention to daily insulin administration, diet and exercise. In the current treatment era, children with T1D are increasingly adopting more flexible insulin regimens facilitated by the introduction of insulin analogs and greater use of insulin pump therapy [1]. Medical nutrition therapy aims to achieve optimal metabolic outcomes by emphasizing the impact of food choices on glucose excursions [2]. As such, dietary education for patients and families with T1D addresses carbohydrate intake in order to match insulin doses with ingested 'carbs' while also providing more traditional aspects of nutrition training, such as daily energy intake and macronutrient consumption. The latter area may also impact growth and metabolic outcomes, including glycemic control, hypertension and dyslipidemia. Managing the dietary behaviors of children with T1D is complex, and data suggest that many children and their families continue to struggle with this fundamental component of diabetes care [3].

In 2006, the SEARCH for Diabetes in Youth study utilized a modified food frequency questionnaire (FFQ) to assess the dietary intake of older children and young adults, ages 10–22 years, with T1D and type 2 diabetes (T2D) [4]. They demonstrated significant nutritional deficits, notably, higher than recommended intakes of total and saturated fat and very low intakes of fruits, vegetables, grains, and fiber. They noted only modest differences between these older children with T1D and T2D. A recent review of adherence to dietary patterns confirmed high intakes of total fat and saturated fat as well as low intakes of fruits, vegetables, and fiber in other US, European, and Asian cohorts of children with T1D [5]. It is well established that dietary patterns begin to develop in early childhood and this developmental stage may represent a more opportune time to intervene in order to promote more healthful dietary behaviors [6] and [7]. However, less is known about the dietary quality of preadolescent children with diabetes in the current era. In 2007, Øverby and colleagues reported high intakes of fat and low intakes of fiber, fruits, and vegetables in an analysis of 550 Norwegian children with T1D, including 203 children aged 2 to 10 years [8]. In a separate analysis, Øverby and colleagues found no major differences in the dietary intakes of Norwegian children with and without T1D ages 9 to 13 years; both groups consumed high fat, low fiber diets with inadequate fruit intake and fiber intake [9]. Maffei and colleagues reported better diets among Italian children ages 6 to 16 years with T1D (n=114, 55 prepubertal and 59 pubertal) compared to age-matched controls (n=448) in terms of lower saturated fat, more fiber, and overall intakes closer to recommended guidelines [10]. Although, nutrition education may improve dietary quality in children with T1D, published data support the notion that broader societal or cultural influences influence the development of dietary patterns in this population. To our knowledge, there are no recent data comparing the dietary intake of young US children with T1D to the general population. The last assessment of very young children with T1D in the U.S. was conducted in 1996, before the introduction of basal analogs and widespread use of insulin pump therapy [11].

Children with T1D are also subject to the unhealthful eating practices of American children that have contributed to the epidemic of childhood obesity. In general, nearly one-third of children with T1D are either overweight or obese, a rate similar to that reported in children in the general population [12], [13] and [14]. Examining assessments of dietary intake in a contemporary sample may help interpret the dietary patterns of children with T1D and contextualize the rise in overweight and obesity in T1D children.

The method for collecting dietary data can significantly impact the reliability of nutritional information [15] and [16]. FFQs, as used in the SEARCH study, are typically utilized for assessments of large populations where the primary focus is on ranking individuals according to various food or nutrient intakes. The use of 24-hour recalls or food records across multiple days is significantly more time and resource intensive. However, these latter dietary assessment methods allow for comparison of absolute intakes of foods and nutrients among individuals, and they provide robust estimates of individual dietary intakes, generally using smaller samples of individuals than the larger study populations that utilize the FFQ. Indeed, a majority of the published literature evaluating the dietary quality of individuals with T1D have focused on detailed assessments in population samples of 30 to 100 participants [11] and [17].

In the present study, we aimed to expand on the existing literature by comparing the dietary patterns of two contemporary cohorts of younger children aged 2 to 12 years, one with and one without T1D. We utilized nutrition data taken from multiple 24-hour dietary recalls to compare the dietary intakes based on United States Department of Agriculture (USDA) guidelines and dietary quality based on the Healthy Eating Index-2005 (HEI-2005) of youth with type 1 diabetes and age-matched youth in the general population participating in the National Health and Nutrition Examination Survey (NHANES) in 2005–2006. As provision of medical nutrition therapy is considered standard of care for children with T1D, we hypothesized that both dietary intakes and overall dietary quality of children with T1D would be significantly better than in children from the general population.

2. METHODS AND MATERIALS

2.1 Study population

Children with T1D who were routinely attending a multidisciplinary pediatric diabetes program and their parents were invited to participate in this study. Eligible children were aged 2 to 12 years with diabetes duration ≥ 1 year. They had a daily insulin dose ≥ 0.5 units per kg, used carbohydrate counting in meal planning, and were intensively treated with multiple (three or more) daily injections or insulin pump therapy. The Committee for Clinical Investigation at Boston Children's Hospital approved the study protocol; parents provided written informed consent for their children, and children ≥ 7 years provided assent. Dietary data were collected over a six-month period from December 2006 to May 2007 and were available for 67 (91%) of 74 families who consented to participate.

Information for children without diabetes was obtained from the publicly available NHANES 2005–2006 (http://www.cdc.gov/nchs/nhanes/nhanes2005-2006/nhanes05_06.htm). NHANES is a nationally representative, cross-sectional survey of the

civilian, non-institutionalized US population conducted by the National Center for Health Statistics (NCHS). NHANES uses a stratified, multistage, probability cluster design that oversamples certain populations, including low-income persons, black persons, and Mexican American persons. NHANES data for the present analysis was limited to age-matched children from whom complete dietary data were available (n=1691).

2.2 Dietary assessment

For each child with T1D, a research dietitian conducted three unannounced 24-hour dietary recalls with the child's primary caregiver over three months following the initial study visit. For young children, parental report of the child's diet using multiple 24-hour dietary recalls has been previously validated [16] and [18]. Dietary recalls were conducted using a computer-based, multiple-pass approach with standardized probes. Data were collected using the Nutrition Data System for Research (NDSR) software (version 2005; the Nutrition Coordinating Center (NCC), University of Minnesota, Minneapolis, MN). Dietary assessments included both weekday and weekend days, and household measures and two-dimensional food models were used to facilitate portion size estimation. Children participating in NHANES completed two 24-hour dietary recalls using a multiple-pass, computer-assisted dietary interview system. Nutrient intakes for children with T1D and healthy controls were calculated using the NCC Food and Nutrient Database and USDA food composition database, respectively.

Nutrition data included total energy intake, food group servings, macronutrient composition, and micronutrient quantities. Dietary recommendations were taken from the USDA, Institute of Medicine, and American Diabetes Association [19] and [20]. We assessed overall diet quality using the HEI-2005 [21]; HEI-2005 total scores can range from 0–100 with higher scores defining greater conformance to USDA guidelines. HEI-2005 total and component (specific food group or nutrient) scores have different ranges. To facilitate direct comparison across component scores, we also calculated the percentage of the maximum HEI-2005 score by dividing the component scores by their respective maximum values and multiplying by 100%. Per this normalization procedure, higher percentages (range 0–100%) reflected higher total or item quality. The USDA's Center for Nutrition Policy and Promotion, which developed the HEI-2005, provided the computer algorithms for calculating total and components scores for HEI- 2005. We created a similar computer algorithm to calculate HEI-2005 scores using the NDSR analyses, an approach which was recently validated [22].

2.3 Demographic and clinical variables

Parents of children with T1D provided demographic and diabetes-specific information during an in-person interview with research staff. Socioeconomic indicators included caregiver education, insurance type, and family structure. Trained medical staff measured the height and weight of children using calibrated scales and stadiometers; age- and sex-adjusted BMI Z score (z-BMI) was calculated using CDC algorithms. Blood pressure (BP) was measured in the sitting position; systolic and diastolic BP percentiles were based on CDC reference ranges [23]. Glycemic control was assessed by hemoglobin A1c (A1c) using a DCCT-aligned Roche analyzer (reference range 4–6%). The American Diabetes

Association (ADA) has established age-specific A1c targets of <8.5% and <8.0% for children aged <6 years and 6–12 years, respectively [24]. Children with T1D were further categorized as meeting or not meeting A1c targets as established by the American Diabetes Association (ADA).

2.4 Statistical analyses

Means ($\pm$ standard errors) and percentages were calculated for continuous and categorical variables, respectively. Sample weights provided by NCHS account for stratification and clustering in the multistage NHANES sampling design. Taylor series linearization methods were used to accommodate sampling weights when calculating means and variance estimates. For children with T1D, standard errors were calculated by dividing the standard deviation by the square root of the sample size. Unpaired *t* tests and chi-square analyses compared differences between children with T1D and healthy controls. Data were analyzed using SAS version 9.1 (SAS Institute, Cary, NC).

3. RESULTS

3.1 Sample population

Children with T1D (*n*=67) utilized intensive diabetes management, with 70% treated with insulin pump therapy. All children had established diabetes with mean diabetes duration of 4.1 ± 0.3 years. On average, children with T1D had good glycemic control with their mean A1c of $7.5 \pm 0.1\%$, although glycemic control varied with A1c levels ranging from 5.8% to 10.3%. In our sample, 78% of the children with T1D achieved ADA A1c target levels.

Age-matched children (*n*=1,691) participating in the NHANES 2005–2006 were evaluated; the weighted NHANES sample represented 35,628,841 children. Demographic and clinical characteristics of both cohorts are presented in Table 1. Children with T1D and from the NHANES cohort did not differ by age or sex. Children with T1D had a higher z-BMI compared to NHANES children, and more children with T1D were either overweight or obese compared to NHANES children (42% vs. 30%, *p*=0.04). Socioeconomic indicators differed between the T1D and NHANES cohorts. The NHANES cohort had a greater percentage of caregivers with less than a high school education, more frequent use of public health insurance, and a higher proportion of children living in single-parent households. Children participating in NHANES were also more likely to be from racial or ethnic minorities compared to children with T1D.

3.2 Dietary intake

The recommended and observed daily intakes of total energy, food group servings, macronutrients and micronutrients for children with T1D and NHANES children are presented in Table 2. Both groups reported similar age-appropriate levels of total energy intake. Although children with T1D consumed more daily servings of vegetables than the NHANES sample, less than 25% of the children consumed the recommended intake of vegetable servings (T1D, 22% and NHANES, 13%, *p*=0.03). Further, less than 50% of all children met the recommended intakes for fruit servings (T1D, 40% and NHANES, 33%, *p*=0.2). Although fewer children with T1D met daily total grain requirements (36% vs. 71%,

$p<.0001$), a greater percentage consumed adequate whole grains compared to NHANES children (12% vs. 5%, $p=.005$). No child with T1D and only 3% of NHANES children met recommendations for daily fiber intake ($p=0.1$). Most children did not meet recommendations for limiting total fat intake (T1D, 25% vs. NHANES, 33%, $p=0.2$) or saturated fat intake (T1D, 12% vs. NHANES, 29%, $p=.002$). Absolute intake of dairy was comparable between both groups, but children with T1D were more likely to meet daily recommendation compared to NHANES children (55% vs. 36%, $p=.001$). Among children with T1D, average vitamin D intake was 250 IU daily (range 22–987 IU) with 49% of the children meeting the recommendation at that time of 200 IU or more daily. Only 15% of children with T1D consumed 400 IU or more of vitamin D daily; vitamin D intakes were not available for the NHANES children. Less than half of children in both groups consumed adequate calcium (T1D, 37% vs. NHANES, 41%, $p=0.5$) or vitamin E (T1D, 94% vs. NHANES, 87%, $p=.08$).

3.3 Dietary quality

HEI-2005 total and component scores for children with T1D and NHANES children are presented in Table 3. Children with T1D had higher HEI-2005 total scores compared to NHANES children suggesting greater overall dietary quality. Children with T1D consumed significantly less energy derived from solid fats and added sugars; this difference (19.1 vs. 8.7, $p<0.0001$) contributed significantly to the overall difference in HEI-2005 total scores between the two groups. Children with T1D also scored higher than NHANES children in the consumption of vegetables, legumes, milk, and meat. NHANES children scored higher on consumption of healthy fats (derived from nuts, seeds, and liquid oil) and restriction of saturated fat intake compared to children with T1D. Both groups had similarly low whole grain component scores. Overall and component HEI-2005 scores expressed as percent of maximum possible score are presented in Figure 1.

4. DISCUSSION

In our sample of preschool and school-aged children, ages 2–12 years, with T1D, dietary recalls demonstrated significant deficits in overall nutrition. Daily intakes of all major food groups were well below recommended levels. On average, 2 in 5 children with T1D met recommendations for daily fruit intake and only 1 in 5 children with T1D met recommendations for daily vegetable intake. The low consumption of grains was offset by higher than recommended levels of total and saturated fat, both of which exceeded guidelines for children with T1D. No child with T1D consumed the recommended amount of daily fiber. The overall dietary quality, assessed by HEI-2005 Index, suggested only modest conformance to USDA guidelines.

Clinical characteristics of our convenience sample of T1D children suggested that our findings of significant nutritional deficits in young children with T1D may, in fact, be a conservative estimate of actual dietary intake in this age group as our sample had greater adoption of modern, intensive physiologic insulin regimens, including pump therapy, and achieved better than average glycemic control, in comparison to other populations [25] and

[26]. However, the use of flexible insulin regimens may have provided for greater laxity in dietary choices [3].

The dietary intakes in this cohort are similar to that described by the SEARCH for Diabetes Study group, which investigated older children, ages 10–22 years, with both T1D and T2D [4]. Notably, however, children with T1D in our sample were more likely to meet daily recommendations for fruits, vegetables, and total grains. These younger children with T1D were also more likely to meet recommendations for limiting total and saturated fat consumption compared to older children with diabetes in the SEARCH study. It is possible that dietary intakes of older children with T2D partially explain these differences, but the authors noted that a vast majority of children (89%) had T1D and differences between older children with T1D and T2D were negligible. We hypothesize that greater parental involvement in daily meal-planning and preparation of food for younger children may explain these differences.

This cohort of young children was enrolled as a convenience sample following their routine clinic appointments. Studies over the last 30 years have frequently evaluated samples ranging from 50–100 children [11] and [17]. The use of three 24-hour recalls has been demonstrated to provide a very robust assessment of diet in preschool and school-aged children [16], [18] and [27]. Indeed, the use of multiple 24-hour dietary recalls is favored over food frequency questionnaires in the estimation of actual intakes as the latter approach is best suited for ranking individuals according to food intake [15]. As such, we do believe that our sample size, albeit significantly smaller than the SEARCH Study and NHANES, provides a reliable estimate of dietary intake in this unique population.

We demonstrated some differences between young children with T1D and age- and sex-matched children from the general US population. Children with T1D consumed significantly more vegetables and significantly fewer total grains when compared to NHANES children. The lower intake of total grains appears to be primarily related to lower intake of added sugars which may support a beneficial impact of nutrition counseling. However, whole grain consumption was generally very low in both children with and without T1D. We have previously reported that the emphasis on carbohydrates in nutrition education for children with T1D may negatively impact perceptions of healthful eating [3]. It is well established that carbohydrates are the principal determinant of postprandial glycemic excursions. Families with T1D may be limiting consumption of more healthful whole grains to minimize postprandial glycemic excursions in an effort to optimize the child's glycemic control.

We also demonstrated that intakes of total fat were above recommended levels for both children with and without type 1 diabetes. However, saturated fat intakes were significantly higher for children with T1D. The lower percentage of total energy derived from carbohydrates appears to be offset by a higher consumption of saturated fat in children with T1D. Further, parents have reported a preference for labeled foods, such as processed and prepackaged foods, as carbohydrate amounts appear clearly on the label providing ease with calculating carbohydrate intake [3]. Such processed foods are commonly higher in saturated fat when compared to more natural foods, such as fruits and vegetables. This finding is

particularly concerning as higher saturated fat intake is associated with increased risk of cardiovascular disease, the major cause of long-term morbidity and mortality in T1D [28].

Finally, we found that average z-BMI scores for young children with T1D were significantly greater than age- and sex-matched children without T1D. Indeed, 42% of intensively-treated, well-managed children with T1D were overweight or obese compared to 30% of children without T1D. Intensive diabetes management has been associated with weight gain in T1D, but recent data suggest that current approaches to flexible insulin therapy using modern insulin analogs are associated with less hypoglycemia resulting in less ingestion of unnecessary calories to raise a low glucose levels [29], [30] and [31]. We hypothesize that dietary factors, such as higher fat intake, play a role in these findings. However, reported energy intakes in children with T1D were lower, albeit not significantly, compared to NHANES children. It is possible that parents of children with T1D are less likely to report added sugar intake due to social desirability compared to the general population; further, parents of children with T1D may inadvertently fail to report, as part of daily dietary intake, the ingestion of rapid-acting carbohydrates for prevention or treatment of hypoglycemia despite standardized prompting by a trained research nutritionist. Differences in physical activity, not assessed in the present analysis, may explain the discrepancy in weight status and energy intake and remains an important area for future investigation.

This study is limited by significant differences in socioeconomic factors, which may explain observed differences in both BMI Z-score and dietary patterns observed in children with and without T1D. Our sample uniquely derives from the New England region, which has lower rates of childhood overweight and obesity compared to the rest of the country yet the children with T1D in our sample had higher rates [32]. Geographic data from NHANES are not publicly available precluding our ability to adjust for regional differences. Further, ethnic and racial differences may be associated with cultural differences in dietary patterns. Additionally, parents of NHANES children were less educated, more likely to have public insurance, and more likely to raise their children in single-parent households, all of which may contribute to the observed poorer dietary quality in that sample. Such socioeconomic differences between our regional sample of children with T1D and the national NHANES sample could likely overestimate the differences in dietary intake and dietary quality, which is particularly concerning given the low dietary quality evident in these children with T1D. Future studies in larger, more diverse populations of young children with T1D warrant investigation. The present report may also be limited by temporal changes in dietary patterns, which may have occurred between the completion of dietary assessments in 2007 and the reporting of these findings.

Preschool and school-aged children with T1D are consuming a high fat, low fiber diet with very low intakes of fruits, vegetables, and whole grains. Dietary patterns for children in the general population tend to track into adolescence and adulthood. The comparison to the SEARCH Study data suggests that these children may be at risk for further deterioration in dietary quality over time. Children with T1D demonstrate modestly better diets compared to the general population, much of which is attributed to reduced consumption of added sugars. Further, young children with T1D are demonstrating high rates of overweight and obesity compared to the general population, which may be related to dietary patterns and factors

related to their diabetes management. Taken together, children with T1D are consuming a diet which may place them at increased risk of future cardiovascular disease. Future efforts to improve overall dietary quality may significantly reduce this risk and merit investigation. Nutrition education targeting children with T1D should continue to reinforce healthful dietary patterns while ensuring success with carbohydrate estimation to optimize metabolic control.

Acknowledgments

This study was supported by an NIH Career Development Grant in Pediatric Endocrinology (K12 DK6396-05), an Eli Lilly Foundation Fellowship Training Grant, the Harvard Pediatric Health Services Research Fellowship (HRSA T32 HP10018-12), the Katherine Adler Astrove Youth Education Fund, and the Maria Griffin Drury Fund. Portions of this manuscript were presented at the 68th Scientific Sessions of the American Diabetes Association (2008). The authors declare that they have no competing interests.

ABBREVIATIONS

CDC	Centers for Disease Control and Prevention
DCCT	Diabetes Control and Complications Trial
FFQ	food frequency questionnaire
HEI	Healthy Eating Index
NCHS	National Center for Health Statistics
NHANES	National Health and Nutrition Examination Survey
T1D	type 1 diabetes
T2D	type 2 diabetes
USDA	United States Department of Agriculture

REFERENCES

1. Mehta SN, Wolfsdorf JJ. Contemporary management of patients with type 1 diabetes. *Endocrinol Metab Clin North Am*. 2010; 39:573–593. [PubMed: 20723821]
2. Bantle JP, Wylie-Rosett J, Albright AL, Apovian CM, Clark NG, Franz MJ, et al. Nutrition recommendations and interventions for diabetes: a position statement of the American Diabetes Association. *Diabetes Care*. 2008; 31:S61–S78. [PubMed: 18165339]
3. Mehta SN, Haynie DL, Higgins LA, Bucey NN, Rovner AJ, Volkening LK, et al. Emphasis on carbohydrates may negatively influence dietary patterns in youth with type 1 diabetes. *Diabetes Care*. 2009; 32:2174–2176. [PubMed: 19741186]
4. Mayer-Davis EJ, Nichols M, Liese AD, Bell RA, Dabelea DM, Johansen JM, et al. Dietary intake among youth with diabetes: the SEARCH for Diabetes in Youth Study. *J Am Diet Assoc*. 2006; 106:689–697. [PubMed: 16647326]
5. Patton SR, Dolan LM, Chen M, Powers SW. Dietary adherence and mealtime behaviors in young children with type 1 diabetes on intensive insulin therapy. *J Acad Nutr Diet*. 2013; 113:258–262. [PubMed: 23351629]
6. Birch LL, Fisher JO. Development of eating behaviors among children and adolescents. *Pediatrics*. 1998; 101:539–549. [PubMed: 12224660]
7. Birch, LL. Acquisition of food preferences and eating patterns in children. In: Fairnorn, CG.; Brownell, KD., editors. *Eating Disorders and Obesity: A Comprehensive Handbook*. New York: The Guilford Press; 2002. p. 75-79.

8. Overby NC, Margeisdottir HD, Brunborg C, Andersen LF, Dahl-Jorgensen K. The influence of dietary intake and meal pattern on blood glucose control in children and adolescents using intensive insulin treatment. *Diabetologia*. 2007; 50:2044–2051. [PubMed: 17687538]
9. Overby NC, Flaaten V, Veierod MB, Bergstad I, Margeisdottir HD, Dahl-Jorgensen K, et al. Children and adolescents with type 1 diabetes eat a more atherosclerosis-prone diet than healthy control subjects. *Diabetologia*. 2007; 50:307–316. [PubMed: 17136391]
10. Maffei C, Morandi A, Ventura E, Sabbion A, Contreas G, Tomasselli F, et al. Diet, physical, and biochemical characteristics of children and adolescents with type 1 diabetes: relationship between dietary fat and glucose control. *Pediatr Diabetes*. 2012; 13:137–146. [PubMed: 21672107]
11. Randecker GA, Smiciklas-Wright H, McKenzie JM, Shannon BM, Mitchell DC, Becker DJ, et al. The dietary intake of children with IDDM. *Diabetes Care*. 1996; 19:1370–1374. [PubMed: 8941466]
12. Ogden CL, Carroll MD, Curtin LR, Lamb MM, Flegal KM. Prevalence of high body mass index in US children and adolescents: 2007–2008. *JAMA*. 2010; 303:242–249. [PubMed: 20071470]
13. Liu LL, Lawrence JM, Davis C, Liese AD, Pettitt DJ, Pihoker C, et al. SEARCH for Diabetes in Youth Study Group. Prevalence of overweight and obesity in youth with diabetes in USA: the SEARCH for Diabetes in Youth study. *Pediatr Diabetes*. 2010; 11:4–11. [PubMed: 19473302]
14. Sandhu N, Witmans MB, Lemay JF, Crawford S, Jadavji N, Pacaud D. Prevalence of overweight and obesity in children and adolescents with type 1 diabetes mellitus. *J Pediatr Endocrinol Metab*. 2008; 21:631–640. [PubMed: 18780597]
15. Willett, W. *Nutritional Epidemiology*. Second ed. Oxford University Press; 1998.
16. Baranowski T, Sprague D, Baranowski JH, Harrison JA. Accuracy of maternal dietary recall for preschool children. *J Am Diet Assoc*. 1991; 91:669–674. [PubMed: 2040780]
17. Patton SR. Adherence to diet in youth with type 1 diabetes. *J Am Diet Assoc*. 2011; 111:550–555. [PubMed: 21443987]
18. Klesges RC, Klesges LM, Brown G, Frank GC. Validation of the 24-hour dietary recall in preschool children. *J Am Diet Assoc*. 1987; 87:1383–1385. [PubMed: 3655169]
19. USDA Food and Nutrition Board. Dietary Reference Intakes (DRIs): Recommended Intakes for Individuals. [<http://www.usda.gov/wps/portal/usda/usdahome>]
20. American Diabetes Association. Standards of medical care in diabetes-2011. *Diabetes Care*. 2011; 34:S11–S61. [PubMed: 21193625]
21. Guenther PM, Reedy J, Krebs-Smith SM. Development of the Healthy Eating Index- 2005. *J Am Diet Assoc*. 2008; 108:1896–1901. [PubMed: 18954580]
22. Miller PE, Mitchell DC, Harala PL, Pettit JM, Smiciklas-Wright H, Hartman TJ. Development and evaluation of a method for calculating the Healthy Eating Index-2005 using the Nutrition Data System for Research. *Public Health Nutr*. 2010; 1–8. [PubMed: 20015421]
23. The fourth report on the diagnosis, evaluation, and treatment of high blood pressure in children and adolescents. *Pediatrics*. 2004; 114:555–576. [PubMed: 15286277]
24. Silverstein J, Klingensmith G, Copeland K, Plotnick L, Kaufman F, Laffel L, et al. Care of children and adolescents with type 1 diabetes: a statement of the American Diabetes Association. *Diabetes Care*. 2005; 28:186–212. [PubMed: 15616254]
25. Paris CA, Imperatore G, Klingensmith G, Pettitt D, Rodriguez B, Anderson AM, et al. Predictors of insulin regimens and impact on outcomes in youth with type 1 diabetes: the SEARCH for Diabetes in Youth study. *J Pediatr*. 2009; 155:183–189. [PubMed: 19394043]
26. Beck RW, Tamborlane WV, Bergenstal RM, Miller KM, Dubose SN, Hall CA. The T1D Exchange clinic registry. *J Clin Endocrinol Metab*. 2012; 97:4383–4389. [PubMed: 22996145]
27. Stein AD, Shea S, Basch CE, Contento IR, Zybert P. Assessing changes in nutrient intakes of preschool children: comparison of 24-hour dietary recall and food frequency methods. *Epidemiology*. 1994; 5:109–115. [PubMed: 8117768]
28. Soedamah-Muthu SS, Chaturvedi N, Witte DR, Stevens LK, Porta M, Fuller JH. Relationship between risk factors and mortality in type 1 diabetic patients in Europe: the EURODIAB Prospective Complications Study (PCS). *Diabetes Care*. 2008; 31:1360–1366. [PubMed: 18375412]

29. The DCCT Research Group. The effect of intensive treatment of diabetes on the development and progression of long-term complications in insulin-dependent diabetes mellitus. *N Engl J Med.* 1993; 329:977–986. [PubMed: 8366922]
30. Svoren BM, Volkening LK, Butler DA, Moreland EC, Anderson BJ, Laffel LMB. Temporal trends in the treatment of pediatric type 1 diabetes and impact on acute outcomes. *J Pediatr.* 2007; 150:279–285. [PubMed: 17307546]
31. Katz ML, Volkening LK, Anderson BJ, Laffel LM. Contemporary rates of severe hypoglycaemia in youth with type 1 diabetes: variability by insulin regimen. *Diabet Med.* 2012; 29:926–932. [PubMed: 22417321]
32. The National Survey of Children's Health. Childhood Obesity Action Network. State Obesity Profiles, 2008. National Initiative for Children's Healthcare Quality, Child Policy Research Center, and Child and Adolescent Health Measurement Initiative. [<http://www.nschdata.org:80/Content/ObesityReportCards.aspx>]

Figure 1.

Dietary quality in children with T1D and age-matched children in the general population (NHANES) presented as percent of maximum HEI-2005 total and component scores; higher percent reflects greater adherence to USDA dietary recommendations. Significant differences are highlighted by (*), $p < 0.05$.

Table 1

Demographic and clinical characteristics of children with T1D and age-matched children in the general population (NHANES)

	T1D (n=67)	NHANES (n=1691)	p value
Age (years)	9.1 (0.3) [4.0–12.9]	8.4 (0.1) [4.0–12.9]	0.2
Sex (% female)	45	49	0.5
Race (% white)	88	59	<0.0001
BMI Z-score (SD)	0.8 (0.1) [−0.6–2.7]	0.5 (0.1) [−4.9–4.0]	0.03
Caregiver education (%)			0.003
High school or less	27	45	
College or more	73	55	
Insurance (% private)	81	58	0.0002
Family structure (% 2-parent)	88	78	0.05
Diabetes duration (years)	4.1 (0.3) [0.6–9.9]		
Insulin regimen (%)			
MDI	30		
CSII	70		
Hemoglobin A1c (%)	7.5 (0.8) [5.8–10.3]		
Hemoglobin A1c (mmol/mol)	59 (9) [40–89]		

Data presented as means (standard error) [range] or percentage.

Abbreviations: MDI, multiple daily injections; CSII, continuous subcutaneous insulin infusion.

Table 2

Dietary recommendations and actual intakes for children with T1D and age-matched children in the general population (NHANES)

	Recommendations ^d			T1D (n=67)	NHANES (n=1691)	p value
	<9 yrs	9 yrs				
Energy intake (kcal)				1646 (50)	1901 (28)	0.07
Fruit (servings)	3	3		1.2 (0.8)	1.0 (0.0)	0.5
Vegetables (servings)	3	4-5		1.4 (0.9)	0.9 (0.0)	0.02
Grains (servings)	4	5-6		4.3 (1.4)	6.7 (0.1)	0.0002
Dairy (servings)	2	3		2.7 (1.3)	2.0 (0.1)	0.08
Carbohydrate (%EI)	60-70	60-70		50.2 (0.8)	54.3 (0.3)	0.02
Protein (%EI)	<20	<20		15.6 (0.5)	13.7 (0.1)	0.0009
Fat (%EI)	<30	<30		34.1 (0.7)	33.2 (0.2)	0.5
Saturated fat (%EI)	<10	<10		13.6 (0.4)	11.8 (0.1)	0.0009
Cholesterol (mg)	<300	<300		185 (11)	215 (9)	0.5
Fiber (g)	25	31		12.7 (0.6)	12.6 (0.3)	0.96
Calcium (mg)	800	1300		955 (47)	960 (23)	0.97
Folate (mg)	200	300		342 (16)	361 (9)	0.7
Iron (mg)	10	8		12.4 (0.6)	14.3 (0.3)	0.2
Magnesium (mg)	130	240		210 (9)	218 (4)	0.7
Niacin (mg)	8	12		18.5 (0.7)	19.8 (0.5)	0.6
Riboflavin (mg)	0.6	0.9		2.1 (0.1)	2.1 (0.1)	0.9
Selenium (mg)	30	40		89 (3)	87 (2)	0.9
Thiamine (mg)	0.6	0.9		1.5 (0.1)	1.5 (0.0)	0.8
Vitamin A (mg)	400	600		646 (36)	491 (17)	0.06
Vitamin B6 (mg)	0.6	1.0		1.5 (0.1)	1.6 (0.1)	0.5
Vitamin B12 (mg)	1.2	1.8		5.6 (0.8)	4.8 (0.2)	0.4
Vitamin C (mg)	25	45		55 (4)	75 (3)	0.2
Vitamin D (IU)	200	200		250 (22)	N/A	
Vitamin E (mg)	7	11		5.2 (0.3)	5.5 (0.1)	0.7
Zinc (mg)	5	8		9.2 (0.4)	9.9 (0.2)	0.6

Data presented as mean (standard error).

Abbreviations: kcal, kilocalorie; EI, energy intake; N/A, not available.

^aBased on 2005–2006 USDA guidelines.

Table 3

HEI-2005 total and component scores from children with T1D and age-matched children in the general population (NHANES) Data presented as mean (standard error).

	Possible Score	T1D (n=67)	NHANES (n=1691)	p value
Total HEI score	0–100	59.6 (0.9)	49.7 (0.6)	0.0006
Total fruit	0–5	1.9 (0.2)	2.6 (0.1)	0.04
Whole fruit	0–5	2.2 (0.2)	2.2 (0.0)	0.9
Total vegetables	0–5	2.8 (0.2)	2.1 (0.1)	0.05
Dark green and orange vegetables, legumes	0–5	1.3 (0.2)	0.4 (0.0)	<0.0001
Total grains	0–5	4.1 (0.1)	4.5 (0.0)	0.1
Whole grains	0–5	0.7 (0.1)	0.9 (0.1)	0.5
Milk	0–10	9.2 (0.2)	6.9 (0.1)	0.001
Meat and beans	0–10	8.4 (0.3)	6.6 (0.1)	0.005
Oil	0–10	2.3 (0.3)	5.6 (0.1)	<0.0001
Saturated fat	0–10	3.8 (0.4)	5.0 (0.1)	0.01
Sodium	0–10	3.7 (0.3)	4.4 (0.2)	0.4
Energy from solid fat, alcohol, added sugar	0–20	19.1 (0.4)	8.7 (0.4)	<0.0001

Data presented as mean (standard error).