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Contextual factors are associated with diet quality in youth with type 1 diabetes

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Abstract

This study examined differences in diet quality by meal type, location, and time of week in youth with type 1 diabetes (T1D). A sample of youth with T1D (n=252; 48% female) age 8 to 18 years

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(13.2±2.8) with diabetes duration ≥1 year (6.3±3.4) completed 3-day diet records. Multilevel linear regression models tested for differences in diet quality indicators by meal type, location and time of week (weekdays versus weekends). Participants showed greater energy intake and poorer diet quality on weekends relative to weekdays, with lower intake of fruit and vegetables, and higher intake of total and saturated fat. Differences in diet quality were seen across meal types, with higher nutrient density at breakfast and dinner than at lunch and snacks. Participants reported the highest whole grain and lowest fat intake at breakfast, but higher added sugar than at lunch or dinner. Dinner was characterized by the highest fruit intake, lowest added sugar, and lowest glycemic load, but also the highest sodium intake. The poorest nutrient density and highest added sugar occurred during snacks. Diet quality was poorer for meals consumed away from home than those consumed at home for breakfast, dinner, and snacks. Findings regarding lunch meal location were mixed, with higher nutrient density, lower glycemic load, and less added sugar at home lunches, and lower total fat, saturated fat, and sodium at lunches away from home. Findings indicate impacts of meal type, location and time of week on diet quality, suggesting targets for nutrition education and behavioral interventions.

Keywords

Diabetes Mellitus; Type 1; Diet; Children; Adolescents; Contextual Factors

Introduction

Diets of youth with type 1 diabetes (T1D) are of suboptimal nutritional quality, exhibiting inadequate intake of fruit and vegetables, whole grains, and excessive intake of total and saturated fat [1, 2]. Such dietary patterns may increase risk of cardiometabolic complications in this population [3]. Evidence suggests that multiple aspects of dietary intake may influence glycemic control [4–8] and cardiovascular risk [5, 9, 10], suggesting the importance of efforts to improve diet quality.

Research in the general population indicates the influence of environmental contexts surrounding eating occasions on dietary intake [11, 12]. Meal type is one such contextual factor. Snack foods among children are more likely than main meals to consist primarily of desserts, salty snacks and sweetened beverages [13]; accordingly, snacking is associated with greater intake of added sugar and oil [14]. Breakfast consumption is related to higher diet quality in children and adults [15, 16]. However, distinguishing nutritional characteristics of other meals have not been studied. Meal location is another contextual factor with demonstrated influence on dietary intake. Eating away from home is associated with greater energy intake and lower diet quality in both children and adults [17, 18]. Intake at school may be influenced by participation in the National School Lunch Program, which is associated with greater nutrient adequacy but also excessive sodium intake [19]. In addition, dietary intake varies considerably with respect to time of week, with lower diet quality in both children and adults on weekends versus weekdays, evidenced by increased fat [20–22], energy dense snack foods [21] and added sugar [22], as well as decreased fiber [22].

Differences in dietary patterns according to these meal-related characteristics have not been examined in youth with T1D, who experience dietary demands related to disease management. Research in the general population supports the potential efficacy of theory-based behavioral interventions to change dietary habits [23]. However, previous research has not tested behavioral approaches to improve dietary intake in this population [1]. Therefore, information on the association of meal contextual factors with dietary intake would be instructive in the development of effective intervention strategies. The purpose of this study was to examine differences in diet quality according to meal type, location, and time of week in a sample of youth with T1D. Several indicators of diet quality are considered, including intakes of food groups, energy and macronutrients, as well as measures of overall diet quality.

Methods

Design, Sample, and Procedures

Data from a cross-sectional study of diabetes and dietary behaviors, conducted from July 2008 through February 2009 at a pediatric diabetes center in Boston, Massachusetts, were used for this secondary analysis. Eligibility criteria included age 8 to 18 years, diagnosis of T1D ≥1 year, daily insulin dose ≥0.5 units/kg, absence of chronic illness (particularly any GI disease such as celiac disease) or medication that interferes with diabetes management or glucose metabolism, and ability to communicate in English. Parents and 18-year-old youth provided informed consent; children younger than 18 years provided assent. Of 455 eligible youth invited to participate, 302 (66.4%) enrolled in the study. In families with multiple siblings enrolled; data from the sibling with the longest diabetes duration were retained, resulting in elimination of 11 subjects. Of the remaining 291 subjects, 252 completed diet records, providing data on 3756 meals. There were no differences in diabetes duration, age, sex, race, income, or parent education between those completing and not completing diet records; however, those completing diet records were more likely to be using an insulin pump (68.7% versus 41.9%, chi square p=.003). Study procedures were approved by the Joslin Diabetes Center Committee on Human Studies along with a *Eunice Kennedy Shriver* National Institute of Child Health and Human Development reliance agreement.

Biomedical data including child height, weight, date of diagnosis, hemoglobin A1c (A1c; reference range 4–6%; Tosoh 2.2 device, Tosoh Corporation, Foster City, CA), insulin regimen, and blood glucose monitoring frequency (from meter download or patient report) were extracted from medical records. Youth reported frequency of moderate and vigorous physical activity [24]. Parents reported demographic characteristics. Families completed three-day food records on the child's dietary intake (two weekdays and one weekend day). Participants were given instructions on how to measure and report food and beverage consumption. Families were asked to use measuring utensils if available or provide their best estimate of portion size, and to note specific details for each food including names of brands or restaurants, and any other labeling information (e.g., low fat/low sugar, etc.). Nutrition Data System for Research software (Nutrition Coordinating Center, University of Minnesota, Minneapolis, MN) was used to analyze food records.

Contextual factors examined as predictors of dietary outcomes included meal type (breakfast, lunch, dinner, or snack), meal location, and time of week (weekday or weekend). Dietary indicators included energy intake, macronutrient distribution (percent energy intake from carbohydrate, protein, total fat and saturated fat), sodium intake, added sugar intake (as percent of energy intake), servings of fruit and vegetables, servings of whole grains, glycemic index (GI), and glycemic load (GL). In addition, the Nutrient-Rich Food score 9.3 (NRF9.3) and Whole Plant Food density (WPFD) were examined as indices of overall diet quality. The NRF9.3 is calculated as the sum of the percent consumed of referent daily value of 9 nutrients to encourage (protein, fiber, vitamin A, vitamin C, vitamin E, calcium, iron, magnesium, and potassium) subtracted by the sum of the percent consumed of referent daily value of 3 nutrients to limit (saturated fat, added sugar, and sodium), expressed per 100 kcal [25]. WPFD is calculated as the number of servings of whole grains, whole fruit, vegetables, legumes, nuts, and seeds per 1000 kcal consumed [26].

Analyses

Separate multilevel linear regression models tested for differences in dietary quality indicators by meal type, location and time of week. This modeling strategy accounts for the correlation between repeated measures (meals) within subjects by including a random intercept. Day of week was dichotomized as weekday versus weekend; meal location was dichotomized as home versus away from home. Due to the non-independence of meal type and location (e.g., most meals consumed at school were lunches, few restaurant meals were breakfasts), comparisons by meal location were conducted separately for each meal type. Statistical significance was adjusted for multiple comparisons using the Sidak method. Meal energy intake was included as a covariate in all models evaluating meal type differences, and in those models examining day of week and location differences if the outcome was significantly related to energy intake in bivariate analyses ($p<0.05$). Models evaluating associations of meal type and time of week with dietary intake required no additional covariates since subjects reported intake for each meal time as well as weekend and weekday times. For models evaluating associations with meal location, potential confounding by age, sex, household income, body mass index percentile, A1c, insulin regimen, and physical activity was examined. Variables associated with the dietary outcome of interest were included as covariates. STATA version 12 (College Station, TX) was used for statistical analyses; statistical significance was defined as $p<.05$.

Results and Discussion

The sample was approximately half female (52%) and predominantly non-Hispanic white (92%) (Table 1). A majority of the parents had at least a college degree (74%). Youth were predominantly receiving pump therapy (69%), with mean A1c of 8.5 ± 1.3% and mean BMI %ile of 70.2 ± 22.5. On average, 34% of youth's energy intake was provided by dinner, 26% by lunch, 22% by snacks, and 19% by breakfast.

Meal diet quality was higher on weekdays versus weekends for most indicators (Table 2), with modestly higher intake of fruit and vegetables ($p=0.006$), lower energy intake ($p=0.001$), and lower proportional intake of total fat ($p=0.01$) and saturated fat ($p=0.003$). These findings are consistent with previous research in the general population demonstrating differences in dietary intake between weekdays and weekends [20–22]. The majority of the sample used insulin pump therapy, which allows considerable flexibility in dietary intake; weekend/weekday differences may reflect less structured eating occasions during weekends and greater likelihood of recreational intake.

Differences in diet quality indicators were observed according to meal type (Table 2). NRF9.3 was highest at breakfast and dinner meals ($p<.0001$), while WPFD was highest at breakfast and lunch ($p<.0001$). Breakfast contained the highest carbohydrate and whole grain intake and the lowest total and saturated fat, though it also contained higher added sugar relative to lunch and dinner (all differences $p<0.001$). At dinner, intakes of energy, protein, fruit and vegetables, and sodium were highest, while glycemic load and added sugar were lowest ($p<0.001$). Snacks contained the lowest NRF9.3 ($p<0.001$), lowest protein ($p<.001$), and highest added sugar ($p<0.001$) of all meals; however, total and saturated fat intake were not different from lunch or dinner.

Findings indicate relevant targets for strategies to improve diet quality in this population. Fruit and vegetable intake was inadequate at all meals, but lowest at breakfast and snacks, suggesting the relevance of targeting these eating occasions in efforts to increase intake of fruit and vegetables. The lower nutrient density of lunches relative to breakfast and dinner suggests the need for continued efforts to improve school lunch offerings [27]. Consistent with previous research suggesting poor nutrient quality associated with snacking [14, 28], participants' snacks contained the lowest nutrient density and highest quantity of added sugar. As snacks comprised on average more than one-fifth of daily energy intake, improving the quality of snacks could meaningfully impact overall diet quality.

The location of meals consumed away from home differed according to meal type. A majority (93%) of breakfasts were consumed at home, with the remainder occurring across various locations. Lunches were consumed predominantly at home (42%) or school (45%); 7% were consumed at restaurants. Dinners were consumed mostly at home (86%) or at restaurants (7%). Snacks were consumed at home (72%), school (13%) or in social contexts (12%).

Comparisons of meal quality by meal location are provided in Table 3. Breakfast meals consumed at home demonstrated higher diet quality than those consumed away from home across all indicators except for intake of carbohydrate, added sugar, and sodium. Quality of lunches consumed at home was more favorable for NRF9.3 ($p=0.03$), GL ($p<.001$) and added sugar ($p<0.001$), and less favorable for total fat ($p=0.006$), saturated fat ($p<0.001$), and sodium ($p<0.001$) than for lunches consumed away from home (predominantly at school). Compared to dinners eaten at home, those consumed away from home (primarily restaurants) exhibited lower dietary quality across multiple indicators: higher energy intake ($p<0.001$), lower NRF9.3 ($p<0.001$), lower WPFD ($p=.006$), higher GI ($p=0.001$), higher GL ($p=.003$), lower fruit and vegetable intake ($p<0.001$), lower whole grain intake ($p=.02$), and higher total fat ($p=0.009$) and added sugar ($p<0.001$). Snacks consumed at home demonstrated more favorable NRF9.3 ($p=0.001$), WPFD ($p=.03$), GI ($p=0.03$), GL ($p<.001$), and intake of whole grains ($p=0.001$), protein ($p<0.001$) and added sugar ($p=0.004$) as compared with those consumed away from home.

Previous research has also indicated poorer quality of food consumed away from home [17, 18]. A number of factors may contribute to these findings. Food choices away from home often include fewer healthful options, and information on nutrient values may not be provided; additionally, they are typically high in fat, sugar, and salt and served in larger portion sizes [29]. Eating occasions away from home may include a greater degree of recreational eating, that is, intake of food primarily for its hedonic value. Additionally, for snacks consumed away from home, families are likely to rely on packaged and processed foods due to their portability. Consequently, efforts to assist families to eat healthfully may include addressing barriers to eating at home and identifying healthful options for meals eaten away from home including choices at frequented restaurants and selection of portable healthful snacks while on the go. Findings also support the importance of policy and advocacy efforts aimed at improving restaurant offerings and providing readily-accessible nutrition information for foods eaten away from home.

Analyses of changes in the US dietary intake over the past decades indicate both an increase in meals consumed away from home [30–32] and an increase in snack consumption [13, 33]. From 1977–2006, the percent of daily energy eaten away from home by children age 2 to 18 increased 45%, from 23.4% to 33.9%, accounting for a significant increase in overall energy intake [34]. Likewise, the daily energy intake from snacks increased 70%, from 240 kcal to 409 kcal from 1977 to 1996 [33]. As both eating out of the home and snack intake were associated with poorer diet quality, these eating occasions represent important targets for interventions to promote healthful eating.

Study participants were recruited from a single diabetes center, of relatively high mean family income and relatively few minorities, which limits generalizability. The sample size was large for a single-site study of youth with T1D; however, there were insufficient meals consumed away from home to evaluate differences by type of location (e.g., fast food versus full-service restaurants). The number of breakfasts consumed away from home was small; thus, findings should be interpreted with caution. In addition, data on meals consumed at school did not specify if these were purchased at school versus brought from home. A notable strength of this study is the evaluation of multiple indicators of diet quality, calculated from 3-day diet records. The comparison of meals across the same subjects also strengthens findings. Most previous research examining the impact of consuming food away from home on diet quality has involved comparisons between individuals who consume more food away from home versus those who consume more at home. Thus, it is not known to what extent differences are attributable to the environmental context versus self-selection bias. For example, in previous research, participants characterized by more frequent home cooking had a higher Healthy Eating Index compared to others [35]. Similarly, participants classified as consuming the majority of meals at home demonstrated the most healthful diets compared to those classified in groups characterized by higher fast food, restaurant, or other away-from home food [36]. In this study, comparisons made within the same individuals strengthen the case for attributing differences to the food environment away from home.

Conclusions

In this study of youth with T1D, eating occasion type, location and time of week were all associated with multiple dimensions of diet quality. Eating is a habitual behavior that is subject to influence by environmental contexts, and youth with T1D are similarly influenced by such contexts. Findings from this study can help direct nutrition education and subsequently inform the development of behavioral interventions to improve diet quality. When working with families, dietitians may assess the relevance of target behaviors such as increasing fruit intake at breakfast and snacks, increasing whole grain intake at dinner, and decreasing added sugar at breakfast. With consideration to each family's situation, youth with T1D may be assisted in improving diet quality through strategies that promote consumption of meals at home, assist in the selection of healthier choices when eating away from home, reduce intake of recreational snacks, and promote the selection of healthier snack choices.

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Table 1

Demographic and health-related characteristics of the sample of youth with type 1 diabetes (n=252)

Characteristic	Mean ± SD or n (%)
Age (years)	13.2 ± 2.8
Sex	
Female	122 (48)
Male	130 (52)
Body Mass Index (BMI) percentile	70.2 ± 22.5
Race/ethnicity	
White, not Hispanic	231 (92)
Hispanic	9 (4)
Black	6 (2)
Other	6 (2)
Highest parent education level	
High school degree or equivalent	22 (9)
Junior college, technical, or some college	43 (17)
College degree	112 (44)
Graduate degree	75 (30)
Family income ($, thousands)	
<30	22 (9)
≥30 to <50	17 (7)
≥50 to <70	31 (13)
≥70 to <100	52 (21)
≥100 to <149	57 (23)
≥150	66 (27)
Duration of diabetes (years)	6.3 ± 3.4
Regimen	
Injection	79 (31)
Pump	173 (69)
Daily blood glucose monitoring frequency	5.4 ± 2.2
Hemoglobin A1c (%)	8.5 ± 1.3
Percent of daily energy intake by meal type	
Breakfast	19.1 ± 6.8
Lunch	25.5 ± 7.4
Dinner	33.8 ± 9.0
Snacks	21.6 ± 11.4

Table 2

Comparison of meal diet quality indicators by time of week and meal type in a sample of youth with type 1 diabetes[1]

	Time of week			Meal type[2]				
	Weekday	**Weekend**	**p[3]**	**Breakfast**	**Lunch**	**Snack**	**Dinner**	**p[4]**
NRF9.3	23.1 ± 1.1	21.6 ± 1.6	0.39	33.3 ± 1.9[a]	23.7 ± 2.0[b]	10.9 ± 1.5[c]	33.8 ± 1.9[a]	**<0.001**
WPF density	2.3 ± 0.1	2.1 ± 0.1	0.07	2.5 ± 0.1[a]	2.6 ± 0.1[a]	2.1 ± 0.1[b]	2.1 ± 0.1[b]	**<0.001**
Glycemic index	59.0 ± 0.5	58.5 ± 0.3	0.34	58.5 ± 0.6	60.1 ± 0.6	58.3 ± 0.5	58.1 ± 0.6	0.29
Glycemic load	27.8 ± 0.3	27.2 ± 0.4	0.22	33.2 ± 0.5[a]	26.7 ± 0.5[b]	28.2 ± 0.4[b]	21.7 ± 0.5[c]	**<0.001**
FV (servings/meal)	0.5 ± 0.03	0.4 ± 0.03	**0.006**	0.2 ± 0.04[a]	0.6 ± 0.04[b]	0.3 ± 0.03[a]	1.1 ± 0.04[c]	**<0.001**
WG (servings/meal)	0.3 ± 0.03	0.2 ± 0.02	0.06	0.7 ± 0.03[a]	0.3 ± 0.03[b]	0.1 ± 0.03[c]	0.2 ± 0.03[c]	**<0.001**
EI (kcal/meal)	401.3 ± 9.0	435.2 ± 11.1	**0.001**	384.1 ± 10.7[a]	531.6 ± 10.8[b]	228.7 ± 8.9[c]	673.3 ± 10.6[d]	**<0.001**
Carbohydrate (%EI)	54.5 ± 0.5	53.2 ± 0.6	**0.047**	61.5 ± 0.8[a]	49.1 ± 0.8[b]	59.9 ± 0.6[c]	45.8 ± 0.8[d]	**<0.001**
Protein (%EI)	13.8 ± 0.2	13.3 ± 0.3	0.06	14.5 ± 0.3[a]	16.7 ± 0.3[b]	8.4 ± 0.2[c]	20.6 ± 0.3[d]	**<0.001**
Total fat (%EI)	30.4 ± 0.4	31.8 ± 0.5	**0.01**	24.0 ± 0.6[a]	33.4 ± 0.6[b]	32.5 ± 0.5[b]	31.9 ± 0.7[b]	**<0.001**
Saturated Fat (%EI)	10.6 ± 0.2	11.4 ± 0.2	**0.003**	9.2 ± 0.3[a]	11.0 ± 0.3[b]	11.5 ± 0.2[b]	11.2 ± 0.3[b]	**<0.001**
Added sugar (%EI)	15.6 ± 0.5	16.5 ± 0.7	0.19	16.3 ± 0.7[a]	8.9 ± 0.7[b]	24.4 ± 0.6[c]	5.5 ± 0.7[d]	**<0.001**
Sodium (mg)	690.8 ± 9.5	695.0 ± 13.3	0.78	591.0 ± 15.3[a]	836.1 ± 15.9[b]	538.3 ± 12.2[c]	966.7 ± 16.7[d]	**<0.001**

NRF9.3-Nutrient rich foods score; WPF-whole plant food; FV-fruit and vegetable intake; WG-whole grain intake; EI-energy intake

[1] Mean predicted diet quality indicator by day of week and meal type from mixed effects models adjusted for energy intake.

[2] Meal location pairwise comparisons adjusted for multiple comparisons; row values with different superscripts denote statistically significant differences ($p<.05$).

[3] *P* value for overall effect of day of week on meal diet quality indicator; statistically significant p values in bold.

[4] *P* value for overall effect of meal type on meal diet quality indicator; statistically significant p values in bold.

Table 3

Comparison of meal diet quality indicators by location for each meal type in a sample of youth with type 1 diabetes[1]

	Meal type and location											
	Breakfast			Lunch			Snack			Dinner		
	Home	**Away**	***P***	**Home**	**Away**	***P***	**Home**	**Away**	***P***	**Home**	**Away**	***P***
NRF9.3	35.1 ± 1.5	19.6 ± 4.4	**0.001**	23.3 ± 1.7	18.8 ± 1.5	**0.03**	19.5 ± 2.4	5.6 ± 3.5	**<0.001**	28.4 ± 1.2	17.5 ± 2.9	**<0.001**
WPF density	2.7 ± 0.1	1.3 ± 0.4	**0.001**	2.5 ± 0.2	2.4 ± 0.1	0.40	2.5 ± 0.2	2.0 ± 0.1	**0.03**	1.8 ± 0.2	1.3 ± 0.1	**0.006**
Glycemic index	58.2 ± 0.5	62.0 ± 1.3	**0.006**	60.5 ± 0.7	60.8 ± 0.6	0.71	56.7 ± 0.7	59.0 ± 1.0	**0.04**	58.6 ± 0.5	64.6 ± 1.2	**<0.001**
Glycemic load	32.2 ± 0.6	31.4 ± 1.8	0.66	31.9 ± 0.8	36.0 ± 0.7	**<0.001**	16.6 ± 0.3	19.0 ± 0.5	**<0.001**	37.1 ± 0.7	42.1 ± 1.6	**0.003**
FV (servings/meal)	0.2 ± 0.04	0.1 ± 0.1	**0.047**	0.7 ± 0.1	0.7 ± 0.1	0.48	0.2 ± 0.02	0.2 ± 0.03	0.22	1.3 ± 0.1	0.7 ± 0.1	**<0.001**
WG (servings/meal)	0.7 ± 0.1	0.2 ± 0.1	**0.001**	0.4 ± 0.05	0.3 ± 0.04	0.16	0.08 ± 0.01	0.02 ± 0.02	**0.001**	0.3 ± 0.03	0.07 ± 0.08	**0.02**
EI (kcal/meal)	377.0 ± 10.0	456.8 ± 29.2	**0.007**	519.2 ± 16.6	542.8 ± 14.7	0.23	225.6 ± 7.2	214.3 ± 9.9	0.27	658.3 ± 17.2	784.3 ± 36.0	**0.001**
Carbohydrate (%EI)	62.0 ± 0.7	60.2 ± 2.2	0.44	45.0 ± 0.9	48.7 ± 0.8	**0.001**	59.3 ± 0.9	61.1 ± 1.2	0.17	41.7 ± 0.6	42.4 ± 1.5	0.66
Protein (%EI)	14.6 ± 0.3	12.7 ± 0.8	**<0.001**	17.4 ± 0.4	16.4 ± 0.4	0.09	8.6 ± 0.3	7.0 ± 0.4	**<0.001**	21.5 ± 0.4	17.4 ± 0.8	**<0.001**
Total Fat (%EI)	23.3 ± 0.7	27.2 ± 1.9	**0.046**	37.6 ± 0.8	35.0 ± 0.7	**0.006**	29.0 ± 0.7	28.7 ± 1.0	0.77	36.8 ± 0.5	40.1 ± 1.2	**0.009**
Saturated Fat (%EI)	8.8 ± 0.3	11.7 ± 0.9	**<0.001**	12.8 ± 0.4	11.5 ± 0.3	**<0.001**	10.2 ± 0.3	9.7 ± 0.5	0.28	13.2 ± 0.2	13.8 ± 0.6	0.32
Added Sugar (%EI)	16.4 ± 0.7	15.4 ± 1.8	0.58	6.8 ± 0.6	10.3 ± 0.5	**<0.001**	23.2 ± 0.9	27.6 ± 1.4	**0.004**	5.0 ± 0.4	8.4 ± 0.9	**<0.001**
Sodium (mg)	557.1 ± 15.0	594.5 ± 44.9	0.42	1127.6 ± 27.3	975.9 ± 23.8	**<0.001**	244.4 ± 7.9	246.4 ± 11.8	0.88	1417.2 ± 24.9	1289.7 ± 61.4	0.05

NRF-Nutrient rich foods score; WPF-whole plant food; FV-fruit and vegetable intake; WG-whole grain intake; EI-energy intake

[1] Mean predicted meal diet quality by location for each meal type from mixed effects models adjusted for energy intake, age, income, glycemic control and physical activity where appropriate; statistically significant p values in bold.