Eating patterns in adolescents with type 1 diabetes: Associations with metabolic control,

insulin omission, and eating disorder pathology

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Abstract

Objective: The purpose of this study was to investigate eating patterns among male and female adolescents with type 1 diabetes (T1D), and the associations with age, zBMI, eating disorder (ED) pathology, intentional insulin omission, and metabolic control. **Method:** The sample consisted of 104 adolescents (58.6% females) with child-onset T1D, mean age of 15.7 years (SD 1.8) and mean zBMI of .4 (SD 0.8). The Child Eating Disorder Examination (ChEDE) assessed meal/snack frequency and ED pathology. T1D clinical data was obtained from the Norwegian Childhood Diabetes Registry. **Results**: A significantly lower proportion of females than males (73.8% vs 97.7%) consumed breakfast on a daily basis. Approximately 50% of both genders ate lunch and 90% ate dinner daily. Among females, skipping breakfast was significantly associated with higher global ED psychopathology, shape concerns, self-induced vomiting, binge eating, insulin omission due to shape/weight concerns, and poorer metabolic control. Less frequent lunch consumption was significantly associated with poorer metabolic control. Skipping dinner was significantly associated with older age, higher dietary restraint, eating concerns, self-induced vomiting, and insulin omission. Among males, less frequent consumption of lunch and evening snacks was associated with attitudinal features of ED, including shape/weight concerns and dietary restraint. **Discussion**: Among adolescents with T1D, irregular or infrequent meal consumption appears to signal potential ED pathology, as well as being associated with poorer metabolic control. These findings suggest the importance of routinely assessing eating patterns in adolescents with T1D to improve detection of ED pathology and to facilitate improved metabolic control and the associated risk of somatic complications.

Keywords: Eating Patterns, Meal Frequency, Type 1 diabetes, Adolescents, Eating Disorders

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Type 1 diabetes (T1D) is a chronic illness caused by an autoimmune destruction of the

insulin producing beta cells in the pancreas. Lack of insulin leads to poor metabolic control as

indicated by elevated blood glucose levels and measured by HbA1c. Over time, elevated

levels of HbA1c can lead to the onset of severe acute and late T1D complications (1-4). T1D

appears to be a risk factor for the development of disturbed eating behaviors (DEB) and eating

disorders (ED), with the prevalence of ED being 2-3 times higher among individuals with

T1D compared to peers without diabetes (5-7). Although estimates vary based upon

measurement specificity (7), the prevalence of disturbed eating behaviors in females with

T1D ranges from approximately 30 to 40% (8, 9), with some reporting rates of up to 50% at

14-years follow-up (10). Available prevalence estimates of DEB in male adolescents are

lower, at approximately 9% (9, 11). Intentional insulin restriction (reducing or omitting

insulin to influence shape or weight) is a uniquely available, diabetes-specific compensatory

behavior engaged in by an estimated 21-37% of young females with T1D (8, 9, 12).

Adolescents with T1D who engage in disturbed eating behaviors have poorer metabolic

control (7), and insulin restriction is associated with a threefold increase in mortality rates

(12).

Irregular or infrequent meal consumption is a dietary restriction behavior observed

across individuals with ED (13). There is evidence that skipping meals is an unhealthy weight

control behavior engaged in by approximately 28% of female and 7% of male adolescents

with T1D (14). A core therapeutic component in the clinical management of ED involves the

normalization of erratic eating behavior, with the introduction of regular timing, frequency,

and pattern of meals and snacks (15, 16). The frequency of consuming specific meals and snacks may variably affect disordered eating behaviors, in addition to the total number of meals/snacks consumed(17) (18).

Despite advances in treatment which have enabled less strict dietary regimes, careful planning to secure appropriate insulin dosage remains a cornerstone of diabetes management (19), as regularity in meal times and eating routines are important for optimal glycemic outcomes (20, 21). However, research on eating patterns and associated clinical outcomes in adolescents with T1D is scarce, lagging behind similar lines of investigation in healthy pre-adolescent and adolescent schoolchildren (22-24), youth with anorexia nervosa (13), adults with T1D (25), obesity (26), bulimia nervosa (18), binge eating disorder (27-29), type 2 diabetes (30), and bariatric surgery candidates (31).

Given the importance of eating behavior for insulin administration and metabolic control, greater knowledge about the frequency and pattern of meal and snack consumption among adolescents with T1D is warranted. The present study addressed three main aims: (1) How frequently are meals and snacks consumed by male and female adolescents with type 1 diabetes? (2) Is the frequency and pattern of meal and snack consumption associated with age, zBMI, eating disorder pathology, insulin omission due to shape/weight concerns or metabolic control? (3) Are there gender differences in the pattern of eating and associations with ED pathology and metabolic control?

METHOD

Participants and Procedure

As described in previous studies (32-34), the Norwegian Childhood Diabetes Registry (NCDR) is a nationwide, population-based registry, which includes all newly diagnosed

children with diabetes since 1989. In the Norwegian healthcare system, all children aged 0 –

14.9 years with suspected diabetes are referred to pediatric services, which perform and

report annual findings of standardized examinations to the NCDR. Children registered in the

NCDR are treated at hospitals and clinics across Norway, representing a large geographic

area. The current study is part of a larger register-based research study of the NCDR, which

originally included 850 participants aged 12–20 years. Between 2011 and 2012, these 850

individuals were invited to participate in an ancillary study using a structured interview to

assess psychosocial aspects and functioning related to T1D. The assessment was conducted at

Oslo University Hospital or another location of the participants' choice (usually their home or

school). A subtotal of 105 individuals (12%) aged 12-20 years agreed to participate and

returned a signed consent form via postal mail. To test baseline differences between

participants and non-participants, we compared our sample to the background T1D population

in the NCDR, which has a completeness of 95% (24). No differences were found for age,

zBMI, T1D duration, number of consultations with the diabetes team, number of consultations

with dieticians, or mode of treatment. Participants were slightly older at the onset of T1D than

the background NCDR population (9.6 vs 8.8 years, $p<0.05$), had somewhat lower HbA1c

(8.6% (70 mmol/mol) vs 8.9% (74 mmol/mol), $p<0.05$), and had fewer episodes of diabetes

ketoacidosis (0.02 vs 0.05, $p<0.05$). However, all effect sizes were small (0.2, −0.2, and −0.2,

respectively). The Regional Ethics Committee for Medical and Health Research (REK)

(#2009/1737a) and the data protection office at Oslo University Hospital approved the study.

Written informed consent was obtained from all participants and their parents if the

participant was below the age of 16 years.

Assessment

The *Child Eating Disorder Examination, v. 12.0 (ChEDE)* is a valid and reliable semi-structured, investigator-based interview which assesses core eating-disorder specific attitudes and behaviors in children and young adolescents up to the age of 18 years (35). A ChEDE global score provides an overall index of ED psychopathology that comprises four subscales: shape concern, weight concern, eating concern, and dietary restraint. Additionally, the ChEDE assessed frequency of binge eating (days), self-induced vomiting (days), excessive exercise (days), and insulin omission due to weight/shape concerns (days) during the past 28 days. The Norwegian version of the ChEDE was found to have adequate psychometric properties (36), including high inter-rater reliability. The internal consistency of the ChEDE subscales *dietary restraint, eating concern*, *weight concern*, and *shape concern* was satisfactory for the present study, with Cronbachs alpha's of .73, .85, .84, and .93, respectively.

Frequency of meal (breakfast, lunch, dinner) and snack (mid-morning, mid-afternoon, evening) consumption over the past week (7 days) was assessed using the "Pattern of Eating" ChEDE item. We note that the one-week timeframe differs from the 28-day period covered by the adult version of the Eating Disorder Examination interview (37), in line with ChEDE guidelines to improve accuracy of recall in youth (35). A 7-point Likert scale is used, with responses ranging from 0 (meal/snack not consumed) to 6 (meal/snack consumed every day). Since the response format is ordinal, but based upon an underlying continuous variable (days), we followed the procedures outlined by Matheson et al. (38) and Elran-Barak et al. (13) which involves transforming data into the numeric values representing the actual number of days meals and snacks were consumed. For the response "3", data was transformed into the

numeric value ("3.5") which represented the midpoint between 3-4 days, i.e., 0 = 0, 1 = 1, 2 = 2, 3 = 3.5, 5 = 5, 6 = 6, and 7 = 7 days.

HbA1c was determined for all participants by high-performance liquid chromatography (Tosoh G7; Tosoh Europe N.V., Belgium). All samples were analyzed in the same central laboratory and standardized according to the Diabetes Control and Complications Trial standards. The reference range was 4.0–6.0% (20-42 mmol/mol); the analytical coefficient of variation was <1%. For the present study, the most recent HbA1c level was used.

Body mass index was calculated based on weight and height (kg/m²) and standardized to a z-score (zBMI) according to age and gender using the Centers for Disease Control and Prevention Growth Charts 2000 (39). *zBMI* is age-adjusted and gender-adjusted BMI appropriate for those younger than 18 years old.

Statistical Analyses

Analyses were conducted using IBM SPSS Statistics for Windows, version 23 (IBM Corp., Armonk, N.Y., USA). We used chi-square analyses with Yates's correction for continuity to test the proportion of females and males reporting "daily" (coded as 7) versus "non-daily" eating (0 to 6). Fisher's exact test was used to test proportions for the mid-morning and mid-afternoon snacks due to less than expected minimum cell counts. Due to non-normality, Independent Samples Mann-Whitney U Tests were used to investigate gender differences in frequency of meal/snack consumption. For bivariate correlations, Spearman's rank order correlation coefficients were used to investigate relationships between frequency of meal/snack consumption and age, zBMI, binge eating (days), self-induced vomiting (days), excessive exercise (days), insulin omission due to weight/shape concerns (days), ChEDE scores (global, dietary restraint, shape concern, weight concern, eating concern), and

metabolic control (H1Abc). Effect sizes were interpreted according to Cohen's (40) criteria of .10 = small effect, .30 = medium effect, and .50 = large effect. Significance values of p < 0.05 were considered significant and all tests were two-tailed.

RESULTS

Sample Characteristics

Of the 104 participants, 61 (58.1%) were female and 44 (41.9%) were male. The mean age was 15.7 years (SD 1.8; range 12-20 years) and age at onset of T1D was 9.6 years (SD 3.5). Mean T1D duration was 5.6 (SD 3.6) years, mean zBMI was .4 (SD 0.8), and mean HbA1c was 8.6% (70 mmol(mol; SD 1.3). A total of 65.3% of the participants used insulin pumps and 33.7% used Multiple daily injection therapy (MDI) with a pen (MDI defined as one or two injections with long lasting insulin/long lasting insulin analog and rapid acting insulin analog to all meals, usually 3-5 times daily). Male and female participants did not differ significantly on age (years), HbA1c, age-adjusted and gender-adjusted body mass index (zBMI), age of onset, duration of diabetes illness (years), or mode of treatment (pump vs pen).

Frequency of Meal/Snack Consumption

As shown in Table 1, a significantly lower proportion of females (73.8%) than males (97.7%) consumed breakfast daily over the past week, $x^2 = 8.86$ (1), $p < .003$. A similar proportion of females and males (approximately 48%) consumed lunch on a daily basis. Approximately 90% of both genders consumed dinner on a daily basis. A non-significant trend was detected showing that a lower proportion of females consumed an evening snack daily, 29.5% versus 48.5%, $x^2 = 3.2$ (1), $p < .07$. As shown in Table 2, females consumed breakfast less frequently than males, and ate significantly fewer evening snacks and fewer total snacks. A supplemental total sample analysis found no significant differences between

patients using insulin pumps versus injection with pen with regard to breakfast (Ms 6.51 vs 6.69, p = .376), lunch (Ms 5.28 vs. 5.75, p = .230), dinner (Ms 6.75 vs. 6.71, p = .814), or the total number of meals (19.2 vs. 18.5, p = .231).

Correlations between eating pattern and ED pathology, insulin omission due to shape/weight concerns, and HbA1c

As shown in Table 3, less frequent breakfast consumption among females was significantly and negatively associated with higher global ChEDE scores, shape concerns, self-induced vomiting, binge eating, intentional insulin omission, and HbA1c (*rhos* = -.29 to -.42). Skipping lunch was significantly and negatively associated with HbA1c (*rho* = -.44). Skipping dinner was significantly associated with older age, increased dietary restraint, eating concerns, self-induced vomiting, and intentional insulin omission (*rhos* = -.027 to -.32). The total number of meals was significantly and negatively correlated with intentional insulin omission, self-induced vomiting, binge eating (*rhos* = -.025 to -.37), and metabolic control (*rho* = .49).

Among males, no significant associations were found between the pattern of eating and age, BMI, self-induced vomiting, binge eating, excessive exercise, intentional insulin omission, or metabolic control. Less frequent evening snack consumption was associated with elevated shape and weight concerns (*rhos* = -.43 and -.43), as well as the global EDE score (*rho* =.42) and skipping lunch was inversely associated with dietary restraint (*rho* = -.31) (data not shown).

DISCUSSION

This interview-based study investigated the frequency and pattern of meal and snack consumption among male and female adolescents with T1D and the associations with age,

zBMI, ED pathology, insulin omission due to shape/weight control, and metabolic control. Female adolescents with T1D consumed breakfast less frequently than males, with 25% skipping daily breakfast. This is in line with a prior study of adolescents with T1D (14), as well as findings from the general population suggesting that 20% of US adolescents skip breakfast, with trends toward decreased breakfast consumption during mid- adolescence, especially among females (41). Skipping breakfast is found to adversely affect appetite regulation and reduced cognitive functioning (23), and specifically, is associated with poor metabolic control among children and adolescents with T1D (42). In our study, roughly 50% of both genders consumed lunch on a daily basis, while the vast majority (i.e., 90%) ate dinner. Although comparable studies of adolescents with T1D are scarce, Øverby et al. found that 95% or more of adolescents with T1D (mean age 11.4 years) self-reported to eat breakfast and dinner more than five times a week, and that compared to their peers without diabetes, there are fewer children and adolescents with T1D who skip meals (42). Furthermore, our findings partly concur with a study of 574 healthy adolescents aged 12 to 17 years, who reported that three-quarters of adolescents ate lunch and over 90% consumed dinner on a regular basis (as defined as 23 of 28 days) (38). Mid-morning and mid-afternoon snacks were rarely consumed (1 to 3 times per week), with less than 5% in our sample reporting daily consumption, whereas evening snacks were consumed by approximately 30% of female and 50% of males. Overall, these rates are lower than reported by Heller et al. (25), who found that 80% of adults with T1D (mean age 47 years) consumed snacks during the week (25). Discrepancies in findings may relate to cultural differences or the social context of eating (43), or the younger age of our sample, for whom school routines which may limit the consumption of daytime snacks. It is also worth noting that T1D self-care may be influenced by psychosocial concerns (e.g. discomfort in front of peers) during school hours. Although

educational status was not measured in our study, the majority of children and adolescents in Norway attend school, thus it is possible that such concerns may have influenced meal consumption, blood glucose monitoring and insulin administration for some of the participants in the current study.

For female adolescents with T1D, irregular or infrequent consumption of meals was associated with poor metabolic control and increased ED pathology, including binge eating, self-induced vomiting, and insulin omission. Among male adolescents with T1D, only attitudinal features of ED pathology, not behavioral features or metabolic control, were significantly associated with eating frequency and eating pattern. Furthermore, findings revealed that the pattern of associations varied across specific types of meals. For instance, we detected a significant and inverse relationship between binge eating and frequency of breakfast consumption (rho = .423), but not lunch or dinner. Prior research has shown that skipping meals is associated with increased binge eating among individuals with bulimia nervosa (13, 28), in line with predictions based on restraint theory (44). Interestingly, snack consumption was unrelated to these indices; although it is possible we observed attenuated effects due to a restricted range of snack frequency, especially infrequent mid-morning and mid-afternoon snacks.

Collectively, these findings highlight the importance of assessing meal frequency and meal patterns among adolescents with T1D, as skipping meals appears to be a potential red flag for ED pathology, including intentional insulin omission for weight control. Although literature on meal frequency per se among patients with T1D is scarce, the association between eating disorder pathology and HbA1c is well established (45-47). Furthermore, one study of adolescents with T1D found that intuitive eating, particularly the effect of emotion on eating, was strongly associated with HbA1c (48). In the present study, we observed the

strongest association ($rho = -.492$) between the total number of meals and metabolic control. According to the International Society for Pediatric and Adolescent Diabetes (ISPAD), matching of insulin dose to dietary intake and blood glucose levels is increasingly encouraged to allow greater flexibility surrounding meal times with the aim of improving quality of life, yet "regularity in meal times and eating routines are still important for optimal glycemic outcomes" and "three meals a day incorporating a wide variety of nutrients" is recommended (19). Since the majority (>98%) of children and adolescent in Norway is taught to set insulin as a bolus (using the pump or the pen) related to carb content in meals and as correction of blood glucose before meals, the youths have the opportunity to be flexible with meals. Most children on insulin pump know how to use the carb content calculator incorporated in the insulin pump. However, they are taught the importance of regular meal consumption to improve metabolic control. Although likely confounding factors such as frequency of blood glucose monitoring and insulin injections were not accounted for in the present study, our findings suggest the importance of regular meal consumption to improve metabolic control in adolescents with T1D, in line with treatment guidelines (19). Diabetes management in children and adolescents targets the administration of appropriate insulin dosage according to dietary intake, and therefore, careful planning of meals in relation to blood glucose levels and subsequent insulin administration is vital.

Despite several studies on disturbed eating behaviors and intuitive eating in T1D, to our knowledge, this is the first study to investigate eating patterns in terms of consumption of specific meals and the associations with eating pathology among male and female adolescents with type 1 diabetes. Although the use of a well-validated semi-structured, face-to-face interview is strength of this study, the cross-sectional design and correlational data are weaknesses. We note that the 7-day timeframe on the ChEDE (35) differs from the 28-day

timeframe assessed by the adult version of the Eating Disorder Examination interview (6th edition, Fairburn & Cooper, 2008), in line with recommended procedures to improve recall accuracy in younger persons. Assessment informed by parental report and self-monitoring techniques, including ecological assessment methods, would have provided richer, more nuanced data and improve recall to extend over a longer period to determine the persistence and stability of findings. We advise that future research in adolescent T1D populations also extend beyond investigations of restraint theory to include potential diabetes-specific triggers of binge or disinhibited eating behaviors, such as perceived blood glucose levels or hypoglycemia (49). Hypoglycemia, for instance, requires eating fast-acting carbohydrates to increase blood glucose levels to prevent insulin shock, and has been previously associated with disinhibited eating behavior among adults with T1D (49). It is also important to note that the observed links between skipping meals and HbA1c may be influenced by other factors which were unmeasured, including the frequency of blood glucose monitoring, and psychological aspects related to self-care. Such factors have been associated with metabolic control in previous studies (50-53), are likely to be intimately related to meals, and should be investigated in relation to meal frequency and eating patterns. Our study included adolescents with T1D and findings may not generalize to adults with T1D. Regularity of food consumption by young persons, to a greater extent than adults, is likely affected by the availability of food and familial influences. Although other psychosocial or economic factors, including access to or limited availability of food, may have affected frequency of meal/snack consumption, the significant associations between meal frequency and eating pathology -- as well as metabolic control-- suggest that findings are nonetheless clinically meaningful. We hope these descriptive data lay the groundwork for future studies and that findings are suggestive for further research in this area.

In conclusion, the present data are clinically relevant and may inform assessment procedures and treatment planning for female adolescents with T1D. Assessment of eating patterns is a simple and straightforward index which could be easily incorporated as a routine screening method in diabetes management, with findings of irregular or infrequent meals triggering a more in-depth, comprehensive assessment of eating disorder pathology, including intentional insulin omission. As stated above, eating patterns, disturbed eating and insulin omission may be influenced by other important psychological aspects related to diabetes self-care and metabolic control. Integrating understanding of such factors to clinical practice may ultimately improve the poor prognosis associated with child-onset T1D co-occurring with eating disorder pathology.

ACKNOWLEDGEMENTS

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Table 1

Proportion of adolescents with Type 1 diabetes reporting daily consumption of breakfast,

lunch, dinner and snacks by gender (%)

	Female (N = 61)	*Male (N=43)*	X^2	*p*-value
Breakfast	73.8%	97.7%	8.86	< .003
Mid-morning snack	0%	4.7%	0.95	0.17 [a]
Lunch	45.9%	46.5%	0.00	1.0
Mid-afternoon snack	3.3%	4.7%	0.00	1.0 [a]
Dinner	88.5%	90.7%	0.01	0.98
Evening snack	29.5%	48.8%	3.23	0.07

Note: [a] Fisher's exact test reported due to less than minimum expected cell count. X^2 = chi-square analysis.

Table 2

Frequency of meal and snack consumption over the past week (M, SD, Md) in male and female adolescents with Type I diabetes (N = 104)

	M (SD)	*Md*	*z*	*p-value*	*Effect size*
Breakfast					
Females	6.4 (1.2)	7	-3.21	< .001	.314
Males	6.9 (.31)	7			
Mid-morning snack					
Females	1.4 (1.7)	0	-.216	0.83	.021
Males	1.7 (2.3)	0			
Lunch					
Females	5.5 (1.9)	6	-.481	0.63	.047
Males	5.7 (1.8)	6			
Mid-afternoon snack					
Females	2.5 (2.1)	2	-1.16	0.24	.114
Males	2.9 (2.3)	3.5			
Dinner					
Females	6.7 (1.1)	7	-.427	0.67	.041
Males	6.8 (.53)	7			
Evening snack					
Females	4.3 (2.4)	5	-3.12	< .002	.305
Males	5.7 (1.7)	6			
Total number meals					
Females	18.6 (2.7)	19	-1.54	0.13	.151
Males	19.5 (1.8)	20			
Total number snacks					
Females	8.1 (3.9)	8	-2.84	< .005	.278
Males	10.4 (4.0)	10.5			

Note: Effect sizes were calculated by $r = z/\sqrt{N}$ and interpreted according to Cohen's (1988) criteria of .10 = small effect, .30 = medium effect, and .50 = large effect. *M* = mean, *SD* = standard deviation, *Md* = median.

Table 3

Correlations between meal and snack consumption and age, Body Mass Index adjusted for age and gender (zBMI), eating disorder pathology, insulin omission due to shape/weight concerns, and metabolic control among female adolescents with Type 1 diabetes (N = 61)

	Age	zBMI	Global ChEDE	Shape Concern	Weight Concern	Eating Concern	Dietary Restraint	Self-induced vomiting (days)	Binge eating (days)	Excessive exercise (days)	Intentional Insulin Omission (days)	HbA$_{1c}$
Breakfast	-.031	-.140	-.250*	-.290*	-.146	-.096	-.153	-.326**	-.423**	-.341**	-.369**	-.254*
Mid-morning snack	.002	.169	.025	.086	-.023	.081	.088	-.051	.091	-.022	-.095	-.138
Lunch	.178	-.105	-.094	-.100	-.154	-.075	.032	-.100	-.179	.087	-.127	-.444**
Mid-afternoon snack	.016	-.037	.034	.037	-.001	.070	-.032	-.134	-.139	-.172	-.019	.054
Dinner	-.266*	-.153	-.215	-.191	-.148	-.305*	-.277*	-.319**	-.111	-.245	-.280*	-.066
Evening snack	-.003	-.241	.040	-.019	.091	.109	.099	-.034	.105	.138	.010	.138
Total Meals	.005	.010	-.243	-.254*	-.179	-.227	-.159	-.328**	-.366**	-.210	-.332**	-.492**

Note: Spearman rho values presented. *p < 0.05,** p < 0.01. Strength of relationships interpreted according to Cohen's (1988) criteria of .10 = small effect, .30 = medium effect, and .50 = large effect. ChEDE = Child Eating Disorder Examination, zBMI = body mass index adjusted for age and gender.