An Examination of Sex Differences in a Disease-Specific Model of Disordered Eating Behaviors in Type 1 Diabetes

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Abstract

Objective Preliminary evidence supports the integration of type 1 diabetes (T1D) disease-specific factors into eating disorder risk models. The current study explored whether cross-sectional associations among constructs included in the modified dual pathway model of eating disorder risk for individuals with T1D are similar across sex among adolescents and young adults with T1D. **Methods** Original study participants were recruited from the T1D Exchange Clinic Network, a U.S. registry of individuals with T1D. Online surveys included measures of general eating disorder risk factors, hypothesized T1D-specific risk factors, and a T1D-specific eating disorder questionnaire. The current study is a secondary analysis with the adolescents (13–17 years; $n=307$; 46.9% female) and young adults (18–25 years; $n=313$; 62.6% female) from the original sample. In the absence of strong measurement invariance for all measures of interest, sex-specific path models were estimated among the adolescent and young adult cohorts. **Results** Only two paths emerged as significant in the female, but not male, adolescent model. In the young adult cohort, all significant paths were the same across sex. **Conclusions** Both general and T1D-specific risk factors are associated with disordered eating behaviors in the T1D population. Patterns of associations were similar across male and female youth with T1D, suggesting that sex-specific prevention approaches to disordered eating behaviors among T1D youth may not be warranted.

Key words: diabetes; eating and feeding disorders; health behavior.

Introduction

Type 1 diabetes (T1D) is a common chronic illness (Karoen et al., 2000), affecting approximately 1.25 million American children and adults (<http://www.diabetes.org/diabetes-basics/statistics/>). T1D involves an immune-mediated destruction of pancreatic beta cells that produce endogenous insulin. T1D management requires daily balancing of exogenous insulin

administration, blood glucose (BG) monitoring, dietary intake, and exercise (American Diabetes Association, 2019a, 2019b). Managing T1D can be challenging, requiring attention to, and alteration of, eating behaviors, which may increase risk of restrictive and overeating behaviors.

Disordered eating behaviors (DEBs) refer to unhealthy behaviors, such as dieting, binge eating, and

purging, and insulin omission to avoid weight gain among individuals with T1D (Baechle et al., 2014; Colton, Olmsted, Daneman, Rydall, & Rodin, 2004). High rates of DEBs are well documented in youth with T1D, with 21–51% reporting these behaviors (Colton et al., 2004; Nip et al., 2019; Wisting, Froisland, Skrivarhaug, Dahl-Jorgensen, & Ro, 2013; Young et al., 2013). T1D may confer additional risk for DEBs due to disease-specific risk factors (e.g., dietary regimen, hunger/satiety disruption), but little work investigates whether there are sex differences in the risk factors for DEBs. This study tested whether a T1D-specific DEB risk model was similarly relevant for male and female adolescents and young adults with T1D.

Modified Dual Pathway Model of Disordered Eating

Until recently, no model of DEBs incorporated T1D-specific factors that may increase risk of DEBs. Peterson, Fischer, and Young-Hyman (2015) adapted the well-established dual pathway model (Stice, 2001) to include T1D-specific factors. The dual pathway model posits that internalization of the thin ideal and pressure to be thin leads to body dissatisfaction, which is associated with DEBs via dieting behavior and negative affect. The modified dual pathway model adds T1D-specific factors, including hunger/satiety disruption, BG fluctuations, and dietary regimen. Preliminary evidence from two cross-sectional studies supports the inclusion of these T1D-specific factors in the modified dual pathway model among adolescents (Peterson et al., 2018; Rancourt et al., 2019), young adults, and adults (Rancourt et al., 2019). While the modified dual pathway model was supported across all age groups, the strength of the associations may vary by age (Rancourt et al., 2019). Neither of these studies, however, explored whether associations among constructs were similar across sex, which has important implications for DEB screening and intervention among adolescents and young adults of both sexes.

Sex Differences in DEBs and Associated Risk Factors

There is substantial evidence that adolescent and young adult females with T1D report more DEBs than their male counterparts (e.g., Araia et al., 2017; Neumark-Sztainer et al., 2002). Adolescent and young adult females with T1D also report higher levels of DEB risk factors than males, including more dietary restraint (e.g., d'Emden et al., 2013), greater body dissatisfaction (e.g., Kaminsky & Dewey, 2014; Neumark-Sztainer et al., 2002), and more diabetes-specific negative affect (Brierley, Johnson, Young, Eiser, & Heller, 2012; Zoffmann, Vistisen, & Due-Christensen, 2014). Further, females with T1D are more likely than males to gain weight over time

(De Keukelaere et al., 2018). In addition to mean level differences, there is evidence that *associations* among constructs relevant to the modified dual pathway model are stronger for females than males (Wisting, Bang, Skrivarhaug, Dahl-Jorgensen, & Ro, 2015; Wisting et al., 2017). For example, female adolescents with T1D reported more frequent meal skipping than males, and this was significantly correlated with DEBs, but only among females (Wisting et al., 2017). Similarly, DEBs were significantly correlated with age, body mass index (BMI) z-scores (zBMI), and insulin omission, but only among female adolescents with T1D (Wisting et al., 2015). In all, little work examines sex differences in T1D-specific DEB risk factors. Preliminary work suggests that females with T1D may report higher mean levels of DEBs and associated risk factors than males, and that the associations among risk factors and DEBs may be stronger among females than males.

Current Study

The current study is a secondary data analysis exploring whether cross-sectional associations among constructs included in the modified dual pathway model are similar across sex. Given evidence that the strength of the associations may vary by age (Rancourt et al., 2019), sex differences were investigated among adolescents and young adults separately. Based on extant work, it was hypothesized that associations among the constructs would be stronger among females than males across both the adolescent and young adult samples.

Methods

Participants

Original study participants were recruited via email in August 2016 from the T1D Exchange Clinic Network, which has enrolled over 30,000 individuals with T1D across over 70 U.S.-based pediatric and adult endocrinology practices. Eligibility, consent, and data collection procedures for the T1D Exchange Clinic Network are published elsewhere (Beck et al., 2012). Inclusion criteria for the original study included aged 13–35 years old and T1D diagnosed for at least 1 year. Participants aged 13–17 years provided both assent and parental consent; those aged 18 years and older provided consent to participate. Participants completed an online survey. Study compensation was either a \$20 electronic gift card or a \$20 donation to a diabetes charity. This study was approved by the Jaeb Center for Health Research Institutional Review Board.

A total of 5,447 T1D Exchange cohort participants were eligible for the larger study and all were offered the opportunity to participate. Per funding limitations, recruitment was capped at 1,000 participants and the

survey was available between August 4 and August 21, 2016. Eligible individuals received an initial email notification about the study, as well as one follow-up reminder email. A total of 975 individuals (17.90%) accessed the survey and 818 (15.02%) from 67 of the 70 clinics completed the survey. Of the 818 participants (82% of the maximum sample size possible), 307 (37.53%) were adolescents (aged 13–17 years; $M = 15.71$, $SD = 1.33$; 46.91% female), 313 (38.26%) were young adults (18–25 years; $M = 21.20$, $SD = 2.10$; 62.62% female), and 198 (24.21%) were adults (26–35 years; $M = 30.51$, $SD = 2.81$; 68.53% female). Compared to T1D Exchange Clinic Network participants who did not participate in the study, those who completed the survey were more likely to be female (58% vs. 48%; $X^2(1) = 25.8$, $p < .001$), non-Hispanic White (85% vs. 80%; $X^2(1) = 9.8$, $p = .002$), have private insurance (81% vs. 76%; $X^2(1) = 9.0$, $p = .003$), use an insulin pump (69% vs. 61%; $X^2(1) = 20.2$, $p < .001$), use continuous glucose monitoring (CGM; 24% vs. 17%; $X^2(1) = 20.7$, $p < .001$), and have lower clinic-reported hemoglobin A1c (HbA1c; 8.3% vs. 8.9%; $t(5221) = 8.2$, $p < .001$).

Age cohorts were based on consensus statements from the Institute of Medicine (Institute of Medicine & National Research Council, 2015), the American Academy of Pediatrics (Hardin, Hackell, & AAP Committee on Practice and Ambulatory Medicine, 2017), and developmental theory (Arnett, 2000, 2006). Only adolescents (13–17 years) and young adults (18–25 years) were included in the current study; the adult cohort (26–35 years) was insufficiently powered to test for sex differences.

Materials

Demographic and Clinical Data

Demographic and clinical data (age, sex, race/ethnicity, health insurance type, insulin pump use, CGM use, most recent HbA1c value, and age at T1D diagnosis) were obtained from medical charts. Clinic-reported zBMI scores (age- and sex-adjusted for participants ≤ 20 years; Centers for Disease Control and Prevention, 2015) were obtained from the exam closest to study completion. Recent change in zBMI was calculated using data from approximately 12 months prior to study participation. For participants over 20 years old, zBMI scores were calculated using National Health and Nutrition Examination Survey (NHANES) data (Kuczmarski et al., 2002). Youth zBMI cutoffs for healthy, overweight, and obesity are based on corresponding adult BMI cutoffs, thus interpretation of adult and youth zBMI scores is appropriate (Cole, Bellizzi, Flegal, & Dietz, 2000).

Disordered Eating Behaviors

The 16-item Diabetes Eating Problem Survey—Revised (DEPS-R; Markowitz et al., 2010) captured diabetes-specific DEBs. Items are rated 0 (*never*) to 5 (*always*) and summed; higher scores indicate more DEBs. Scores of ≥ 20 suggest high risk for an eating disorder. Acceptable internal consistency was observed in the current sample of adolescents ($\alpha_{\text{female}} = .87$; $\alpha_{\text{male}} = .85$) and young adults ($\alpha_{\text{female}} = .84$; $\alpha_{\text{male}} = .85$).

Negative Affect

The Problem Areas in Diabetes Survey (PAID) captured negative emotions related to diabetes. Participants completed either the 26-item teen (Weissberg-Benchell & Antisdel-Lomaglio, 2011) or 20-item adult version (Polonsky et al., 1995). Items are rated 1 (*not a problem*) to 6 (*serious problem*). Items from the teen version are summed; items from the adult version are summed, and then multiplied by 1.25 for a total score between 0 and 100. Higher scores indicate more diabetes-specific negative affect. Scores were standardized within age-specific versions and then combined. Acceptable internal consistency was seen in the current sample of adolescents ($\alpha_{\text{female}} = .97$; $\alpha_{\text{male}} = .95$) and young adults ($\alpha_{\text{female}} = .95$; $\alpha_{\text{male}} = .96$).

Body Dissatisfaction

The 6-item Body Image subscale of the Screen for Early Eating Disorder Signs (SEEDS; Powers, Richter, Ackard, & Craft, 2016) captured body dissatisfaction. Items are rated 1 (*very dissatisfied*) to 7 (*very satisfied*), recoded, and summed. Higher scores indicate more body dissatisfaction. Acceptable internal consistency was observed in the current sample of adolescents ($\alpha_{\text{female}} = .92$; $\alpha_{\text{male}} = .87$) and young adults ($\alpha_{\text{female}} = .90$; $\alpha_{\text{male}} = .89$).

Dietary Restraint

Dietary restraint was measured using the 3-item Restraint subscale of the Three Factor Eating Questionnaire (TFEQ-R18V2; Cappelleri et al., 2009). Items are rated 1 (*definitely true*) to 4 (*definitely false*), with higher scores indicating greater dietary restraint. Data support its use with adults (Cappelleri et al., 2009) and adolescents (Maayan, Hoogendoorn, Sweat, & Convit, 2011). Internal consistency was acceptable in the current sample of adolescents ($\alpha_{\text{female}} = .90$; $\alpha_{\text{male}} = .85$) and young adults ($\alpha_{\text{female}} = .81$; $\alpha_{\text{male}} = .89$).

Hunger and Satiety Disruption

Diabetes-specific hunger/satiety was assessed using the 20-item Diabetes Treatment and Satiety Scale (DTSS-20; Young-Hyman, Davis, Looney, Grigsby, &

Peterson, 2011). Items are rated 0 (*never*) to 5 (*always*), with higher sum scores indicating greater hunger/satiety dysregulation. While previous research supports the internal consistency of this measure (Peterson et al., 2018; Young-Hyman et al., 2011), internal consistency was low in the current sample of adolescents ($\alpha_{\text{female}} = .58$; $\alpha_{\text{male}} = .55$) and young adults ($\alpha_{\text{female}} = .52$; $\alpha_{\text{male}} = .50$; Rancourt et al., 2019).

Dietary Regimen

A 6-item dietary regimen questionnaire was developed for the larger study (Rancourt et al., 2019). Items captured specific food-choice behaviors related to managing T1D (e.g., *I try to stick to a certain number of calories to manage my diabetes*) and are rated 1 (*very true*) to 5 (*very untrue*). Lower sum scores indicate a more restrictive dietary regimen. Acceptable internal consistency was observed among adolescents ($\alpha_{\text{female}} = .82$; $\alpha_{\text{male}} = .79$) and young adults ($\alpha_{\text{female}} = .78$; $\alpha_{\text{male}} = .82$) in the current sample.

Procedures

Survey data were collected and managed using Research Electronic Data Capture (REDCap) tools hosted by the Jaeb Center for Health Research.

Data Analytic Strategy

Descriptive statistics were generated using SPSS (v24). Measurement invariance testing and path analyses were conducted in MPlus 8 software using maximum likelihood estimation (Múthen & Múthen, 1998-2017). Multiple group (male vs. female) confirmatory factor analysis was used to test for measurement invariance separately for each age cohort. Per Rancourt et al. (2019), path models were estimated separately for adolescents and young adults, with age, T1D duration, insurance status, minority status, sex, current zBMI, HbA1c, and time since BMI measured (months since last measurement) included as covariates to all paths (Figure 1). Model fit was evaluated based on the root mean square error of approximation (RMSEA), comparative fit index (CFI), and standardized root mean square residual (SRMR). Exploratory tests of indirect effects were conducted on final path models using MODEL INDIRECT.

Results

Preliminary Descriptives

Among adolescents, no sex differences on demographic and T1D characteristics were observed. In young adults, females had a longer duration of T1D compared to males ($p < .001$; Table I). Across adolescent and young adult cohorts, all but two variables of interest demonstrated sex differences (Table II).

Compared to males, female participants reported more DEBs, greater body dissatisfaction, more T1D-specific negative affect, greater dietary restraint, and a more restrictive T1D dietary regimen, as well as higher zBMI. Correlations by sex and cohort are provided in Supplementary Tables 1 and 2. Based on the recommended DEPS-R cut-score of ≥ 20 , 29.64% of adolescents ($n = 91$) and 34.50% of young adults ($n = 108$) were at risk for an eating disorder. More females than males reported problematic levels of DEBs in both age groups (adolescents: 42.36% vs. 18.40%; young adults: 41.32% vs. 23.08%).

Measurement Invariance Testing

Among adolescents, only dietary restraint and hunger/satiety disruption emerged as strongly invariant across sex. Body dissatisfaction and dietary regimen demonstrated weak invariance, and the DEB and T1D-specific negative affect measures were not invariant across sex (Supplementary Table 3). As strong measurement invariance is required for all variables in order to conduct multiple group tests of the path model, path analyses were conducted separately by sex for the adolescent cohort.

Measurement invariance testing in the young adult cohort revealed that only dietary restraint and dietary regimen emerged as strongly invariant across sex. All remaining measures demonstrated weak invariance (Supplementary Table 4). Based on these findings, and for the reason stated above, path models were estimated separately by sex for the young adult cohort.

Adolescents

Path models for the male, $X^2(7) = 14.67$, $p = .041$, CFI = .97, RMSEA = .08, SRMR = .04, and female groups, $X^2(7) = 2.12$, $p = .953$, CFI = .95, RMSEA = .00, SRMR = .02, demonstrated acceptable fit. Most significant paths were similar across sex (Table III). Only two paths reached significance in the female, but not the male, model. A more permissive dietary regimen was associated with more DEBs ($p < .01$), and greater body dissatisfaction was associated with more dietary restraint ($p < .01$) in female adolescents. Hunger/satiety disruption was not significantly associated with any variable in either model.

Exploratory tests of four indirect effects suggested three significant indirect pathways among females, but only two among males. For both sexes, a more restrictive dietary regimen was associated with greater dietary restraint, which in turn was associated with more DEBs ($p < .01$). Greater body dissatisfaction was associated with greater T1D-specific negative affect, which was associated with more DEBs ($p = .013$). Among females, greater body dissatisfaction was associated with more dietary restraint, which was associated with more DEBs ($p < .01$).

Figure 1. Modified dual pathway model adapted from [Rancourt et al. \(2019\)](#). (Copyright © 2019 Wiley Periodicals, Inc.)

Note: Dashed lines indicate disease-specific pathways.

Young Adults

Path models for both the male ($X^2(7) = 1.59$, $p = .979$, CFI = 1.00, RMSEA = .00, SRMR = .02), and female groups ($X^2(7) = 6.21$, $p = .516$, CFI = 1.00, RMSEA = .00, SRMR = .03), demonstrated acceptable fit. Contrary to hypotheses, all paths that emerged as significant were the same across sex ([Table III](#)). Of note, hunger/satiety disruption was associated with a more restrictive dietary regimen ($ps < .012$). One indirect effect path was significant and suggested that greater body dissatisfaction was associated with more T1D-specific negative affect, which in turn was associated with more DEBs ($ps < .01$).

Discussion

The current study examined potential sex differences in a T1D-specific model of DEBs for adolescents and young adults with T1D. Consistent with prior research, females endorsed higher levels DEBs than males, regardless of age. Contrary to hypotheses, similar patterns of associations were observed across males and females for adolescents and young adults. As in previous work ([Rancourt et al., 2019](#)), more permissive dietary regimen, higher body dissatisfaction, and

higher T1D-specific negative affect all had significant direct effects on DEBs among both males and females. Results underscore the importance of including T1D-specific risk factors for both sexes in clinical and research endeavors targeting DEBs.

While the overarching models looked similar across sex, there were a few notable exceptions in the adolescent cohort. Among adolescent females there was a significant relationship between dietary regimen and DEBs, such that less restrictive dietary regimen was associated with more DEBs. Further, greater body dissatisfaction was related to greater dietary restraint in adolescent females, but not males. While females with T1D report more dietary restraint and body dissatisfaction than males ([d'Emden et al., 2013](#)), we are unaware of studies that distinguish between a T1D-specific dietary regimen that involves dietary restriction (e.g., limiting carbohydrates) and general dietary restraint. The current study suggests the need to distinguish these two types of dietary restraint in the context of assessing risk for DEBs, especially among adolescent females.

Contrary to expectations, there were no differences observed in the relationships between proposed DEB risk factors and DEBs by sex among young adults. These findings suggest that assessing for mean

Table I. Demographic Means/Counts (Standard Deviation/Percent) by Sex and Cohort

Characteristics	Females	Males	<i>p</i>	Effect size
Adolescents (<i>n</i> = 307)				
Female	144 (46.9%)	163 (53.1%)		
Age (years)	15.89 (1.33)	15.60 (1.32)	.117	.18
Time since diagnosis (years)	7.45 (3.51)	7.87 (3.78)	.318	-.11
Time since BMI measurement	4.53 (3.70)	3.95 (3.69)	.169	.16
Race/ethnicity			.172	.13
White Non-Hispanic	115 (83.71%)	142 (81.79%)		
Black Non-Hispanic	6 (3.26%)	4 (4.47%)		
Hispanic or Latino	16 (7.82%)	8 (8.31%)		
Other Race/Ethnicity	7 (5.21%)	9 (5.43%)		
Insurance status			.458	.07
Private insurance	104 (76.5%)	125 (80.1%)		
Other insurance	31 (22.8%)	31 (19.9%)		
No insurance	1 (0.7%)	0 (0%)		
Insulin pump	97 (68.31%)	111 (68.52%)	.969	.002
Continuous glucose monitoring	30 (21.12%)	36 (22.09%)	.839	.01
Most recent HbA1c	8.56% (1.52%)	8.51% (1.61%)	.784	.03
Young Adults (<i>n</i> = 313)				
Female	196 (62.6%)	117 (37.4%)		
Age (years)	21.39 (2.05)	20.90 (2.16)	.050	.23
Duration since diagnosis (years)	11.84 (4.68)	9.96 (5.11)	< .001	.39
Time since last BMI measure (months)	4.37 (3.42)	4.75 (3.55)	.377	-.11
Race/ethnicity				
White Non-Hispanic	158 (80.6%)	98 (83.8%)	.680	.07
Black Non-Hispanic	9 (4.6%)	5 (4.3%)		
Hispanic or Latino	16 (8.2%)	10 (8.5%)		
Other Race/Ethnicity	13 (6.6%)	4 (3.4%)		
Insurance status			.985	.01
Private insurance	155 (81.2%)	93 (80.9%)		
Other insurance	34 (17.8%)	21 (18.3%)		
No insurance	2 (1.0%)	1 (0.8%)		
Insulin pump	135 (69.2%)	83 (72.2%)	.584	.03
Continuous Glucose Monitoring	66 (21.64%)	66 (21.09%)		
Most Recent HbA1c	8.39% (1.80%)	8.30% (1.75%)	.358	.05

Note. Welch test statistics interpreted. One young adult identified as transgender. Insurance status missing for 15 adolescents and 7 young adults. Insulin modality missing for 3 adolescents and 3 young adults. Continuous glucose monitor use status missing for 2 adolescents. HbA1c information missing for 1 young adult. Effect size is Hedge's *g* or Cramer's *V*.

Table II. Comparison of Means (Standard Deviation) of Variables of Interest Across Sex by Cohort

	Females	Males	<i>p</i>	Hedge's <i>g</i> (unbiased)
Adolescents				
Disordered eating behaviors	18.56 (11.66)	11.84 (9.54)	< .001	.63
Body dissatisfaction	24.15 (8.97)	17.33 (7.99)	< .001	.80
Hunger/satiety disruption	1.93 (0.43)	1.89 (0.42)	.410	.09
Diabetes-specific negative affect ⁺	0.26 (1.05)	-0.23 (0.89)	< .001	.51
Dietary regimen	22.33 (5.70)	23.62 (4.97)	.036	-.24
Dietary restraint	2.02 (0.84)	1.48 (0.63)	< .001	.74
zBMI	0.90 (0.72)	0.53 (1.07)	< .001	.40
Change in zBMI	-0.08 (0.20)	0.04 (0.37)	.137	-.26
Young adults				
Disordered eating behaviors	18.82 (10.40)	14.14 (10.31)	< .001	.45
Body dissatisfaction	26.54 (7.72)	20.33 (7.85)	< .001	.80
Hunger/satiety disruption	1.84 (0.41)	1.79 (0.38)	.259	.13
Diabetes-specific negative affect ⁺	0.16 (0.97)	-0.26 (0.99)	< .001	.43
Dietary regimen	21.67 (5.44)	23.27 (5.43)	.012	-.29
Dietary restraint	2.22 (0.73)	1.78 (0.82)	< .001	.56
zBMI	0.50 (1.85)	0.13 (1.11)	.035	.23
Change in zBMI	0.20 (0.46)	0.17 (0.41)	.776	.06

Note. Adolescents were 13–17 years old. Young adults were 18–25 years old. ⁺Scaled score due to difference in number of questions on teen version. zBMI = BMI *z*-score. Welch test statistics were interpreted. Bolded = *p* < .05.

Table III. Unstandardized and Standardized Path Estimates from Path Model for Adolescents and Young Adults by Sex

Path	Adolescents (<i>n</i> = 307)				Young adults (<i>n</i> = 313)			
	Females		Males		Females		Males	
	<i>b</i>	β	<i>b</i>	β	<i>b</i>	β	<i>b</i>	β
Disordered eating behaviors ON								
Body dissatisfaction	.37	.29	.28	.23	.53	.39	.48	.36
Dietary restraint	2.11	.15	3.02	.20	1.15	.08	1.26	.10
Diabetes-specific negative affect	6.04	.55	4.71	.44	4.22	.40	3.64	.35
Hunger/satiety disruption	.38	.01	.81	.04	1.49	.06	1.54	.06
Dietary regimen	.33	.16	.07	.03	.25	.13	.38	.20
Dietary restraint ON								
Body dissatisfaction	.03	.36	.01	.13	.03	.29	.04	.39
Dietary regimen	−.05	−.32	−.04	−.31	−.06	−.40	−.06	−.40
Body dissatisfaction ON								
Change in zBMI	7.68	.17	−2.50	−.162	−1.52	−.12	−4.31	−.22
Diabetes-specific negative affect ON								
Body dissatisfaction	.07	.56	.04	.38	.06	.43	.05	.41
Dietary restraint	.11	.09	.12	.08	.07	.05	.04	.04
Hunger/satiety disruption	.07	.03	.12	.06	.26	.11	.07	.03
Dietary regimen WITH								
Change in zBMI	−.004	−.004	.35	.19	−.46	−.14	−.57	−.26
Hunger/satiety disruption	−.04	−.02	−.24	−.11	−.40	−.18	−.41	−.20
Change in zBMI WITH								
Hunger/satiety disruption	.002	.02	.01	.05	.02	.06	−.004	−.02
Test of indirect effects								
Diet. regimen → Diet. restraint → DEBs	−.10	−.05	−.12	−.06	−.06	−.03	−.08	−.04
Body diss. → Diet. restraint → DEBs	.07	.05	.03	.03	.03	.02	.05	.04
Body diss. → Neg. affect → DEBs	.39	.30	.20	.17	.23	.17	.19	.14
Diet. restraint → Neg. affect → DEBs	.65	.05	.55	.04	.28	.02	.15	.01

Note. zBMI = BMI z-score. DEBs = Disordered eating behaviors. Bolded statistics indicate significant at $p < .05$. β = standardized effect and can be interpreted as effect size (Kline, 2005). Models estimated separately by sex.

differences is insufficient to conclude that risk varies by sex. While mean differences were observed in the current study, the *associations* between the constructs were similar across male and female young adults.

Interestingly, our results showed that hunger/satiety disruption did not differ by sex. This finding is somewhat different than general population studies, which demonstrate sex differences in constructs related to the experience of hunger, such as perceived satiety and meal satisfaction (e.g., Monrroy et al., 2019). We assessed hunger/satiety disruption related to T1D (e.g., hunger accompanying hypoglycemia), which may be interpreted differently than general hunger. For example, there may be fewer gender-focused stereotypes associated with T1D-specific hunger compared to experiences of general hunger. It was surprising, however, that hunger/satiety disruption was unrelated to DEBs. Given this lack of findings and the low internal consistency of the measure used, further work is needed to better understand this potential risk factor and its utility in predicting DEBs in the T1D population.

While not the primary aim of this study, our findings support work suggesting that some DEB measures may not be statistically equivalent across sex (e.g., Schaefer, Harriger, Heinberg, Soderberg, & Kevin Thompson, 2017). Most study measures did not demonstrate strong metric invariance across sex,

precluding direct quantitative comparisons of the path model across sex. Notably, the measure of DEBs demonstrated poor measurement fit in both age cohorts, suggesting additional psychometric work is needed. With samples of approximately 150–180 participants per gender, per age cohort, this study was underpowered for testing measurement invariance of longer measures (e.g., PAID), which may have impacted findings. While measurement testing provides future directions for examining study constructs, ultimately, the focus of this study was to highlight clinically relevant factors associated with DEBs to provide guidance for assessment and intervention in the T1D population.

Clinicians working with adolescents and young adults with T1D may benefit from assessing DEBs, as well as tracking risk factors for DEBs over time. While the DEPS-R needs additional psychometric testing, this measure provides important information on T1D-specific DEBs, and is brief and easily scored. Increased scores on measures of body dissatisfaction (SEEDS) and diabetes-specific negative affect (PAID) may represent increased DEB risk and indicate the need for a more comprehensive eating disorder assessment. Providers also may benefit from assessing dietary regimen and dietary restraint to understand the extent to which patients are conflating the two in ways that are leading to maladaptive dietary behaviors.

The current study has a number of strengths, including a large sample size, the application of path analysis, and roughly equal numbers of males and females in both age cohorts. Nonetheless, there are several limitations worth noting. First, only 15% of the eligible T1D Exchange cohort was captured. There also were differences between responders and nonresponders, such that participants were more likely to be female, Caucasian, have private insurance, use diabetes devices, and have a lower A1c. Thus, findings may not generalize to more diverse populations. Nevertheless, similar response patterns have been documented in other T1D Exchange studies (Jaser et al., 2017; Petry et al., 2018) and other T1D studies (Litchman, Edelman, & Donaldson, 2018; Moskvich et al., 2019). Further, the T1D Exchange cohort is a large, national sample with more geographic and demographic diversity than could be obtained from a single clinic. Second, strong measurement invariance was not obtained for most study measures, requiring models be estimated separately by sex. The DEB and hunger/satiety disruption measures demonstrated poor psychometrics, warranting additional psychometric investigations of these measures. Third, we did not collect objective glucose data (e.g., with continuous glucose monitors). This is a valuable next step to identify temporal relationships between glucose fluctuations, hunger/satiety disruption, and DEBs as suggested by Peterson et al. (2015). Finally, data from the current study are cross-sectional, precluding conclusions about causal relationships among study variables. Longitudinal designs are needed to test the temporal ordering of constructs and identify mechanistic pathways for intervention.

In conclusion, this study supports the potential utility of both medical and psychological approaches to reduce DEBs among adolescents and young adults with T1D of both sexes. While sex-based norms of DEB risk factors and DEBs themselves may be needed, clinical assessments and interventions targeting body dissatisfaction, T1D-specific negative affect, and dietary restraint, may contribute to reduced risk of DEBs across both males and females with T1D. For adolescent females in particular, our study extends prior work and suggests that a less restrictive dietary regimen is also an important risk factor to assess for DEBs. Although further examination is needed, it is clear that routine screening for DEBs among both male and female youth in T1D clinics may help identify at-risk individuals and prevent psychological and medical comorbidities.

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Supplementary Data

Supplementary data can be found at: <https://academic.oup.com/jpepsy>.

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