Momentary Predictors of Insulin Restriction Among Adults With Type 1 Diabetes and Eating Disorder Symptomatology

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OBJECTIVE

Individuals with type 1 diabetes who restrict insulin to control weight are at high risk for diabetes-related complications and premature death. However, little is known about this behavior or how to effectively intervene. The aim of the current study was to identify predictors of insulin restriction in the natural environment that might inform new treatment directions.

RESEARCH DESIGN AND METHODS

Eighty-three adults with type 1 diabetes and a range of eating disorder symptomatology completed 3 days of ecological momentary assessment. Participants reported emotions, eating, and insulin dosing throughout the day using their cellular telephone. Linear mixed models were used to estimate the effects of heightened negative affect (e.g., anxiety) before eating and characteristics of the eating episode (e.g., eating a large amount of food) on the risk of insulin restriction.

RESULTS

Individuals who reported greater-than-average negative affect (general negative affect and negative affect specifically about diabetes) during the study period were more likely to restrict insulin. Momentary increases in anxiety/nervousness and guilt/disgust with self before eating (relative to an individual's typical level) further increased the odds of restricting insulin at the upcoming meal. Insulin restriction was more likely when individuals reported that they broke a dietary rule (e.g., "no desserts").

CONCLUSIONS

Results suggest that insulin restriction might be decreased by helping patients with type 1 diabetes respond effectively to heightened negative affect (e.g., anxiety, guilt) and encouraging patients to take a less rigid, punitive approach to diabetes management.

Intentionally underdosing or omitting insulin to lose weight is a significant problem in the clinical management of type 1 diabetes (1–3). Studies indicate 30–40% of young women with type 1 diabetes engage in this behavior (4–6), tripling their risk of early and severe neuropathy, nephropathy, and retinopathy and premature death (1,7,8). Rather than being a transient problem of youth with type 1 diabetes, insulin restriction for weight loss, as well as other eating disorder (ED)

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symptomatology, is likely to persist and reoccur (9–11). Although studies document the prevalence and effect of this behavior, little is known about the factors that influence the momentary decision to withhold insulin or how best to intervene. Conventional treatments for EDs are largely ineffective in reducing intentional insulin restriction among individuals with type 1 diabetes, highlighting the need for more research to delineate key treatment targets (12–15).

Intentional insulin restriction is often conceptualized as a form of purgative behavior and described within the context of bulimia nervosa (16). Previous studies with populations without diabetes have suggested a dual pathway to bulimic symptomatology (17). First, studies have indicated individuals with bulimia nervosa binge and purge in response to heightened negative affect (18). Purging appears to be independently triggered by negative affect, occurring in the absence of a binge 39% of the time (19).

Second, studies have found individuals with bulimia nervosa are more likely to purge when they consume amounts or types of food that they consider unacceptable and experience a loss of control and guilt or shame for their eating. This may include times in which they consumed an objectively large amount of food as well as times in which they ate a small or normal amount of food but violated a personal rule (e.g., "no desserts") (20).

The aim of the current study was to identify real-time precursors and correlates to insulin restriction among individuals with type 1 diabetes exhibiting a range of ED symptomatology. It is informed by previous literature on antecedents to ED behavior that have not been tested in this unique population. We examined general negative affect as well as affect specifically related to diabetes as predictors of intentional insulin restriction (21,22). We also tested the relative importance of characteristics of the eating episode (e.g., eating a large amount of food) in predicting this specific purge behavior. Given the minimal amount of information about this patient population (6,23), we identified momentary fluctuations in experience (e.g., heightened negative affect) as well as more stable, individual differences (e.g., a general tendency to experience high negative affect) that increase the odds of restricting insulin in the natural environment.

A secondary aim was to investigate the effect of insulin restriction on postmeal affect. Although studies have indicated that purging decreases negative affect (suggesting that it is reinforced by emotional relief) (18), research has also indicated that ED behaviors may have emotional trade-offs, reducing some painful emotions (e.g., anxiety) while increasing others (e.g., guilt) (24).

RESEARCH DESIGN AND METHODS

Participants

Participants were recruited through Duke University Medical Center and University of North Carolina patient registries, online advertisements, and flyers placed in nearby clinics as part of a larger investigation of EDs in type 1 diabetes. Recruitment materials described the study as an investigation of eating and weight concerns and their effect on type 1 diabetes management. Interested individuals contacted the study coordinator for eligibility screening. Participants had to be 18–65 years of age and have type 1 diabetes. They also had to screen negative for hypoglycemic unawareness (25) and for cognitive disabilities that preclude independent diabetes management.

Eligibility criteria for the larger investigation included a score $\geq$20 on the Diabetes Eating Problem Survey–Revised (DEPS-R) (26). The DEPS-R is a diabetes-specific measure of ED symptomatology that includes items that assess insulin restriction as a maladaptive weight-control strategy (e.g., "I try to keep my blood sugar high so that I will lose weight") as well as attitudes related to this behavior (e.g., "losing weight is an important goal to me"). DEPS-R scores $\geq$20 have been associated with higher HbA_{1c} (27). After exceeding the initial study recruitment target (n = 63), we opened enrollment to individuals with lower DEPS-R scores ($<$20; n = 20) to capture the continuum of ED pathology from full and subthreshold EDs to subclinical eating and weight concerns. This permitted us to answer additional questions of the data set and also allowed results to not be limited to individuals with more extreme pathology, which is a subset of this larger at-risk population (10).

Procedure

The study protocol was approved by the Duke University Health Systems Institutional Review Board. Participants documented informed consent before data collection and signed a release for their physician to be contacted for health information (e.g., diagnosis). Participants completed a blood draw to determine HbA_{1c}; self-report measures, including readministration of the DEPS-R, which is time sensitive, and the Brief Symptom Inventory (28); and a clinician-administered ED diagnostic interview (Eating Disorder Examination-16.0 [29]). Participants then underwent placement of a sensor for continuous glucose monitoring (CGM) and completed 3 days of ecological momentary assessment (EMA) in which they used their cellular phones to report emotions, eating, and insulin dosing throughout the day.

EMA

EMA was conducted using Ifbyphone, an automated telephone survey system that enables investigators to create study-specific questions and obtain quantitative responses via random and participant-initiated telephone calls. Participants received randomly generated calls 1–2 times an hour (from 8:00 A.M. to 10:00 P.M.) and placed calls immediately after eating to report meals/snacks throughout the day. They could also place an incoming call if they missed a random call but were instructed to do so within 20 min of the prompt. Each call took 1–2 min to complete.

Surveys used voice prompts to present each item, and participants responded by pressing telephone keys. Participants rated current emotions (happy, sad, frustrated, angry, anxious or nervous, guilty, or disgusted with yourself) and responded to two diabetes-specific items: "How upset do you feel about your diabetes or diabetes management?" and "How much do you want to put diabetes out of your mind?" using a 6-point Likert scale (1 = not at all, 6 = very much). When reporting a meal/snack, participants were also asked the time that they had started eating and the following questions characterizing the eating episode:

1) "Did you break a food rule or routine, such as eating off schedule or eating foods that you would typically not allow yourself to have?"
2) "Did you eat a large amount of food, more than would be typical of others in a similar situation?"
3) "Did you eat until you were uncomfortably full?"
4) "Did you experience a loss of control over your eating?"
5) "Do you feel guilty, shameful, or disgusted with yourself for your eating?"

The first three items were dichotomous ("yes" or "no"). The remaining items used the 6-point scale described above. At each eating report, participants were also asked: "Did you take enough insulin to cover your food?" They could press keys indicating "yes," "maybe," or "no." Participants were instructed to respond "no" if they intentionally took less insulin than was needed (underdosed) or completely omitted a necessary insulin dose.

Before beginning the 3-day assessment, participants were trained in telephone survey procedures. They reviewed a participant booklet with construct definitions and identified personal examples of anchor items for scaled responses (e.g., sad at a "1" vs. sad at a "6") and examples of their own dietary rules, if they had any. Dietary rules were described to participants as personal guidelines for eating that one tries hard to adhere to (e.g., "no desserts"). Participants' rules could be grounded in personal beliefs about how particular foods affect their blood glucose (BG), their weight, or both.

CGM was performed using the Medtronic iPro or iPro2 and was masked to reduce experimental reactivity. OneTouch meters and test strips were provided to participants for daily self-monitoring of BG for CGM calibration.

Data Analytic Strategy

Data Preparation and Bivariate Correlations

To determine the level of participation, we calculated the percentage of random calls completed by participants and the number of eating reports over the 3-day period. We time-synced the eating report, random prompt, and CGM data. We identified eating episodes that occurred when participants were below 70 mg/dL by examining three CGM data points before a meal, which represented 15 min before eating.

We examined distributions for all key variables. We used the CGM data to calculate participants' mean BG and the percent of total time each participant spent above 180 mg/dL during the 3 days. We tested the expected positive relationship between participants' metabolic control and the percentage of eating episodes for which insulin was restricted using partial Pearson correlation coefficients controlling for insulin pump use.

Predictors of Insulin Restriction

Insulin restriction at each eating occasion was defined as responding "no" to the question: "Did you take enough insulin to cover your food?" Episodes in which participants responded "maybe" to this question were excluded because this response was likely to also capture uncertainty about carbohydrate or insulin calculations (data not reported). We excluded eating episodes that occurred when BG was below 70 mg/dL, given that low BG might affect mood, eating, and insulin dosing but not reflect ED symptomatology. We also excluded eating episodes for which CGM data were missing and the BG level could not be ascertained.

We used a multilevel modeling approach to account for the nesting of observations of insulin restriction (30) and distinguish among within- and between-person effects (e.g., fluctuations in negative affect relative to the individual's typical level vs. an individual's typical level of negative affect relative to the group) (31,32). Given our aim of broad applicability, analyses were first conducted using the full sample. We then repeated these analyses using only participants who met the threshold for clinically significant symptoms as indicated by a DEPS-R score $\geq$20 on at least one of the two administrations and/or ED symptoms reported on the Eating Disorder Examination-16.0 that met criteria for an ED diagnosis (10).

Emotional State Before Eating. We used affect ratings from answered random calls and constrained usable eating episodes to those with affect reports within 60 min of a meal. Lag time between the affect report and start of eating was statistically controlled. We first tested a composite variable of general negative affect (computed as the mean of five items: sad, frustrated, angry, anxious/nervous, guilty/disgusted with self) as a predictor of insulin restriction. We then tested each emotion individually to determine which emotions incurred the greatest risk for insulin restriction. Our diabetes-specific items (e.g., upset about diabetes) were not included in the composite negative affect variable and were tested separately.

We used a two-level generalized linear mixed-modeling strategy with random intercepts and person-mean centering (see Supplementary Appendix A for additional information). We used the SAS PROC GLIMMIX procedure with maximum likelihood adaptive Gauss-Hermite quadrature estimation, logit link function, binary distribution, between-within method to estimate denominator degrees of freedom, and odds ratio (OR) display command.

Characteristics of the Eating Episode. We again used the GLIMMIX procedure with person-mean centering to predict insulin restriction with continuous time-varying predictors (e.g., loss of control). For dichotomous time-varying predictors (e.g., break a rule), we used grand-mean centering (see Supplementary Appendix B). After examining the individual effect of each of the predictors on risk of insulin restriction, we entered all predictors simultaneously to determine which characteristics of the eating episode remained significant after statistically controlling for the other characteristics. Although characteristics of the eating episode are likely related (e.g., eating a large amount of food may be associated with more guilt), conceptually they are distinct and may provide unique targets for intervention (33).

Insulin Restriction Predicting Postmeal Affect

Secondary analyses tested whether insulin restriction predicted a composite negative affect variable before conducting follow-up analyses predicting individual affect states (e.g., anxiety) and diabetes-specific variables (e.g., upset about diabetes). We used a two-level linear mixed modeling strategy using PROC MIXED procedure with maximum likelihood estimation, between-within estimator of denominator degrees of freedom, and an unstructured assumption for residual variances. The effect of insulin restriction was grand-mean centered (see Supplementary Appendix C).

RESULTS

Sample Characteristics

Eighty-three adults with type 1 diabetes participated in the study. The sample was mostly Caucasian (86.7%) and female (88%), consistent with the demographics of other ED populations (34). Participants were aged from 18 to 68 years (mean, 41.89; SD, 12.43). Most participants were at least college-educated and used an insulin pump (Table 1).

Descriptive Information

Five participants discontinued the study prematurely (e.g., completed self-report measures but did not complete EMA), and four were missing most or all of their CGM data due to technical failures (e.g., sensor dislodged). The remaining participants responded to an average of 96.46% of the random prompts and reported a total of 1,002 meals/snacks. Mean number of eating episodes reported per day was 4 (mean over the 3 days, 12.85; SD, 3.38).

Table 1—Participant demographics (*N* = 83)

Characteristic	Mean (SD) or %
Age (years)	41.89 (12.43)
Female sex	88.00
Race/ethnicity	
Caucasian/white	86.70
African American/black	10.80
Asian/Pacific-Islander	1.20
Hispanic	1.20
Marital status	
Never married	22.90
Married	63.90
Separated/divorced	12.00
Widowed	1.20
Highest level of education	
High school graduate or GED	6.00
Some college/technical school	19.30
Bachelor degree	54.20
Graduate degree	20.50
Age at type 1 diabetes diagnosis (years)	18.46 (10.73)
Duration of type 1 diabetes (years)	23.43 (13.39)
Treatment regimen	
Insulin pump therapy	62.70
Multiple daily injections	37.30
HbA_{1c} (%)	8.8 (2.32)
HbA_{1c} (mmol/mol)	73 (2)

Thirty-six eating episodes were missing necessary self-report data (e.g., time of eating). An additional 168 eating episodes were excluded from analyses because of missing CGM data, and 73 episodes were excluded for BG below 70 mg/dL. This left 455 eating episodes that had reports of insulin restriction of "yes" or "no" (rather than "maybe") in response to the question "Did you take enough insulin to cover your food?" Participants reportedly dosed appropriately for 353 of these eating episodes and restricted insulin for 102 of these episodes (22%).

Intraclass correlation coefficients (ICCs) indicated that 50.7% of the variability in insulin restriction and a substantial portion of the variance in affect (ranging between 15.3 and 53.5%) were attributable to within-person fluctuations rather than between-person differences. Sadness exhibited the lowest proportion of variability due to between-person characteristics (ICC = 0.47), and "upset about diabetes" (ICC = 0.74) and "diabetes out of mind" (ICC = 0.85) showed the highest proportion of variance due to between-person factors.

Frequency of Insulin Restriction and Relationship to Metabolic Control

Participants' frequency of insulin restriction was variable, with some participants reporting never restricting insulin during the 3-day assessment and others reporting restricting bolus insulin 100% of the time (mean, 14.82%; SD, 23.63%). Frequency of insulin restriction was not significantly correlated with insulin pump use or other demographics.

BG ranged from 40 to over 400 mg/dL (mean, 184.21; SD, 59.11). On average, participants spent 43.23% (SD, 24.07%) of their total time above 180 mg/dL. The percentage of eating episodes in which participants reported insulin restriction was correlated with their mean BG (r = 0.55, $P < 0.001$) and percent of time spent above 180 mg/dL (controlling for insulin pump use) (r = 0.51, $P < 0.001$).

Predictors of Insulin Restriction

Emotional State Before Eating

There were 299 eating episodes (70 with insulin restriction) that had affect reports within 60 min before the meal and were included in the current analyses. Negative affect before eating was a significant predictor of insulin restriction (Table 2), indicating both between-person (OR, 6.77; $P < 0.01$) and within-person effects (OR, 2.58; $P < 0.05$). Thus, a participant with an average negative affect rating 1 unit higher than the mean affect reported by our sample was 6.77-times more likely to report insulin restriction. Moreover, after controlling for one's average level, every 1-point increase in negative affect before eating more than doubled the risk of restricting insulin for that eating occasion.

Follow-up analyses testing individual emotions as predictors of insulin restriction indicated significant between-person effects for all negative affect variables, including diabetes distress. Compared with individuals who were at the sample average, individuals who were more prone to higher negative affect before eating were two- to five-times more likely to restrict insulin (all $P < 0.05$). The largest OR was observed for individuals who tended to report higher-than-average levels of sadness (OR, 5.22). This was followed by the tendency to report anger (OR, 3.94), frustration (OR, 3.87), guilt or disgust with self (OR, 3.82), anxiety or nervousness (OR, 3.50), the desire to put diabetes out of mind (OR, 3.14), and feeling upset about diabetes (OR, 2.15).

Within-person effects were found for "anxiety or nervousness" and "guilty or disgusted with self." Every 1-point increase in intensity of these affective states (above one's average level) nearly doubled the odds of insulin restriction at the upcoming meal or snack (OR, 1.72–1.84).

Characteristics of the Eating Episode

Between- and within-person effects were observed for "large amount of food," "loss of control," and "guilt for eating" (OR, 1.46–140.41). There was also a significant within-person effect for "break a rule" (OR, 11.07) but no between-person effect. There were no significant between- or within-person effects of "uncomfortably full" on insulin restriction (Table 3). When the effects of all characteristics of eating episodes were accounted for in a single model predicting insulin restriction, only two effects remained significant: the between-person effect of "guilt for eating" (OR, 4.47) and the within-person effect of "break a rule" (OR, 7.76).

Table 2—Fixed-effect estimates for affect predicting subsequent insulin restriction

Parameter	β	SE	OR	95% CI
Intercept	−1.52*	0.59		
Lag time	−0.68	0.97	0.51	0.08–3.44
Negative affect				
Between-persons effects	1.91**	0.56	6.77	2.21–20.69
Within-persons effects	0.95*	0.46	2.58	1.04–6.43
Intercept	−2.14**	0.64		
Lag time	−0.79	0.96	0.45	0.07–3.01
Happy				
Between-persons effects	−0.86	0.45	0.42	0.17–1.04
Within-persons effects	0.39	0.27	1.47	0.87–2.50
Intercept	−1.99**	0.62		
Lag time	−1.15	0.96	0.32	0.05–2.09
Sad				
Between-persons effects	1.65**	0.58	5.22	1.66–16.44
Within-persons effects	−0.1	0.28	0.90	0.52–1.56
Intercept	−1.96**	0.62		
Lag time	−1.03	0.96	0.36	0.05–2.36
Angry				
Between-persons effects	1.37*	0.56	3.94	1.30–11.97
Within-persons effects	0.38	0.33	1.47	0.76–2.82
Intercept	−2.06**	0.61		
Lag time	−0.87	0.96	0.42	0.06–2.75
Frustrated				
Between-persons effects	1.35**	0.41	3.87	1.71–8.75
Within-persons effects	0.34	0.23	1.40	0.89–2.21
Intercept	−2.19**	0.64		
Lag time	−0.69	0.96	0.5	0.08–3.34
Nervous/anxious				
Between-persons effects	1.25**	0.44	3.50	1.47–8.37
Within-persons effects	0.61*	0.29	1.84	1.03–3.27
Intercept	−2.15***	0.62		
Lag time	−0.74	0.97	0.48	0.07–3.23
Guilty/disgusted with self				
Between-persons effects	1.34**	0.43	3.82	1.63–8.92
Within-persons effects	0.54*	0.27	1.72	1.01–2.93
Intercept	−2.19**	0.63		
Lag time	−0.76	0.96	0.47	0.07–3.10
Upset about diabetes				
Between-persons effects	0.77*	0.32	2.15	1.14–4.04
Within-persons effects	0.21	0.28	1.24	0.71–2.15
Intercept	−2.66**	0.95		
Lag time	−1.83	1.17	0.16	0.02–1.63
Not think about diabetes				
Between-persons effects	1.14*	0.44	3.14	1.30–7.60
Within-persons effects	−0.20	0.51	0.82	0.30–2.23

N people, 55–69; *N* occasions, 225–299. *$P < 0.05$. **$P < 0.01$. ***$P < 0.001$.

Insulin Restriction Predicting Postmeal Affect

Individuals who tended to restrict insulin reported higher levels of guilt/disgust with self (β = 1.15, $P < 0.01$), "upset about diabetes" (β = 1.24, $P < 0.05$), and "diabetes out of mind" (β = 1.51, $P < 0.05$) after eating, regardless of whether they had restricted insulin on that particular occasion. Further, eating occasions for which individuals restricted insulin were associated with lower levels of happiness (β = −0.39, $P < 0.01$) and higher levels of sadness (β = 0.28, $P < 0.05$), frustration (β = 0.65, $P < 0.001$), anger (β = 0.45, $P < 0.001$), guilt/disgust with self (β = 0.57, $P < 0.0001$), anxiety/nervousness (β = 0.27, $P < 0.05$), and feeling upset about diabetes (β = 0.44, $P < 0.01$) relative to the individual's typical level.

Analyses Limited to Participants With Clinically Significant Symptoms

Constraining the sample to participants with clinically significant ED symptoms (*n* = 58 with sufficient data) did not reduce variability in insulin restriction (range, 0–100% of reported eating episodes; mean, 18.91%; SD, 25.22%) or change the pattern of results obtained with the full sample. In all cases, β estimates for between- and within-person effects were similar, although with the smaller sample size, some effects were reduced to a trend.

CONCLUSIONS

Individuals with type 1 diabetes who restrict insulin to control weight suffer early and severe diabetes-related medical complications and premature death (1,7,8). There is little evidence that existing interventions for EDs are effective for these patients (14,15,35), highlighting the need for more research to effectively target this life-threatening weight-regulation strategy. The current study used EMA methods to study insulin restriction in the natural environment. These methods allowed for real-time precursors and correlates of insulin restriction to be identified, providing a clearer picture of behavioral pathways and distinct targets for intervention. Results may inform understanding of this behavior and novel treatment directions (e.g., the use of momentary intervention to improve emotion regulation).

Negative affect was associated with increased odds of restricting insulin. Although studies have found emotional problems are related to poor diabetes management (36,37), the current study extends previous research by demonstrating that a momentary increase in negative affect is an antecedent to insulin restriction, which has not previously been reported. The current study specifically identified heightened anxiety/nervousness and guilt/disgust with self before eating as precipitants to insulin restriction. This suggests that helping individuals respond effectively to these emotions might decrease insulin restriction and possibly improve metabolic control.

The current study also extends previous findings of the association between emotional problems and poor diabetes management by demonstrating that even relatively mild elevations in the average level of negative affect (e.g., elevations in sadness above the sample mean of 1.48) may increase the odds of insulin restriction. Milder elevations

Table 3—Fixed-effect estimates of characteristics of eating episodes predicting insulin restriction

Parameter	β	SE	OR	95% CI
Intercept	−3.22***	0.57		
Break a rule				
Between-persons effects	1.40	1.76	4.06	0.12–136.84
Within-persons effects	2.40***	0.53	11.07	3.90–31.38
Intercept	−2.56***	0.49		
Uncomfortably full				
Between-persons effects	3.69	2.22	39.91	0.48–>999.99
Within-persons effects	0.47	0.55	1.60	0.54–4.72
Intercept	−2.65***	0.48		
Large amount of food				
Between-persons effects	4.94*	2.12	140.41	2.04–>999.99
Within-persons effects	1.40**	0.53	4.05	1.43–11.53
Intercept	−2.47***	0.43		
Guilt for eating				
Between-persons effects	1.77***	0.40	5.84	2.65–12.88
Within-persons effects	0.53***	0.15	1.71	1.27–2.29
Intercept	−2.52***	0.45		
Loss of control				
Between-persons effects	2.17***	0.53	8.74	3.05–25.02
Within-persons effects	0.38**	0.14	1.46	1.11–1.91

This table presents results of five separate models examining the effects of each of the eating episode characteristics on insulin restriction. See CHARACTERISTICS OF THE EATING EPISODE in RESULTS for the results of the single model examining the effect of all five eating episode characteristics on insulin restriction. Dichotomous predictors (i.e., "break a rule," "uncomfortably full," and "large amount of food") were grand-mean centered, such that the between-person estimates represent a comparison of someone who endorses a particular characteristic (e.g., "break a rule") on 100% of eating occasions to someone who never endorses the characteristic. Simultaneous occurrences of the two events (i.e., dichotomous eating episode characteristics and insulin restriction) were relatively infrequent, resulting in high SE estimates and large CIs. *$P < 0.05$. **$P < 0.01$. ***$P < 0.001$.

in negative affect might be missed in routine screening. They might also have a different mechanism of association with insulin restriction than clinical elevations in negative affect (e.g., depression), which would be important for treatment planning. For example, although depression might be associated with poor diabetes management via avolition, milder feelings of sadness might trigger vulnerable individuals to restrict insulin to lose weight to promote general feelings of well-being. Importantly, depression was not heavily endorsed in our sample ($n = 4$), despite individual differences in sadness emerging as a predictor of insulin restriction.

Participants' perception of breaking a dietary rule, as well as the general tendency to feel guilty or ashamed of one's eating, was associated with increased odds for insulin restriction, above other aspects of the eating episode. This highlights that perceiving one's eating as bad or wrong is more important than the actual eating behavior (e.g., whether the individual ate a large amount of food). Although it is not uncommon for individuals with type 1 diabetes to follow rules and routines, even in the context of flexible intensive insulin therapy (38), if deviations from these self-imposed guidelines feel like a personal failure, they may lead to insulin restriction. Helping patients develop a less critical or punitive approach to diabetes management, specifically in the realm of eating but also more generally (e.g., appreciating the multitude of factors that affect BG), might decrease ED symptoms. This may be facilitated by provider education regarding how they counsel patients about managing diabetes as well as educating families who, in effort to help patients maintain good metabolic control, might inadvertently encourage a rigid approach to management.

Feeling upset about diabetes or wanting to avoid thinking about diabetes was an individual difference that doubled-to-tripled the odds of restricting insulin. These feelings were relatively stable among individuals who omitted insulin, although some fluctuation was observed. This finding adds to the very limited data on the association between insulin restriction and diabetes distress (11). Negative feelings about type 1 diabetes may have predated management problems and potentially increased vulnerability to an ED or they may have been perpetuated by poor diabetes management. Conventional treatments for EDs (12,13) might need to be adapted to more fully address the role of diabetes distress in ED symptomatology among individuals with type 1 diabetes.

The same results were observed when the sample was constrained to only participants who met the threshold for clinically significant ED symptoms. This highlights the generalizability of the findings to the full continuum of ED symptomatology. It also suggests that the between-person effects that were identified may specifically discriminate the presence or absence of insulin restriction rather than being a general marker of ED pathology.

The current study had limitations. We assessed only a small set of potential predictors to minimize participant burden and maximize study participation. It is possible that other predictors of insulin misuse are equally important, or more important, that were not tested here. The variable "How much do you want to put diabetes out of your mind?" was also added after some participants completed the study, and this might have weakened our power to detect its observed effect. We also lost a significant number of eating episodes due to missing CGM data or the absence of affect reports 60 min before eating.

The current study relied on participant self-report, and participants were not instructed to keep meal logs, which would be necessary to use insulin pump data to evaluate the adequacy of insulin doses. This decision was made to reduce participant burden and experimental reactivity but is a limitation of the study. We also focused exclusively on bolus insulin and used a relatively brief assessment period (3 days) to minimize participant burden. Including long-acting insulin and longer observation periods might reveal different results.

Participants responded to prompts about the characteristics of the eating episode (e.g., whether they broke a dietary rule) at the same time that they reported whether they restricted insulin for that meal. Thus, their temporal

sequence cannot be ascertained. Participants were also not asked whether insulin restriction was specifically for weight control during the momentary data collection. Some episodes of insulin restriction might have been related to other issues (e.g., being too busy). However, insulin restriction was observed exclusively among participants who met the threshold for clinically significant ED symptoms, providing support that these responses reflected ED symptomatology.

Future studies should differentiate underdosing insulin and completely omitting an insulin dose. Future studies might also examine the time-course of affect to determine whether participants respond to mounting negative affect with insulin restriction and whether affect changes pre- to postmeal.

The current study identified momentary experiences and individual differences that are associated with increased odds of insulin restriction among individuals with a range of ED symptomatology. Findings may inform treatment of this high-risk population.

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