THESIS

MINDFULNESS AND EATING BEHAVIOR IN ADOLESCENT GIRLS AT RISK FOR DEVELOPING TYPE 2 DIABETES

Submitted by

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ABSTRACT

MINDFULNESS AND EATING BEHAVIOR IN ADOLESCENT GIRLS AT RISK FOR DEVELOPING TYPE 2 DIABETES

Mindfulness interventions to address disinhibited eating have increased in popularity. Yet, there is surprisingly limited research explicitly describing the relationship of mindfulness with disinhibited eating, particularly in adolescents. In theory, mindfulness may be inversely related to disinhibited eating because present-moment attention promotes an individual's ability to recognize and respond effectively to internal hunger and fullness cues, as well as to differentiate between physiological hunger signals and other internal or external stimuli for eating. The primary goal of this study was to evaluate the relationship of dispositional mindfulness to eating in the absence of hunger (EAH) in adolescent girls at risk for type 2 diabetes (T2D). The secondary objective was to evaluate the interactions among mindfulness, hunger state, and a propensity for loss-of-control eating (LOC) in the prediction of eating behaviors, both with and without hunger. Participants were 107 adolescent girls (12-17 years) from diverse racial/ethnic backgrounds. Adolescents self-reported dispositional mindfulness, were evaluated for LOC by validated interview, and participated in two successive, standardized laboratory test meals to assess eating when hungry from a buffet lunch and EAH from a snack array. Adolescents rated state appetite before and after the meal and snacks. In analyses adjusting for age (years), race/ethnicity, body composition (percent body fat, lean mass, and height), and depressive symptoms, mindfulness was inversely related to EAH. Accounting for similar covariates, meal energy intake was not affected by mindfulness, but instead was

predicted by a significant interaction of state hunger by LOC. Girls with LOC and high hunger ate the most as compared to girls with LOC and lower hunger or to girls without LOC. Results from the current study suggest that mindfulness may play a role in more effective regulation of food intake in girls at-risk for T2D; however, a propensity for LOC eating may be particularly salient for overeating in a state of high hunger.

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INTRODUCTION

Mindfulness and Eating Behavior in Adolescent Girls at Risk for Developing Type 2 Diabetes

A mindfulness movement has gained momentum in the last 15 years, partially due to mounting empirical evidence supporting the idea that mindfulness promotes both psychological and physical health through adaptive self-regulation processes (Creswell, 2017; Hill, Masuda, Melcher, Morgan & Twohig, 2015). Mindfulness refers to a non-judgmental state of purposeful awareness that brings attention to the present moment and allows for the recognition and consideration of internal and external experiences without the pressure to alter the moment or take immediate action (Kabat-Zinn, 1994). Mindfulness has dispositional or trait-like characteristics, but also may be learned and developed through training (Shapiro, Carlson, Astin, & Freedman, 2006). In adults, mindfulness-based interventions have gained popularity as a therapeutic modality to address disinhibited eating patterns that contribute to excess weight gain and type 2 diabetes (T2D; Godfrey, Gallo, & Afari, 2015; Godsey, 2013); however, there is limited information expressly describing the relationship of dispositional mindfulness to disinhibited eating in adolescents.

Disinhibited eating refers to a lack of self-regulation over consumption, including behaviors such as eating in the absence of hunger (EAH) and loss-of-control eating (LOC; Shomaker, Tanofsky-Kraff, & Yanovski, 2011). EAH is the non-homeostatic intake of palatable food in response to emotional or external cues, such as the availability of palatable food, in the absence of physiological hunger, and it is a common form of disinhibited eating in youth with overweight and obesity (Kral et al., 2012; Kral & Faith, 2007; Shomaker et al., 2010a; Wilfley et

al., 2011). Externality theory suggests that individuals prone to obesity are less sensitive to internal cues and highly sensitive to external cues to eat (Schachter & Rodin, 1974). In early studies, youth with obesity ate significantly more when presented with easily accessed snacks (Costanzo & Woody, 1979) and were more influenced by external cues such as the availability or taste of food (Schachter, 1971; Schachter & Rodin, 1974) than their lean counterparts. Additional, more recent studies have also demonstrated a positive, cross-sectional association of EAH, as assessed by survey and test meal intake, with body mass index (BMI) in adolescents (Fisher et al., 2007; Kelly et al., 2015; Shomaker et al., 2010b; Tanofsky-Kraff et al., 2011; Vannucci et al., 2013).

Another prevalent form of disinhibited eating is LOC, referring to perceived overeating accompanied by a subjective sense of not being able to control what or how much one is eating (American Psychiatric Association, 2013). A propensity for LOC is frequently reported in adolescents with overweight and obesity (Tanofsky-Kraff, 2008) and in adolescents with obesity-related comorbidities including T2D (Wilfley et al., 2011). Youth who endorse LOC not only are more likely to have overweight and obesity (Shomaker et al., 2010a; Tanofsky-Kraff et al., 2004; Vannucci et al., 2013), but also gain excess weight and body fat over time (Field et al., 2003; Field et al., 2012; Sonneville et al., 2013; Stice, Cameron, Killen, Hayward, & Taylor, 1999; Stice et al., 2002; Tanofsky-Kraff et al., 2006; Tanofsky-Kraff et al., 2009), and show a worsening in components of metabolic health that elevate T2D risk (Radin et al., 2015; Tanofsky-Kraff et al., 2011).

Mindfulness interventions to address disinhibited eating have increased in popularity; yet, there is surprisingly limited empirical evidence explicitly describing the relationship of mindfulness with disinhibited eating, particularly in adolescents. In theory, mindfulness may be

inversely related to disinhibited eating because present-moment attention promotes an individual's ability to recognize and respond effectively to internal appetitive cues of hunger and fullness, as well as to differentiate between physiological hunger signals and other internal or external stimuli for eating (Brown, Ryan, & Creswell, 2007; Olson & Emery, 2015). As displayed in Figure 1, I posited that more mindful adolescents would have a greater awareness of their internal signals of hunger and fullness. This awareness may facilitate an ability to differentiate between internal and external stimuli for eating, which could ultimately lead to an interruption of the path from disinhibited eating to the development of T2D.

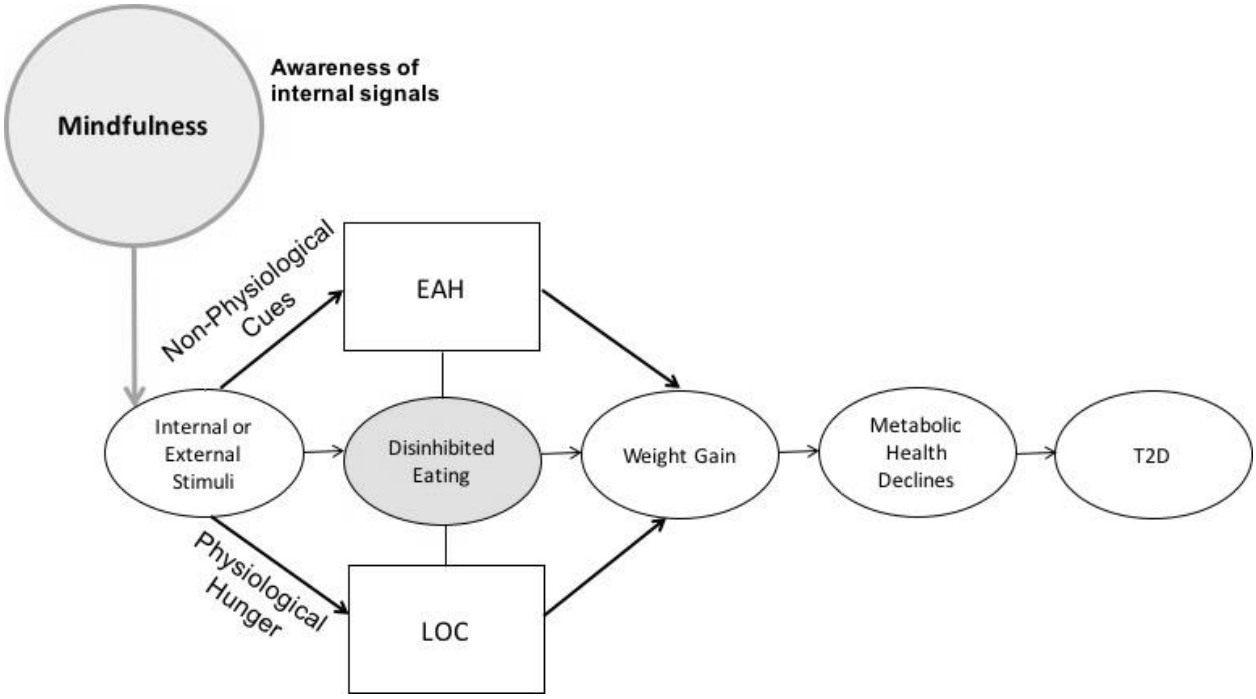

Figure 1. A conceptual model of mindfulness and eating behavior in adolescent girls at risk for developing type 2 diabetes.

Nearly all existing studies characterizing the cross-sectional relationship of mindfulness with disinhibited eating have been conducted in adults. In adults with T2D, mindfulness is inversely associated with self-reported eating in response to emotions or external cues (Tak et al.,

2015). In healthy adult women, dispositional mindfulness was negatively related to trait eating disinhibition, the tendency to eat more due to an over responsiveness to external food cues and negative affect (Lattimore, Fisher, & Malinowski, 2011). Using self-report survey measures in non-clinical samples of adults, dispositional mindfulness has also been associated with less reported eating in response to emotions (Pidgeon, Lacota, & Champion, 2013), less disordered eating (Masuda, Price, & Latzman, 2012), and fewer symptoms of disinhibited-type eating disorders including bulimia nervosa (Lavender, Jardin, & Anderson, 2009).

Mindfulness has been proposed to facilitate improved awareness of and attention to internal and external experiences, including physiological hunger and satiety signals, and thus, theoretically, may help individuals to regulate eating in response to hunger, as opposed to other emotional or environmental cues (Brown, Ryan, & Creswell, 2007; Olson & Emery, 2015). Yet, despite the promising initial evidence that mindfulness training may mitigate disinhibited eating, understanding the basic relationship of dispositional mindfulness to disinhibited eating is essential for informing targeted intervention efforts. In addition, extant data have focused upon adults, with very little attention to adolescents. Adolescence is an important age span for the emergence of or possible worsening of disinhibited eating (Neumark-Sztainer, Wall, Larson, Eisenberg, & Loth, 2011; Stice et al., 2006), and therefore, may serve as a key point in development to prevent persistence of disinhibited eating into early adulthood (Goldschmidt, Wall, Loth, Bucchianeri, & Neumark-Sztainer, 2014). Both cross-sectional (Shomaker et al., 2010a; Tanofsky-Kraff, 2008; Tanofsky-Kraff et al., 2004; Vannucci et al., 2013) and longitudinal (Field et al., 2003; Sonneville et al., 2013; Stice et al., 2002; Tanofsky-Kraff et al., 2009) data show that adolescents' disinhibited eating is associated with overweight and obesity and relates to greater gains in BMI and worsening indicators of metabolic health over time.

Consistent with a small body of data in adults (Roberts & Danoff-Burg, 2010; Sala & Levinson, 2017; Tak et al., 2015), one prior study in adolescents reported that dispositional mindfulness related to lower odds of LOC patterns in adolescent girls at risk for T2D (Pivarunas et al., 2015). However, the relationship of mindfulness to other aspects of disinhibited eating in adolescents is not known, and may shed light on the extent to which mindfulness-based intervention approaches could benefit youth at risk for excess weight gain and T2D.

Current Study

The current study is a secondary data analysis of a cohort of 107 adolescent girls taking part in a T2D prevention clinical trial. Data from the baseline assessment were used. A successive series of standardized, laboratory test meals were administered to evaluate the relationship of dispositional mindfulness to EAH in adolescent girls at risk for T2D. The study focused on girls because, as compared to boys, girls have a two-fold greater risk for youth-onset T2D (Dabelea et al., 2014). Youth-onset T2D is rapidly on the rise and manifests with a more aggressive disease course and earlier mortality than adult-onset T2D (Copeland et al., 2011; Hirst, 2013; Lynch et al., 2013; Nadeau et al., 2016). I anticipated that there were would be an inverse relationship between mindfulness and EAH, such that adolescents endorsing higher levels of dispositional mindfulness would display less EAH than adolescents who reported lower levels of mindfulness. This hypothesis was based upon the notion that mindfulness involves present-moment attention to the full range of thoughts and emotions that may precede EAH, and thus, mindfulness was anticipated to translate into better identification, acceptance, and differentiation of internal experiences to self-regulate eating (Hill, Masuda, Melcher, Morgan, & Twohig, 2015). Because mindfulness and LOC patterns have been previously related (Pivarunas et al., 2015), I sought to determine the relationship of mindfulness to EAH after accounting for

reported LOC, in order to ensure that any identified findings indicated a unique association of mindfulness with EAH. Likewise, I also accounted for body composition and other demographic factors that have been related to disinhibited eating.

As a secondary objective, I explored whether mindfulness, LOC, and state hunger interacted in the prediction of eating behaviors, both with and without hunger. Specifically, based on previous findings (Stojek et al., 2016), I expected that LOC would have a significant interaction with mindfulness, such that being prone to uncontrolled eating, in combination with less present-moment awareness, would have the strongest effect on observable EAH. Additionally, because attention (or lack of attention) to hunger cues was a key aspect of the conceptual model through which mindfulness regulates eating behavior, I adjusted for hunger state in all models and tested its interactions with mindfulness and LOC. The main focus was on predictors of EAH as measured snack intake, but for comparison, we also evaluated predictors of eating while hungry as meal intake.

METHODS

Participants and Procedure

The current study represents a secondary data analysis of 107 adolescent girls taking part in a T2D prevention behavioral clinical trial. For the purposes of the current project, only baseline data prior to the intervention were examined. Participants in this cohort were healthy adolescent (12-17 years) girls recruited through the National Institutes of Health clinical trials website, local community postings in libraries and supermarkets, direct mailings to area families, and through school-parents' listservs in Washington, DC and the greater metropolitan area. Recruitment materials targeted parents of adolescent girls who were concerned about their daughter being at risk for diabetes. All girls were determined to be at risk for T2D by having overweight or obesity (body mass index [BMI] ≥ 85th percentile) and having one or more first- or second-degree relative with prediabetes, T2D, or gestational diabetes. Other criteria for study inclusion were mild to moderately elevated depressive symptoms (≥16 on the Center for Epidemiologic Studies-Depression Scale, CES-D; Radloff, 1977) and English-speaking. Exclusion criteria included current major depressive disorder or psychiatric symptoms requiring treatment; T2D (fasting glucose >126 mg/dL, 2-hour OGTT glucose >200 mg/dL); medication that could affect insulin resistance, body weight, or mood (such as antidepressants, stimulants, or insulin sensitizers); pregnancy; and current participation in weight loss or psychotherapy treatment programs. Adolescents provided written assent and their parents or guardians gave written consent for participation. The study was approved by the Institutional Review Board of the Eunice Kennedy Shriver National Institute of Child Health and Human Development. Adolescents were financially compensated for their time and effort in participating.

Adolescents were seen at the National Institutes of Health Hatfield Clinical Research Center following an overnight fast. Participants were screened for general health and a family history of T2D with a medical history and a physical examination conducted by an endocrinologist or a nurse practitioner. Adolescents completed measurements of body composition, an interview to assess eating behavior, questionnaires to evaluate depressive symptoms and dispositional mindfulness, and they participated in a series of successive test meals to objectively characterize eating when hungry and EAH. The following measures were evaluated in the current study.

Measures

Body composition. Height was measured to the nearest millimeter three times by stadiometer and fasting weight was measured to the nearest 0.1 kg on a calibrated scale. BMI was calculated as weight (kg) divided by the square of height (m) and BMI *z* scores were calculated according to the Centers for Disease Control and Prevention 2000 standards. Percentage of body fat (fat mass/total body mass x 100) and lean mass (kg) were assessed with dual-energy X-ray absorptiometry (iDXA, GE Healthcare, Madison, WI).

Loss-of-control (LOC) eating. The presence of recent (past month), objective and subjective binge eating episodes were evaluated by trained interviewers with the Eating Disorder Examination (EDE) Overeating Section version 12.0D (Fairburn & Cooper, 1993). The EDE has shown good discriminant validity, internal consistency, and concurrent validity (Cooper, Cooper, &Fairburn, 1989) and has shown good test-retest reliability (Rizvi, Peterson, Crow, & Agras, 2000). All interviews were audio-recorded and randomly selected EDEs were co-rated to verify inter-rater reliability for loss-of-control presence. For this study, presence (at least 1 episode in

the past month) and absence of loss-of-control eating (objective and/or subjective binge episodes) were considered.

Trait mindfulness. Dispositional mindfulness was assessed with the reliable and validated 15-item Mindful Attention and Awareness Scale (Brown & Ryan, 2003); the survey is included in Appendix A. Using a Likert scale ranging from 1 (almost always) to 6 (almost never), participants answered items such as "I find myself doing things without paying attention." The total score is calculated as the sum of all items with higher scores indicating more dispositional mindfulness. Because one item overlapped with mindful eating ("I snack without being aware that I'm eating"), the total summed score was also computed without the mindful eating question.

Eating while hungry and eating in the absence of hunger (EAH). Following a previously validated procedure to assess eating behaviors in adolescence (Shomaker et al., 2010b), participants were given a buffet lunch meal at approximately 12:00 pm and instructed to eat until no longer hungry. The buffet lunch meal was comprised of approximately 11,000 kcal and had multiple items varying in macronutrient content. A wide assortment of foods typically liked by adolescents was included (Shomaker et al., 2010b). Sixty minutes after the initiation of the lunch meal, participants were presented with a 4,055-kcal array of generous proportions of highly palatable snack foods. Participants were instructed to taste the foods, rate their liking/disliking for the foods on a brief rating form, and to eat as much of the foods as they would like. The snack period was 15-minutes. During the snack array, non-food activities were made available including hand-held computer games, drawing, playing cards, and magazines.

Each food and drink item consumed from the lunch buffet meal and from the snack array was measured using the difference in weight (g) of each item before and after the meal. Energy

(kcal) consumed was calculated by the standards set forth from the US Department of Agriculture National Nutrient Database for Standard Reference and from the manufacturer labels on packaged food items. Eating while hungry was evaluated based on total energy (kcal) consumed at the lunch meal. EAH was assessed based on total energy (kcal) consumed during the snack array.

State hunger. Girls completed brief, state ratings of hunger directly before the lunch meal, directly after the lunch meal (and prior to the snacks), and directly after the snacks. They rated their subjective feelings of hunger on a visual analog scale ranging from 1 = "not at all" to 100 = "extremely." We evaluated pre-meal hunger and post-meal/pre-snack hunger as predictors of meal intake and EAH, respectively.

Data Analysis

All analyses were conducted using IBM SPSS Statistics 23. Analyses were performed from basic to more advanced. Data were cleaned and adjusted for outliers. Valid outliers were adjusted in order to fall inside 1.5 times the interquartile range above the 75th percentile or below the 25th percentile, as is standard in Tukey's boxplot (Tukey, 1977). In descriptive analyses, independent samples *t*-tests and chi-square statistics were conducted to compare adolescents with and without LOC eating on key variables. Hierarchical multiple regression models were performed with the dependent variables of eating while hungry (buffet meal intake kcal) and EAH (snack intake kcal). The covariates of age (years), race/ethnicity, body composition (percent body fat, lean mass, and height), and depressive symptoms were entered in the first step. Given that all adolescents had mild-to-moderate depressive symptoms, I also controlled for degree of depressive symptoms to ensure the any relationships of mindfulness with eating behavior were not explained by degree of depression symptoms. When evaluating EAH, buffet

meal intake also was included as a covariate. In the second step of the models, hunger just prior to eating (meal or snacks) was included. Then, the main effects of mindfulness and LOC were entered in level three. Finally, the two-way interactions among mindfulness, LOC, and state hunger were entered into the fourth step. I also evaluated the three-way interaction, which was not significant for the prediction of either meal intake or EAH, and thus, was not included in the analyses. Additionally, one item on the MAAS overlapped with mindful eating. I removed this item and conducted a secondary analysis without the item; because all analyses remained unchanged, the data are not reported. Following standard recommendations (Aiken & West, 1991), the continuous variables of mindfulness and state hunger were centered before being entered as main effects into the models and prior to computing interaction terms. Post-hoc power analyses revealed insufficient power to detect small (.20) effects, but adequate power to detect both medium (.93) and large (> .99) effects.

RESULTS

Preliminary Analyses

One hundred seven adolescent girls (age 14.53 ± 1.63 years) participated. Demographic, anthropometric, psychological, and eating characteristics for adolescents with and without LOC are presented in **Table 1**. Statistical comparisons of these variables by LOC status revealed several, unadjusted between-group differences in BMI percentile, obesity, and EAH, such that adolescents with LOC, on average, had significantly higher BMI percentiles ($p < .01$) and tended to consume more food during the EAH paradigm ($p = .05$) as compared to adolescents without LOC. Adolescents with LOC were also significantly more likely to have obesity ($p < .05$) than adolescents without LOC. Although the difference did not reach statistical significance, adolescents with LOC tended have poorer mindfulness than those without LOC ($p=.07$).

Prior to the meal, adolescents endorsed moderate-to-high levels of hunger, on average (67.13 ± 25.73, possible range 1-100), supporting the notion that meal intake represented eating when hungry. Conversely, after the meal and prior to the snack period, girls reported very low levels of state hunger, on average (0.64 ± 1.01), validating the paradigm that snack intake represented EAH.

Table 1. *Demographic, anthropometric, psychological, and eating characteristics for adolescent girls with and without loss-of-control (LOC) eating*

Characteristic[a]	No LOC	LOC	*p*
n	65	42	
Age (years)	14.51 ± 1.69, 12-17	14.57 ± 1.55, 12-17	.84
BMI[b] (kg/m^2)	32.13 ± 7.35, 23-51	33.79 ± 5.04, 26-46	.17
BMI (%ile)	94.77 ± 4.08, 85-99	96.86 ± 2.68, 87-99	.002
Body fat (%)	42.19 ± 6.12, 31-57	43.47 ± 4.93, 32.4-51	.26
Depressive symptoms	24.92 ± 7.17, 16-46	25.20 ± 7.23, 17-46.5	.85
Trait mindfulness	59.91 ± 12.31, 32-85	55.36 ± 12.63, 28-84	.07
Pre-meal hunger	68.20 ± 24.34, 16-100	65.48 ± 27.96, 9-100	.60
Post-meal/pre-EAH[c] hunger	.67 ± 1.04, 0-2.5	.60 ± .97, 0-2.5	.71
Meal intake (kcal)	1466.41 ± 531.71, 688-3032	1634.78 ± 630.28, 447-3032	.14
EAH (kcal)	357.96 ± 158.39, 100-809	419.37 ± 149.08, 122-678	.05
Non-Hispanic Black	60.0%	64.3%	.66
Obesity (BMI ≥95%ile)	63.1%	83.3%	.02

[a] Values presented are Mean ± SD, range, unless otherwise noted as percentage.
[b] BMI = body mass index.

Predictors of EAH

In **Table 2,** I summarize the results from the hierarchical regression models examining the main and interactional effects of adolescents' trait mindfulness, LOC, and state hunger on EAH. In level 1, covariates accounted for a combined 15.8% of the variance in snack intake. Entered at level 2, the main effect of post-meal/pre-EAH state hunger was not significant (p = .25). The main effect of mindfulness entered at level 3 was a significant predictor of EAH (p = .03) and explained an additional 5.4% of the variance in EAH. As depicted in **Figure 2**, there was a significant inverse relationship between trait mindfulness and snack intake (b = -2.94, p = .03), such that the more dispositionally mindful an adolescent was, the less snacks she ate in the absence of hunger. Adolescents who were more mindful ate 2.94 kcal less for every 1-unit increase on the MAAS scale (range 15 – 90); that is to say, every 10-unit increase in mindfulness was related to consuming 29.4 fewer calories. There were no significant interactions among mindfulness, LOC, and hunger as entered in level 4 (ps > .05).

Table 2. *Multiple hierarchical regressions predicting adolescent girls' eating in the absence of hunger (EAH; kcal)*

Level	Variable entered	β[a]	*SE*	*b*[b]	R^{2c}	ΔR^2
Level 1	Meal intake (kcal)	.06	.03	.20	.158**	.158**
	Race (Black)	-30.92	30.73	-.10		
	Age (y)	-1.08	9.42	-.01		
	Body fat (%)	5.04	2.77	.18		
	Lean body mass (kg)	.95	2.75	.05		
	Height (cm)	4.38	2.83	.19		
	Depressive symptoms	.56	2.18	.03		
Level 2	Post-meal hunger	-.65	1.17	-.05	.161	.003
Level 3	Mindfulness	-2.94**	1.37	-.24**	.215**	.054**
	Loss-of-control (LOC; presence)	28.46	30.33	.09		
Level 4	Mindfulness x post-meal hunger	.15	.18	.24	.262	.047
	LOC x post-meal hunger	-12.54	7.66	-.18		
	Mindfulness x LOC	4.50	2.40	.23		

[a] β = unstandardized regression coefficient at each step.
[b] *b* = standardized regression coefficient at each step.
[c] R^2 = proportion of variability in the dependent variable accounted for by model.
** $p < .05$

Relationship of mindfulness to energy consumption in the absence of hunger in adolescents

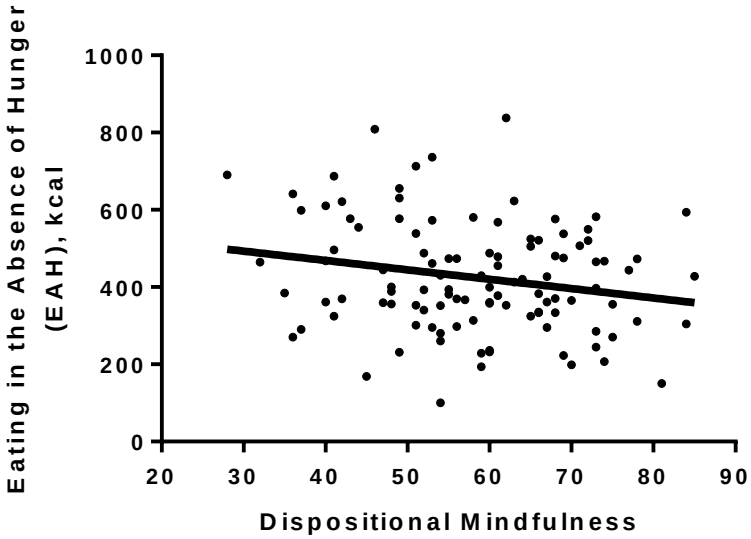

Figure 2. Dispositional mindfulness was inversely associated with eating in the absence of hunger (EAH; kcal; β = -.24, p = .03), after accounting for age, race/ethnicity, body composition (percent body fat, lean mass, and height), depressive symptoms, and total calories consumed during the buffet meal.

Predictors of Meal Intake

In **Table 3,** I summarize the results from the hierarchical regression models examining the main and interactional effects of adolescents' trait mindfulness, LOC, and state hunger on meal intake. In level 1, covariates accounted for a combined 22.7% of the variance in meal intake. Specifically, lean body mass ($p < .001$) and height ($p < .05$) were significant predictors of intake such that adolescents with greater lean mass ate more and those who were taller ate less, accounting for all other covariates in the model. The main effect of pre-meal state hunger entered at level 2 was non-significant ($p = .10$), and the main effects of mindfulness and LOC entered at level 3 also were non-significant (all ps > .05). However, at level 4, the addition of the interaction terms among mindfulness, LOC, and hunger explained an additional, combined 4.7% of the variance in meal intake ($p = .10$). If the non-significant interaction term of mindfulness by LOC was not included in the model, the additional accounted for variance of 4.6% was significant ($p < .05$). Specifically, there was a significant two-way interaction between adolescents' LOC eating status and pre-meal state hunger on meal intake ($p = .02$). As depicted in **Figure 3**, there was a significant positive relationship between pre-meal state hunger and meal intake only in adolescent girls with LOC eating ($b = .39$, $p = .02$), whereas there was no relationship between state hunger and meal intake in adolescents without LOC ($p = .73$). Adolescent girls with LOC and relatively high state hunger ate the most, as compared to girls with LOC and lower hunger or compared to girls who did not endorse LOC. Adolescents with LOC ate 9.97 more kcal for every 1-unit increase on a visual analog scale for hunger (range: 0 – 100): said differently, every 10-unit increase in hunger (e.g. moving from a little hungry to slightly hungry) was related to consuming 99.7 kcal more. The interactions of mindfulness by hunger and mindfulness by LOC were not significant (ps > .05).

Table 3. *Multiple hierarchical regressions predicting adolescent girls' total energy meal intake (kcal)*

Level	Variable entered	β[a]	*SE*	*b*[b]	R^{2c}	ΔR^2
Level 1	Race (Black)	85.38	107.09	.07	.227***	.227***
	Age (y)	-44.17	32.63	-1.30		
	Body fat (%)	-.69	9.69	-.01		
	Lean body mass (kg)	38.71***	8.81	.55***		
	Height (cm)	-21.05**	9.66	-.24**		
	Depressive symptoms	4.67	7.59	.06		
Level 2	Pre-meal hunger	3.36	2.02	.15	.248	.021
Level 3	Mindfulness	-4.35	4.73	-.10	.262	.014
	Loss-of-control (LOC; presence)	86.27	106.22	.07		
Level 4	Mindfulness x pre-meal hunger	-.08	.16	-.04	.309	.047
	LOC x pre-meal hunger	9.97**	4.18	.30**		
	Mindfulness x LOC	3.03	8.35	.042		

[a] β = unstandardized regression coefficient at each step.
[b] *b* = standardized regression coefficient at each step.
[c] R^2 = proportion of variability in the dependent variable accounted for by model.
*** $p < .001$.
** $p < .05$

Interaction between reported loss-of-control (LOC) and pre-meal state hunger for the prediction of meal intake in adolescents

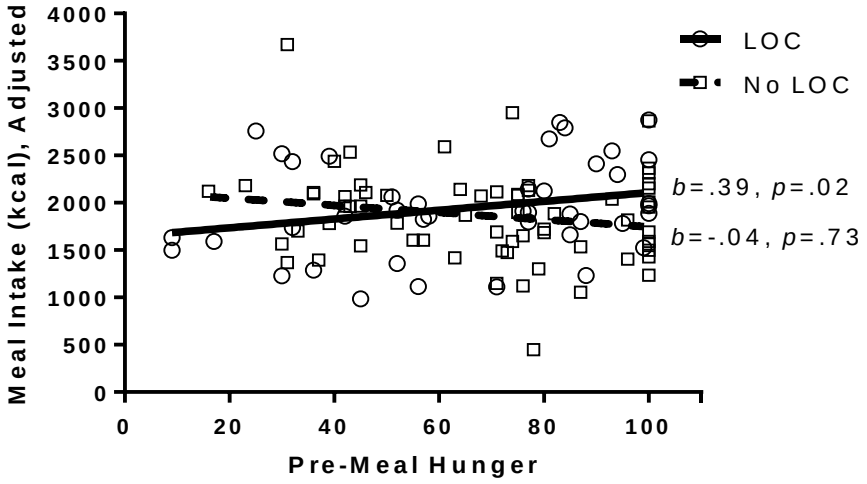

Figure 3. Loss-of-control eating (LOC) status moderates the relationship between pre-meal state hunger and meal intake (kcal; β = .30, p = .02) accounting for age, race/ethnicity, body composition (percent body fat, lean mass, and height), and depressive symptoms, such that only in adolescent girls with LOC, state hunger was positively related to meal intake (β = .39, p = .02), but not among girls without LOC (p = .73).

DISCUSSION

Mindfulness-based interventions have shown promising preliminary results as a therapeutic modality for disinhibited eating in adults with overweight and obesity and those with T2D (Katterman, Kleinman, Hood, Nackers, & Corsica, 2014; Rogers, Ferrari, Mosely, Lang, & Brennan, 2017; Ruffault, 2016). Yet, there is a paucity of descriptive work to explain how dispositional mindfulness relates to eating behavior, and even less work to understand the possible connection between mindfulness and disinhibited eating in adolescents. The primary objective of the current study was to evaluate the relationship of dispositional mindfulness with eating in the absence of physiological hunger in adolescents at risk for T2D, using a series of standardized laboratory test meals. Additionally, I explored the interactions among mindfulness, LOC, and state hunger in the prediction of eating behavior.

In concordance with my hypothesis, there was an inverse association between mindfulness and observable EAH. Adolescents who endorsed higher levels of dispositional mindfulness consumed less energy in the absence of hunger. This effect was after accounting for body composition, depressive symptoms, prior meal intake, and LOC, meaning that the relationship of mindfulness to EAH was independent of these potentially confounding factors. This finding is consistent with previous preliminary data examining the relationship between mindfulness and reported disinhibited eating in adolescents at risk for T2D (Pivarunas et al., 2015), mindfulness and laboratory eating in healthy adults (Arch et al., 2016), and studies investigating mindfulness and self-reported disinhibited eating in college-aged students and adults (Jordan, Wang, Donatoni, & Meier; 2014; Lavender, Gratz, & Tull, 2011; Murphy, Mermelstein, Edwards, & Gidycz, 2012; Roberts & Danoff-Burg, 2010; Tak et al., 2015). In

pre-test/post-test trials of adults with overweight or obesity, mindfulness interventions have been associated with a better appraisal of hunger cues versus emotional cues to eat over eight weeks (Kidd, Graor, & Murrock, 2013) and fewer LOC episodes over 10 weeks (Baer, Fischer, & Huss, 2005). In preliminary adult randomized controlled trials evaluating the effects of a mindfulness-based group program on eating behavior and weight outcomes in adults with overweight, mindfulness has been associated with fewer LOC episodes (Kristeller, Wolever, & Sheets, 2014) and greater reductions in BMI (Tapper et al., 2009) over a six- to eight-month follow-up, as compared to psycho-educational/cognitive-behavioral groups or wait list controls. Of note, mindfulness was related to EAH, but not to eating when hungry, suggesting a particular application of mindlessness for self-regulation over eating in response to appetitive cues in adolescents at risk for T2D. Exploration of dispositional mindfulness has implications for informing why mindfulness training may be a useful strategy for addressing overeating in adolescents with depressive symptoms who are at risk for developing T2D. As mindfulness encompasses moment-by-moment awareness of the emotional experience without judgment and with acceptance (Kabat-Zinn, 1994), one possible explanation is that adolescents who are more dispositionally mindful may have the natural propensity to accept what they are experiencing in the moment without feeling pressured to take an action or "fix" an unpleasant feeling through coping mechanisms such as EAH or emotional eating. Another characteristic of mindfulness is attunement to internal and external environment; more mindful teens may also be more in tune with their physiological hunger and fullness signals, which may be beneficial for forming long-term healthy eating behaviors (Caldwell, Baime, & Wolever, 2012).

Given previous research supporting LOC as a moderator of emotional eating patterns and weight gain (Stojek et al., 2016), I explored the interaction of LOC with mindfulness in the

prediction of food intakes. Contrary to my hypothesis, LOC and mindfulness did not show a significant interaction in the prediction of EAH or meal intake. Instead, there was an interaction of LOC and state hunger in the prediction of meal intake. State hunger and meal intake were significantly related to eating more at the buffet meal only when adolescents reported LOC. Said differently, having LOC and high levels of hunger put adolescent girls at the highest risk for excessive intake. Although these findings were exploratory and require replication, they have considerable applied and clinical significance. One potential explanation is that hunger sensations are a precipitant to overeating in adolescents who are prone to feeling a lack of control over eating. Indeed, previous data support the notion that disinhibition or losing control over eating may be triggered by hunger sensations. For instance, in a multi-site study of children and adolescents with LOC, Tanofsky-Kraff et al. (2007) found that youth often reported feeling physically hungry as one key trigger to a recalled LOC episode. Data from the current study appear to demonstrate this concept as measured in the laboratory with objective food intake. In other laboratory test meal studies, youth with LOC have been shown to experience hunger differently than youth without LOC. For example, in a study of youth ages 6-12 with overweight or obesity, children who reported a recent history of LOC-type eating ate more total energy during laboratory test meals than children who did not report LOC-type eating and, even after eating larger amounts of food, became hungrier approximately an hour earlier than children without LOC eating (Mirch et al., 2006). In another laboratory test meal study, youth with LOC consumed more energy and ate more protein and fat than youth without LOC (Hilbert, Tuschen-Caffier, & Czaja, 2010); these results were completely accounted for by higher pre-prandial hunger and baseline satiety in the children with LOC. Notably, in adults with binge eating disorder (Masheb & Grilo, 2006; Masheb, Grilo, & White, 2011), eating meals more often is

related to less frequent LOC episodes, suggesting that managing hunger levels by not letting oneself become very hunger may attenuate the incidence of overeating and LOC episodes. Given these findings, it follows that higher levels of hunger may trigger LOC eating episodes; however, the cross-sectional nature of our data inhibits the ability to determine directionality. Feeling higher levels of hunger could trigger a LOC episode, but it is also possible that LOC may trigger feeling subjectively higher hunger. Investigating the concept that adolescents who are at risk for T2D and have LOC eating may be at higher risk for overeating episodes when they feel hungrier has implications for how we might treat LOC eating behavior, particularly in weight-loss seeking samples due to the relatively high occurrence of LOC eating within this population (Tanofsky-Kraff et al., 2007). Further exploration of how hunger may relate to disinhibited eating episodes is needed. Interventions that include a combination of teaching attention to hunger signals, how to restructure eating to avoid extreme levels of both hunger and fullness, and mindfulness training might be valuable to youth with LOC.

Considerations and Future Directions

The current data add to a small, but growing body of literature supporting the potential utility of mindfulness-based interventions for weight management and metabolic outcomes. Although the research on mindfulness-based interventions for positive mental health outcomes in adults is abundant (Khoury, Sharma, Rush, & Fournier, 2015), data supporting this notion in adolescents is only emerging (Kallapiran, Koo, Kirubakaran, & Hancock, 2015; Sibinga et al., 2016) and, to date, there has been limited but promising investigation into dispositional mindfulness or the mechanisms behind mindfulness training and outcomes regarding eating behavior (Arch et al., 2016; Carmody, Baer, Lykins, & Olendzki, 2009). Future studies

including ecological momentary assessment and longitudinal data will be important to add to the current knowledge.

Although the current study adds meaningful contribution to understanding the relationship of mindfulness with disinhibited eating in adolescents, there are limitations to be addressed. The current data were cross-sectional, resulting in an inability to determine a cause and effect relationship. Future research utilizing an experimental induction of state mindfulness in adolescents would allow for stronger conclusions about the directionality of effects. Longitudinal studies are also necessary to evaluate mindfulness as a prospective risk factor for changes in disinhibited eating. Further, I acknowledge the exploratory nature of the interactions among mindfulness, LOC, and state hunger on eating behavior; the extent to which we can interpret these findings depends upon replication in additional studies. Also, to what degree the findings from the current study may be generalizable to populations outside of adolescents at risk for T2D is unknown, given the specific characteristics of the sample in addition to the possibility that laboratory eating paradigms may not replicate day-to-day eating.

Despite these limitations, the current study has important strengths. To our knowledge, there has been limited investigation on the relationship between mindfulness and EAH in adolescents. Strengths of the current study include objective measurements of body composition using DXA, in addition to the objective measurement of eating behavior in the laboratory as opposed to relying on self-report measures of energy intake, which generally show very poor concurrent or predictive validity (Goran, 1998). We accounted for several important, potentially confounding factors in our analyses, including body composition and depression symptoms, indicating that the reported relationships existed above and beyond these covariates. Moreover, the sample was racially/ethnically diverse and represented a population at high risk for sustained

obesity and T2D. Given the disproportionate risk for and exponential rise of T2D in this population, our study adds meaningful contributions to the literature on mindfulness and associated eating behavior.

In summary, in the current laboratory test meal study I found evidence for a link between dispositional mindfulness and EAH in adolescents at risk for developing T2D; however, dispositional mindfulness was not associated with eating when hungry. Instead, exploratory analysis revealed a significant interaction between LOC and state hunger on meal intake such that teens prone to uncontrolled eating ate the most in a state of high hunger. These findings suggest that interventions to increase mindfulness may be useful in decreasing disinhibited eating in adolescents at risk for T2D. Mindfulness-based training to foster interoceptive awareness and recognition of hunger cues may be important for helping at risk youth to develop long-term healthy eating behavior.

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APPENDIX A

Mindfulness Attention and Awareness Scale

Below is a collection of statements about your everyday experience. Please indicate how frequently or infrequently you currently have each experience. Please answer according to what really reflects your experience rather than what you think your experience should be. Please treat each item as a separate item.

1. I could be experiencing some emotion and not be conscious of it until some later time.
   Almost Always
   Very Frequently
   Somewhat Frequently
   Somewhat Infrequently
   Very Infrequently

2. I break or spill things because of carelessness, not paying attention, or thinking of something else.
   Almost Always
   Very Frequently
   Somewhat Frequently
   Somewhat Infrequently
   Very Infrequently

3. I find it difficult to stay focused on what's happening in the present.
   Almost Always
   Very Frequently
   Somewhat Frequently
   Somewhat Infrequently
   Very Infrequently

4. I tend to walk quickly to get where I'm going without paying attention to what I experience along the way.
   Almost Always
   Very Frequently
   Somewhat Frequently
   Somewhat Infrequently
   Very Infrequently

5. I tend not to notice feelings of physical tension or discomfort until they really grab my attention.
   Almost Always
   Very Frequently

Somewhat Frequently
Somewhat Infrequently
Very Infrequently

6. I forget a person's name almost as soon as I've been told it for the first time.
   Almost Always
   Very Frequently
   Somewhat Frequently
   Somewhat Infrequently
   Very Infrequently

7. It seems I am "running on automatic," without much awareness of what I'm doing.
   Almost Always
   Very Frequently
   Somewhat Frequently
   Somewhat Infrequently
   Very Infrequently

8. I rush through activities without being really attentive to them.
   Almost Always
   Very Frequently
   Somewhat Frequently
   Somewhat Infrequently
   Very Infrequently

9. I get so focused on the goal I want to achieve that I lose touch with what I am doing right now to get there.
   Almost Always
   Very Frequently
   Somewhat Frequently
   Somewhat Infrequently
   Very Infrequently

10. I do jobs or tasks automatically, without being aware of what I'm doing.
    Almost Always
    Very Frequently
    Somewhat Frequently
    Somewhat Infrequently
    Very Infrequently

11. I find myself listening to someone with one ear, doing something else at the same time.
    Almost Always
    Very Frequently
    Somewhat Frequently
    Somewhat Infrequently
    Very Infrequently

12. I drive places on "automatic pilot" and then wonder why I went there.
    Almost Always
    Very Frequently
    Somewhat Frequently
    Somewhat Infrequently
    Very Infrequently

13. I find myself preoccupied with the future or the past.
    Almost Always
    Very Frequently
    Somewhat Frequently
    Somewhat Infrequently
    Very Infrequently

14. I find myself doing things without paying attention.
    Almost Always
    Very Frequently
    Somewhat Frequently
    Somewhat Infrequently
    Very Infrequently

15. I snack without being aware that I'm eating.
    Almost Always
    Very Frequently
    Somewhat Frequently
    Somewhat Infrequently
    Very Infrequently