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# Effects of a Mindfulness-Induction on Subjective and Physiological Stress Response in Adolescents At-Risk for Adult Obesity

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## Abstract

**Background:** Mindfulness-training may benefit stress response and stress-eating, yet few studies have experimentally tested these effects in adolescents. In this short communication, we report whether a brief mindfulness-induction affected acute stress response and stress-eating in adolescents at-risk for adult obesity. We explored disordered eating as a moderator.

**Method:** Twenty-nine adolescents (age 14±2y) at-risk for adult obesity participated in a within-subjects, randomized crossover experiment. Following a 10-minute mindfulness or neutral-induction on different days in random order, the Trier Social Stress Test adapted for adolescents was administered, followed by an ad libitum lunch meal. Physiological stress response (heart rate, blood pressure) and subjective stress response (anxiety, mindlessness) were determined with area under the curve with respect to increase. Stress-eating was measured as test meal energy consumed. Global disordered-eating and binge-eating were assessed with the Eating Disorders Examination-Questionnaire.

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Author Statement

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**Results:** Relative to a neutral-induction, a mindfulness-induction reduced state anxiety response ($p$=.04). There were significant interactions of induction-type by global disordered-eating ($p$=.02) and binge-eating ($p$=.03), such that the mindfulness-induction most reduced anxiety response in adolescents with relatively lower global disordered-eating and those with no binge-eating. Induction-type also interacted with binge-eating in predicting diastolic blood pressure ($p$=.03). A mindfulness-induction, versus neutral-induction, most reduced diastolic blood pressure response in adolescents with binge-eating.

**Conclusions:** Brief mindfulness-training may alter some aspects of acute stress response, with variations by disordered-eating. Future research should test alternative mindfulness induction-types (e.g., acceptance/self-compassion) to improve our understanding of how mindfulness-training may benefit adolescents at-risk for adult obesity.

### Keywords

adolescent; mindfulness; stress; disordered-eating; binge-eating

## 1. Introduction

Dispositional mindfulness—a continuum of the propensity for non-judgmental present-moment attention (Kabat-Zinn, 1994)—can be taught and may address disordered-eating (Godfrey, Gallo, & Afari, 2015), maladaptive eating that includes binge-eating or consumption of a large amount accompanied by a sense of loss-of-control (American Psychiatric Association, 2013). Most studies on mindfulness/disordered-eating have been in adults (Katterman, Kleinman, Hood, Nackers, & Corsica, 2014). Yet, binge-eating typically emerges in adolescence (Swanson, Crow, Le Grange, Swendsen, & Merikangas, 2011) and predicts excess weight gain and worsening metabolic problems (Tanofsky-Kraff et al., 2012). Adolescence is characterized by increases in perceived stress, disordered-eating, and heightened subjective (e.g. anxiety) and physiological (e.g., heart rate, blood pressure) stress sensitivity (Loth, van den Berg, Eisenberg, & Neumark-Sztainer, 2008; Romeo & McEwen, 2006). Stress may also increase reliance on eating to cope with difficulties (i.e., stress-eating), which likely affects obesity and cardiometabolic disease risk (Johnson, Cohen, Kasen, & Brook, 2002). Although mindfulness offers a promising approach for reducing stress and associated eating among adults, scant experimental studies have tested whether inducing mindfulness affects these facets in adolescents.

From an affective theoretical framework, mindfulness may alleviate anxiety that precipitates the onset and exacerbation of binge-eating (Rosenbaum & White, 2013). State anxiety predicts greater intake among adolescents with binge-eating and precedes naturalistic binge-eating (Ranzenhofer et al., 2014; Shank et al., 2017). From a neurobiological framework, the hedonic value of food is enhanced during anxiety-provoking situations (Adam & Epel, 2007). In line with these frameworks, mindfulness-training to alleviate anxiety/stress could be anticipated to reduce disordered-eating.

In associational adult studies, higher dispositional mindfulness has been associated with lower perceived stress (Brown & Ryan, 2003), more adaptive stress-responding (e.g., lower heart rate; Bullis, Bøe, Asnaani, & Hofmann, 2014), and healthier eating (Ouwens, Schiffer,

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Visser, Raeijmaekers, & Nyklíček, 2015). In college students, higher mindfulness has been related to altered cortisol/anxiety response to a laboratory stressor (Brown, Weinstein, & Creswell, 2012; Lucas-Thompson, Miller, Seiter, & Prince, 2019), healthier eating (Jordan, Wang, Donatoni, & Meier, 2014), and less binge-eating (Roberts & Danoff-Burg, 2010). In adolescents with overweight/obesity, higher mindfulness also has been associated with less disordered-eating, binge-eating, and eating in the absence of hunger (Annameier et al., 2018; Pivarunas et al., 2015).

In a small body of experimental studies, brief (approximately 10–25 minute) mindfulness-inductions reduced perceived stress after a laboratory stressor in adults (Creswell, Pacilio, Lindsay, & Brown, 2014) and decreased snack food consumption among college students (Arch et al., 2016). Understanding acute effects of brief mindfulness-induction on stress response/stress-eating in adolescents is needed.

To address this gap, we evaluated effects of brief mindfulness-induction on acute subjective/physiological stress response/stress-eating in adolescents at-risk for adult obesity, based upon above-average body mass index (BMI) or obesity family history. In line with previous research (e.g., Arch et al., 2016; Creswell et al., 2014), mindfulness-induction was expected to lower state anxiety, mindlessness (inverse of mindfulness), heart rate (HR), systolic/diastolic blood pressure (SBP/DBP) stress response, and decrease stress-eating. We explored global disordered-eating (continuum of maladaptive eating attitudes/behaviors) and binge-eating (presence/absence of uncontrolled overeating) as moderators. Distinct obesity subtypes are likely undergirded by different mechanisms and require different interventions (Gillman & Hammond, 2016). Thus, exploring variability in effects of mindfulness-induction by disordered-eating offers utility for future adaptations of mindfulness-training for adolescents at-risk for adult obesity.

## 2. Method

### 2.1. Participants

Participants were $N$=29 boys and girls (45%) 12–17y ($M$±$SD_{age}$ 14.4±1.8y) who identified as non-Hispanic White (62%), Hispanic (35%), or Asian/Pacific Islander (3%; Supplemental Table 1). Adolescents were selected for being at-risk for adult obesity based on BMI≥70th percentile or obesity family history (parental BMI≥30 kg/$m^2$). Most adolescents had obesity (59%; BMI≥95$^{th}$ percentile). Participants were recruited for a study about health behaviors through letters/flyers to area-families, physician offices, and other advertisements. Exclusion criteria were psychiatric symptoms that could impede compliance, major medical problems (e.g., diabetes), medication use affecting weight/mood, and pregnancy (females). The Institutional Review Board approved all procedures.

### 2.2. Procedures

A within-subjects, randomized crossover experiment occurred on two days 6±4weeks apart. Participants were instructed to fast after 10:00pm before both visits. On day one, after consent/assent, height (cm)/weight (kg; unblinded) were measured to compute BMI (kg/$m^2$) and BMI-$z$/percentile (Kuczmarski et al., 2002) and the disordered-eating survey was

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administered. On both days, adolescents were served a standardized breakfast shake at ~9:00am. The laboratory stress-eating paradigm was administered at ~11:00am. After resting for 10-minutes, adolescents were exposed in random order to either a 10-minute audio-recorded mindfulness-induction involving focused-breathing, shown to increase breath/body awareness, or an audio-recorded neutral-induction to focus on whatever came to mind (Hafenbrack, Kinias, & Barsade, 2014). Next, the Trier Social Stress Test (TSST) adapted for adolescents (Yim, Quas, Cahill, & Hayakawa, 2010) was administered. The TSST involves preparation (3-minutes) and delivery of a 5-minute speech and a challenging 4-minute oral arithmetic task in front of a neutral evaluator, and consistently demonstrates robust subjective/objective adolescent stress-response (Seddon et al., 2020). Finally, adolescents were served a 4,500-kcal lunch and instructed, “eat as much as you normally would” (Tanofsky-Kraff et al., 2009). Foods were individually weighed before/after eating. Energy intake was determined from manufacturer data. Stress-eating measured with this paradigm relates to heightened food-reward sensitivity (Smith et al., 2020).

## 2.3. Measures

### 2.3.1. Subjective/Physiological Stress Response.—

Subjective/physiological stress was assessed at rest start/end, induction end, and TSST end. State anxiety was measured on the reliable/valid 6-item State-Trait Anxiety Inventory for Children–State Version ($\alpha$s=.62–.85 across intervals; Kirisci, Clark, & Moss, 1997). State mindlessness was assessed with the reliable/valid 5-item Mindfulness Attention and Awareness Scale–State Version ($\alpha$s=.83–.85; Brown & Ryan, 2003). HR and SBP/DBP were recorded using a cuff-fitted monitor on the non-dominant arm. Areas-under-the-curve with respect to increase ($AUC_i$) were computed to summarize stress responses (Pruessner, Kirschbaum, Meinlschmid, & Hellhammer, 2003).

### 2.3.2. Disordered-eating.—

Global disordered-eating and binge-eating in the past four weeks were measured with the reliable/valid Eating Disorders Examination-Questionnaire (EDE-Q; Carter, Stewart, & Fairburn, 2001; Fairburn & Beglin, 1994). The global scale averages all items ($\alpha$=.94). Adolescents were considered to have binge-eating when they endorsed, “Have there been times when you have eaten what most people would regard as an unusually large amount of food?” and “Have you experienced a sense of loss of control overeating?” Those who endorsed neither or one item only were considered to have no binge-eating or overeating without loss-of-control.

## 2.4. Data Analysis

Outliers were winsorized to 1.5 times the interquartile range >75$^{th}$ percentile or <25$^{th}$ percentile (6% data). Linear mixed models were performed with the dependent variables of anxiety, mindlessness, HR, SBP/DBP ($AUC_i$) and stress-eating (kcal) using restricted maximum likelihood estimation to handle missing data. Main effects were induction-type and disordered-eating or binge-eating. Two-way interactions of induction-type by disordered-eating or binge-eating were examined separately, due to the small sample and to avoid multi-collinearity problems. Global disordered eating was analyzed as a continuous variable; we plotted significant interactions using a median split to aid interpretation. There were no induction-order effects by disordered eating, but those who received the neutral-

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induction first had a higher BMI-*z* and were younger. We controlled for induction-order (mindfulness/neutral first), age, BMI-*z*, sex, and initial levels of respective outcomes.

## 3. Results

### 3.1. Subjective/Physiological Stress Response

There was a main effect of induction-type on state anxiety $AUC_i$ ($p$=.04; Table 1). In the mindfulness-induction, adolescents had no increase in anxiety compared to an increase in the neutral-induction (mindfulness:95%CI −14.37, 11.58 vs. neutral:95%CI 3.95, 26.23). Main effect of induction-type on mindlessness $AUC_i$ was not significant ($p$=.26), with no change in either condition (mindfulness:95%CI −6.64, 6.09 vs. neutral:95%CI −9.53, 3.03). There were no main effects of induction-type on HR or SBP/DBP ($p$-values>.12).

Main effects of global disordered-eating and binge-eating on state anxiety, mindlessness, and physiological responses were non-significant ($p$-values>.08). There were interactions of induction-type by disordered-eating ($p$=.02) and binge-eating ($p$=.03) in predicting anxiety $AUC_i$. Reduction in anxiety from the mindfulness-induction was more pronounced among adolescents with relatively lower (Figure 1a) versus higher (Figure 1b) disordered-eating. Similarly, reduction in anxiety in the mindfulness-induction was only observed among adolescents without binge-eating (Figure 1c/d). There were no interactive effects on mindlessness ($p$-values>.47).

Additionally, there was an induction-type by binge-eating interaction predicting DBP $AUC_i$ ($p$=.03). There was greater reduction in DBP response following the mindfulness versus neutral-induction among adolescents with binge-eating, whereas the difference in DBP response among adolescents without binge-eating was less pronounced after mindfulness versus neutral-inductions (Figure 1e/f). No other interactions were significant ($p$-values>.09).

### 3.2. Stress-Eating

There was no main effect of induction-type on stress-eating (mindfulness:814±62kcal vs. neutral:755±59kcal, $p$=.21). Likewise, there were no main or interactive effects of disordered-eating/binge-eating on stress-eating ($p$-values>.52).

## 4. Discussion

A brief 10-minute mindfulness-induction produced less state anxiety compared to a neutral-induction. Following a mindfulness-induction, adolescents reported no change in state anxiety, whereas they experienced an anxiety increase in the neutral-induction. These findings fit with past adult studies finding an inverse relationship between mindfulness and distress tolerance/maladaptive stress responses (e.g., Brown et al., 2012). Repeated inductions of mindfulness in prolonged mindfulness-training may be explanatory in lowering anxiety symptomatology and improving coping (Sibinga et al., 2013). This finding has potentially relevant clinical implications. Cultivating mindfulness in the face of stress may help adolescents at-risk for adult obesity to alleviate anxiety.

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Mindfulness-induction effects on state anxiety were moderated by disordered-eating and binge-eating. Adolescents with lower disordered-eating/no binge-eating exhibited lower anxiety response after a mindfulness-induction, whereas those with more disordered-eating/binge-eating did not benefit. One possibility is that higher trait anxiety, frequently accompanying disordered-eating, renders state anxiety less malleable during a brief mindfulness-induction (Goldschmidt, Aspen, Sinton, Tanofsky- Kraff, & Wilfley, 2008). Prolonged training could be anticipated to overcome initial barriers, as mindfulness-based intervention programs have led to improved anxiety and eating in adults (O'Reilly, Cook, Spruijt- Metz, & Black, 2014). Furthermore, the mindfulness-induction in this study was breath-awareness only, which may be less effective than attention plus acceptance/compassion-training (Lindsay, Young, Brown, Smyth, & Creswell, 2019). Future research should disentangle effects of attention and acceptance/compassion for adolescents with disordered-eating/binge-eating.

Unexpectedly, mindfulness-induction did not have main or interactive effects on state mindlessness, physiological stress, or stress-eating. Brevity of the mindfulness-induction and/or omission of acceptance/self-compassion-training may have reduced potency. It is also possible that state anxiety is a more tangible and/or malleable construct than mindfulness/mindlessness. Mindfulness/mindlessness may be difficult to describe for adolescents, particularly under stressful circumstances (Creswell et al., 2014). Additionally, some research suggests individuals with obesity or disordered-eating have blunted cardiovascular reactions to stress (Phillips, 2011), potentially making mindfulness-induction effects on stress responding difficult to detect in this population. It will be important to test these potential explanations.

There was a moderating effect of mindfulness-induction by binge-eating on DBP. Adolescents with binge-eating experienced lower DBP response after a mindfulness versus neutral-induction, which was not apparent in those without binge-eating. This finding points to an interesting distinction between subjective and physiological stress-responding among adolescents with and without binge-eating. Adolescents with binge-eating may experience subjective and physiological stress differently, consistent with previous studies showing these two dimensions of stress response are often misaligned (Lucas- Thompson, 2012). Individuals with binge-eating tend toward more negative subjective stress appraisals (Hansel & Wittrock, 1997) and lower distress tolerance (Anestis, Selby, Fink, & Joiner, 2007). Physiological measurements may shed light on objective internal/physical stress experiences. Further investigation of the distinction between subjective-physiological stress responses among adolescents with binge-eating is warranted.

The current study used a small sample with limited representation of racial/ethnic minorities, a wide age range, and previous mindfulness practice was not measured, limiting inferences. Mechanisms by which a mindfulness-induction changed anxiety/DBP remain unclear. Mindfulness-induction did not affect state mindlessness, which may have been due to mindfulness-induction brevity, attention-training versus acceptance/self-compassion, and/or difficulty explicitly reporting mindlessness. Small samples are prone to greater standard error/less robust estimates of effect and interaction results were exploratory/hypothesis-generating. Interpretability depends upon future replication.

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In conclusion, a brief mindfulness-induction potentially may reduce state anxiety among adolescents at-risk for adult obesity. Adolescents without disordered-eating benefited more from a mindfulness-induction to reduce anxiety response to stress than those with disordered-eating. In contrast, only adolescents with binge-eating had lower DBP stress response following a mindfulness-induction. Future research with a larger sample size, lengthier mindfulness-training, and/or acceptance/self-compassion induction may increase our understanding of mechanisms underlying potential benefits of mindfulness-training in adolescents at-risk for adult obesity.

## Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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## Highlights

- Few experimental studies have tested acute effects of mindfulness in adolescents
- A brief, 10-minute mindfulness-induction reduced state anxiety response to stress
- Mindfulness-induction reduced anxiety in teens with less disordered/binge-eating
- Mindfulness lowered diastolic blood pressure only in adolescents with binge-eating
- Mindfulness-induction did not affect heart rate response to stress or stress-eating

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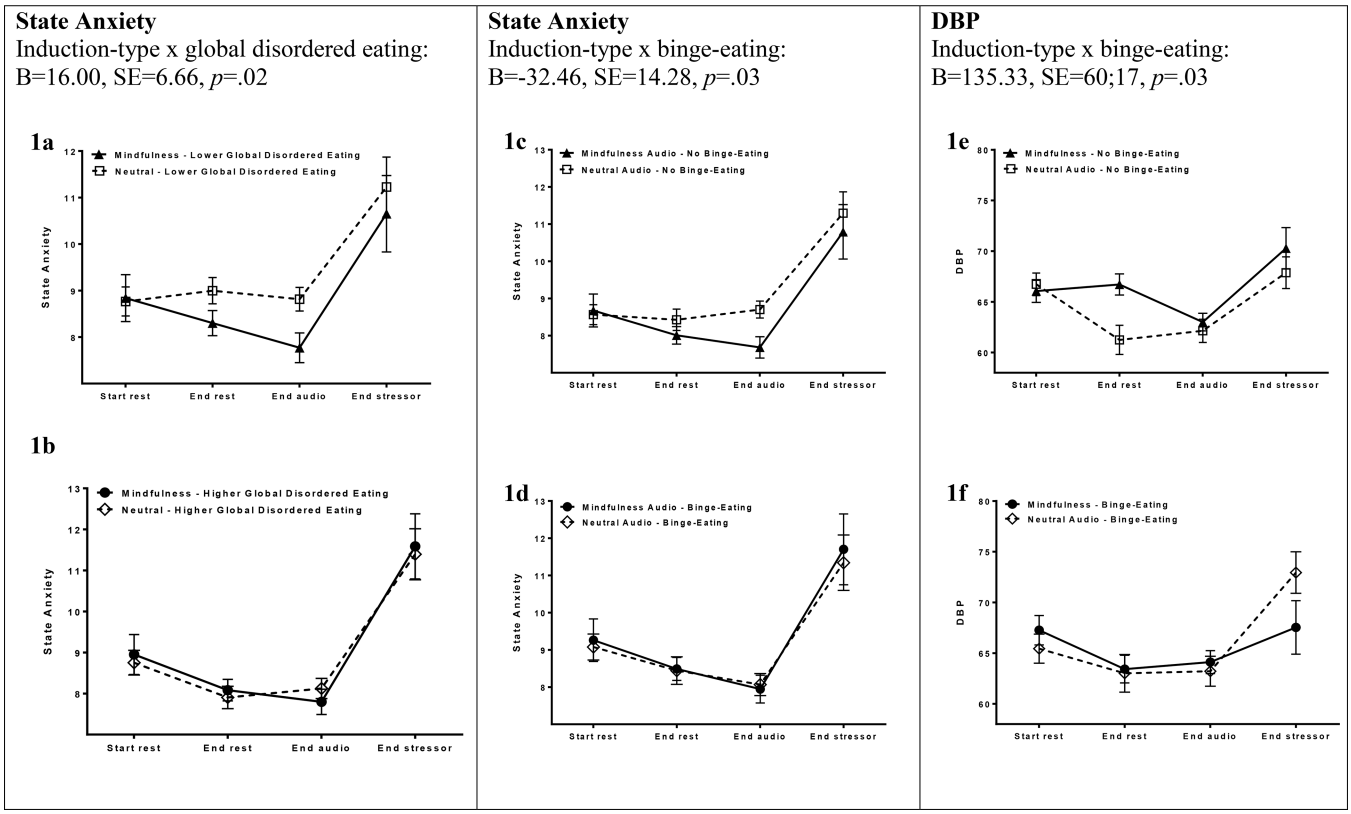


**Figure 1.**

During a mindfulness-induction versus neutral-induction, area under the curve with respect to increase ($AUC_i$) for state anxiety among adolescents with relatively lower global disordered eating (**1a**) versus relatively higher global disordered-eating (**1b**), depicted as a median-split (Eating Disorder Examination-Questionnaire global score <.1.726 vs. ≥ 1.727); and adolescents with absence of binge-eating versus presence of binge-eating for $AUC_i$ for state anxiety (**1c/d**) and diastolic blood pressure (DBP; **1e/f**).

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**Table 1**

Summary of Linear Mixed Models Predicting Subjective Stress Response and Physiological Stress Response

| | State Anxiety | | | State Mind*less*ness | | | HR | | | SBP | | | DBP | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Predictors** | **B** | **SE** | ***p*** | **B** | **SE** | ***p*** | **B** | **SE** | ***p*** | **B** | **SE** | ***p*** | **B** | **SE** | ***p*** |
| **Step 1**: Audio Induction Type | −16.43 | 7.46 | .04 | 2.98 | 2.60 | .26 | −54.66 | 41.63 | .20 | −100.08 | 96.73 | .31 | −81.51 | 52.26 | .13 |
| **Step 2a**: Global Disordered Eating | 3.62 | 4.85 | .46 | 2.03 | 2.98 | .50 | −4.99 | 19.97 | .81 | −57.90 | 45.37 | .22 | 12.90 | 25.70 | .62 |
| **Step 2b**: Binge-Eating | −2.10 | 10.29 | .84 | −10.84 | 5.80 | .08 | −35.70 | 40.67 | .39 | −37.50 | 98.13 | .71 | −20.46 | 53.58 | .71 |
| **Step 3a**: Audio Type × Global Disordered Eating | 16.00 | 6.66 | .02 | 2.56 | 2.56 | .33 | −31.99 | 25.48 | .22 | −42.61 | 73.25 | .57 | −50.96 | 28.46 | .09 |
| **Step 3b**: Audio Type × Binge-Eating | −32.46 | 14.28 | .03 | −1.88 | 5.37 | .73 | 64.10 | 54.51 | .25 | 54.54 | 155.32 | .73 | 135.33 | 60.17 | .03 |

*Note.* B = Unstandardized estimate; SE = Standard error; HR = Heart rate; SBP = Systolic blood pressure; DBP = Diastolic blood pressure; Audio Induction Type was dummy-coded: 1 = mindfulness audio-recording and 2 = neutral audio-recording. All outcomes were measured as area under the curve with respect to increase ($AUC_i$). Covariates within each model included: sex, age, BMI-*z* score, audio type order (mindfulness or neutral first), and initial level (start of rest period) of the respective outcome variable. Estimates are displayed from each step upon entry into the model.