HHS Public Access
Author manuscript
J Behav Med. Author manuscript; available in PMC 2017 April 01.

Published in final edited form as:
J Behav Med. 2016 April ; 39(2): 201–213. doi:10.1007/s10865-015-9692-8.

Effects of a mindfulness-based intervention on mindful eating, sweets consumption, and fasting glucose levels in obese adults: data from the SHINE randomized controlled trial

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Abstract

We evaluated changes in mindful eating as a potential mechanism underlying the effects of a mindfulness-based intervention for weight loss on eating of sweet foods and fasting glucose levels. We randomized 194 obese individuals (*M* age = 47.0 ± 12.7 years; BMI = 35.5 ± 3.6; 78 % women) to a 5.5-month diet-exercise program with or without mindfulness training. The mindfulness group, relative to the active control group, evidenced increases in mindful eating and maintenance of fasting glucose from baseline to 12-month assessment. Increases in mindful eating were associated with decreased eating of sweets and fasting glucose levels among mindfulness group participants, but this association was not statistically significant among active control group participants. Twelve-month increases in mindful eating partially mediated the effect of intervention arm on changes in fasting glucose levels from baseline to 12-month assessment. Increases in mindful eating may contribute to the effects of mindfulness-based weight loss interventions on eating of sweets and fasting glucose levels.

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Conflict of interest Ashley E. Mason, Elissa S. Epel, Patricia J. Moran, Mary Dallman, Robert H. Lustig, Michael Acree, Peter Bacchetti, Barbara A. Laraia, Frederick M. Hecht, and Jennifer Daubenmier declare that they have no conflicts of interest. Jean Kristeller participated in a paid webinar on ‘mindful snacking’ for Allidura Consumer.

Human and animal rights and Informed consent All procedures followed were in accordance with ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2000. Informed consent was obtained from all patients for being included in the study.

Keywords

Mindful eating; Fasting glucose; Sweet foods; Obese adults; Mindfulness intervention

Introduction

Americans' sugar consumption has risen dramatically over the past several decades (Profiling Food Consumption in America, 2003; Wells & Buzby, 2008). Consuming sugar-sweetened foods, such as soft drinks and sugar-laden processed foods (Gross et al., 2004; Schulze et al., 2004), may increase risk for obesity and type 2 diabetes, which is one of the fastest growing and most expensive chronic medical conditions in the United States (American Diabetes Association, 2013; Mokdad et al., 2001). In addition to their high caloric density, sugar-laden foods can alter the innate satiety system (e.g., Rada et al., 2005). Specifically, overeating sugar-laden foods may disrupt satiety signaling systems (Avena et al., 2008) by altering homeostatic physiological mechanisms that regulate energy intake and biasing individuals toward increased hedonic eating (Bellisle et al., 2012; Colantuoni et al., 2002). Ubiquitous access to sugar-laden foods, coupled with constant opportunities for mindless eating, such as while watching television, driving, working at a computer, or otherwise multitasking (Ogden et al., 2013; Wansink, 2007), can increase risk for eating beyond homeostatic need. Taken together, these factors provide opportunities for the development or exacerbation of metabolic dysregulation (Chaput et al., 2011; Lake & Townshend, 2006).

To date, most weight-loss trials report short-term reductions in weight and other indices of metabolic health, yet these improvements tend to be lost during longer-term follow-up (Byrne et al., 2003; Mann et al., 2007). A growing body of literature suggests that mindfulness-based interventions may aid longer-term weight loss or maintenance and improve metabolic health (O'Reilly et al., 2014). Mindful eating includes making deliberate food choices, cultivating awareness of interoceptive cues related to food intake, attending to physical versus psychological cues to eat, and appropriately responding to these cues (Kristeller & Wolever, 2010). Mindful eating has been associated with greater diet-related self-efficacy, weight loss, self-reported mindful eating, and physical activity relative to control groups (Kristeller & Hallett, 1999; Kristeller et al., 2013; Miller et al., 2013; Timmerman & Brown, 2012). Mindful eating may be particularly effective in modifying the disrupted underlying process in food intake regulation linked to 'liking' versus 'wanting' high-fat and sweet foods (Finlayson & Dalton, 2012; Finlayson et al., 2007): A core set of practices from the Mindfulness-Based Eating Awareness Training (MB-EAT; Kristeller & Wolever, 2010) that were used within the present intervention involve guiding individuals to attend to taste awareness, satistaction, and sensory-specific satiety. Doing so may disrupt a tendency to overeat foods with high fat and sugar, fat, and/or salt content, while retaining or even heightening awareness of food preferences (Kristeller & Wolever, 2010). A recent systematic literature review reported that in 18 of 21 studies, participants assigned to mindfulness-based interventions evidenced improvements in targeted eating behaviors (O'Reilly et al., 2014). Few randomized controlled trials, however, have examined either the effects or mechanism of mindfulness-based interventions on metabolic health (Dalen et al., 2010; Miller et al., 2013). For example, psychological distress is associated with impaired glycemic control in type 2 diabetics, and may be another pathway by which mindfulness-based interventions improve glycemic control (Ismail et al., 2004; Rosenzweig et al., 2007). Yet, few rigorous controlled trials have examined the mechanisms by which mindfulness-based interventions targeting eating behavior may improve metabolic health. Although these interventions often include mindful eating components (O'Reilly et al., 2014), we know little about whether changes in self-reported mindful eating mediate effects of mindfulness training on metabolic health.

The present study

We recently conducted a randomized controlled trial examining the impact of a 5.5-month mindfulness-based diet and exercise intervention compared to an active control (diet and exercise only) on metabolic outcomes over a 1.5-year period (Daubenmier et al., in press). Those enrolled in the mindfulness intervention evidenced better maintenance of fasting glucose reductions from baseline to 12-month assessment in comparison to the active control group, who showed a statistically significant increase in fasting glucose over this 12-month time period. We examine changes in mindful eating as a potential mechanism for this effect in the present study.

We hypothesized that mindfulness intervention participants would report reduced eating of sweets and evidence decreased fasting glucose levels at the first post-intervention assessment (6 months), whereas the active control participants would not. We further predicted that the mindfulness intervention would evidence maintenance of these effects at a follow-up assessment (12 months). Additionally, we predicted that increases in mindful eating would be associated with reductions in both eating of sweets and fasting glucose among mindfulness intervention participants, but did not expect to observe these associations in the active control participants. Lastly, we predicted that increases in mindful eating would mediate the impact of group assignment on eating of sweets and fasting glucose.

Methods

Study design

We randomized obese adults (BMI ≥ 30) in a 1:1 ratio to a 5.5-month diet and exercise weight-loss program, either with or without mindfulness-based eating and stress reduction components. A database manager not involved in participant enrollment used a computer-generated random allocation sequence with random block sizes of 4–8 for participant randomization. The University of California, San Francisco (UCSF) Institutional Review Board approved of all study procedures, and all participants provided informed consent. Participants were enrolled for the intervention and follow-up assessments for a total of 18 months. Here, we completed analyses using data from the first 12 months, as we did not assess self-reported eating of sweets at 18 months. See Daubenmier et al. (in press) for detailed study design and methodology. This trial is registered at clinicaltrials.gov (NCT00960414).

Participants

We recruited participants from the San Francisco Bay Area community through newspaper advertisements, flyers, online postings, and referrals made within UCSF medical clinics. The study was advertised as a comparative weight loss intervention that involved lifestyle changes in diet, exercise, and stress management. Recruitment materials did not provide specific details regarding differences across intervention groups, but rather focused on an overarching theme of lifestyle changes for weight management. Inclusion criteria included body mass index (BMI) between 30 and 45.9, abdominal obesity (waist circumference > 102 cm for men and > 88 cm for women, and an age of 18 years or older. Exclusion criteria included type 1 or type 2 diabetes (fasting glucose ≥ 126); pregnancy; breastfeeding or fewer than 6 months post-partum; corticosteroid and/or immune-suppressing or immune-modulating medications, prescription weight-loss medications; untreated hypothyroidism; history of coronary artery disease; and history of or active bulimia (see Daubenmier et al., in press). If eligible, participants completed a stress reactivity task and adiposity assessment procedures at two separate visits prior to randomization. We required these two visits for enrollment and randomization, but did not use results to exclude participants. We enrolled 6 cohorts from July 2009 thru February 2012 and completed data collection in October of 2013.

Intervention

Participants in each condition received intervention in a group format at a UCSF medical center. All participants attended 12 weekly evening sessions, 3 biweekly sessions, and one session 4 weeks later (each evening session was 2–2.5 h), as well as an all-day weekend session (5.0 h for the active control group, 6.5 h for the mindfulness intervention group). All sessions occurred over the course of the first 5.5 months of study involvement and were led by a registered dietitian in the active control and co-led by a registered dietitian and mindfulness instructor in the mindfulness intervention. See Daubenmier et al. (in press) for further intervention details.

Diet and exercise components were similar in each intervention. The diet component focused on modest calorie reduction: We asked participants to set a goal of reducing food intake of their choice by 500 calories, similar to that used in the Mindfulness-Based Eating program (MB-EAT; Kristeller & Wolever, 2010) and focused on decreasing calorically-dense, nutrient-poor foods such as refined carbohydrates, and increasing fresh fruit and vegetable consumption, as well as healthy oils and proteins. The exercise component focused on increasing activity throughout the day as well as structured aerobic and anaerobic exercise, such as bicycling, swimming, strength training, and walking.

Mindfulness intervention group—Participants in the mindfulness intervention group received mindfulness training across several domains. Mindfulness group participants learned mindful eating techniques and flexible, self-directed caloric reduction, and increases in activity level [as taught in the Mindfulness Based Eating Awareness Training (MB-EAT) program; Kristeller & Wolever, 2010]. Mindful eating training involved guided eating meditations and discussion of mindful eating practices of (1) attending to physical hunger, stomach fullness, and taste satisfaction (sensory-specific satiety), (2) increasing awareness of these practices in “mini-meditations” prior to meals, and (3) identifying food craving, and emotional and other triggers to eat. We did not instruct participants to avoid particular foods. Instead, we taught them to practice savoring and awareness of food tastes and textures, with a particular focus on drawing hedonic value from smaller amounts of highly preferred food, such as sweets. The MB-EAT model also incorporates mindfulness-based stress reduction (MBSR) techniques (Kabat-Zinn & Hanh, 2009) including body scan meditation, self-acceptance and loving kindness meditation, mindful yoga, and mindful sitting meditation, which were somewhat augmented in the current study (see Daubenmier et al., in press). We encouraged participants to spend up to 30 min per day in meditation practice. We specifically encouraged participants to use mindful eating principles while eating meals and snacks and to practice chair yoga, loving kindness meditation, body scans, and seated mindfulness meditation. We provided participants with materials (e.g., CDs with guided mindfulness practices) for home use, as well as paper logbooks in which participants recorded their engagement with these practices.

Active control group—Active control group participants received additional content to ensure equivalence across intervention groups in a number of dimensions. To ensure equivalence in time spent in the group setting and with an instructor, these participants received additional information about nutrition and physical activity, such as socio-political issues that impact food choice and how to make well-informed decisions about diet products. Instructors taught cognitive-behavioral and progressive muscle relaxation tools for stress management, and participants were given weekly home assignments that reinforced diet and exercise lessons. We provided participants with materials (e.g., CDs with progressive muscle relaxation) for home practice.

Measures

Measures used in these analyses were collected from participants at baseline, 6- and 12-month assessments.

Mindful eating—Participants completed the 28-item Mindful Eating Questionnaire (MEQ; Framson et al., 2009), which was developed to assess mindful eating in the general population. The MEQ comprises five subscales (awareness, distraction, disinhibition, emotional, and external subscales), the mean of which represents a mindful eating summary. Scale developers posited these subscales as assessing key mindfulness skills in the context of eating. The awareness sub-scale captures the important processes of attending to the tastes, smells, and textures of foods. The distraction sub-scale captures the recognition of habit-based eating, such as while multitasking, that is divorced from the true need to eat. Relatedly, the disinhibition, emotional, and external subscales focus on awareness of eating triggers. Likert scale response options range from 1 (*never/rarely*) to 4 (*usually/always*), with higher scores reflecting greater mindful eating. In the current analysis, we used the mean total MEQ score after omitting three MEQ items specifically tapping eating of sweet foods.[1] The modified MEQ evidenced adequate internal reliability at each assessment (baseline $\alpha = 0.74$; 6 months $\alpha = 0.77$; 12 months $\alpha = 0.83$).

[1]Results do not change when using the full MEQ.

Percentage of calories from sweet foods and desserts (sweets)—Participants completed an online version of 2005 Block Food Frequency Questionnaire (FFQ; Boucher et al., 2006), a 110-item questionnaire based on the NHANES (National Health and Nutrition Examination Survey) dietary recall data. The Block FFQ aims to estimate usual and customary consumption of a wide array of nutrients and food groups and several versions have been validated across a wide array of samples (French et al., 2000; Johnson et al., 2007). Nutrition Quest (Berkeley, CA, USA) provided nutrient calculations. A category that captures the percentage of calories from sweets comprises 33 typical sweet food and dessert items. We instructed participants to complete the questionnaire based on their food choices over the past 30 days. We computed sweet intake as the percentage of calories eaten from these 33 categories over the course of a "typical" 24-h period. We excluded five participants (baseline assessment, n = 3; 6-month assessment, n = 2) from analyses with sweets due to out-of-range total caloric intake per day (<500 or >5000 calories per day), as caloric estimates outside of these limits are considered unrealistic (Willett, 2012).

Fasting glucose—We conducted fasting blood draws and anthropometric measurement at the UCSF General Clinical Research Center (GCRC). We used standardized clinical assays to obtain fasting blood glucose measurements at each assessment. We assessed height at the first assessment, and thereafter calculated body mass index (BMI = Weight/Height^2) at each assessment.

Analytic strategy

We conducted all analyses in SPSS 22.0 (IBM Corp., 2013). To reduce disproportionate influence of outliers in analyses, we winsorized statistical outliers (≥4 SD outside of the mean) and set them to the next highest value (Wilcox, 2012) for the mindful eating, eating of sweets, and fasting glucose variables. There were four fasting glucose outliers (two each above and below the mean) across three participants. There were four sweets outliers (all above the mean) across four participants. There were no mindful eating outliers. In total, these transformations impacted fewer than 1 % of the data from these three variables (8 of 989 data points). Analyses revealed the same patterns of statistical significance when we dropped these outliers (rather than transformed them). We present results of analyses using the complete (winsorized) dataset.

We used ANCOVA to test our prediction that the group assignment would predict changes in eating of sweets and fasting glucose such that mindfulness intervention participants would report increased mindful eating, reduced eating of sweets, and reduced fasting glucose at the first post-intervention assessment (6 months), whereas the active control participants would not. Models predicted change in each outcome from baseline to 6- and 12-month assessments and adjusted for each outcome assessed at baseline.

We used multiple regression to test our prediction that increased mindful eating would associate with reduced eating of sweets and fasting glucose within mindfulness intervention participants, but not within active control participants. We adjusted for each outcome assessed at baseline and assessed for reverse-causation by predicting mindful eating at 6- or

12-month assessments (after accounting for mindful eating at baseline) from changes in both fasting glucose and eating of sweets.

We used mediation analysis to test our prediction that increases in self-reported mindful eating would mediate the effect of group assignment on fasting glucose and eating of sweets at each outcome assessment. We used SPSS INDIRECT (Hayes, 2009; Preacher & Hayes, 2004) and used 5000 bootstrapped samples to allow for construction of asymmetric confidence intervals.

Results

Participant flow

Figure 1 illustrates the flow of participants through the trial. Of 194 participants enrolled in the trial, 156 (80.4 %) completed the 6-month assessment, and 149 (76.8 %) completed the 12-month assessment. Participants were largely female, and White, and the average age was 47.0 ± 12.7 years with a mean BMI of 35.5 ± 3.6 kg/m^2. Participants did not statistically significantly differ in study variables at baseline across intervention arms except for the percentage of calories from sweets and desserts. Specially, at baseline, mindfulness participants (11.69 %) relative to control participants (15.57 %) endorsed eating significantly fewer calories from sweets and desserts [M_Δ = 3.88 % $SE(M_\Delta)$ = 1.36 %, p = 0.005, 95 % CI (1.18, 6.57)]. Participants who completed the 12-month assessment reported significantly less mindful eating at baseline (M = 2.60 ± 0.32) relative to those who did not [M = 2.72 ± 0.32; p = 0.024, 95 % CI (0.02, 0.23)]. We observed no other statistically significant associations with attrition. Baseline demographic and study variables appear in Table 1.

Change in mindful eating, eating of sweets, and fasting glucose by group

Figure 2 shows the effects of group assignment on changes in mindful eating, eating of sweets, and fasting glucose. Table 2 shows mean values of each variable at baseline, 6-and 12-month assessments.

Mindful eating—Mindfulness intervention participants [M_Δ = 0.32; $SE(M_\Delta)$ = 0.04], relative to control participants [M_Δ = 0.23; $SE(M_\Delta)$ = 0.04], trended toward greater increases in mindful eating from baseline to 6 months, p = 0.097, diff = −0.09, 95 % CI (−0.19, 0.02). Similarly, mindfulness intervention participants [M_Δ = 0.33; $SE(M_\Delta)$ = 0.04], relative to control participants [M_Δ = 0.22; $SE(M_\Delta)$ = 0.04], showed greater increases in mindful eating from baseline to 12 months, p = 0.036, diff = −0.11, 95 % CI (−0.22, −0.01). Groups were not significantly different in post-intervention maintenance of mindful eating (from 6 to 12 months). Analyses by MEQ subscales revealed that mindfulness intervention participants [M_Δ = 0.29; $SE(M_\Delta)$ = 0.06], relative to control participants [M_Δ = 0.06; $SE(M_\Delta)$ = 0.06], showed significantly greater increases in the awareness subscale from baseline to 12 months, p = 0.007, diff = −0.23, 95 % CI (−0.39, −0.06). Mindfulness intervention participants [M_Δ = 0.02; $SE(M_\Delta)$ = 0.04] also evidenced better maintenance (6–12 months) in the awareness subscale of the MEQ relative to control participants [M_Δ = −0.12; $SE(M_\Delta)$ = 0.05], diff = −0.14, 95 % CI (−0.27, −0.02), p = 0.023.

Eating of sweets—Intervention groups did not significantly differ in change in eating of sweets from baseline to 6 months, $p = 0.54$, or 12 months, $p = 0.12$, after adjusting for baseline eating of sweets. Intervention groups did, however, differ in change in eating of sweets from 6 to 12 months, $p = 0.035$, diff = 2.17, 95 % CI (0.16, 4.18), such that control participants [$M_{\Delta} = 2.22$; $SE(M_{\Delta}) = 0.73$] evidenced a substantial increase in eating sweets from 6 to 12 months relative to mindfulness intervention participants [$M_{\Delta} = 0.05$; $SE(M_{\Delta}) = 0.70$].

Fasting glucose—Intervention groups did not significantly differ in change in fasting glucose from baseline to 6 months, $p = 0.63$ (Table 2). Control participants had a significantly greater increase in fasting glucose from baseline to 12 months [$M_{\Delta} = 2.33$ mg/dL; $SE(M_{\Delta}) = 0.79$] than the mindfulness intervention participants [$M_{\Delta} = 0.02$; $SE(M_{\Delta}) = 0.74$], $p = 0.035$, diff = 2.31 mg/dL, 95 % CI (0.16, 4.46). Intervention groups did not significantly differ in post-intervention maintenance of fasting glucose from 6 to 12 months, $p = 0.28$.

Change in mindful eating as a predictor of change in eating of sweets and fasting glucose

Across the entire sample, increases in mindful eating from baseline to 6 and 12 months nearly significantly predicted decreases in fasting glucose in those time periods and decreased eating of sweets from baseline to 6 months (Table 3). To ascertain if these effects differed by group, we tested moderation analyses of group assignment × change in mindful eating from baseline to 6 and 12 months predicting changes in each eating of sweets and fasting glucose in those time periods.

Group assignment did not significantly interact with changes in mindful eating to predict changes in eating of sweets from baseline to 6 months [$b = -1.03$, $SE(b) = 1.42$, $p = 0.47$] or 12 months [$b = -0.47$, $SE(b) = 1.34$, $p = 0.73$]. To further examine associations between changes in mindful eating and changes in both eating of sweets and fasting glucose, we conducted subgroup analyses. Results suggested that changes in mindful eating from baseline to 6 months (but not 12 months) predicted reductions in eating of sweets within the mindfulness intervention group, but less so in the control group (Table 3; Fig. 3).

Group assignment did not interact with change in mindful eating to predict changes in fasting glucose from baseline to 6 months [$b = -0.74$, $SE(b) = 1.53$, $p = 0.63$] or 12 months [$b = -0.51$, $SE(b) = 1.60$, $p = 0.75$]. Subgroup analyses indicated that changes in mindful eating from baseline to 6 and 12 months predicted reductions in fasting glucose at both times, within the mindfulness intervention group, but not the control group (Table 3; Fig. 3). These models did not remain significant when reversed. That is, changes in fasting glucose from baseline to 6 and 12 months did not predict changes in mindful eating at those times.

Mindful eating as a mediator of mindfulness intervention on fasting glucose

Criteria for mediation (Hayes, 2009) were met for a model testing change in mindful eating from baseline to 12 months as a mediator of the association between group assignment and change in fasting glucose from baseline to 12 months. That is, (1) group assignment predicted change in mindful eating from baseline to 12 months (Path A), (2) change in mindful eating from baseline to 12 months predicted change in fasting glucose from baseline to 12 months (Path B), and (3) group assignment predicted change in fasting glucose from baseline to 12 months (Path C; see Fig. 4). These criteria were not met for models testing change in mindful eating from baseline to 12 months as a mediator of associations between group assignment and changes in eating of sweets from baseline 12 months. Mediation analysis provided evidence that change in mindful eating from baseline to 12 months partially mediated the effect of group assignment on fasting glucose from baseline to 12 months (Fig. 4), explaining an estimated 15 % of the effect, $b = -0.36$, $SE_b = 0.25$, 95 % CI (−1.09, −0.03).

Adjusting for BMI

Given established associations between glucose control and overweight (Kahn & Flier, 2000) we examined how accounting for changes in BMI would impact the observed associations between changes in mindful eating and changes in fasting glucose in the trial sample and in the mindfulness group. In the entire sample, the association between 6-month changes in mindful eating and fasting glucose remained statistically significant ($\beta = -0.18$, $p = 0.015$) after adjusting for 6-month change in BMI (6-month change in BMI also significantly predicted change in fasting glucose such that greater reductions in BMI were associated with greater reductions in fasting glucose, $\beta = 0.18$, $p = 0.019$). Similarly, in the mindfulness group, the association between 6-month changes in mindful eating and fasting glucose remained significant ($\beta = -0.21$, $p = 0.038$) after adjusting for change in BMI. In the mindfulness group, 6-month change in BMI also significantly predicted change in fasting glucose such that greater reductions in BMI were associated with greater reductions in fasting glucose, $\beta = 0.22$, $p = 0.029$.

In the entire sample, the association between 12-month changes in mindful eating and fasting glucose weakened ($\beta = -0.12$, $p = 0.098$) after adjusting for 12-month change in BMI (12-month change in BMI significantly predicted change in fasting glucose such that greater reductions in BMI were associated with greater reductions in fasting glucose, $\beta = 0.30$, $p < 0.001$). Similarly, in the mindfulness group, the association between 12-month changes in mindful eating and fasting glucose weakened ($\beta = -0.17$, $p = 0.11$) after adjusting for 12-month change in BMI (In the mindfulness group, 12-month change in BMI significantly predicted change in fasting glucose such that greater reductions in BMI were associated with greater reductions in fasting glucose, $\beta = 0.27$, $p = 0.011$).

Discussion

We examined the effects of a mindfulness-enhanced diet and exercise intervention versus a standard (active control) diet and exercise intervention on self-reported mindful eating, eating of sweet foods, and fasting glucose in obese adults over a 12-month interval.

Although both intervention groups evidenced increases in mindful eating, the mindfulness intervention group reported greater increases in mindful eating from baseline to 12 months (relative to the active control group). Both intervention groups had similar reductions in eating of sweets from baseline to 6 and 12 months. The mindfulness intervention group, however, maintained this reduction in eating of sweets from 6 to 12 months, whereas the active control group showed a substantial increase in eating of sweets during this period. Intervention groups showed a differential change in fasting glucose from baseline to 12-month assessments. Fasting glucose increased substantially among active control participants but did not increase among mindfulness intervention participants during this time. Taken together, these results suggest that the mindfulness intervention may have reduced individuals' preferences for sweets and/or their portion sizes of sweets. These behavioral changes persisted as long as 6 months post-intervention, as indexed by both self-report (eating of sweets) and a biological marker (fasting glucose).

Despite increases in mindful eating in both groups, subgroup analyses revealed that participants in the mindfulness group showed a statistically significant coupling between increases in mindful eating and decreases in eating of sweets and fasting glucose. It is possible that the mindfulness intervention group completed the mindful eating questionnaire differently at 6- and 12-month assessments, as some findings suggest that mindfulness questionnaires may be interpreted differently among those who have and who have not completed mindfulness training (Baer, 2003; Bergomi et al., 2013). The MEQ was indeed developed to be sensitive to a general quality of attention to eating experience in the general population, rather than specifically developed within the context of training in mindful eating. Consequently, it is understandable that participants in the control group also reported higher levels of such attention during the course of their program. Participants in the mindfulness group received specific training in attending to physiological hunger and internal satiety cues and how to respond mindfully to non-homeostatic cues to eat. For example, a core aspect of the mindful eating intervention was a number of mindful eating practices targeting heightened awareness of sensory-specific satiety (Havermans et al., 2009; Hetherington, 1996), particularly in relation to sweets (e.g., chocolate, cookies). Previous interventions using MB-EAT have reported that participants regularly endorse lesser liking of sweet foods and greater satisfaction with far smaller amounts of sweet foods after training in mindful eating (Kristeller & Wolever, 2010). We also instructed participants in how to observe physical hunger and fullness on 10-point scales to limit mindless or excess eating. In contrast, participants in the control group were simply instructed to "eat when hungry and stop when full" and taught cognitive-behavioral techniques to use when responding to non-homeostatic cues to eat. Although both groups of participants endorsed reductions in speed of eating, reduced mind-wandering while eating, and increased attention to the experience of tasting their food, mindfulness group participants may have been doing so in qualitatively different ways. Indeed, although both groups reported increased mindful eating, the mindfulness group, relative to the control group, evidenced greater increases in the awareness subscale. Our data indicate that the strategies used by the mindfulness group were more tightly linked to food choice and glucose control than those of the control group.

We previously reported that this mindfulness intervention reduced fasting glucose such that, from baseline to 12 months, the mindfulness group maintained fasting glucose. In contrast, participants in the active control group showed increased fasting glucose (Daubenmier et al., in press). In the current study, we examined whether changes in mindful eating accounted for the effects of the mindfulness intervention on fasting glucose. Mediation analyses indicated that increases in mindful eating partially mediated the effect of intervention group assignment and reduced fasting glucose from baseline to 12 months. Thus, inclusion of mindful eating training into standard diet and exercise weight management programs may help promote long-term stabilization of fasting glucose levels in obese adults.

Data presented here dovetail with previous findings underscoring the impact of mindfulness when eating (Kristeller & Hallett, 1999; Kristeller et al., 2013; Miller et al., 2013; Timmerman & Brown, 2012). Specifically, mindful attention while eating facilitates reductions in the frequency of binge and compulsive eating as well as the quantity of food eaten on these occasions. This may result from increased sensitivity to interoceptive cues and decreased sensitivity to environmental triggers. Researchers highlight modern-day opportunities for mindless eating, such as eating while driving or watching television, as well as ubiquitous non-homeostatic cues to eat, such as advertisements strategically placed near drive-thru restaurants, and dishes of free candy placed in highly trafficked office areas. For example, individuals in office settings ate more sweets from a candy dish placed closer to their desks, and also when the dish was clear rather than opaque (Wansink et al., 2006). These observations highlight that proximity and visibility factors can shape eating of sweets. Similarly, people eat more sweet and prototypic snack foods, regardless of palatability (e.g., stale popcorn) when the food is served in larger (relative to smaller) containers (Wansink & Kim, 2005). Thus, attuning individuals' attention to mindful awareness of physical hunger and observing the experiences of wanting (and not wanting) to eat readily available sweet foods may reduce mindless eating in these contexts. The current study contributes to our understanding by documenting specific changes in eating of sweet foods.

Important study limitations include the type and frequency of participant assessment, and a relatively homogenous, non-diabetic obese sample. Notably, the modest 2.8 mg/dL increase in fasting glucose within the control group was within the normal range. Analyses relied on self-report measures of dietary intake, which are retrospective and often biased (Thompson et al., 2010). Self-reports of mindfulness constructs may differ across populations who do and do not receive mindfulness training (Bergomi et al., 2013). Hence, group differences in associations between mindful eating at 6 and 12 months and both eating of sweets and fasting glucose may be due in part to effects independent of the mindfulness intervention. Another measurement limitation is the structure of the Block FFQ, which loosely defines intake in regard to standard serving sizes (e.g., "1–2 cookies" is the smallest portion a participant can endorse). Given the mindfulness intervention's focus on enjoying very small amounts of foods, especially sweet foods, the structure of the Block FFQ may not have captured such distinctions in serving size. Thus, if individuals in the mindfulness group decreased intake consistently below a standard serving size, the FFQ was not sensitive to this. Furthermore, data for these analyses came from the FFQ, rather than from a multiple-pass 24-h dietary recall, which may have provided more precise dietary intake information (Johnson, 2002; Jonnalagadda et al., 2000). Participants were unaware that they could be randomized to a group with a mindfulness focus, and this is both a strength and weakness of our study design; that is, participants were recruited with the knowledge that they would be entering a study aimed at weight loss involving diet and exercise interventions. They were informed that the intervention could include stress management techniques, but were not informed that augmentation could include extensive mindfulness instruction. Future research should investigate the role of self-selection into mindfulness-based activities. A future trial focused on understanding the most potent aspects of a mindfulness intervention could enable participants to self-select into an intervention arm. This could contribute to the development of an intervention specifically for individuals who are open to conceptualizing mindfulness as part of their healthcare. Demonstrated efficacy of mindfulness-based interventions could lead to increased public awareness and utilization of mindfulness-based practices targeting (among other outcomes) physiological health outcomes. This study was conducted at an integrative medicine center in an urban area with ready access to healthful foods, and participants who elected to participate may have been those who were more likely or willing to engage in lifestyle changes, such as changing their eating behavior away from sweet and processed foods and toward healthier whole foods. It will be important to ascertain the feasibility, acceptability, and effectiveness of mindful eating interventions for individuals living in communities in which inexpensive, sugar-laden foods are more readily accessible, heavily promoted, and financially subsidized than are healthful foods.

These analyses highlight the importance of mindful eating as a target of change when intervention goals are to reduce eating of sweet foods and to maintain glucose metabolism. These results suggest that inclusion of mindful eating components into standard diet-exercise weight management programs may promote long-term stabilization of reduced eating of sweets and maintenance of fasting glucose levels in obese adults without diabetes.

Acknowledgments

This research was supported by funding from the National Institutes of Health (NCCIH) to Frederick M. Hecht (1P01AT005013; K24AT007827) and Jennifer Daubenmier (K01AT004199). Ashley E. Mason was supported by NCCIH (T32AT003997). This publication was supported by the National Center for Advancing Translational Sciences, National Institutes of Health, through UCSF-CTSI Grant Number UL1 TR000004. Its contents are solely the responsibility of the authors and do not necessarily represent the official views of the NIH.

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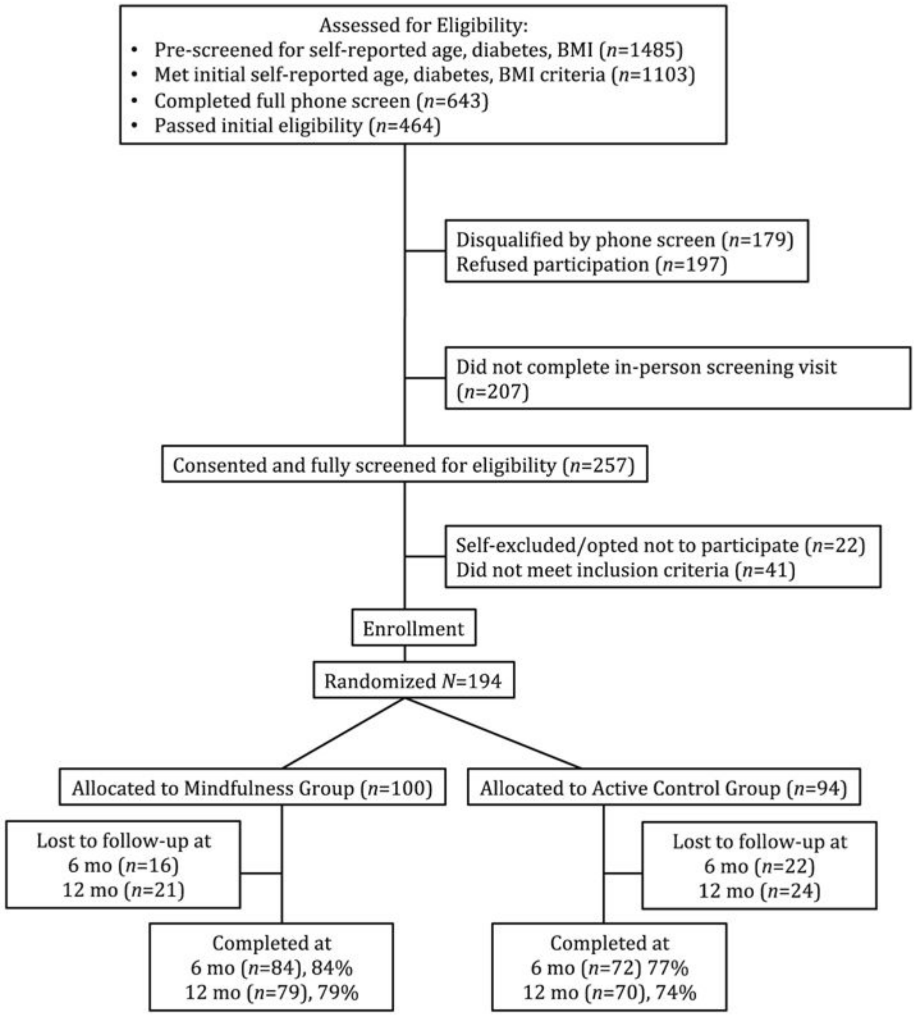

Fig. 1.

Recruitment, randomization, and follow-up of participants in the Supporting Health by Integrating Nutrition and Exercise (SHINE) randomized controlled trial

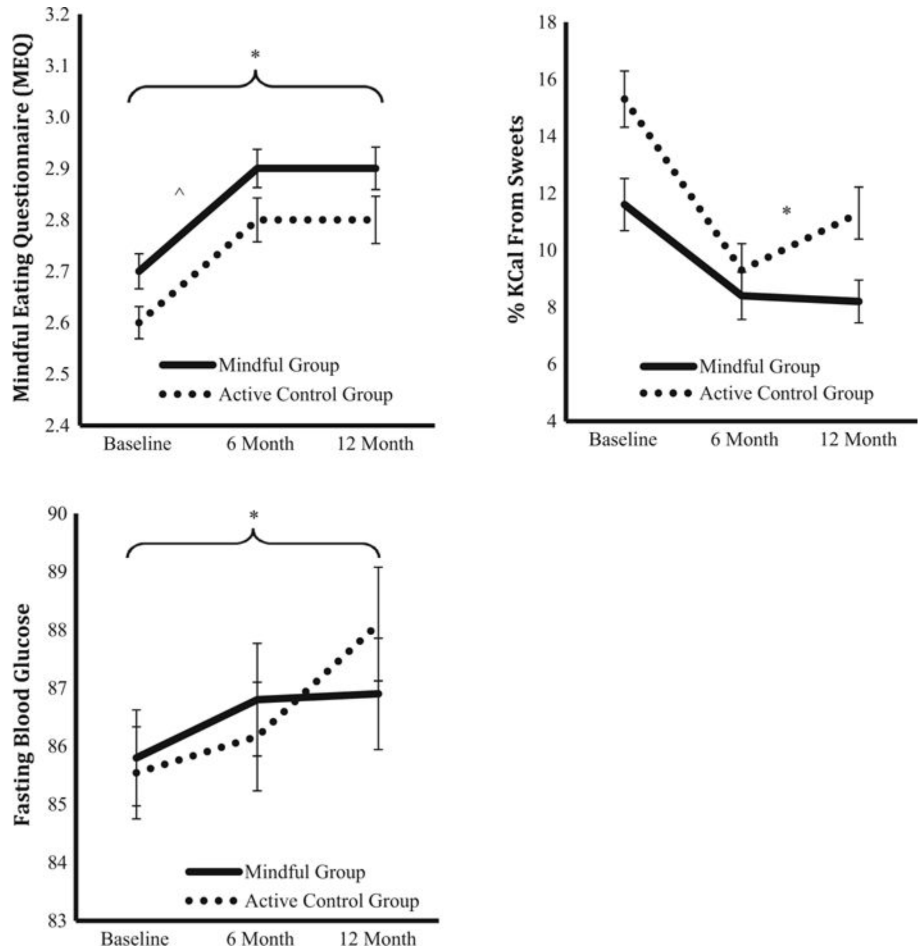

Fig. 2.

Effects of intervention group assignment on change in mindful eating, eating of sweets, and fasting glucose across three measurement timepoints. *Note* *$p < 0.05$; ^$p < 0.10$. *Symbols* reflect statistical differences across groups per ANCOVA results. *Error bars* are standard errors of the mean

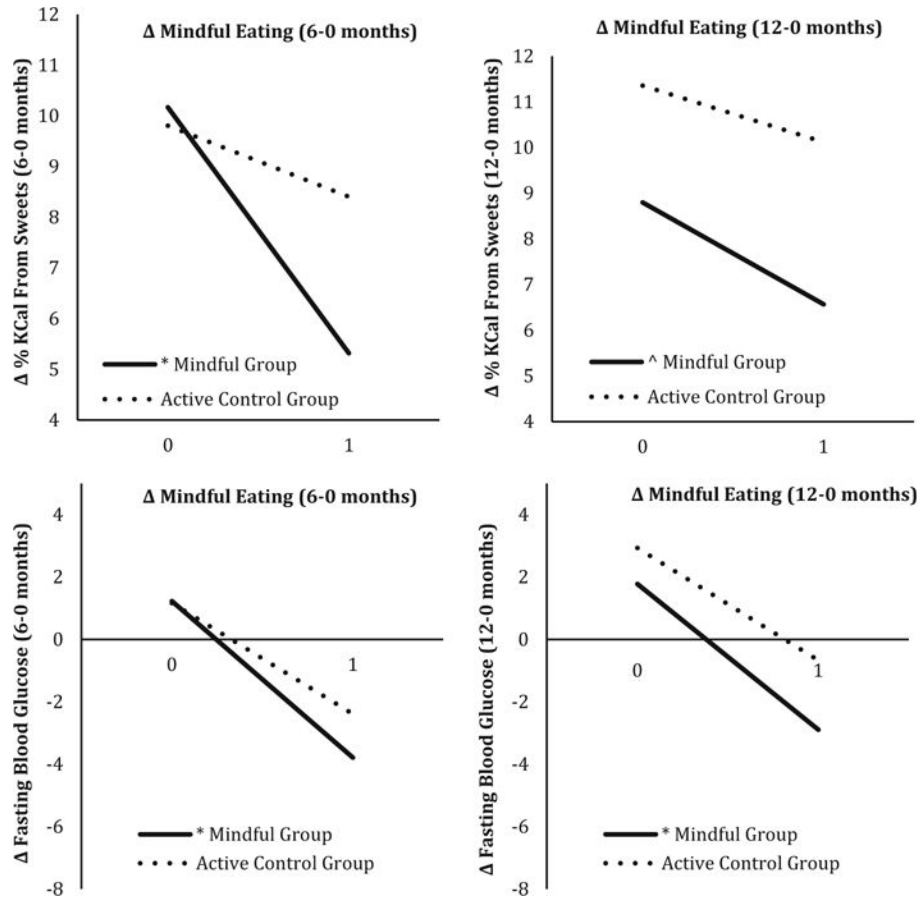

Fig. 3.

Changes in mindful eating as a predictor of changes in % Kcal from sweets and desserts and fasting blood glucose. *Note* *$p \le 0.05$; ˆ$p = 0.108$. Δ indicates change from baseline to 6 or 12 months (6 months—baseline; 12 months—baseline). *Lines* depict unstandardized regression parameters presented in Table 3. Δ Mindful Eating values fall within variable range for Δ Mindful Eating for both groups (Mindful Group and Active Control group)

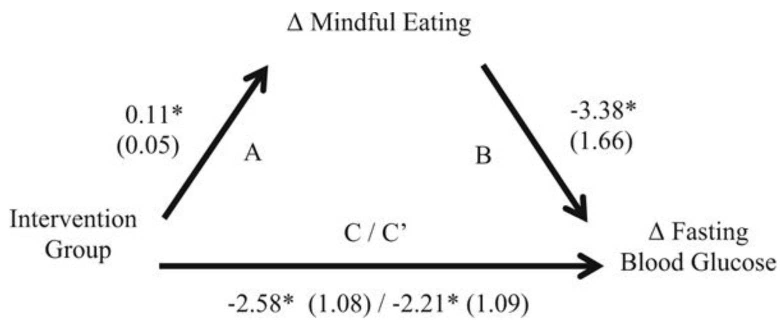

Fig. 4.

Change in mindful eating from baseline to 12 months mediates association between group assignment and change in fasting glucose from baseline to 12 months. *Note* *$p \leq 0.05$. Δ indicates change from baseline to 12 months (12 months—baseline). Covariates include fasting glucose and mindful eating at baseline. Data are presented as [unstandardized *b* (SE)]. Point estimate of mediated effect, [$b = -0.38$, SE(b) = 0.25], bias-corrected and accelerated 95 % CI (−1.09, −0.03)

Table 1

Baseline characteristics of participants randomized to the mindfulness and active control groups

	Active control ***n*** **= 94**	**Mindfulness** ***n*** **= 100**	**Total sample** ***N*** **= 194**
Age (years)	46.8 ± 12.4	47.2 ± 13.1	47.0 ± 12.7
Biological sex (female)	76 (80.9 %)	79 (79.0 %)	155 (79.9 %)
Ethnic origin			
Caucasian (non-hispanic)	50 (53.2 %)	64 (64.0 %)	114 (58.8 %)
Black	12 (12.8 %)	13 (13.0 %)	25 (12.9 %)
Hispanic/Latino	16 (17.0 %)	7 (7.0 %)	23 (11.9 %)
Asian/Pacific Islander	11 (11.7 %)	8 (8.0 %)	19 (9.8 %)
Native American	2 (2.1 %)	0 (0.0 %)	2 (1.0 %)
Other/did not endorse	3 (3.2 %)	8 (8.0 %)	11 (5.7 %)
BMI	35.6 ± 3.8	35.4 ± 3.5	35.5 ± 3.6

Data are Mean ± SD or Count (%)

BMI Body Mass Index

Table 2

Mean values of study variables at baseline, at both 6 and 12 months

Baseline	**Active control** ***n*** **= 94**	**Mindfulness** ***n*** **= 99–100**	**Total sample** ***N*** **= 193–194**
Sweets (%Kcal/24 h)	15.3 % (9.8 %)	11.6 % (9.1 %)	13.4 % (9.6 %)
Fasting glucose (mg/dL)	85.5 ± 7.7	86.8 ± 8.1	86.2 ± 7.9
ME (MEQ mean score)	2.6 ± 0.3	2.7 ± 0.3	2.6 ± 0.3
6 Months	Active control *n* = 69–72	Mindfulness *n* = 82–84	Total sample *N* = 147–156
Sweets (%Kcal/24 h)	9.3 % (7.7 %)	8.4 % (7.3 %)	8.8 % (7.5 %)
Fasting glucose (mg/dL)	86.2 ± 7.9	86.8 ± 8.5	86.5 ± 8.2
ME (MEQ mean score)	2.8 ± 0.4	2.9 ± 0.3	2.9 ± 0.4
12 Months	Active control *n* = 76–79	Mindfulness *n* = 78–79	Total sample *N* = 145–149
Sweets (%Kcal/24 h)	11.3 % (7.6 %)	8.2 % (6.5 %)	9.6 % (7.2 %)
Fasting glucose (mg/dL)	88.1 ± 7.8	86.9 ± 8.5	87.4 ± 8.2
ME (MEQ mean score)	2.8 ± 0.4	2.9 ± 0.4	2.9 ± 0.4

Data are Mean ± SD or Count (%). Sweets = Percentage of daily calories from sweets and desserts as assessed by the Block Food Frequency Questionnaire; ME = Mindful Eating as assessed by the Mindful Eating Questionnaire (MEQ) without three items tapping eating of sweets

Table 3

Multiple regression subgroup analyses predicting change in fasting glucose and eating of sweets from change in mindful eating in full sample and within each intervention group

Outcome	Δ Outcome at 6 or 12 months	β	*b*	SE(*b*)	95 % CI lower	95 % CI upper	*p*
Full sample							
Eating of sweets	6	−0.12	−2.59	1.35	−5.26	0.08	0.057
	12	−0.11	−2.05	1.30	−4.61	0.51	0.116
Fasting glucose	6	−0.23	−4.56	1.47	−7.46	−1.65	0.002
	12	−0.22	−4.63	1.56	−7.71	−1.55	0.003
Mindfulness group							
Eating of sweets	6	−0.18	−3.41	1.55	−6.50	−0.33	0.030
	12	−0.14	−2.23	1.37	−4.97	0.50	0.108
Fasting glucose	6	−0.27	−5.02	1.88	−8.77	−1.27	0.009
	12	−0.24	−4.67	2.00	−8.66	−0.67	0.023
Active control group							
Eating of sweets	6	−0.05	−1.40	2.51	−6.41	3.61	0.579
	12	−0.06	−1.23	2.42	−6.07	3.60	0.611
Fasting glucose	6	−0.16	−3.56	2.44	−8.42	1.31	0.149
	12	−0.16	−3.60	2.51	−8.62	1.42	0.156

See Table 1 note for variable descriptions. All models adjust for outcome at baseline. Predictor is change in mindful eating from baseline to 6 or 12 months corresponding with outcome