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Reduced Reward-driven Eating Accounts for the Impact of a Mindfulness-Based Diet and Exercise Intervention on Weight Loss: Data from the SHINE Randomized Controlled Trial

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Abstract

Many individuals with obesity report overeating despite intentions to maintain or lose weight. Two barriers to long-term weight loss are reward-driven eating, which is characterized by a lack of control over eating, a preoccupation with food, and a lack of satiety; and psychological stress. Mindfulness training may address these barriers by promoting awareness of hunger and satiety cues, self-regulatory control, and stress reduction. We examined these two barriers as potential mediators of weight loss in the Supporting Health by Integrating Nutrition and Exercise (SHINE) randomized controlled trial, which compared the effects of a 5.5-month diet and exercise intervention with or without mindfulness training on weight loss among adults with obesity. Intention-to-treat multiple mediation models tested whether post-intervention reward-driven eating and psychological stress mediated the impact of intervention arm on weight loss at 12-and 18-months post-baseline among 194 adults with obesity (BMI: 30–45). Mindfulness (relative to control) participants had significant reductions in reward-driven eating at 6 months (post-intervention), which, in turn, predicted weight loss at 12 months. Post-intervention reward-driven eating mediated 47.1% of the total intervention arm effect on weight loss at 12 months [β=-0.06,

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SE(β)=0.03, *p*=.030, 95% CI (−0.12, −0.01)]. This mediated effect was reduced when predicting weight loss at 18 months (*p*=.396), accounting for 23.0% of the total intervention effect, despite similar weight loss at 12 months. Psychological stress did not mediate the effect of intervention arm on weight loss at 12 or 18 months. In conclusion, reducing reward-driven eating, which can be achieved using a diet and exercise intervention that includes mindfulness training, may promote weight loss (clinicaltrials.gov registration: NCT00960414).

Keywords

Reward-driven eating; mindful eating; weight loss; obesity; behavioral intervention

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Lifestyle interventions using diet and exercise are first-line treatments for obesity; however, these interventions tend to result in poor long-term weight loss (Barte et al., 2010; Mann et al., 2007; Wadden, Butryn, & Byrne, 2004; Wu, Gao, Chen, & Van Dam, 2009). For example, one meta-analysis of 80 studies on lifestyle interventions for weight loss reported that participants lost 5–9% of their initial body weight after 6 months, but regained half of the weight after 4 years (Franz et al., 2007). Psychological factors, including disinhibited eating (Elfhag & Rössner, 2005; McGuire, Wing, Klem, Lang, & Hill, 1999; Wing & Hill, 2001) and poor abilities to cope with psychological stress (Byrne, 2002), are associated with weight regain following initial weight loss. Hence, weight regain can occur in part because most lifestyle interventions target changes in diet and exercise (Appel et al., 2011; Franz et al., 2007; Gardner et al., 2007) without comprehensively attending to drivers of overeating, such as reward-related behavior and psychological stress.

The modern food environment is replete with hyper-palatable, calorically dense, highly-processed foods, making weight loss challenging (Gearhardt, Davis, Kuschner, & Brownell, 2011; Wansink, 2007). Such foods possess pharmacokinetic properties that powerfully activate reward neurocircuitry (Gearhardt et al., 2011). Many individuals with obesity report reward-driven eating, which is characterized by a loss of control over one's eating, a lack of satiety, and a preoccupation with food (Epel et al., 2014). Reward-driven eating echoes the hallmarks of addictive behaviors, such as intense cravings and an inability to stop overeating despite best intentions and negative consequences. Reward-driven eating can override homeostatic mechanisms of hunger and satiety and lead to overeating and weight gain (Moodie et al., 2013). Furthermore, excessive consumption of highly palatable foods can alter central dopaminergic and opioidergic systems that regulate reward sensitivity (Volkow, Wang, & Baler, 2011). These alterations may induce brain changes similar to those found in classic models of addiction (Volkow, Wang, Fowler, Tomasi, & Baler, 2012), specifically, increased sensitivity to reward. Greater sensitivity to reward is associated with overeating, future weight gain (Davis et al., 2007; Davis, Strachan, & Berkson, 2004), and greater likelihood of dropping out of a weight management program (Koritzky, Dieterle, Rice, Jordan, & Bechara, 2014). Hence, reward-driven eating may be one important risk factor for poor weight loss.

Psychological stress is a second factor that may compromise weight loss. There is substantial overlap in the neurocircuitries underlying psychological stress, eating behavior,

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and energy homeostasis (Dallman, 2010; Sinha & Jastreboff, 2013). Indeed, both greater psychological stress and difficulties coping with psychological stress increase risk for weight regain (Stubbs et al., 2011). Individuals with obesity who endorse greater psychological stress and who have few coping strategies at their disposal may be more likely to use food to reduce negative emotions, such as those associated with stress (Byrne, 2002; Elfhag & Rössner, 2005). Eating to feel better when experiencing negative emotions or when in unpleasant situations, or eating to avoid worries and problems, is associated with greater BMI, and increases in these types of eating are associated with weight gain (Boggiano, Wenger, Turan, Tatum, Sylvester, et al., 2015; Boggiano, Wenger, Turan, Tatum, Morgan, et al., 2015).

Acute isolated stressors, as well as chronic ongoing stressors, change consumptive behavior in both animals and humans (Torres & Nowson, 2007). Animal studies show that feeding generally decreases in times of stress, unless palatable food is available, in which case feeding increases (Dallman, 2010). Similarly, human studies report that increased self-reported psychological and physiological reactivity to stressors predict shifts toward greater eating of highly palatable food (Tomiyama, Dallman, & Epel, 2011). Furthermore, vulnerable subgroups, such as dieters and self-identified emotional eaters, eat more palatable food when stressed (Epel, Lapidus, McEwen, & Brownell, 2001; Kandiah, Yake, Jones, & Meyer, 2006; Zellner et al., 2006). Indeed, longitudinal cohort studies report that psychological stress is a stronger risk factor for weight gain among individuals who are overweight or obese than for individuals of normal weight (Block, He, Zaslavsky, Ding, & Ayanian, 2009; Kivimäki et al., 2006). Thus, reductions in psychological stress may be an important target in lifestyle interventions for weight loss.

In the last decade, researchers have begun to examine the effects of mindfulness-based interventions on psychological stress and obesity-related eating behaviors including emotionally or externally driven eating and binge eating (Katterman, Kleinman, Hood, Nackers, & Corsica, 2014; O’Reilly, Cook, Spruijt-Metz, & Black, 2014). Mindfulness-based interventions such as Mindfulness-based Stress Reduction (MBSR; Kabat-Zinn & Hanh, 2009) and Mindfulness-based Eating Awareness Training (MB-EAT; Kristeller & Wolever, 2010) focus on increasing awareness of present-moment experience (e.g., internal experiences of thoughts, emotions, and body sensations), with a non-judging and accepting attitude. These interventions purport to increase self-regulatory capacity by interrupting highly conditioned patterns, decreasing emotional reactivity, and increasing distress tolerance and self-acceptance (Katterman et al., 2014; O’Reilly et al., 2014; Vago & Silbersweig, 2012).

Reductions in psychological stress and a reward-based drive to eat are both plausible mechanisms that may promote weight loss following mindfulness training. In the context of eating, mindfulness interventions aim to increase awareness of homeostatic hunger (hunger driven by caloric needs) and satiety cues (how hungry or full one feels). Mindfulness interventions also aim to cultivate abilities to distinguish between emotional and physical hunger and to tolerate food cravings or urges to eat without overeating (Alberts, Thewissen, & Raes, 2012; Forman et al., 2013; Marchiori & Papies, 2014). In the context of stress and emotion regulation, mindfulness interventions aim to bolster self-regulation, increase

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attentional focus, and promote adaptive coping (Kabat-Zinn & Hanh, 2009; Tang et al., 2007). Recent reviews suggest that mindfulness interventions can reduce overeating and psychological stress (Goyal et al., 2014; Katterman et al., 2014; O'Reilly et al., 2014). Yet, few long-term rigorous randomized controlled trials have examined to what extent improvements in these areas lead to better weight loss.

Daubenmier and colleagues (Daubenmier et al., In Press) conducted a randomized controlled trial comparing a 5.5-month diet and exercise intervention with versus without training in mindfulness-based eating awareness, stress management, and emotion regulation training on weight loss at 12 and 18 months post-baseline. Primary trial results indicated that mindfulness participants, relative to control participants, evidenced 1.9 kg and 1.7 kg greater weight loss at 12 and 18 months post-baseline, respectively, which approached statistical significance. Current expert opinion in mediation analysis clarifies that examination of indirect effects is not predicated on the existence of a statistically significant total (intervention) effect (Hayes, 2013). In other words, it remains important to examine factors that may account for the effect of intervention arm on weight loss, and we therefore tested for such indirect effects (Hayes, 2013; Zhao, Lynch, & Chen, 2010). We hypothesized that mindfulness participants would experience larger reductions in reward-driven eating and psychological stress from pre- to post-intervention, and that these reductions would mediate an association between intervention arm (mindfulness versus control) and weight loss at 12 and 18 months post-baseline.

Method

Design

The current study reports on data from the Supporting Health by Integrating Nutrition and Exercise (SHINE) clinical trial (Clinicaltrials.gov registration: NCT00960414). Adults with obesity (BMI 30–45) were randomized in a 1:1 ratio to a 5.5-month diet and exercise weight-loss program with or without mindfulness training for eating awareness, stress management, and emotion regulation. See (Daubenmier et al., In Press) for detailed study design and methodology. The University of California, San Francisco (UCSF) Committee on Human Research approved all study procedures and all participants provided informed consent.

Participants

Participants were recruited 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 comparison of two weight loss interventions that both involved changes in diet, exercise, and stress management, yet differed in the emphasis placed on each. To avoid selective attrition post-randomization, recruitment materials did not specifically state that mindfulness would be taught in one of the groups. Additional inclusion criteria included abdominal obesity (waist circumference > 102 cm for men and >88 cm for women) and age 18 years or older. Exclusion criteria included type 1 or type 2 diabetes mellitus (fasting glucose ≥ 126 or hemoglobin A1C (HbA1c) between 6.0–6.5% with an abnormal oral glucose tolerance test); pregnancy; breastfeeding or fewer than 6

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months post-partum; corticosteroid and/or immune-suppressing or immune-modulating medications; prescription weight-loss medications; untreated hypothyroidism; history of or active bulimia; current meditation or yoga practice; engagement in any other structured weight management or weight-loss program; or participation in MBSR (see Daubenmier et al., In Press). If eligible, participants completed assessment procedures at two separate visits prior to randomization.

Interventions

Both intervention arms included 12 weekly group evening sessions (2–2.5 hours), 3 biweekly sessions, 1 follow-up session four weeks later, and an all-day weekend session near the eighth week (5.0 hours for the active control group, 6.5 hours for the mindfulness intervention group) across a 5.5-month period. Registered dietitians led the control group sessions. Different registered dietitians and experienced mindfulness instructors led the mindfulness group sessions. See (Daubenmier et al., In Press) for further intervention details.

Diet-Exercise Guidelines—Diet and exercise components were the same in each intervention arm. Participants set a goal of reducing daily food intake of their choice by 500 calories. Moreover, participants were encouraged to focus on decreasing calorically dense, nutrient-poor foods such as refined carbohydrates, and increasing fresh fruits and vegetables, 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—The mindfulness intervention included mindfulness training for eating awareness, stress management, emotion regulation, and exercise. Mindful eating practices, modeled on the Mindfulness-Based Eating Awareness Training program (MB-EAT), were designed to promote awareness and self-regulation of emotions, physical hunger, stomach fullness, taste satisfaction, food cravings, and other eating triggers in the context of reduced caloric intake (Kristeller, Wolever, & Sheets, 2014). We did not instruct participants to avoid particular foods, but encouraged them to eat favorite foods in smaller portions that fit within their calorie goals. We also encouraged participants to practice awareness and savoring of food tastes and textures, with a particular focus on drawing hedonic value from smaller amounts of highly preferred foods, such as sweets. Mindfulness training for stress management and emotion regulation incorporated components of mindfulness-based programs (Kabat-Zinn & Hanh, 2009; Segal, Williams, & Teasdale, 2012) including sitting meditation, mindful yoga, loving kindness meditations towards self and others, and mindful walking. We also taught participants a brief extended exhalation breathing technique to promote initial physiological relaxation. Home practice guidelines included meditation practice for up to 30 minutes a day and 6 days a week, eating meals mindfully, use of mini-meditations, and mindful walking.

Active control—The control intervention included additional content to ensure equivalence across intervention arms on a number of dimensions. To account for the additional time, attention, social support, and expectations of benefit that the mindfulness

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participants may have experienced during the mindfulness training, control participants received additional information about nutrition and physical activity. This included in-depth presentations on nutrition concepts, discussion of socio-political issues that impact food choice, how to make well-informed decisions about diet products, and tutorials on strength training with exercise bands. To account for the active ingredients of a mindfulness-based approach to stress management training, control participants received instruction in progressive muscle relaxation and cognitive-behavioral skills, although at a lower dose than in the mindfulness intervention. To reduce participant burden while ensuring perceptions of benefit, the control group sessions were reduced from 2.5 to 2.0 hours after session 9. Participants completed weekly assignments at home that reinforced diet and exercise lessons.

Measures

All measures were assessed at baseline, immediately post-intervention (6 months), 12 months, and 18 months.

Reward-based eating—The 9-item Reward-based Eating Drive (RED) scale (Epel et al., 2014) assesses three dimensions of the hedonic drive to eat: 1) loss of control, 2) lack of satiety, and 3) preoccupation with food. It contains 2 items from the Binge Eating Scale (BES; (Gormally, Black, Daston, & Rardin, 1982), 4 items from the Three Factor Eating Questionnaire (TFEQ; Stunkard & Messick, 1985), and 3 original items. Sample items include, "*When I start eating, I just can't seem to stop*" (lack of control); "*I don't get full easily*" (lack of satiety); and "*Food is always on my mind*" (preoccupation with food). In this study, participants answered items from these scales on 4-point and 3-point scales, with lower scores indicating less loss of control / lack of satiety / preoccupation with food. We therefore computed z-scores (which have a mean of 0 and standard deviation of 1) before averaging all items, as done in Study 1 of the RED validation publication (Epel et al., 2014). Higher scores reflect higher reward-driven eating. At baseline, scale internal consistency in this current sample was good (α=.80), and the mean score was 0 (SD = 0.61, range = −1.38 to 1.50).

Psychological stress—The 10-item Perceived Stress Scale (PSS; S Cohen, Kamarck, & Mermelstein, 1983) assesses current perceptions of stress over the past month. Participants responded to items on a scale from 0 (*never*) to 4 (*fairly often*), and the summed responses represent a total scale score. The PSS measures the degree to which one perceives aspects of one's life as uncontrollable, unpredictable, and overloading. Sample items include, "*In the last month, how often have you felt that you were on top of things*?" and "*In the last month, have often have you felt nervous and "stressed*"?" Higher scores reflect higher perceived psychological stress. At baseline, scale internal consistency in the current sample was good (α=.86), and the mean score was 14.41 (SD = 5.76, range = 1 to 30).

Weight—Participants' weight was assessed at each study visit to the nearest 0.1 kg on a calibrated digital scale (Wheelchair Scale 6002, Scale-Tronix, Carol Stream, IL). Participants wore a hospital gown for each weighing and were weighed on the same scale at each assessment.

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Analytic strategy

We tested reward-driven eating (using the RED) and psychological stress (using the PSS) at post-intervention (6 months) as mediators of the effects of the intervention arm on weight at 12 and 18 months in two separate models. Both models included baseline values of weight and the mediators (RED and PSS), as this residualized method is recommended over the use of change scores (Bland & Altman, 1994; J. Cohen, Cohen, West, & Aiken, 2003). We selected this temporal sequence to strengthen causal evidence of mediation, as recommended in the literature (Hayes, 2013). We used Mplus software to program all statistical analyses, and used Maximum Likelihood (ML) estimation and used 1000 bootstrapped samples to generate bias-corrected 95% asymmetrical confidence intervals around the indirect effect. Analyses maximally retained participants by excluding only participants who were missing both mediators (RED and PSS) assessed at 6 months and weight at 12 months (Model 1) or 18 months (Model 2). This method retains more data relative to other methods of multiple mediator analysis, such as SPSS INDIRECT (Preacher & Hayes, 2008), which includes only participants with complete data for all variables.

Unlike prior approaches toward mediation analysis (e.g., Baron & Kenny, 1986), current expert opinion in mediation methodology asserts that it is appropriate to simultaneously test all paths, including indirect effects through a mediator (Hayes, 2009; MacKinnon & Fairchild, 2009; Zhao et al., 2010), regardless of the presence of a statistically significant total intervention effect (Zhao et al., 2010). We therefore tested mediation models that simultaneously examined RED and PSS at 6 months as mediators of the effect of intervention arm on weight at 12 months (Model 1) and 18 months (Model 2). We dummy coded intervention arm (control=0; mindfulness=1). Each model provided regression coefficients for the (i) effect of the intervention on the hypothesized mediators (Path A); (ii) association of the mediator variables with weight (Path B); (iii) *total intervention effect* (Path C, which represents the effect of intervention arm on weight with no mediators in the model); (iv) *direct intervention effect* (Path C', which represents the effect of intervention arm on weight when mediators are included in the model); and (v) *indirect intervention effect* (Path AB, which represents the effect of intervention arm on weight through the mediator; see (Hayes, 2013; Pearl, 2011; Zhao et al., 2010) for detailed review of total, direct, and indirect effects). We determined the proportion of the intervention effect attributed to each mediator by dividing the indirect intervention effect (Path AB) by the total intervention effect (Path C).

Results

Participant Characteristics and Attrition

Participants (N = 194) in the two intervention arms were similar on baseline variables (Table 1). The majority of participants were female (82%) and White (59%). The average age was 47.0 ±12.7 years and the average BMI was 35.5 ±3.6. See (Daubenmier et al., In Press) for additional participant details. Retention was similar for the mindfulness and control participants at 6 months (84.0% and 77.0%; p=.21), 12 months (79.0% and 74.0%, p=.50), and 18 months (81.0% and 71.0%, p=.13). See Table 2 for mean values of study variables at each assessment.

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Two participants were missing both mediators at 6 months and weight at 12 (but not 18) months due to inability to attend those assessments. They were therefore excluded from the 12-month analysis and retained in the 18-month analysis. One participant was missing both mediators at 6 months and weight at 18 (but not 12) months due to inability to attend those assessments. This participant was therefore excluded from the 18-month analysis yet retained in the 12-month analysis. Sample sizes in the 12-month (n=158) and 18-month (n=159) analyses were similar.

Weight loss at 12 months (Model 1)—As shown in Figure 1, the effect of the intervention arm on RED at 6 months was statistically significant (β=-0.36; p=.003) whereas the effect on PSS approached significance (β=-0.21; p=.096). This means that mindfulness relative to control participants reported lower levels of RED and marginally lower levels of PSS. As shown in Table 3 and consistent with results from the randomized trial (Daubenmier et al., In Press), the effect of intervention arm on initial weight loss at 12 months approached significance (total effect; p=.077). Inclusion of RED and PSS in the model, however, reduced this effect (direct effect; p=.308). RED at 6 months was positively associated with weight loss at 12 months (β=0.18; p=.001), but PSS was not (β=-0.03; p=.539).

The largest indirect effect through RED explained 47.1% of the total intervention effect on weight loss at 12 months (see Table 3). In contrast, the indirect effect through PSS explained 4.5% of the total intervention effect on weight loss at 12 months, and was not statistically significant. Thus, we observed an indirect effect (in the absence of total or direct effects) of intervention arm on weight loss at 12 months through RED.

Weight loss at 18 months (Model 2)—As shown in Figure 1, and similar to Model 1, the effect of intervention arm on RED at 6 months was statistically significant (β=-0.35; p=.004) whereas the effect on PSS approached significance (β=-0.21; p=.094). As shown in Table 3, the effect of intervention arm on weight loss at 18 months was not statistically significant before (total effect; p=.296) or after (direct effect; p=.472) accounting for RED and PSS. Neither RED (β=0.06; p=.350) nor PSS (β=0.03; p=.556) were significantly associated with weight loss at 18 months. As shown in Table 3, the indirect effects via PSS (which explained 7.0% of the total effect) and RED (which explained 23.0% of the total effect) were not statistically significant.

Discussion

We examined reward-driven eating and psychological stress as two mechanisms by which a 5.5-month diet and exercise intervention with or without adjuvant mindfulness training might impact long-term weight loss in adults with obesity. Mindfulness participants reported significantly lower levels of reward-driven eating than control participants at post-intervention (6 months). Furthermore, reductions in reward-driven eating at 6 months mediated the effect of intervention arm on weight loss at 12 months. Hence, these data illustrate that among adults with obesity, mindfulness training, when combined with diet and exercise, may promote greater reductions in reward-driven eating compared to diet-exercise programs without mindfulness training. In addition, these reductions were, in turn,

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associated with weight loss at 12 months, suggesting that *decreases* in reward-driven eating were responsible for a significant proportion of the weight loss experienced by participants, and this effect held after accounting for (above and beyond) any mediating effects of changes in perceived stress. These results indicate that decreases in reward-driven eating are associated with longitudinal decreases in weight, thus building on prior research documenting cross-sectional and longitudinal associations between reward-driven eating and BMI (Epel et al., 2014). Thus, reward-driven eating may be an important target of intervention for lifestyle programs focused on weight loss.

Many individuals with obesity struggle to lose weight, or maintain weight loss, in part because the immediate and highly pleasurable qualities of food override their intentions to restrict eating. Indeed, although traditional lifestyle interventions provide information regarding what an individual can do in the service of a weight loss goal (e.g., reducing caloric intake, increasing physical activity), they lack a focus on how to cope with the discomfort that arises from implementing these changes (e.g., food cravings, physical discomfort that can accompany exercising). Results presented here suggest that a weight loss intervention that incorporates mindfulness training reduces reward-driven eating more than a standard weight loss intervention, and this reduction suggests that mindfulness may be helpful in beginning to address *how* to cope with the implementation of lifestyle changes that promote weight loss. Hence, targeting reductions in reward-driven eating may be useful in the pursuit of weight loss.

Mindfulness is widely investigated as a stress-reduction intervention; hence we had expected that reductions in psychological stress among mindfulness participants would mediate the effects of intervention arm on weight loss. Contrary to this hypothesis, pre-post-intervention change in psychological stress did not significantly mediate the effects of intervention arm on weight loss. This finding is inconsistent with the growing body of evidence linking stress and adiposity (Mason & Epel, Forthcoming; Sinha & Jastreboff, 2013).

One possible explanation for these findings is that our study sample reported below-national levels of psychological stress (Sheldon Cohen & Janicki-Deverts, 2012). Thus, this sample may have not been poised to experience large reductions in stress or stress-related eating. A second possible explanation is that the brief 10-item Perceived Stress Scale (PSS) is a retrospective index of general psychological stress. It therefore does not assess nuanced information on *types* of stress, which is an important determinant of associations between stress and obesity (Block et al., 2009). For example, longitudinal studies suggest that stress due to work-related issues and family relationships predict weight gain among obese and overweight individuals (Kivimäki et al., 2006; Nyberg et al., 2012). Mindfulness participants evidenced a trend toward reduced general perceptions of stress at post-intervention. Future studies may more clearly delineate associations between stress reduction and obesity by selecting individuals who report high levels of work-related or family stress and using measures that specifically assess these stressors (Grzywacz, Almeida, & McDonald, 2002; Schuster, Kessler, & Jr, 1990; Vagg & Spielberger, 1998). Additionally, future studies should capture both experiences of psychological stress and maladaptive responses to psychological stress (Laitinen, Ek, & Sovio, 2002). Future studies may also select for individuals who report more stress-related eating, given recent data

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linking stress-related eating to greater central fat distribution (Tsenkova, Boylan, & Ryff, 2013). Furthermore, future studies may also tailor intervention content to directly address stressors specific to their study populations (e.g., work- or family-related stress, stress-induced or emotional eating). Finally, we compared the mindfulness intervention against a rigorous active control that included limited progressive muscle relaxation training and cognitive behavioral methods to manage stress eating. It may be that these added components reduced the effect size of the between-arm difference in changes in perceived stress. This study potentially demonstrates the importance of comparing mindfulness interventions against active control conditions, as other rigorous tests of mindfulness-based interventions using active controls have found null results (Goldberg et al., 2015; MacCoon, MacLean, Davidson, Saron, & Lutz, 2014; Shallcross et al., 2015).

The drive to overeat highly palatable food for reward may represent one important behavioral obstacle to weight loss. Craving is a key driver of compulsive and reward-driven behavior (Pelchat, 2002; Volkow et al., 2012), and mindfulness-based approaches have shown promise in targeting reductions in craving (Alberts, Mulkens, Smeets, & Thewissen, 2010; Alberts et al., 2012; Forman & Butryn, 2015). The mindful eating techniques taught in this intervention involved identifying and responding adaptively to food cravings, as well as providing skills for emotion regulation that would allow individuals to sit with, rather than act upon, the physical and psychological discomfort that can accompany the experience of food craving (Hamilton, Fawson, May, Andrade, & Kavanagh, 2013; May, Andrade, Kavanagh, & Hetherington, 2012). This aspect of mindfulness training may explain why mindfulness participants experienced greater reductions in reward-driven eating, which, in turn, was associated with weight loss.

Importantly, 6-month reductions in reward-driven eating did not predict weight loss at 18 months (Figure 1). The effects of intervention arm (mindfulness versus control) on weight loss were roughly similar at 12 months (*M* diff across arms=1.9 kg) and 18 months (*M* diff across arms=1.7 kg), with the mindfulness participants losing more weight (Daubenmier et al., In Press). Hence, the weakening of the mediation effect in the 18-month analysis was not the result of a sizable loss of intervention effects on weight. Of note, reward-driven eating also did not show meaningful changes between 12 and 18 months (Table 2). This underscores conclusions of other trials reporting the differential importance of distinct mechanisms impacting weight change during, shortly after, and longer after, weight-loss interventions (Kiernan et al., 2013).

A diversity of biological, environmental, and psychological factors impact weight gain and obesity status, including genetics, family history, the food environment, psychological stress, and the neurocircuitry of reward. Obesity reflects a variety of different causes or primary dysregulations. Identifying the most potent targets and developing interventions that specifically address them will be pivotal to increasing the effectiveness of obesity interventions (Kiernan, 2012). Data presented here add to literature suggesting that reward-driven eating tracks with weight change (Epel et al., 2014), and that focusing on reward-driven eating in the context of weight loss interventions may yield better weight loss.

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This study has several notable methodological limitations. First, we used self-report measures to assess both psychological mediators. Self-report measures may be influenced by social desirability or by individuals' desires to believe that their behavior has changed, especially among individuals who successfully lost weight. The development of behavioral (Epstein, Salvy, Carr, Dearing, & Bickel, 2010) and biological (Daubenmier et al., 2014; Mason et al., 2015) measures of reward-driven eating may offer greater insight into the process of weight loss via reductions in this construct. Second, we used a broad, retrospective self-report measure of general perceived stress which may not have assessed the facets of stress that contribute to excess adiposity. Specific measures of type of stress (Grzywacz et al., 2002; Schuster et al., 1990; Vagg & Spielberger, 1998) and stress-induced eating (Burgess, Turan, Lokken, Morse, & Boggiano, 2014; Tsenkova et al., 2013) may help clarify associations among mindfulness training, psychological stress, eating behavior, and weight loss. Third, there was not a statistically significant total effect of intervention arm on weight loss, which suggests that the associations between intervention components and their hypothesized intervention targets might be strengthened through further intervention component refinement.

Conclusion

These analyses suggest that integrating mindfulness components into a diet-exercise weight loss intervention leads to greater reductions in reward-driven eating. These reductions in reward-driven eating, in turn, are associated with greater weight loss, suggesting that decreases in reward-driven eating are a mechanism by which interventions impact weight change. Future interventions should target reductions in reward-driven eating so as to improve weight loss outcomes.

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Reference

Alberts HJEM, Mulkens S, Smeets M, Thewissen R. Coping with food cravings. Investigating the potential of a mindfulness-based intervention. Appetite. 2010; 55(1):160–163. [PubMed: 20493913]

Alberts HJEM, Thewissen R, Raes L. Dealing with problematic eating behaviour. The effects of a mindfulness-based intervention on eating behaviour, food cravings, dichotomous thinking and body image concern. Appetite. 2012; 58(3):847–851. [PubMed: 22265753]

Appel LJ, Clark JM, Yeh H-C, Wang N-Y, Coughlin JW, Daumit G, Brancati FL. Comparative effectiveness of weight-loss interventions in clinical practice. New England Journal of Medicine. 2011; 365(21):1959–1968. [PubMed: 22085317]

Baron RM, Kenny Da. The moderator-mediator variable distinction in social psychological research: conceptual, strategic, and statistical considerations. Journal of Personality and Social Psychology. 1986; 51(6):1173–82. [PubMed: 3806354]

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

Barte JCM, Ter Bogt NCW, Bogers RP, Teixeira PJ, Blissmer B, Mori TA, Bemelmans WJE. Maintenance of weight loss after lifestyle interventions for overweight and obesity, a systematic review. Obesity Reviews. 2010; 11(12):899–906. [PubMed: 20345430]

Bland JM, Altman DG. Regression towards the mean. BMJ: British Medical Journal. 1994; 308(6942): 1499. [PubMed: 8019287]

Block JP, He Y, Zaslavsky AM, Ding L, Ayanian JZ. Psychosocial stress and change in weight among US adults. American Journal of Epidemiology. 2009; 170(2):181–192. [PubMed: 19465744]

Boggiano MM, Wenger LE, Turan B, Tatum MM, Morgan PR, Sylvester MD. Eating tasty food to cope. Longitudinal association with BMI. Appetite. 2015; 87:365–370. [PubMed: 25596500]

Boggiano M, Wenger LE, Turan B, Tatum MM, Sylvester MD, Morgan PR, Burgess EE. Real-time sampling of reasons for hedonic food consumption: Further validation of the Palatable Eating Motives Scale. Name: Frontiers in Psychology. 2015; 6:744.

Burgess EE, Turan B, Lokken KL, Morse A, Boggiano MM. Profiling motives behind hedonic eating: Preliminary validation of the Palatable Eating Motives Scale. Appetite. 2014

Byrne SM. Psychological aspects of weight maintenance and relapse in obesity. Journal of Psychosomatic Research. 2002; 53(5):1029–1036. [PubMed: 12445592]

Byrne SM, Cooper Z, Fairburn CG. Psychological predictors of weight regain in obesity. Behaviour Research and Therapy. 2004; 42(11):1341–1356. [PubMed: 15381442]

Cohen, J.; Cohen, P.; West, SG.; Aiken, LS. Applied multiple regression/correlation analysis for the behavioral sciences. Routledge; 2003.

Cohen S, Janicki-Deverts D. Who's stressed? Distributions of psychological stress in the United States in probability samples from 1983, 2006, and 20091. Journal of Applied Social Psychology. 2012; 42(6):1320–1334.

Cohen S, Kamarck T, Mermelstein R. A global measure of perceived stress. Journal of Health and Social Behavior. 1983; 24(4):385–396. [PubMed: 6668417]

Dallman MF. Stress-induced obesity and the emotional nervous system. Trends in Endocrinology & Metabolism. 2010; 21(3):159–165. [PubMed: 19926299]

Daubenmier J, Lustig RH, Hecht FM, Kristeller JL, Woolley J, Adam T, Epel E. A new biomarker of hedonic eating? A preliminary investigation of cortisol and nausea responses to acute opioid blockade. Appetite. 2014; 74:92–100. [PubMed: 24291355]

Daubenmier J, Moran PJ, Kristeller JL, Acree M, Bacchetti P, Kemeny M, Hecht F. Effects of a mindfulness-based weight loss program in obese adults: A randomized clinical trial. Obesity. In Press

Davis C, Patte K, Levitan R, Reid C, Tweed S, Curtis C. From motivation to behaviour: A model of reward sensitivity, overeating, and food preferences in the risk profile for obesity. Appetite. 2007; 48(1):12–19. [PubMed: 16875757]

Davis C, Strachan S, Berkson M. Sensitivity to reward: Implications for overeating and overweight. Appetite. 2004; 42(2):131–138. [PubMed: 15010176]

Elfhag K, Rössner S. Who succeeds in maintaining weight loss? A conceptual review of factors associated with weight loss maintenance and weight regain. Obesity Reviews. 2005; 6(1):67–85. [PubMed: 15655039]

Epel E, Lapidus R, McEwen B, Brownell K. Stress may add bite to appetite in women: A laboratory study of stress-induced cortisol and eating behavior. Psychoneuroendocrinology. 2001; 26(1):37–49. [PubMed: 11070333]

Epel E, Tomiyama AJ, Mason A, Laraia BA, Hartman W, Ready K, Kessler D. The Reward-Based Eating Drive Scale: A self-report index of reward-based eating. PloS One. 2014; 9(6):e101350. [PubMed: 24979216]

Epstein LH, Salvy SJ, Carr KA, Dearing KK, Bickel WK. Food reinforcement, delay discounting and obesity. Physiology & Behavior. 2010; 100(5):438–445. [PubMed: 20435052]

Forman EM, Butryn ML. A new look at the science of weight control: How acceptance and commitment strategies can address the challenge of self-regulation. Appetite. 2015; 84:171–180. [PubMed: 25445199]

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

Forman EM, Butryn ML, Juarascio AS, Bradley LE, Lowe MR, Herbert JD, Shaw JA. The mind your health project: A randomized controlled trial of an innovative behavioral treatment for obesity. Obesity. 2013; 21(6):1119–1126. [PubMed: 23666772]

Franz MJ, VanWormer JJ, Crain AL, Boucher JL, Histon T, Caplan W, Pronk NP. Weight-loss outcomes: A systematic review and meta-analysis of weight-loss clinical trials with a minimum 1-year follow-up. Journal of the American Dietetic Association. 2007; 107(10):1755–1767. [PubMed: 17904936]

Gardner CD, Kiazand A, Alhassan S, Kim S, Stafford RS, Balise RR, King AC. Comparison of the Atkins, Zone, Ornish, and LEARN diets for change in weight and related risk factors among overweight premenopausal women: the A TO Z Weight Loss Study: a randomized trial. JAMA. 2007; 297(9):969–977. [PubMed: 17341711]

Gearhardt A, Davis C, Kuschner R, Brownell K. The addiction potential of hyperpalatable foods. Current Drug Abuse Reviews. 2011; 4(3):140–145. [PubMed: 21999688]

Goldberg SB, Wielgosz J, Dahl C, Schuyler B, MacCoon DS, Rosenkranz M, Davidson RJ. Does the Five Facet Mindfulness Questionnaire Measure What We Think It Does? Construct Validity Evidence From an Active Controlled Randomized Clinical Trial. Psychological Assessment. 2015

Gormally J, Black S, Daston S, Rardin D. The assessment of binge eating severity among obese persons. Addictive Behaviors. 1982; 7(1):47–55. [PubMed: 7080884]

Goyal M, Singh S, Sibinga EM, Gould NF, Rowland-Seymour A, Sharma R, et al. Meditation programs for psychological stress and well-being: a systematic review and meta-analysis. JAMA Internal Medicine. 2014; 174(3):357–368. [PubMed: 24395196]

Grzywacz JG, Almeida DM, McDonald DA. Work-family spillover and daily reports of work and family stress in the adult labor force. Family Relations. 2002; 51(1):28–36.

Hamilton J, Fawson S, May J, Andrade J, Kavanagh DJ. Brief guided imagery and body scanning interventions reduce food cravings. Appetite. 2013; 71:158–162. [PubMed: 23962401]

Hayes AF. Beyond Baron and Kenny: Statistical mediation analysis in the new millennium. Communication Monographs. 2009; 76(4):408–420.

Hayes, AF. Introduction to mediation, moderation, and conditional process analysis: A regression based approach. Guilford Press; 2013.

Kabat-Zinn, J.; Hanh, TN. Full catastrophe living: Using the wisdom of your body and mind to face stress, pain, and illness. New York: Random House LLC; 2009.

Kandiah J, Yake M, Jones J, Meyer M. Stress influences appetite and comfort food preferences in college women. Nutrition Research. 2006; 26(3):118–123.

Katterman SN, Kleinman BM, Hood MM, Nackers LM, Corsica JA. Mindfulness meditation as an intervention for binge eating, emotional eating, and weight loss: A systematic review. Eating Behaviors. 2014; 15(2):197–204. [PubMed: 24854804]

Kiernan M. Treatment matching for obesity: Identifying mediators of psychosocial and behavioral intervention components. International Journal of Obesity Supplements. 2012; 2(S1):S23–S25. [PubMed: 25089190]

Kiernan M, Brown SD, Schoffman DE, Lee K, King AC, Taylor CB, Perri MG. Promoting healthy weight with "stability skills first": A randomized trial. Journal of Consulting and Clinical Psychology. 2013; 81(2):336. [PubMed: 23106759]

Kivimäki M, Head J, Ferrie JE, Shipley MJ, Brunner E, Vahtera J, Marmot MG. Work stress, weight gain and weight loss: evidence for bidirectional effects of job strain on body mass index in the Whitehall II study. International Journal of Obesity. 2006; 30(6):982–987. [PubMed: 16418750]

Koritzky G, Dieterle C, Rice C, Jordan K, Bechara A. Decision-making, sensitivity to reward, and attrition in weight management. Obesity. 2014; 22(8):1904–1909. [PubMed: 24771588]

Kristeller JL, Wolever RQ. Mindfulness-based eating awareness training for treating binge eating disorder: The conceptual foundation. Eating Disorders. 2010; 19(1):49–61. [PubMed: 21181579]

Kristeller JL, Wolever RQ, Sheets V. Mindfulness-Based Eating Awareness Training (MB-EAT) for binge eating: A randomized clinical trial. Mindfulness. 2014; 5(3):282–297.

Laitinen J, Ek E, Sovio U. Stress-Related Eating and Drinking Behavior and Body Mass Index and Predictors of This Behavior. Preventive Medicine. 2002; 34(1):29–39. [PubMed: 11749094]

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

MacCoon DG, MacLean KA, Davidson RJ, Saron CD, Lutz A. No sustained attention differences in a longitudinal randomized trial comparing mindfulness based stress reduction versus active control. PloS One. 2014; 9(6):e97551. [PubMed: 24955584]

MacKinnon DP, Fairchild AJ. Current directions in mediation analysis. Current Directions in Psychological Science. 2009; 18(1):16–20. [PubMed: 20157637]

Mann T, Tomiyama AJ, Westling E, Lew A-M, Samuels B, Chatman J. Medicare’s search for effective obesity treatments: diets are not the answer. American Psychologist. 2007; 62(3):220. [PubMed: 17469900]

Marchiori D, Papies EK. A brief mindfulness intervention reduces unhealthy eating when hungry, but not the portion size effect. Appetite. 2014; 75:40–45. [PubMed: 24361312]

Mason, A.; Epel, E. Stress and obesity. In: Brownell, K.; Walsh, T., editors. Eating Disorders and Obesity: A Comprehensive Handbook. Vol. 3. Guilford Press; (Forthcoming)

Mason A, Lustig R, Brown R, Acree M, Bacchetti P, Moran P, Epel E. Acute responses to opioidergic blockade as a biomarker of hedonic eating among obese women enrolled in a mindfulness-based weight loss intervention trial. Appetite. 2015; 91:311–320. [PubMed: 25931433]

May J, Andrade J, Kavanagh DJ, Hetherington M. Elaborated Intrusion theory: A cognitive-emotional theory of food craving. Current Obesity Reports. 2012; 1(2):114–121.

McGuire MT, Wing RR, Klem ML, Lang W, Hill JO. What predicts weight regain in a group of successful weight losers? Journal of Consulting and Clinical Psychology. 1999; 67(2):177. [PubMed: 10224727]

Moodie R, Stuckler D, Monteiro C, Sheron N, Neal B, Thamarangsi T, Casswell S. Profits and pandemics: Prevention of harmful effects of tobacco, alcohol, and ultra-processed food and drink industries. The Lancet. 2013; 381(9867):670–679.

Nyberg ST, Heikkilä K, Fransson EI, Alfredsson L, De Bacquer D, Bjorner JB, et al. Job strain in relation to body mass index: Pooled analysis of 160 000 adults from 13 cohort studies. Journal of Internal Medicine. 2012; 272(1):65–73. [PubMed: 22077620]

O’Reilly GA, Cook L, Spruijt-Metz D, Black DS. Mindfulness-based interventions for obesity-related eating behaviours: a literature review. Obesity Reviews. 2014; 15(6):453–461. [PubMed: 24636206]

Pearl, J. The mediation formula: A guide to the assessment of causal pathways in nonlinear models. DTIC Document; 2011.

Pelchat ML. Of human bondage: food craving, obsession, compulsion, and addiction. Physiology & Behavior. 2002; 76(3):347–352. [PubMed: 12117571]

Preacher KJ, Hayes AF. Asymptotic and resampling strategies for assessing and comparing indirect effects in multiple mediator models. Behavior Research Methods. 2008; 40(3):879–891. [PubMed: 18697684]

Schuster TL, Kessler RCRHA Jr. Supportive interactions, negative interactions, and depressed mood. American Journal of Community Psychology. 1990; 18(3):423–438. [PubMed: 2264558]

Segal, ZV.; Williams, JMG.; Teasdale, JD. Mindfulness-based cognitive therapy for depression. Guilford Press; 2012.

Shallcross AJ, Gross JJ, Visvanathan PD, Kumar N, Palfrey A, Ford BQ, Mauss IB. Relapse prevention in major depressive disorder: Mindfulness-based cognitive therapy versus an active control condition. Journal of Consulting and Clinical Psychology. 2015; 83(5):964–975. [PubMed: 26371618]

Sinha R, Jastreboff AM. Stress as a common risk factor for obesity and addiction. Biological Psychiatry. 2013; 73(9):827–835. [PubMed: 23541000]

Stubbs J, Whybrow S, Teixeira P, Blundell J, Lawton C, Westenhoefer J, Raats M. Problems in identifying predictors and correlates of weight loss and maintenance: implications for weight control therapies based on behaviour change. Obesity Reviews. 2011; 12(9):688–708. [PubMed: 21535362]

Stunkard AJ, Messick S. The three-factor eating questionnaire to measure dietary restraint, disinhibition and hunger. Journal of Psychosomatic Research. 1985; 29(1):71–83. [PubMed: 3981480]

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

Tang Y-Y, Ma Y, Wang J, Fan Y, Feng S, Lu Q, Posner MI. Short-term meditation training improves attention and self-regulation. Proceedings of the National Academy of Sciences. 2007; 104(43): 17152–17156.

Tomiyama AJ, Dallman MF, Epel E. Comfort food is comforting to those most stressed: Evidence of the chronic stress response network in high stress women. Psychoneuroendocrinology. 2011; 36(10):1513–1519. [PubMed: 21906885]

Torres SJ, Nowson CA. Relationship between stress, eating behavior, and obesity. Nutrition. 2007; 23(11):887–894. [PubMed: 17869482]

Tsenkova V, Boylan JM, Ryff C. Stress eating and health. Findings from MIDUS, a national study of US adults. Appetite. 2013; 69:151–155. [PubMed: 23747576]

Vagg PR, Spielberger CD. Occupational stress: Measuring job pressure and organizational support in the workplace. Journal of Occupational Health Psychology. 1998; 3(4):294. [PubMed: 9805278]

Vago DR, Silbersweig DA. Self-awareness, self-regulation, and self-transcendence (S-ART): A framework for understanding the neurobiological mechanisms of mindfulness. Frontiers in Human Neuroscience. 2012:6. [PubMed: 22375109]

Volkow ND, Wang G, Fowler J, Tomasi D, Baler R. Food and drug reward: Overlapping circuits in human obesity and addiction. Curr Topics Behav Neurosci. 2012; 11:1–24.

Volkow ND, Wang G-J, Baler RD. Reward, dopamine and the control of food intake: Implications for obesity. Trends in Cognitive Sciences. 2011; 15(1):37–46. [PubMed: 21109477]

Wadden TA, Butryn ML, Byrne KJ. Efficacy of Lifestyle Modification for Long-Term Weight Control. Obesity Research. 2004; 12(S12):151S–162S. [PubMed: 15687411]

Wansink, B. Mindless Eating: Why We Eat More Than We Think. Random House LLC; 2007.

Wing RR, Hill JO. Successful weight loss maintenance. Annual Review of Nutrition. 2001; 21(1):323–341.

Wu T, Gao X, Chen M, Van Dam RM. Long-term effectiveness of diet-plus-exercise interventions vs. diet-only interventions for weight loss: a meta-analysis. Obesity Reviews. 2009; 10(3):313–323. [PubMed: 19175510]

Zellner DA, Loaiza S, Gonzalez Z, Pita J, Morales J, Pecora D, Wolf A. Food selection changes under stress. Physiology & Behavior. 2006; 87(4):789–793. [PubMed: 16519909]

Zhao X, Lynch JG, Chen Q. Reconsidering Baron and Kenny: Myths and truths about mediation analysis. Journal of Consumer Research. 2010; 37(2):197–206.

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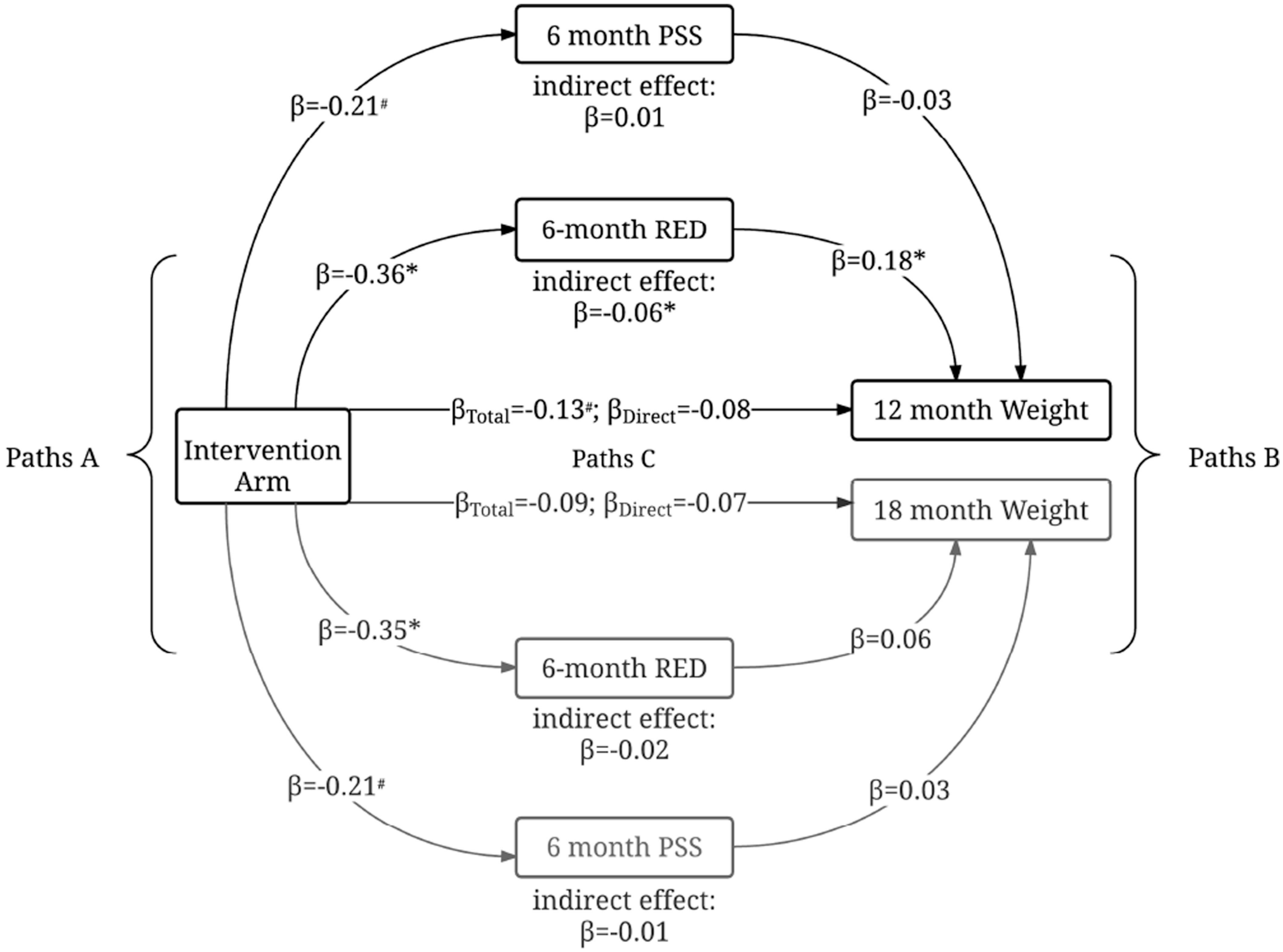

Figure 1.

Reward-driven eating and psychological stress as mediators of the effects of intervention arm (control versus mindfulness) on weight at 12- and 18- months post-baseline.

Note. $^{*}p < .05$; $^{\#}p < .10$. See Table 2 note. Analyses account for weight (kg), RED, and PSS at baseline. Intervention arm coded as 0 (control) and 1 (mindfulness).

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Table 1

Baseline participant characteristics.

Variable	Mean (SD) or N (%)		
	Full Sample (*N*=194)	**Mindfulness (*n*=100)**	**Control (*n*=94)**
Demographics			
Age (years)	47.0 (12.7)	47.2 (13.0)	46.8 (12.4)
Sex (female)	160 (82.0%)	79 (79.0%)	81 (86.0%)
Race/Ethnicity			
Other	10 (5.2%)	7 (7.0%)	3 (3.2%)
White	115 (59.3%)	65 (65.0%)	50 (53.2%)
Black	25 (12.9%)	13 (13%)	12 (12.8%)
Latino	23 (11.9%)	7 (7.0%)	16 (17.0%)
Asian/Pacific Islander	19 (9.8%)	8 (8%)	11 (11.7%)
Native American	2 (1.0%)	0 (0.0%)	2 (2.1%)
Health Characteristics			
Weight (kg)	97.2 (14.4)	97.7 (14.1)	96.7 (14.8)
Body Mass Index (BMI)	35.5 (3.6)	35.4 (3.5)	35.6 (3.8)
Reward-based Eating Drive (RED)	0.00 (0.61)	−0.02 (0.59)	0.02 (0.63)
Perceived Stress Scale (PSS)	14.41 (5.76)	14.38 (6.06)	14.43 (5.46)

Note. Reward-based Eating Drive (RED) scale scores are computed as the mean of all items following item-level z-score transformation.

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Table 2

Means and standard deviations for study variables for each model.

Model	Variable	Mindfulness Baseline (M, SD)	Mindfulness 6 Months (M, SD)	Mindfulness 12 Months (M, SD)	Mindfulness 18 Months (M, SD)	Control Baseline (M, SD)	Control 6 Months (M, SD)	Control 12 Months (M, SD)	Control 18 Months (M, SD)
Model 1: 12 months (*n*=158)	RED	0.04 (0.61)	−0.07 (0.60)	−0.09 (0.57)	−0.06 (0.62)	0.05 (0.59)	0.12 (0.61)	0.10 (0.66)	0.07 (0.69)
	PSS	14.27 (6.04)	13.18 (6.01)	14.13 (6.33)	13.31 (5.89)	14.41 (5.35)	14.22 (5.53)	14.54 (6.66)	14.54 (5.91)
	Weight	98.10 (13.98)	92.5 (13.67)	92.64 (13.47)	92.9 (14.63)	95.09 (13.25)	90.33 (12.05)	90.93 (14.29)	90.74 (14.08)
Model 2: 18 months (*n*=159)	RED	0.03 (0.62)	−0.07 (0.60)	−0.09 (0.57)	−0.06 (0.62)	0.04 (0.60)	0.12 (0.60)	0.10 (0.65)	0.08 (0.680)
	PSS	14.12 (6.18)	13.18 (6.01)	14.13 (6.33)	13.31 (5.89)	14.30 (5.40)	14.08 (5.58)	14.53 (6.60)	14.44 (5.90)
	Weight	98.35 (14.08)	92.5 (13.67)	92.64 (13.47)	92.9 (14.63)	94.86 (13.30)	90.27 (11.96)	90.87 (14.18)	90.66 (13.96)

Note. RED = Reward-based Eating Drive Scale; PSS = Perceived Stress Scale; Weight in Kg. RED Scale scores are computed as the mean of all items following item-level z-score transformation.

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Table 3

Total, direct, and indirect effects of Reward-based Eating Drive (RED) scale and Perceived Stress Scale (PSS) on weight at 12-month and 18-month assessments.

Weight (kg)	Effect	β	SE(β)	95% CI Lower	95% CI Upper	*p*
12 months (*n*=158)	Total	−0.13	0.08	−0.28	0.01	.077
	Direct	−0.08	0.07	−0.22	0.07	.308
	Indirect: PSS	0.01	0.01	−0.02	0.03	.608
	Indirect: RED	−0.06	0.03	−0.12	−0.01	.030
18 months (*n*=159)	Total	−0.09	0.09	−0.27	0.08	.296
	Direct	−0.07	0.09	−0.25	0.11	.472
	Indirect: PSS	−0.01	0.01	−0.03	0.02	.624
	Indirect: RED	−0.02	0.03	−0.07	0.03	.396

Note. Total effects represent the effects of intervention arm on weight (kg) at 12 and 18 months when including weight assessed at baseline in the model. Direct effects represent the effects of intervention arm on weight at 12 and 18 months after including weight assessed at baseline and both the Perceived Stress Scale (PSS) and Reward-based Eating Drive (RED) scale assessed at baseline and 6 months, in the model. Indirect effects represent the effects of PSS and RED assessed at 6 months on weight at 12 and 18 months after including baseline values of weight, PSS, and RED in the model. When testing PSS and RED within independent mediation models predicting weight at 12 months, the pattern and significance of results for RED ($\beta = -0.06$; $p=.036$) and PSS ($\beta=-0.01$; $p=.630$), remained unchanged. Independent models predicting weight at 18 months remained non-significant.