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Evaluation of a Mindful Eating Mobile Intervention

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B.A., Florida International University, 2018

Advisor: Linda W. Craighead, Ph.D.

An abstract of

A thesis submitted to the Faculty of the

James T. Laney School of Graduate Studies of Emory University

in partial fulfillment of the requirements for the degree of

Master of Arts

in Clinical Psychology

2021

Abstract

Evidence-based interventions for eating pathology are well-established and specific strategies to address a range of symptoms that have been clearly identified. However, many individuals do not seek treatment and/or do not receive treatment that incorporates evidence-based strategies. Mobile interventions (Mhealth apps) have increasingly gained attention as a way to extend or supplement treatments and may increase accessibility to evidence-based strategies. Currently available mobile interventions that target eating behavior typically utilize self-monitoring of food intake as a central component. The present study reports on the efficacy of a brief mobile intervention that promotes adaptive eating behaviors through self-monitoring of appetite cues and mindfulness while eating. Young adult females (ages 18-30) with eating and weight concerns were recruited and randomized to the mobile intervention (*n*=95) or to a waitlist (*n*=94). Participants using the app for 3 weeks reported more mindful eating as well as general mindfulness, and lower symptoms of disordered eating compared to the waitlist. Change in binge eating was associated with change in mindful eating. The improvement in binge eating symptoms was maintained at a 3-week post-intervention follow-up, and post-intervention mindful eating added to the prediction of binge eating at follow-up. The results of this initial evaluation are promising and provide preliminary support for a mindful eating app as a viable initial step for individuals with eating concerns who are not seeking traditional treatment. Continued investigation of the potential for apps to promote mindful eating as either a stand-alone intervention or as an initial intervention for disordered eating within a stepped care model seems warranted.

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Eating disorders (EDs) are serious psychiatric conditions that manifest as persistent disordered eating behaviors and present a significant threat to the physical and psychological health of those affected, as they are associated with considerable comorbidities, elevated healthcare costs, high morbidity, and poor quality of life (Santomauro et al., 2021). The 2019 Global Burden of Disease Study estimated that there were 13.6 million cases of Bulimia Nervosa (BN) or Anorexia Nervosa (AN), 17.3 million cases of Binge-Eating Disorder (BED), and 24.6 million cases of Other Specified Feeding or Eating Disorder (OSFED) globally in 2019 (Santomauro et al., 2021). OSFED applies to presentations of disordered eating that cause clinically significant distress and/or impairment, but do not meet the full criteria for any of the feeding and eating disorders in the DSM-5 (i.e., subclinical cases). Notably, even subclinical levels of disordered eating are associated with distress and increased risk for diagnosable eating disorders. For any level of disordered eating, young adult females constitute the population at highest risk although many such individuals do not seek treatment for their concerns, either minimizing awareness of its impact on their well-being or believing that they should be able to handle these issues on their own.

Given the impairments associated with disordered eating, it is important that treatment options are accessible and that alternatives that appeal to populations who might not otherwise seek treatment become available. Out of the current evidence-based treatments for clinically diagnosable eating disorders, at least for BN and BED, cognitive behavioral therapy (CBT) is considered the first-line treatment (de Jong et al., 2020). Fairburn's version, called enhanced cognitive-behavioral therapy (CBT-E; Fairburn, 2008), is a transdiagnostic intervention that has been adapted so as to be suitable for treating a wide range of presentations of eating pathology

(de Jong et al., 2020). A central element, if not the most critical component associated with effectiveness in CBT, CBT-E and related treatments, is some type of self-monitoring which is typically centered around food intake. The monitoring is used to guide efforts to normalize eating patterns (Fairburn, 2008). The establishment of a normal eating pattern has been described as "fundamental to successful treatment whatever the form of the eating disorder" (Murphy et al., 2010, p. 619). Self-monitoring of food intake has been evaluated as a stand-alone intervention in non-clinical or smaller samples and is sufficient to significantly reduce binge eating for some individuals (Barakat et al., 2017). However, many individuals find food monitoring aversive or find it increases their preoccupation with food (i.e., how much they think about food) exacerbating some of the associated eating-related difficulties (Lindgreen et al., 2021; Dicker & Craighead, 2004).

Substantial evidence is now available to suggest that intervention for disordered eating does not necessarily require food monitoring, and that mindful eating practices can make significant contributions to improving eating patterns as well as feelings of self-efficacy and control over one's intake (Yu et al., 2020; Katterman et al., 2014; Linardon et al., 2021; Sala et al., 2020). One version of cognitive behavioral therapy that does not require food monitoring is called Appetite Awareness Training (AAT; Craighead, 2006) or Appetite-focused CBT (AF-CBT). These interventions emphasize monitoring of appetite, meaning internal cues of hunger and satiety. Initial evaluations indicate that such interventions improve disordered eating behaviors at a level as similar to traditional CBT (McIntosh et al., 2016; Dicker & Craighead, 2004).

Considerable research has shown that mindfulness may serve as a protective factor against excessive food intake, with some experts suggesting that being more mindful helps by

increasing awareness of internal emotional cues while decreasing unhelpful responses (eating and/or restriction) to such cues (Hsu & Forestell, 2021; Sala et al., 2020). Mindfulness-based eating awareness training (MB-EAT; Kristeller et al., 2014) was designed to reduce binge eating. In this intervention self-monitoring of binge episodes (labeling episodes as small, medium, and large) is used rather than food intake and the target is increased self-efficacy and feeling in control of eating. Appetite-focused CBT interventions can be conceptualized as a more targeted form of mindfulness with the emphasis being somewhat more narrowly focused on increased awareness of internal appetite cues. Both types of intervention promote mindful eating practices.

Despite the development of a range of evidence-based treatments for eating pathology, many individuals remain under-treated or do not receive any form of intervention (Griffiths et al., 2018; Kazdin et al., 2016). Failure to receive treatment is likely due to many factors: a lack of access to mental health resources, the cost of treatment, the stigma associated with mental health, etc. (Juarascio et al., 2015; Griffiths et al., 2018; Kazdin et al., 2016). Even for those who do obtain treatment, studies have shown that the interventions being used are often not evidence-based (Fairburn & Wilson, 2013; Cooper & Bailey-Straebler, 2015; Kazdin et al., 2016; de Jong et al., 2020). For instance, “the number of eating disorder specialist clinicians who report adhering to evidence-based protocols is between 6 and 35%, with far more clinicians reporting using an eclectic mix of techniques derived from evidence-based interventions and some techniques that are not even supported at that level” (Waller, 2016, p. 3). Even more concerning is that many clinicians who report using an empirically-supported treatment for eating pathology often omit the elements of those interventions considered most essential, including self-monitoring (von Ranson et al., 2013; Waller, 2016). Taken together, the need for more

successful dissemination of evidence-based interventions targeting maladaptive eating habits is clear, over and above traditional therapy or other interventions for eating disorders.

In an effort to address this concerning treatment gap, more technology-based interventions have been developed that could promote more widespread dissemination of current evidence-based strategies for EDs. These technology-based interventions have the potential to help overcome existing barriers that may interfere with individuals receiving the help they need (Mani et al., 2015). In order to effectively "close" the treatment gap, however, such internet-based interventions need to make sure to incorporate the core aspects of current evidence-based approaches for EDs and further examination of the efficacy and effectiveness of internet and mobile interventions targeting eating behavior is critical.

Many currently available apps (to reduce disordered eating or to promote weight loss) are based around self-monitoring of food intake. Self-monitoring is considered an essential component of CBT based interventions; however, as noted it can be problematic, as many individuals find it aversive, refuse to do it, and/or report that monitoring food increases their cognitive preoccupation with food (Dicker & Craighead, 2004). Relatively few apps that specifically focus on appetite monitoring have been systematically evaluated to assess acceptability, usage, or effectiveness. Craighead and colleagues developed an app designed to promote mindful eating that is centered around appetite monitoring. In previous research, appetite monitoring had been rated as less aversive, requiring less effort, and being more focused on what is important (Jones, 2012; Hildebrandt & Latner, 2006). Additionally, more individuals reported being willing to monitor their appetite compared to logging food and/or nutritional values (Dicker & Craighead, 2004). The goal of appetite monitoring is to reduce the amount of intake in a given episode (i.e., binge or overeating episodes). It offers an alternative way to shift

attention away from amount of food per episode, as is noted in MB-EAT, and instead tracks fullness after eating as the method of promoting more moderate intake. We hypothesize that the relatively greater focus on appetite cues may provide more specific guidance regarding amounts than the broader instructions provided in general mindfulness training to attend to both physical sensations and emotions.

The present study provides an initial evaluation of a mobile app, the "Mindful Eating Coach" designed to promote mindful eating very specifically and, in so doing, to improve eating and weight concerns. The study also investigated the relationships between eating specific mindfulness and more general mindfulness as well as between both types of mindfulness and eating symptoms. Female college students who self-reported heightened concern with their eating and/or weight were recruited for the study. Preliminary data indicated that participants understood how to use the app and found it helpful (Marx, 2016). The app features a variety of tools drawn from the empirical literature on the treatment of disordered eating. These include: psychoeducation on mindful eating, reminders (or "coaching alerts"), self-monitoring of hunger and fullness (using a rating scale ranging from 0-7), self-monitoring of mindfulness while eating (using a 3 point scale), and graphs that track use of strategies and show progress.

The first aim of the study was to determine if use of the app would specifically increase mindful eating as well as self-reports of mindfulness more generally. The second aim was to determine if use of the app would improve symptoms of disordered eating. We hypothesized that individuals who used the mobile intervention for three weeks would report improved mindful eating, general mindfulness, and less eating pathology (binge eating and preoccupation with food/weight) compared to a waitlist control group, and that these improvements would be maintained at 3 weeks follow-up. The third aim was to investigate the relationship between mindful eating and improvement in disordered eating. We hypothesized that changes in mindful

eating and eating symptoms would be correlated at post-intervention and that mindful eating at post-test would predict maintenance of treatment gains at a follow-up assessment.

Materials and Methods

Participants

Participants were 189 young adult females aged 18 to 30. Sample demographics are summarized in Table 1. Participants were recruited via university student listservs, flyers posted within and around campus, and announcements made in college courses (permitted by instructors). Announcements and emails described the study as a research study assessing the efficacy of a mindful eating electronic app. If interested, individuals were instructed to contact the researchers for additional information.

Interested individuals received an email including a screening questionnaire and a brief overview of the study, which was described as assessing a brief mobile mindful eating intervention aimed at helping young women develop a healthier relationship with food and eating. They were asked to commit to attending two laboratory visits plus an additional one-time completion of questionnaires at home. They were informed that this mobile intervention was not considered to be an appropriate stand-alone treatment for those with clinically significant eating concerns and were provided with referrals for community treatment providers.

To determine study eligibility, individuals who were still interested after learning more about the study were asked to complete and return the screening questionnaire via email. Eligibility criteria included: current Emory undergraduate or graduate student between the ages of 18-30, use of an iPhone with an operating system iOS 8.0 or greater, concerns with eating/weight/shape, interest in using a mindful eating app, consent to random assignment, and willing to not use any other eating/weight apps (i.e., apps for calorie counting, weight

management, eating practices) for the duration of the study. Potential participants signed a screening consent form attached to the questionnaire. The screening questionnaire included questions about contact information, date of birth, sex, race/ethnicity, year in school, extent of concern with weight/eating, and prior treatment for weight management and/or disordered eating. Eligible participants were then scheduled for two laboratory visits.

Procedure

Participants attended two laboratory visits (each 30-60 minutes in duration) approximately three weeks apart. A link for an online follow-up questionnaire was emailed to participants three weeks after their second visit. Compensation included a $30 gift card sent via email after completion of the second visit and a $20 gift card sent via email after completion of the follow-up questionnaire. Procedures are described in detail below. All study procedures were approved by the Emory University Institutional Review Board.

Visit 1. After providing written informed consent in the lab, participants were asked to complete questionnaires via the Qualtrics survey platform assessing eating pathology, general trait mindfulness, mindful eating, eating disorder history, and prior use of any related mobile interventions[1]. Participants were randomly assigned to either the mobile intervention group (MI) or a waitlist control (WC) group using a random number generator. Those assigned to the waitlist control group were asked to return in 3 weeks to receive the intervention while those assigned to the mobile intervention group were given instructions for using the app and asked to return in 3 weeks. All participants were reminded of their next visit as well as their agreement to refrain from using other related apps/interventions.

[1] Other self-report measures not included here.

Visit 2. Participants completed the same questionnaires from visit 1. At this time, participants in the mobile intervention group had used the app for a total of three weeks. Participants in the waitlist control group were provided instructions for using the app. All participants were reminded of their agreement to refrain from using other related apps/interventions as well as to complete a final assessment in 3 weeks.

Follow-up Assessment. Three weeks after their second study visit (six weeks since their entry into the study), participants received an email with a link to complete follow-up questionnaires online via Qualtrics. They were a reminded they would earn an additional $20 upon completion of these follow-up assessments. Questionnaires administered at follow-up were identical to those administered at visits 1 and 2. Following the receipt of data from the app and the completion of online questionnaires, a member of the research staff emailed compensation ($20 electronic gift card) directly to the participant. This concluded all individuals' study participation.

Data protection and participant privacy. Appropriate steps were taken to preserve participant anonymity and privacy, including the use of anonymous subject identification numbers and secure storage of all electronic and paper data.

Intervention Conditions

Mobile Intervention condition. Participants in the mobile intervention condition received the app and instruction in its use at the first study visit. Participants were instructed to read material that described the rationale for and practice of mindful eating as well as the use of the various tools within the app. They were then asked to demonstrate the use of the app to insure they had understood the instructions, and any questions about its purpose or use were answered by research staff. Participants were also directed to additional material on mindful

eating and the use of the app available on the Craighead Lab website (http://craigheadlab.weebly.com/mindful-eating-coach-app.html). Participants were encouraged to contact the research staff with any questions or issues that might arise during their use of the app. After the second visit, individuals in the mobile intervention condition were informed that they were not required to use the app for the next three weeks (until the follow-up assessment) but could continue using it as desired.

Waitlist Control condition. Participants in the waitlist control condition received no intervention during the first three weeks of the study (i.e., the weeks between visit 1 and visit 2). At visit 2, they received the app and instruction in its use in a procedure identical to that given at visit 1 for the mobile intervention condition. At the end of the visit, participants were asked to use the app to practice mindful eating for the next three weeks (i.e., the weeks between visit 2 and the follow-up assessment).

"Mindful Eating Coach" App

The "Mindful Eating Coach" app was designed to prompt participants to "self-coach". The app includes rating appetite and mindfulness for each eating episode as well as prompts to notice what went well or would be useful to remember next time. The app contains five "coaching tools": coaching alerts, appetite ratings, mindfulness ratings, lessons, and history. Participants also receive psychoeducational material drawing from existing literature on mindful eating and appetite monitoring (Craighead, 2006; Kristeller et al., 2014; Mathieu, 2009; Rossy, 2012). To scaffold participants' practice of mindful eating, the app contains five "coaching tools": coaching alerts, appetite ratings, mindfulness ratings, lessons, and history.

Coaching alerts. This intervention utilizes reminders, or "coaching alerts," that prompt participants to practice mindful eating at various points during the day. These alerts are intended

to scaffold the practice of mindful eating until it becomes automatic. In this study alerts were set via the "Calendar" app available on all iPhones. Alerts appeared as notifications on the lock screen of users' iPhones; they remain on the screen until the user dismisses them or performs another function on their iPhone. Participants were asked to choose four alerts that corresponded with their personal goals from a list of 18 provided by the researchers; these pre-written alerts were written to be consistent with the psychoeducational material provided. Participants were encouraged to set an alert for first thing in the morning and then at three other times during the day. Participants were instructed to have four alerts set for the duration of their required use of the app, but they were informed that they could change the timing and the content of these alerts anytime, as desired.

Appetite ratings. Appetite ratings are the app's primary tool and allow users to electronically rate the intensity of their hunger and fullness before and after eating. These ratings are one of three tools that participants were instructed to use each time they ate. The use of appetite monitoring draws upon practices from Appetite Awareness Training (AAT; Craighead, 2006), a clinical intervention demonstrated to reduce disordered eating in a variety of populations (Allen & Craighead, 1999; Craighead & Allen, 1995; Dicker & Craighead, 2004). In the app, appetite ratings are made on a visual analog scale that ranges from "Too Hungry" to "Too Full". The scale used in the app mimics the 7-point Likert scale used in AAT. The scale is color-coded such that the extremes of the scale are red, which fades to orange and then becomes green in the middle of the scale; participants are informed that their goal is to "stay in the green," that is to avoid waiting until they are too hungry to eat and not to eat beyond the point of moderate fullness. Participants were instructed to rate their appetite before and after each eating

episode, with the intention of helping them attend to internal hunger and satiety cues and use this information to guide their eating decisions.

Mindfulness ratings. After a person rates hunger and fullness, they are asked to rate how mindful they were while eating. These mindfulness ratings utilize three icons: participants select the "sunny" icon if they felt they were able to stay mindful while eating, the "partly cloudy" icon if they felt they were only partly mindful, and the "cloudy" icon if they had difficulty staying mindful. These ratings, along with the lessons described below, are intended to increase users' awareness of their ability to eat mindfully, reinforce progress, and identify areas for improvement.

Lessons. Finally, after completing mindfulness ratings, users can identify lessons they would like to remember from that eating episode. If the user indicates that she ate mindfully, she is asked to indicate what went well by selecting items from a pre-written list (e.g., "Didn't wait and get too hungry," or "Ate slowly"). If the user indicates that she had difficulty eating mindfully, she is asked to indicate what she would like to remember to do differently next time by selecting items from a pre-written list (e.g., "Plan ahead to avoid getting too hungry," or "Remember foods or amounts that didn't feel good"). Users also have the option to type in personal lessons in addition to selecting from the provided options; these personal lessons are compiled in a list under the app's history tool for later viewing. The goal of this tool is to help users learn from their past eating experiences rather than becoming self-critical or feeling guilty. Negative judgements/feelings are hypothesized to interfere with the accurate processing of and subsequent recall of important information. As noted earlier, theories of self-compassion propose that the reduction of shame and self-criticism allows individuals to process negative information without becoming overwhelmed by it or losing their motivation to change (Neff, 2003a, 2003b).

History. The history tool allows users to track their progress with the aid of several graphs. These graphs utilize data from the user's past appetite and mindfulness ratings and allow the user to monitor her progress over time and identify new goals.

Additional coaching resources. The psychoeducational material on mindful eating and the use of the app remains available to users throughout the intervention via the app's "coaching" tab. This allows users to refer back to this material on an as-needed basis. Additionally, participants were informed of the availability of supplemental information available on the Craighead Lab website. This supplementary information included a description of the difference between mind*ful* and mind*less* eating, an explanation of how mindful eating differs from traditional dieting, instructions on how to adapt self-coaching for personal eating and weight goals, and an example of a day of successful "self-coaching" using the app.

Self-Report Measures

Demographics and history. Participants were asked to provide demographic information including their date of birth, racial/ethnic identity, self-reported height and weight (including weight history), past/present ED diagnosis (if applicable); experience with mindfulness meditation and mindful eating, past/present use of health/diet/weight loss apps, and reasons for signing up for the study.

Disordered eating measures.

Binge Eating Scale (BES; Gormally et al., 1982). This 16-item self-report measure is used to assess behaviors (e.g., bingeing), cognitions (e.g., preoccupation with food), and feelings (e.g., guilt) related to binge eating. Total scores range from 0 to 46, with higher scores indicating more severe cognitions, behaviors, and feelings related to binge eating. Severe binge eating is typically indicated by scores ≥ 27, whereas scores ≤ 17 suggest mild (or absent) binge eating

(Greeno et al., 1995). Test-retest reliability is good (r = .87; Timmerman, 1999) and internal consistency is high (α = .85; Gormally et al., 1982).

Preoccupation with Eating, Weight, and Shape Scale (PEWS; Craighead & Niemeier, 1999; Craighead et al., 2002). This 8-item self-report measure, adapted from the Modifying Distressing Thoughts Questionnaire (Clark et al., 1989), is used to assess cognitive preoccupation with food/eating and weight/shape. The PEWS is comprised of two subscales: preoccupation with food/eating and preoccupation with weight/shape. Respondents rate on a scale from 1 ("Not at all") to 6 ("Extremely") how distressing their thoughts are, how difficult they are to stop, and how much they interfere with concentration. Scores are then averaged to obtain separate subscale scores as well as a PEWS total score. Higher scores indicate greater cognitive preoccupation with food/eating and weight/shape. Preliminary analyses suggest adequate convergent validity, discriminant validity, sensitivity to change, and internal consistency (α = .84; Niemeier et al., 2002).

Mindfulness measures.

Mindful Eating Scale (MES; Hulbert-Williams et al., 2014). The MES is a 28-item self-report measure. Items are rated on a 4-point Likert scale from 1 ("Never") to 4 ("Usually"). An exploratory factor analysis of the MES revealed six factors (Hulbert-Williams et al., 2014): acceptance (e.g., "I wish I could control my hunger"), awareness (e.g., "I stay aware of my food whilst I'm eating"), nonreactivity (e.g., "Once I've decided to eat, I have to eat straight away"), routine (e.g., "I have a routine for when I eat"), act with awareness (e.g., "I eat automatically without being aware of what I'm eating"), and unstructured eating (e.g., "I snack when I'm bored"). Scores are then averaged to obtain separate subscale scores as well as a MES total score. Higher scores indicate higher levels of mindful eating. The factors have shown adequate internal

consistency (α's = 0.60-0.89), and convergent validity has been demonstrated between these factors and other measures of mindfulness, acceptance, and eating pathology (Hulbert-Williams et al., 2014).

Five Facet Mindfulness Questionnaire (FFMQ; Baer et al., 2006; Van Dam et al., 2009). This 39-item self-report measure is used to assess five facets of general mindfulness: observing (e.g., "I notice the smells and aromas of things"), describing ("I'm good at finding the words to describe my feelings"), acting with awareness (e.g., "I am easily distracted"), nonjudging (e.g., "I criticize myself for having irrational or inappropriate emotions"), and nonreactivity (e.g., "I watch my feelings without getting lost in them"). Items are rated on a 5-point Likert scale from 1 ("Never or very rarely true") to 5 ("Very often or always true"). The FFMQ yields subscale scores as well as a total score. Higher scores denote higher levels of general trait mindfulness. Convergent and discriminant validity, construct validity (i.e., relationship with meditation experience), and incremental validity of the FFMQ has been demonstrated in several samples (Baer et al., 2006; Baer et al., 2008). All five subscores and the total score have also shown adequate to good internal consistency (α's = 0.75-0.91; Baer et al., 2006).

Data Preparation

One participant withdrew before the first session assessment and 7 were excluded for failure to complete the 3-week post-test questionnaires. Thus, data from a total of 181 participants (N_{MI}=89, N_{WC}=92) were included in the post-intervention outcome analyses. In addition, 10 participants from the MI group failed to complete one or more of the 6-week follow-up questionnaires and were excluded from the follow-up analysis. Values for specific measures were imputed if a participant had missed less than 25% of that questionnaire.

Baseline group differences were examined across all participants with pre-intervention measures (*N*=188). Change scores for the disordered eating (i.e., binge eating and preoccupation with food/weight) and mindfulness measures (i.e., mindful eating and general trait mindfulness) were computed by subtracting visit 1 scores ("pre") from visit 2 ("post") scores for each measure.

Analyses

All analyses were performed using SPSS version 26. In order to examine the effects of the MI on pre-post changes in the BES, PEWS, FFMQ, and MES, ANCOVAs were conducted using group as a between-subjects factor, pre-intervention scores as the covariate, and post-intervention scores as the dependent variable. Correlation analyses were used to examine whether pre-post changes in mindfulness measures (i.e., MES and FFMQ) were associated with pre-post changes in eating pathology (i.e., BES and PEWS). Follow-up data for those initially assigned to MI was analyzed using a one-way repeated-measures ANOVAs on the scores at pre, post, and 3 weeks post-treatment. Finally, linear regression analyses were used to examine post-intervention mindful eating as a potential predictor of change in binge eating from pre-intervention to 3-week follow-up.

Results

Demographics. Sample demographics are summarized in Table 1.

Study retention. The consort diagram depicted in Figure 1 demonstrates the flow of participants during the course of study participation. Overall, study retention was high (96.3%), 181 out of 188 participants completing visit 2 (89 in MI and 92 in WL). There were no differences between groups in total number of dropouts ($X^2_{(1, N=188)}$=1.335, p=.248).

Baseline group differences. One-way analyses of variance (ANOVAs) revealed no baseline differences in age ($F_{(1, 185)}$=1.77, p=.19) or baseline BMI ($F_{(1, 184)}$=.53, p=.47) between the MI and WC groups. Chi-square analyses additionally revealed no differences in ethnicity ($\chi^2_{(1, N=188)}$=.36, p=.55), race ($\chi^2_{(3, N=188)}$=1.16, p=.76), experience with mindfulness/meditation ($\chi^2_{(1, N=188)}$=1.38, p=.24), experience with mindful eating ($\chi^2_{(1, N=188)}$=1.07, p=.30), or past self-monitoring experience ($\chi^2_{(1, N=188)}$=.28, p=.60). Fisher's exact test was used where the assumptions of Chi-square analyses were violated and indicated that the groups did not differ in history of past ED diagnosis (p=.49, *FET*) or history of past eating- or weight-related treatment (p=.17, *FET*). The groups also did not differ on any of the measures of disordered eating (all p's>.1).

Intervention Outcomes

Mindfulness. We predicted that individuals who completed the mobile intervention (MI) would report more mindful eating at post-test than waitlist controls (WC). An ANCOVA revealed a significant treatment effect on post-intervention mindful eating (Group: $F_{(1,180)}$=30.57, p<.001, η^2=.147), controlling for pre-intervention scores.

Additionally, we predicted that individuals in the MI group would report significantly higher general mindfulness at post-intervention relative to those in WC. Indeed, ANCOVA revealed a significant treatment effect on post-intervention trait mindfulness (Group: $F_{(1,180)}$=18.56, p<.001, η^2=.09), adjusting for pre-intervention scores.

Eating pathology. We predicted that individuals who completed the MI would report significantly reduced binge eating symptoms at post-intervention relative to WC. An ANCOVA revealed a significant treatment effect on post-intervention binge eating (Group: $F_{(1,180)}$=8.58, p=.004, η^2=.046), adjusting for pre-intervention scores.

Additionally, we predicted that individuals who completed the mobile intervention (MI) would report lower preoccupation with food/weight than waitlist controls (WC). An ANCOVA revealed a significant treatment effect on post-intervention preoccupation with food/weight (Group: $F_{(1,180)}$=5.11, p=.03, η^2=.028), controlling for pre-intervention scores.

Correlation between changes in mindfulness and eating pathology. We examined whether improvements in mindfulness were associated with reductions in eating pathology. Pearson correlations revealed that pre-intervention to post-intervention changes in mindful eating were associated with changes in binge eating (MI: $r_{(87)}$=-.51, p<.001; WC: $r_{(90)}$=-.28, p=.008) and preoccupation with food/weight (MI: $r_{(87)}$=-.33, p=.002; WC: $r_{(90)}$=-.20, p=.07) with the relationship being stronger within the intervention group, whereas pre-intervention to post-intervention changes in general mindfulness were not associated with changes in binge eating (MI: $r_{(87)}$=-.1, p=.36; WC: $r_{(90)}$=.01, p=.92) or preoccupation with food/weight (MI: $r_{(87)}$=-.11, p=.3; WC: $r_{(90)}$=.001, p=.99) within either group.

Maintenance at Follow-Up

Participants who failed to complete one or all of the measures at follow-up were excluded from the following analyses (i.e., we only included participants who had data available at all three time points for the measures examined in each particular analysis).

Mindfulness. For the MI group, we predicted that the post-test improvements in mindful eating and general mindfulness within the MI group would be maintained at 3 weeks follow-up. One-way repeated-measures ANOVA (n=79) revealed a significant effect of Time (pre, post, follow-up) for mindful eating ($F_{(2,156)}$=46.38, p<.001, η^2=.37). Pairwise comparisons revealed that the pre to post changes were significant ($t_{(78)}$=-7.49, p<.001, Cohen's d=.84) and the intervention effects were maintained, as there was not a significant change between post-

intervention and follow-up ($t_{(78)}$=.61, p=.54, Cohen's d=.07). Similarly, one-way repeated-measures ANOVA (n=78) revealed a significant effect of Time on general mindfulness ($F_{(2,154)}$=20.53, p<.001, η^2=.21). Pairwise comparisons revealed that the pre to post changes were significant ($t_{(77)}$=-4.15, p<.001, Cohen's d=.37) and that further improvement in general mindfulness occurred during the follow-up period (post-intervention vs follow-up: $t_{(77)}$=-2.28, p=.03, Cohen's d=.17).

Eating pathology. We predicted that the post-test improvements in binge eating and preoccupation with food/weight within the MI group would be maintained at 3 weeks follow-up. One-way repeated-measures ANOVA (n=78) revealed a significant effect of Time on binge eating ($F_{(2,154)}$=33.23, p<.001, η^2=.30). Pairwise contrasts demonstrated that binge eating improved significantly from pre to post ($t_{(77)}$=4.65, p<.001, Cohen's d=.40) and continued to decrease between post-intervention and follow-up ($t_{(77)}$=-3.40, p=.001, Cohen's d=.23). Additionally, one-way repeated-measures ANOVA (n=79) revealed a significant effect of Time on preoccupation with food/weight ($F_{(2,156)}$=12.53, p<.001, η^2=.14) with significant pre to post changes ($t_{(78)}$=6.30, p<.001, Cohen's d=.68), but no further improvement occurred during follow-up, ($t_{(78)}$=-1.08, p=.29, Cohen's d=.18).

Mindful Eating as a Predictor

A series of regression analyses were conducted to examine whether mindful eating at post-intervention predicted change in binge eating between pre-intervention and follow-up. The regression analyses were conducted using participants who completed both measures (i.e., BES and MES) at all three time points (n=78). First, simple regression analyses demonstrated that pre-intervention binge eating was a significant predictor for both post-intervention mindful eating ($F_{(76)}$=22.41, p<.001, R^2=.23) and binge eating at follow-up ($F_{(76)}$=105.29, p<.001, R^2=.58).

Second, simple regression analysis demonstrated that post-intervention mindful eating significantly predicted binge eating at follow-up ($F_{(76)}$=30.48, p<.001, R^2=.29). Lastly, multiple regression revealed that post-intervention mindful eating significantly predicted binge eating at follow-up (β=-.21, $t_{(75)}$=-2.74, p=.008) and explained an additional 3.8% of the variance in binge eating at follow-up ($F_{(2,75)}$=60.87, p<.001, R^2=.62), when controlling for pre-intervention binge eating.

Discussion

The present study aimed to evaluate the efficacy of a brief (i.e., three-week) mobile intervention, the Mindful Eating Coach, on mindful eating and eating pathology for young adult females reporting concerns about eating and weight. Our first aim was to demonstrate that use of the app would lead to improved mindful eating and perhaps improve general mindfulness as well. Consistent with our predictions, results indicated significant improvement on both measures compared to controls. Our second aim was to determine if this brief app intervention would be sufficient to reduce symptoms of disordered eating. Consistent with our predictions, 3 weeks of use resulted in reduced binge eating and preoccupation with food/weight. Those improvements were maintained, and the effect on binge eating was further enhanced over the 3-week follow-up. Notably, reductions in both symptom measures during treatment were associated with increases in mindful eating, but not with general mindfulness, suggesting mindful eating as a possible mechanism of the MI. Mindful eating at post-intervention accounted for a significant proportion of the variance in binge eating symptoms at follow-up, further providing evidence for the relationship between mindful eating and binge eating symptoms.

The brief mobile intervention used in this study, which incorporates strategies drawn from evidence-based cognitive behavioral interventions, was useful for young adult females with

heightened eating and weight concerns. Three weeks of the intervention reduced binge eating symptoms with a moderate effect size, which is similar to effect sizes reported for self-help mindfulness interventions for a range of other problem areas such as anxiety and depression (Cavanagh, et al., 2014; Spijkerman et al., 2016). While additional research is required to test for generalizability to clinical populations, these findings may have implications for the treatment of disordered eating more broadly. Importantly, individuals presenting with eating pathology often do not receive adequate treatment. The accessibility of mobile interventions may enable wider dissemination and may reduce treatment barriers for this population. Notably, the current findings provide initial evidence for an alternative method for individuals presenting with eating pathology to access evidence-based intervention.

In addition to demonstrating the efficacy of MI on binge eating symptoms, the present study provides insight into a candidate mechanism of therapeutic change. Analyses for different dimensions of eating pathology (i.e., binge eating and preoccupation with food/weight) and mindfulness (i.e., mindful eating and general mindfulness) allowed for exploration of specific pathways by which the MI may exert its effect. Specifically, while MI led to increases in mindful eating and (to a lesser extent) general mindfulness during the intervention period, reductions in binge eating symptoms were only associated with improvements in mindful eating, not general mindfulness. Furthermore, the change in mindful eating was greater in the initial 3 weeks and while that post-intervention improvement was well maintained, general mindfulness (as well as binge eating) continued to improve over follow-up. These results suggest that, as would be expected since mindful eating was the target, app use improved mindful eating first. However, over a longer period of time mindful eating appeared to support both general mindfulness and continued improvement in binge eating. Thus, mindful eating may be a candidate mechanism by

which MI elicited the initial reductions in binge eating symptoms. Consistent with this conceptualization, mindful eating at 3 weeks (post-intervention) significantly predicted individuals' binge eating symptoms at follow-up, supporting the notion that the app successfully targets mindful eating which is likely driving the effects on eating symptoms.

There are several limitations to the current study. First, interpretation of mindful eating as a candidate mechanism of the reduction in binge eating symptoms is limited by the lack of temporal precedence in the experimental design. Specifically, measures of mindful eating and binge eating symptoms were collected at the same time points. As such, while our results demonstrate an association between changes in mindful eating and binge eating symptoms from pre- to post-intervention, we cannot establish a causal relationship. Nonetheless, our results serve to generate hypotheses for future work regarding the possible role of mindful eating in driving the therapeutic change. In support of this hypothesis, mindful eating at post-intervention predicted and accounted for a significant proportion of the variance in binge eating symptoms at three weeks follow-up. Second, the present study offers some limited understanding of how changes in mindful eating and trait mindfulness were achieved. While the app was designed to teach skills targeting mindful eating, administration of the intervention was self-guided; thus, we are unable to determine, based on the data collected, how improvements in mindful eating were achieved (e.g., what specific behaviors they engaged in that helped them eat more mindfully). Additionally, the use of self-report measures as well as the correlational nature of some analyses limit both the accuracy of the data obtained and our understanding of how the reported changes occurred. Lastly, the sample in the present study included only university women with elevated but largely subclinical concerns about eating and weight. As such, the generalizability of the present results to other populations (e.g., clinical samples, men, adolescents) is limited.

Taken together, the present study provides initial evidence for a mobile intervention for disordered eating and informs future work in the development and optimization of interventions for eating and weight concerns. Future work should include assessment of mindful eating at multiple time points throughout the intervention to evaluate temporal patterns of change between mindful eating and binge eating symptoms. Lab-based studies may also be used to experimentally manipulate the theorized "active ingredient" of the intervention, controlling for other elements of the intervention (e.g., participants in one group could participate in substantial experiential practice of mindful eating in the lab before receiving the app while another group does not). In addition, future studies using the MI would do well to include qualitative feedback as well as look at individual differences in pretreatment participant characteristics to promote better understanding of factors that facilitate change in mindful eating. For instance, numerous participants in the present study indicated that the intervention helped them attune to their hunger and fullness sensations, suggesting that interoceptive awareness (and in particular awareness of hunger and satiety signals) may be one possible mechanism of this intervention. Further, future research may examine the utility of enhanced delivery methods (e.g., with the addition of some professional support in the form of a guided self- help intervention) and/or the effectiveness of this mobile intervention for different aims (e.g., for the prevention of eating disorders in vulnerable populations, or as an adjunct to more intensive psychotherapies for clinical eating disorders). The integration of this and other empirically-supported self-help interventions within a stepped care model for the prevention and treatment of eating disorders is a particularly promising avenue for future research, given the considerable cost savings offered by stepped care models (Kass et al., 2017; Wilfley et al., 2013).

In conclusion, this study demonstrated the efficacy of a brief, self-guided mobile intervention for young adult women with heightened eating and weight concerns. The high rate of completion indicates that the intervention was acceptable to this population. Participants who used the "Mindful Eating Coach" app over a period of three weeks reported more mindful eating and greater general mindfulness than a waitlist control. In addition, participants using the app reported fewer symptoms of disordered eating including binge eating and preoccupation with weight and shape. These reductions in symptoms were correlated with improvement in mindful eating but not improved general mindfulness. The post-intervention effects of using the app were well maintained over a 3-week follow-up period. Mindful eating and preoccupation with eating and weight remained stable while further improvement was noted in binge eating and general mindfulness. Regression analyses predicting follow-up binge eating supported the conclusion that the improved mindful eating at post-test contributed to the maintenance and continued improvement of binge eating. Given the enormous potential offered by mobile interventions to extend the reach of evidence-based interventions and increase access to quality care, continued rigorous examination of the effectiveness and mechanisms of these interventions is warranted.

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Table 1.

Sample Demographics

	Mean + SD
Age (n=188)	22.39 ± 3.20 (range: 18.16-30.98)
BMI (n=187)	24.65 ± 5.12 (range: 16.00-48.65)
	n (%)
Ethnicity (n=189)	
Hispanic/Latino	12 (6.3%)
Not Hispanic/Latino	177 (93.7%)
Race (n=189)	
Asian	43 (22.8%)
Black	21 (11.1%)
White	112 (59.3%)
Mixed or other	13 (6.9%)
English as first language (n=189)	
Yes	158 (83.6%)
No	31 (16.4%)
Past ED diagnosis (n=188)	
Yes	7 (3.7%)
No	181 (96.3%)
Past ED treatment (n=189)	
Yes	10 (5.3%)
No	179 (94.7%)
Past mindfulness/meditation experience (n=189)	
Yes	82 (43.6%)
No	107 (56.4%)
Past experience with self-monitoring eating (n=189)	
Yes	147 (77.8%)
No	41 (21.8%)

Table 2.

Correlations between variables at baseline.

	BMI	BES	PEWS	MES
BES	.229** n=186			
PEWS	.152* n=186	.641** n=188		
MES	-.038 n=186	-.603** n=188	-.576** n=188	
FFMQ	-.073 n=186	-.319** n=188	-.251** n=188	.368** n=188

Note. BMI= Body Mass Index; BES=Binge Eating Scale; PEWS=Preoccupation with Eating, Weight, and Shape Scale; MES=Mindful Eating Scale; FFMQ=Five Facet Mindfulness Questionnaire

*Correlation is significant at $p<.05$

**Correlation is significant at $p<.01$

Table 3.

Variable means at pre, post, and follow-up for the MI group.

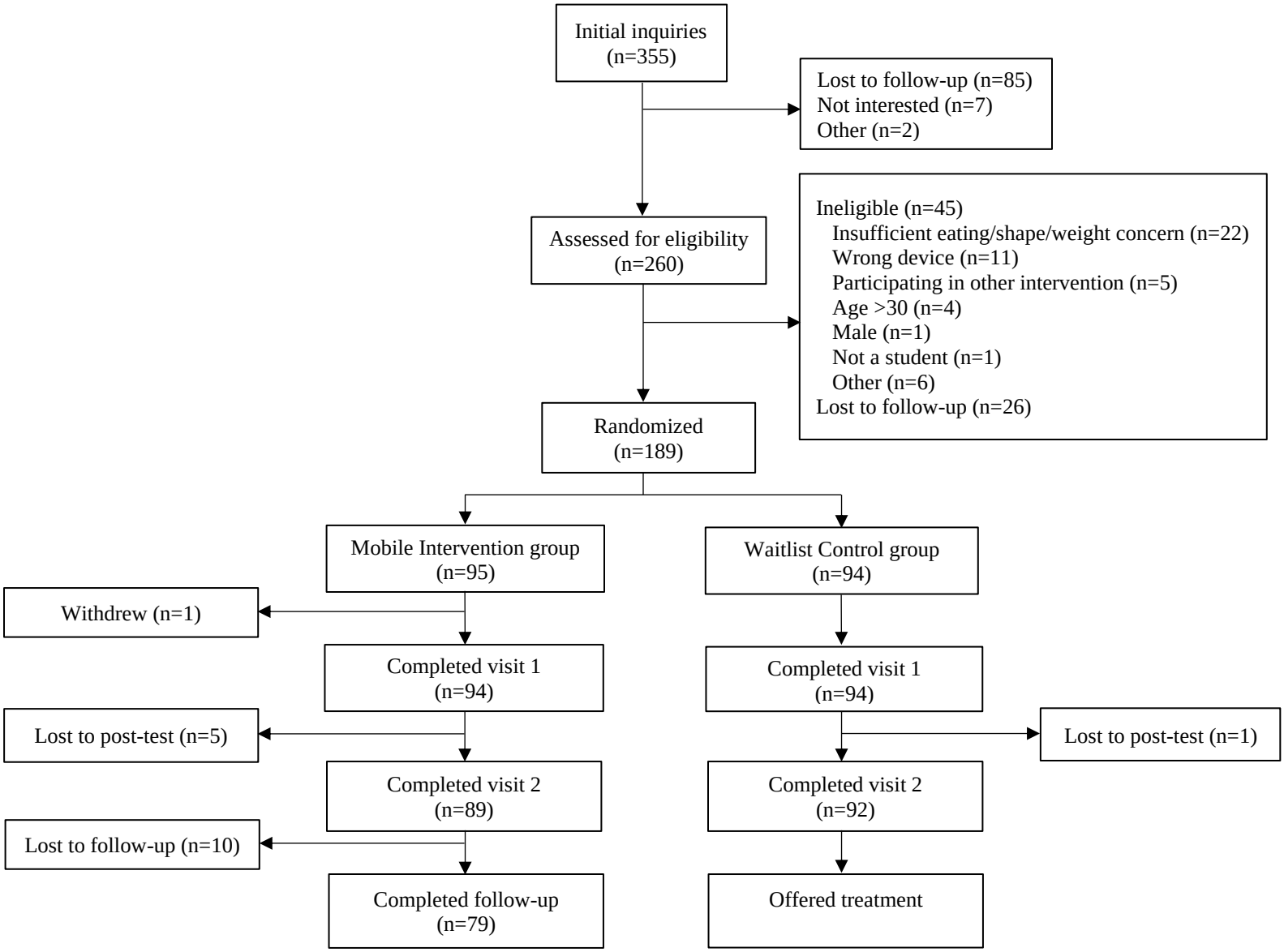
	Means (SD)		
	Pre-intervention	Post-intervention	Follow-up
BES	15.86 (7.20) n=78	13.01 (6.98) n=78	11.03 (7.84) n=78
PEWS	3.63 (1.28) n=79	2.78 (1.21) n=79	3.00 (1.14) n=79
MES	75.05 (9.37) n=79	81.70 (8.38) n=79	81.29 (9.56) n=79
FFMQ	76.47 (12.57) n=78	80.93 (11.54) n=78	82.96 (12.80) n=78

Note. BES=Binge Eating Scale; PEWS=Preoccupation with Eating, Weight, and Shape Scale;

MES=Mindful Eating Scale; FFMQ=Five Facet Mindfulness Questionnaire

Figure 1.

Consort diagram depicting flow of participants.



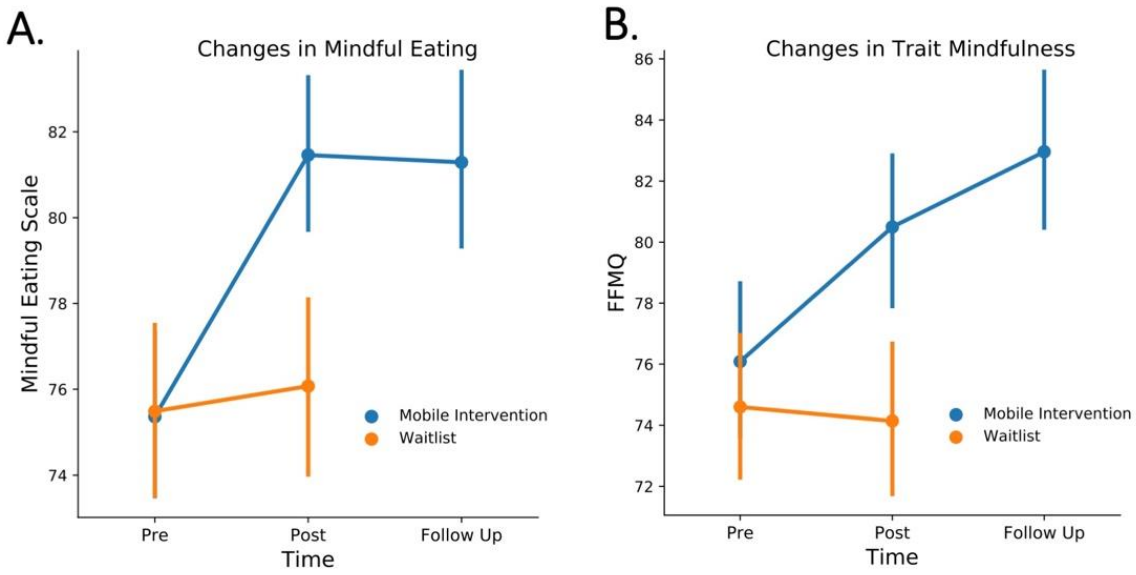


Figure 2. Change in MES (A) and FFMQ (B) scores in the MI group and WC group from pre-intervention (MES: n_{MI}=89, n_{WC}=92; FFMQ: n_{MI}=89, n_{WC}=92), post-intervention (MES: n_{MI}=89, n_{WC}=92; FFMQ: n_{MI}=89, n_{WC}=92), and three-week follow-up (MES: n_{MI}=79; FFMQ: n_{MI}=78). Follow-up data were not available for the WC condition.

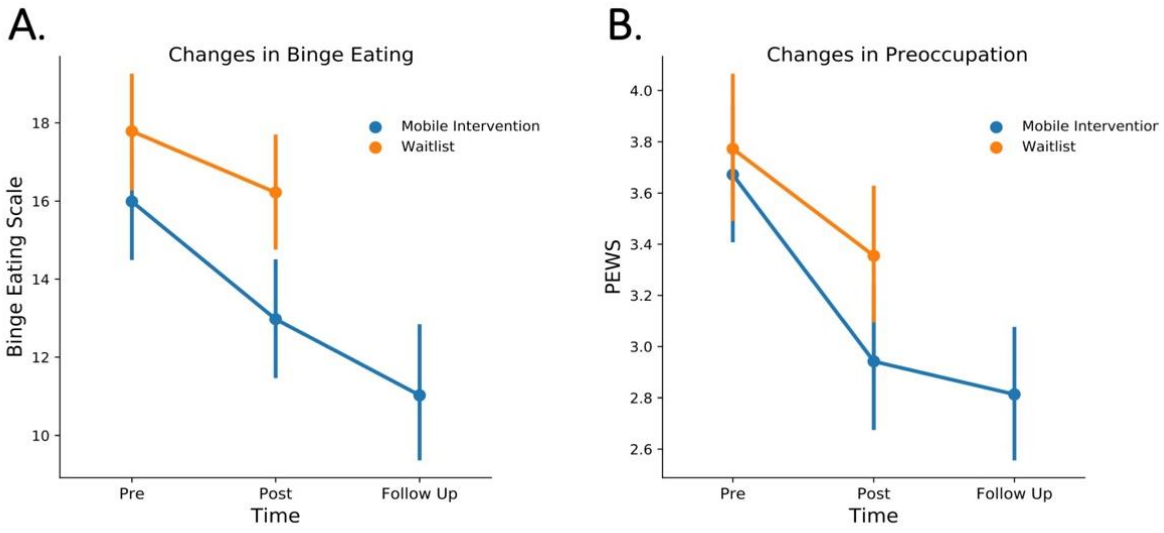


Figure 3. Change in BES (A) and PEWS (B) scores in the MI group and WC group from pre-intervention (BES: n_{MI}=89, n_{WC}=92; PEWS: n_{MI}=89, n_{WC}=92), post-intervention (BES: n_{MI}=89, n_{WC}=92; PEWS: n_{MI}=89, n_{WC}=92), and three-week follow-up (BES: n_{MI}=78; PEWS: n_{MI}=79). Follow-up data were not available for the WC condition.

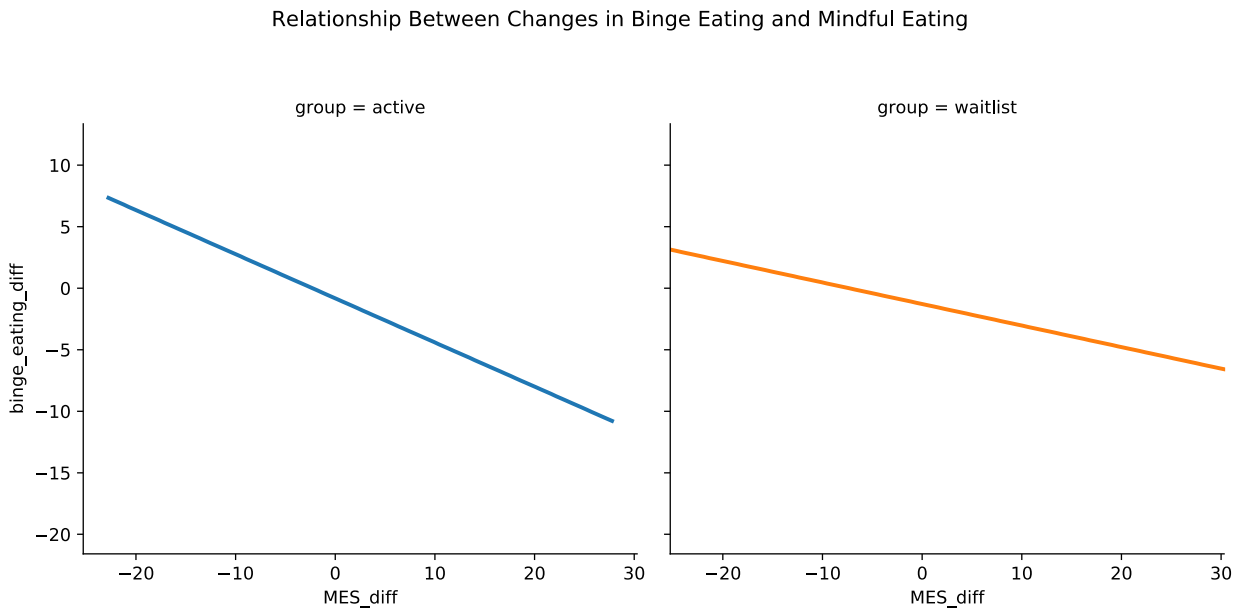


Figure 4. Relationship between pre- to post-intervention changes in binge eating and mindful eating between the MI group (*n*=89) and WC group (*n*=92).