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Feasibility of a multiple-component mindfulness intervention for Chinese adolescents living with overweight: A pilot randomized trial

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Abstract

The prevalence of obesity among Chinese adolescents is rising rapidly, and theoretically informed, scalable weight management interventions are needed. We developed and evaluated the feasibility and preliminary effects of an mHealth nutrition education and mindful snacking intervention for weight loss and improved dietary practices among Chinese adolescents with overweight. We examined whether including implementation intention formation (using if–then plans) improved outcomes. With user consultation, we created a 3-week mindful eating intervention delivered as 10 videos to user smartphones. Participants ($n = 55$) were randomly assigned to mindful eating or mindful eating + planning. Forty-six (83.6%) participants (age = 16.35 ± 0.48 years; body mass index [BMI] = 25.79 ± 2.05 kg/m^2) completed the intervention. Both groups exhibited significant pre- to post-intervention weight loss (M = 1.42 and 1.79 kg, respectively); decreases in snacking frequencies, emotional eating, external eating, and trait craving; and

significant increases in mindful eating and eating self-efficacy. No significant intervention group differences were observed. User experience data ($n = 16$) indicated acceptability and meaningful behavior change. Findings suggest that a smartphone-delivered mindfulness-based intervention for Chinese adolescents living with overweight is feasible and efficacious.

KEYWORDS

Chinese adolescents, implementation intentions, mHealth intervention, mindful eating, snacking, weight loss

INTRODUCTION

In 2015, China had the highest number of children and adolescents living with obesity in the world (GBD 2015 Obesity Collaborators, 2017). In 2018, overweight and obesity prevalence rates among 6- to 18-year-olds assessed were 13.5 and 6.0 percent, respectively (Wang et al., 2020). Obesity interventions in China have mostly targeted children and have had some success in stabilizing prevalence (Feng et al., 2017; Zhang, Wang, et al., 2018). However, interventions for adolescents are needed (Guo et al., 2019; Zhang, Wang, et al., 2018), and targeting adolescent snacking may be an effective approach.

There has been a significant increase in snacking in China, particularly among children and adolescents (Liu et al., 2019; Zhai et al., 2014). Snacking patterns of Chinese youth typically include consumption of unhealthy snacks (i.e. high energy-dense snack foods that are high in fat, sugar, or salt) and sugar/artificially sweetened beverages (Liu et al., 2019; Zhai et al., 2014). Frequent consumption of such foods and beverages has been found to be associated with a higher risk of overweight/obesity of Chinese adolescents (Liu et al., 2019; Yang et al., 2016). In addition, adolescents tend to snack in response to environmental or emotional cues rather than hunger (Lu et al., 2016; Xian et al., 2021), which has been suggested as an important contributor to overconsumption and weight gain (Fay et al., 2015; Feig et al., 2018).

Mindfulness-based interventions (MBIs) for weight loss show promise (Carrière et al., 2018; Warren et al., 2017). For example, based on a review of 18 studies, Carrière et al. (2018) found moderate effects of MBIs on pre–post-weight loss (∼3.5% of initial body weight) in predominately adult samples affected by overweight or obesity. One theoretical framework that underpins the MBIs is the intention, attention, and attitudes (IAA) model proposed by Shapiro et al. (2006), which suggests that three factors, that is, intention, attention, and attitudes, are fundamental components of MBIs. According to this model, intentionally attending to the present-moment experience with a non-judgmental attitude leads to a shift in experiential perspective (i.e. reperceiving/decentering), which can enable self-regulation, values clarification, psychological flexibility, and emotional exposure and therefore further positive outcomes. MBIs have been shown to be more effective on weight regulation when they adopt these basic mindfulness components to explicitly regulate participants' eating behaviors (Mantzios & Wilson, 2015). In these mindfulness-based eating interventions (E-MBIs), participants are taught to non-judgingly pay attention to the acting of eating, including the sensory properties of food, bodily sensations while eating, as well as internal

and external stimuli for eating (Mantzios & Wilson, 2015; Tapper, 2017). In addition to intentional awareness and acceptance, decentering also acts as an effective strategy underpinning positive weight outcomes of E-MBIs, which refers to disengaging from automatic responses to typically cognitive or affective triggers for eating and creating the potential for more conscious choices (Tapper, 2017). These strategies appear to facilitate one another, and different interventions can vary in the emphasis they place on each type of strategy (Tapper, 2017).

Adolescents appear willing to engage in, and able to benefit from, MBIs for health and well-being (Semple & Burke, 2019; Zoogman et al., 2015). E-MBIs may have the potential to promote weight loss of adolescents living with overweight/obesity by improving their eating regulation. However, to date, only a few studies have pilot tested E-MBIs for adolescents. Barnes and Kristeller (2016) established the acceptability of a school hosted mindfulness-based eating awareness intervention in a sample of predominantly African-American adolescents with overweight/obesity. Daly et al. (2016) examined a 6-week after-school satiety-focused E-MBI in a sample of Latino girls living with obesity and reported positive outcomes for the intervention group, although attrition was high (43%). Kumar et al. (2018) demonstrated the feasibility of a four-session family-based E-MBI in a sample of predominantly White adolescents with obesity. All of these interventions were delivered face-to-face. Although promising, more evidence is needed on the effects of E-MBIs in adolescents living with overweight/obesity and if effectiveness depends on delivery platform and dosage.

Some studies report that the utilization of mindfulness skills beyond an intervention is difficult for youth (Zenner et al., 2014). Mindfulness reminders may boost skills use in everyday life (Sapthiang et al., 2019). In the present study, we examined whether MBI outcomes for eating behaviors and weight loss in adolescents could be bolstered by including implementation intention planning, that is, planning to use mindfulness strategies in everyday situations. This approach is based on Gollwitzer's (1993) model of action phases. According to this model, the performance of a behavior involves two phases: the motivational phase in which individuals form an intention to engage in a particular behavior, and the volitional phase, which is concerned with the processes of translating intention to action. Planning techniques help individuals in the volitional stage of behavior to move from behavioral intentions to actual behavior. "If–then" plans, which require individuals to link a motivational and/or situational cue of unhealthy behaviors ("if") to an intended new behavioral response ("then"), have been effective in promoting healthy eating (Adriaanse et al., 2011; O'Connor et al., 2015). We assessed the value added of if–then planning (Hagger & Luszczynska, 2014) in our MBI for adolescents. This is a novel combination as, to date, there has been little crosstalk between mindfulness approaches and health behavior models, despite the potential of the latter to augment behavioral outcomes (Beattie et al., 2019).

Identifying the optimum form and implementation for weight management interventions for adolescents is challenging. Chinese high schools are not conducive intervention contexts given pressured curricula and expectations of long study days (typically 7:00 a.m. to 9:00 p.m.) (Zhao et al., 2015). Pressure on parents and the school staff limits their availability for intervention support. Innovative approaches to intervention delivery for adolescent weight reduction in China are needed. mHealth interventions have proliferated due to the ubiquitous nature of smartphone use, which appear be feasible and potentially effective among youth (Fedele et al., 2017; Wickham & Carbone, 2015). However, mHealth is still at an early stage of development in China. In addition, evidence for the feasibility of mHealth platforms in delivering E-MBIs is limited (Lyzwinski et al., 2019; Mason et al., 2018). In this study, we evaluated the feasibility of an E-MBI delivered via WeChat, the most widely used social networking platform in China.

Study aims

Our aims were as follows: (i) to develop an mHealth E-MBI intervention for weight reduction in Chinese adolescents living with overweight and to test feasibility and preliminary effects using a pilot feasibility randomized trial; (ii) to examine whether if–then planning improved intervention outcomes by comparing the preliminary outcomes of the E-MBI and E-MBI + Planning condition; and (iii) to examine intervention effects on adolescents' self-reported weight loss, snacking, eating styles (i.e. emotional eating, external eating, and mindful eating), trait craving, and eating self-efficacy.

We hypothesized that the intervention would be feasible. We set out a priori indicators of feasibility based on recommendations for the design of feasibility evaluations of health interventions (Bowen et al., 2009; Murray et al., 2016) and outcomes from similar studies. (i) Our target sample was 16 for each group (as explained in Section 2.2). (ii) We set 70 percent retention and measure completion as a feasibility marker given this is achieved by most mobile phone-delivered weight loss interventions (Lyzwinski, 2014). (iii) We expected to receive three if–then plans per participant in the E-MBI + Planning group and proposed that 80 percent of participants completing these plans would indicate acceptability of this component (Hagger & Luszczynska, 2014). The quality of plans was also evaluated. (iv) We proposed no significant adverse events and that less than 10 percent of the sample reported unresolvable technical issues would indicate feasibility. (v) Acceptability was set at 80 percent overall positive post-intervention ratings and interview feedback.

In terms of preliminary effects, it was hypothesized that (i) participants in both E-MBI and E-MBI + Planning groups would report significant post-intervention reductions in weight, snacking frequency, emotional eating, external eating, and trait craving and increases in mindful eating and eating self-efficacy and (ii) those in the E-MBI + Planning condition would report greater changes in all outcomes than the E-MBI only condition.

METHODS

Ethics and recruitment

This study was conducted following the protocols approved by the University of Leeds Research Ethics Committee (Faculty of Medicine and Health; reference number: PSC-325).

Following study information and consent, psychology teachers from three high schools in Beijing and Nanjing, China, agreed to recruit in their schools. Both passive (i.e. posters) and active (i.e. schoolteacher's recommendation) recruitment approaches were utilized (Lam et al., 2016). Students interested in participating in a healthy snacking and weight management program were invited to contact the researcher via email or WeChat. Young people were eligible to take part if they were Chinese adolescents aged 16 to 18 years, with self-report body mass index (BMI) $\geq$24 kg/m^2, self-identified snackers, motivated to lose weight, not having a self-reported or diagnosed eating disorder, and willing and able to take part in the intervention via WeChat and complete measures. The BMI reference proposed by the National Health Commission of the People's Republic of China (NHC, 2018) suggested that cutoff points for screening overweight in Chinese adolescents aged 16 to 18 years ranged from 23.3 to 24.0 kg/m^2. In this study, a cutoff point of 24.0 kg/m^2 was used to make the recruitment more feasible. Each

participant provided informed consent via WeChat message. Separate informed consent was also obtained from adolescents who took part in the follow-up interviews.

Planned sample size

Studies of weight management interventions for young adults report a low recruitment rate (7.5% to 48%) (Lam et al., 2016). As our mHealth intervention had relatively low participant burden (e.g. short duration, flexible, and self-paced), we proposed that a recruitment rate of 25 percent would indicate feasibility. Guidance for designing pilot studies (Julious, 2005; Sim & Lewis, 2012) suggests sample sizes between 12 and 25 for each condition. As attrition rates commonly observed in mHealth interventions are around 25 percent (Brindal et al., 2013; Mason et al., 2018), we aimed to recruit at least 16 participants for each group.

Intervention

User consultation informed intervention development. Four single-sex focus groups with a total of 24 Chinese adolescents (12 boys and 12 girls; 16–18 years) reported snacking patterns, motivations, and influencing factors as well as intervention needs and preferences. Consultation identified two target snacking behaviors, namely, unhealthy choices and snacking in the absence of hunger. Using consultation outputs and the Behavior Change Wheel (BCW; Michie et al., 2014), three main strategies were selected to change these target behaviors: *nutrition education* to promote adolescents' healthy food choice for snacking, *mindfulness-based healthy eating skills* to reduce snacking in the absence of hunger, and *planning* to improve the usage of mindful snacking skills. The outline of intervention sessions and the logic model of the intervention are presented in Table S1 and Figure S1.

Nutrition education aimed to provide adolescents with the knowledge about the relationship between snacking and body weight as well as daily nutrient intake recommended by the Chinese Nutrition Society (CNS) and teach them to consciously make healthy snack choice by reading food labels via a short video. *Mindfulness-based healthy eating skills* include education and meditation-based practices (both formal and informal) aiming at improving participants' mindful eating behavior (i.e. non-judgingly paying attention to the sensory experience of eating) as well as mindful decision-making around eating (i.e. awareness and evaluation of internal and external stimuli for eating, such as hunger and satiety, emotional eating, external eating, and craving) (Mantzios, 2021). Based on the IAA model (Shapiro et al., 2006), *intentional awareness* was the main mindfulness component adopted in this intervention, as it has been suggested that acceptance and decentering can be arise spontaneously from repeated practice at present-moment awareness (Tapper, 2017). The attitude of *acceptance* was also emphasized, both explicitly and implicitly. These were applied to snacking behavior in the form of eight short videos (3–10 min each), with graphics, animations, and cultural references relevant to Chinese adolescents (see Table S1 and Figure S2). The *if–then planning* materials involved a structured list of 16 "if" statements representing three domains of mindless eating (i.e. distraction, disinhibition, and judgment) and three domains of common triggers for adolescent snacking (i.e. emotional eating, external eating, and food cravings) drawing on the user consultation, and 14 "then" statements representing new mindful approaches to use. This was explained in Video 10 (see Tables S1, S4, and S5). As the planning technique was intended to promote adolescents' usage

of mindfulness-based healthy eating skills in daily life, this video was sent only to the E-MBI + Planning group in the final week, after the participants had been explained about the rationale for the common snacking triggers and mindfulness-bases solutions. They were asked to make three if–then plans (i.e. select their three most likely "if" scenarios and "then" strategies to try) and to submit a screenshot of these to the researcher. Intervention videos, user consultation interviews, and rationale for the intervention development can be found at https://doi.org/10.17605/OSF.IO/BG27Q.

Intervention content was created by the first author who is experienced in mindfulness. Content was endorsed by two mindfulness experts and one behavior change expert as including established components of E-MBIs and planning, respectively. The intervention was delivered via WeChat weekly for 3 weeks (Table 1). A pretest acceptability consultation was conducted with seven adolescents aged 16 to 18 years (M = 16.7 years, *SD* = 0.76). Each participant was invited to watch three to four videos and then gave their feedback on the video content. Results showed the intervention videos to be clear, understandable, and engaging to adolescents.

Study design and procedure

This was a pre–post-pilot feasibility randomized trial. After giving informed consent via WeChat message, adolescents who met the inclusion criteria received a link to baseline assessments. Data were later anonymized by assigning unique IDs. Participants were assured that the schoolteachers would not be informed of their participation or withdrawal and had no access to their research data.

Intervention content and assessments received by each group throughout the study are shown in Table 1. Participants were sent links to the videos on the first day of each week over three consecutive weeks, which they could access without time limits, although they were

TABLE 1 Intervention content and assessments received by each intervention group throughout the study

	E-MBI group	E-MBI + Planning group
Week 1	(Day 1) Baseline assessments Video 1. Welcome Video 2. Making healthier choices for snacking Video 3. Six kinds of hunger Video 4. Listening to your stomach practice	(Day 1) Baseline assessments Video 1. Welcome Video 2. Making healthier choices for snacking Video 3. Six kinds of hunger Video 4. Listening to your stomach practice
Week 2	(Day 8) Video 5. Emotional eating and external eating Video 6. Exploring your six kinds of hunger Video 7. One bite at a time practice	(Day 8) Video 5. Emotional eating and external eating Video 6. Exploring your six kinds of hunger Video 7. One bite at a time practice
Week 3	(Day 15) Video 8. Food cravings Video 9. Urge surfing practice	(Day 15) Video 8. Food cravings Video 9. Urge surfing practice Video 10. Planning
Week 4	(Day 28) Post-intervention assessments	(Day 28) Post-intervention assessments

Abbreviation: E-MBI, mindfulness-based eating intervention.

encouraged to complete videos weekly. Participants were randomly assigned to the E-MBI ± Planning via simple computer-generated randomization (Suresh, 2011) just before receiving Week 3 content. The only difference between the two conditions was that, in the third week, those in the E-MBI + Planning condition received Video 10 (*Planning*) and were asked to make and submit three if–then plans. On the last day of the fourth week, participants received a link to post-intervention assessments to complete within 3 days. Throughout the intervention, participants could contact the researcher by WeChat; a few did about minor details, but there were no substantive questions about the intervention.

Pre- and post-intervention self-report assessments were administrated via Wenjuanxing (wjx.cn), a commonly used Chinese online survey platform. Participants were invited to take part in a post-intervention interview via WeChat or by audio recording their responses to questions and sending the recording to us within 2 weeks. Each participant received ¥50 (£5.60) for taking part in the interview, paid via WeChat.

Quantitative measures

Self-report measures of height and body weight, eating styles, food craving, eating self-efficacy, and snacking were taken at baseline and 1 week after intervention end. At baseline, participants also rated their motivation to participate, and at post-intervention, their perception of the acceptability of the intervention.

Body mass index

Participants were required to report their weight (kg) and height (cm) measured within 2 days at both baseline and post-intervention. The BMI scores were calculated by dividing each individual's weight by the square of their height (kg/m^2).

Eating styles

Emotional eating and *external eating* were assessed using the Dutch Eating Behavior Questionnaire (DEBQ; Van Strien et al., 1986). The DEBQ consists of 33 items assessing three obesity-related eating styles (i.e. emotional eating, external eating, and restrained eating), with response options from 1 (*never*) to 5 (*very often*). In this study a 30-item Chinese version of the DEBQ, which has shown adequate psychometric properties in Chinese adolescents (Wu et al., 2017), was used. Cronbach's alpha reliability coefficients for emotional eating and external eating were .95 and .85, respectively. *Mindful eating* was assessed via the Mindful Eating Questionnaire (MEQ; Framson et al., 2009). In this study, a revised Chinese version of the MEQ was used (C-MEQ-R; Zhang et al., 2022). The C-MEQ-R consists of 23 items measuring four domains of mindful eating, with higher summary scores indicating higher levels of mindful eating. Internal consistency in the present sample at baseline was $\alpha = .83$ and for subscales was *intentional awareness* (.77), *disinhibition* (.78), *emotional response* (.85), and *attentive eating* (.83).

Food craving

Food craving was measured using the Food Cravings Questionnaire—Trait-reduced (FCQ-T-r; Meule et al., 2014). The 15-item FCQ-T-r asks respondents to evaluate the cognitive, physiological, and behavioral aspects of their food craving. Responses are scored on a 6-point scale ranging from 1 (*never*) to 6 (*always*), with high scores indicating high food craving. The Chinese version of the FCQ-T has shown good validity and reliability among female college students (Miao & Qian, 2016) but has not been widely used in adolescents. Internal consistency in the present sample at baseline was $\alpha = .94$.

Eating self-efficacy

Eating self-efficacy was measured using the Weight Efficacy Lifestyle Questionnaire Short Form (WEL-SF; Ames et al., 2012). This eight-item questionnaire evaluates self-confidence for controlling eating behavior in various situations on a scale from 0 (*strongly disagree*) to 10 (*strongly agree*). The WEL-SF yields a global scale of eating self-efficacy, with high scores indicating high level of self-efficacy. The Chinese version of the WEL-SF has shown good validity and reliability in adults living with obesity (Zhang, Yang, et al., 2018) but had not been used in adolescents. Internal consistency at baseline was $\alpha = .92$.

Snacking

Snacking was assessed using a modified Beverage and Snack Questionnaire (BSQ; Neuhouser et al., 2009). The original questionnaire contained questions regarding the frequency of snacks (eight items) and beverage (nine items) consumption during the last week. Our focus group study informing the intervention development showed that this questionnaire covered typical snack and beverage categories consumed by Chinese adolescents in urban areas. One food category (i.e. meat products) and one beverage item (i.e. sugar-sweetened milk tea, soya drinks, and coffee drinks) were added. Food brands listed as examples in each category were replaced with those most frequently consumed by Chinese adolescents. The same response scale was used for each item: never or less than 1 per week, 1 per week, 2–4 per week, 5–6 per week, 1 per day, 2–3 per day, and more than 4 per day. Responses for foods/beverages in each item were coded continuously according to middle value for each response category as (per week): 0, 1, 3, 5.5, 7, 17.5, and 28. Unhealthy snack consumption was represented using the sum of self-report frequency of six out of nine snack items, with low-fat/nonfat snacks excluded. Unhealthy beverage consumption was represented using the sum of 6 out of 10 beverage items, with 100 percent fruit juice, flavored water, and sugar-free fizzy drinks being excluded.

Acceptability

After intervention, participants rated intervention acceptability via nine statements relating to their satisfaction, time demands, convenience, enjoyment, perceived usefulness, and actual usage of the intervention on a 5-point scale (1 = *strongly disagree*; 5 = *strongly agree*).

Qualitative data

Follow-up interviews explored participants' satisfaction, perceived meaningful behavioral changes and barriers, as well as usefulness of intervention components (Table S2). Interviews were conducted by the first author via WeChat, which took up to 45 min.

Analysis plan

Quantitative data were analyzed using SPSS 22.0. Multivariate analysis of variance (ANOVA) and chi-squared tests were conducted to examine group differences at baseline. A series of 2 (time) × 2 (group) repeated measures ANOVA with time (pre- and post-intervention) as the within-subjects factor and condition (E-MBI and E-MIB + Planning condition) as the between-subjects factor was conducted for weight, BMI, eating styles (i.e. mindful eating, emotional eating, and external eating), food craving, eating self-efficacy, and snacking frequency. Significant main effects of time were interpreted as the indicator for intervention effectiveness. Significant interaction effects were interpreted as the difference in effectiveness of intervention conditions. Effect sizes were calculated using partial eta squared (η_p^2) (Bakeman, 2005). As this study involved multiple comparisons, only effects at $p < .01$ level were considered as statistically significant to control the Type I error inflation.

Qualitative data were transcribed in full in Chinese. Content analysis driven by the study aims was conducted on the Chinese transcripts. Progressing through analysis line by line, each section of text that had a distinct meaning was coded as either relevant to one or more driving questions (Table S2) or irrelevant. Descriptive labels were then assigned to relevant text. Key extracts for reporting were translated to English.

RESULTS

The final sample included 46 adolescents aged 16 to 18 years (M = 16.35 years, $SD = 0.48$), with 60.9 percent female. The BMI ranged from 24.16 to 32.19 kg/m^2, with a mean of 25.79 kg/m^2 ($SD = 2.05$). Three participants (two in E-MBI group and one in E-MBI + Planning group) fell into the obesity category (above 28 kg/m^2).

Acceptability and feasibility

Recruitment, retention/measure completion, and engagement

Participant recruitment and flow are detailed in Figure 1. All participants came from the same school, in which the teacher introduced this program to several first- and second-year classes (approximate total $n = 400$). A total of 84 adolescents added our WeChat account to their contacts. After initial contact, 69 adolescents consented to take part. Twelve were excluded for not meeting the inclusion criteria (see Figure 1), and two withdrew before completing the pre-intervention measures. The remaining 55 were randomly allocated into E-MBI ($n = 26$) or E-MBI + Planning group ($n = 29$). In a survey study we conducted in this school prior to the program ($n = 184$), 22.5 percent of adolescents reported a BMI above 24 kg/m^2. Among

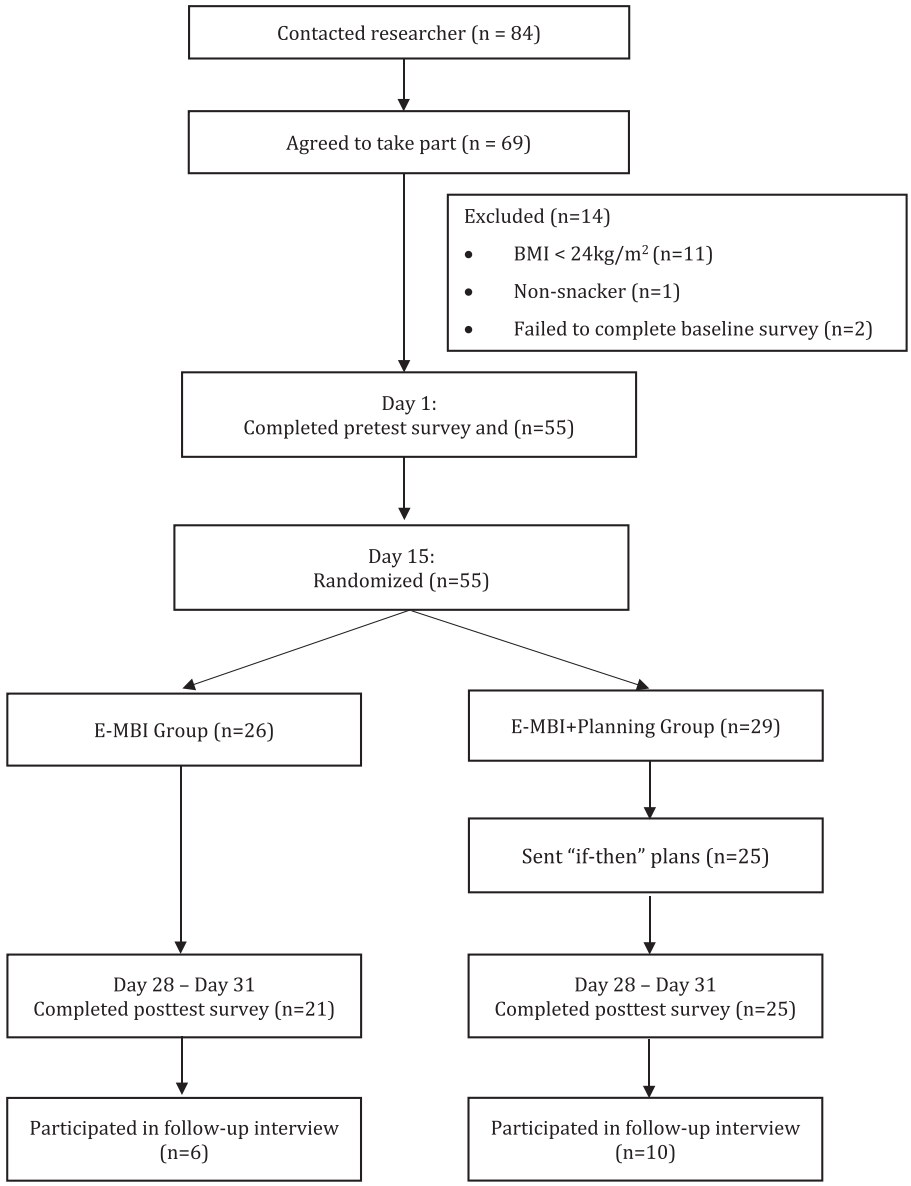

FIGURE 1 Participant recruitment and flow through the study. BMI, body mass index; E-MBI, mindfulness-based eating intervention

400 adolescents reached by the teacher in School 1, it is estimated that there were approximately 90 adolescents with a BMI above 24 kg/m^2. Fifty-five enrolled in this study, indicating a recruitment rate of 61.1 percent. This exceeded our a priori criteria for recruitment rate (25%) and our initial goal of recruitment (16 for each group), indicating that recruiting for this intervention is highly feasible with active support from school staff.

Of the 55 participants who were randomized, 9 (16.4%) withdrew from the study without giving a reason. In the E-MBI group, 5 (4 girls and 1 boy) withdrew, and 21 out of 26 (80.7%) completed the intervention and post-intervention measures. In the E-MBI + Planning group,

4 (all boys) withdrew, and 25 out of 29 (86.2%) completed the intervention and post-intervention measures. Each video was viewed 47 to 72 times (expected 46 times if everyone had watched their allocated videos once), except for the *planning* video, which was viewed 38 times (expected 25 times) (Table S3). The video-sharing website shows the number of views but not the numbers of participants who had watched the video.

If–then plans

Three if–then plans from all 25 participants in the E-MBI + Planning condition were returned, totaling 75 plans. No participants reported barriers regarding planning during the intervention. Overall, the plans participants formed appeared reasonable. In all these plans, the selected "then" condition appeared to be a rational solution to the "if" condition (e.g. "If I feel like having a snack when I am bored, then I will take a moment to check my hunger level, choose to eat if I feel my stomach needs food, and stop eating when I am no longer feeling hungry"). All 16 "if" conditions and 14 "then" conditions provided in the *planning* video were used by at least one participant. The most frequently selected "if" conditions related to emotional eating, external eating, and disinhibition (Table S4). The most frequently selected "then" behaviors were to choose healthy snacks by reading labels, to evaluate hunger level and eat only in response to physical hunger, and to decide ahead of time how much to eat in one sitting (Table S5).

Acceptability ratings and technical problems/adverse events

No adverse events were observed or reported during the intervention. Acceptability was rated an average of 4.4/5 ($SD = 0.52$) in the E-MBI group and 4.6/5 ($SD = 0.38$) in the E-MBI + Planning condition. In both conditions, rating of satisfaction, usefulness, and usage of the intervention content were also high (4.14–4.72 out of 5).

Preliminary intervention effects—Quantitative outcomes

Participant characteristics

A chi-squared test of independence was performed to examine condition difference for gender. As a result of participant attrition, the difference in percentage of girls between groups showed a marginal trend toward significance: $\chi^2(1, N = 46) = 2.85$, $p = .091$. There were no significant condition differences in age, BMI, and motivation (Table S6).

Intervention effects on weight loss, snacking frequency, eating styles, food craving, and eating self-efficacy

As shown in Table 2, a consistent pattern in the results of ANOVAs was observed, with a significant main effect of time on all outcome measures including weight ($F(1, 44) = 24.19$, $p < .001$, $\eta_p^2 = .36$), BMI ($F(1, 44) = 27.57$, $p < .001$, $\eta_p^2 = .39$), consumption frequencies of snack food (total snack food: $F(1, 44) = 10.30$, $p = .002$, $\eta_p^2 = .19$; unhealthy snack food: $F(1, 44) = 10.98$,

TABLE 2 Mean scores (*SD*) of weight, BMI, eating styles, craving, weight efficacy, and snacking frequency at pre- and post-intervention assessments by condition

Measures	Time point	M ± *SD*		Time	Group	Time × Group
		E-MBI group ($n = 21$)	E-MBI + Planning group ($n = 25$)			
Weight (kg)	T_1	77.12 ± 11.49	71.86 ± 9.42	$F(1, 44) = 24.19$, $p < .001^{***}$, $\eta_p^2 = .36$	$F(1, 44) = 3.22$, $p = .080$, $\eta_p^2 = .068$	$F(1, 44) = 0.36$, $p = .549$, $\eta_p^2 = .00$
	T_2	75.69 ± 11.49	70.03 ± 9.00			
BMI (kg/m^2)	T_1	25.84 ± 2.25	25.77 ± 1.93	$F(1, 44) = 27.57$, $p < .001^{***}$, $\eta_p^2 = .39$	$F(1, 44) = 0.13$, $p = .72$, $\eta_p^2 = .00$	$F(1, 44) = 1.35$, $p = .25$, $\eta_p^2 = .030$
	T_2	25.33 ± 2.31	24.96 ± 1.50			
Snacking food (times per week)	T_1	18.38 ± 17.03	18.84 ± 16.82	$F(1, 44) = 10.30$, $p = .002^{**}$, $\eta_p^2 = .19$	$F(1, 44) = 0.13$, $p = .72$, $\eta_p^2 = .00$	$F(1, 44) = 0.21$, $p = .65$, $\eta_p^2 = .00$
	T_2	9.33 ± 5.14	11.60 ± 9.54			
Unhealthy food (times per week)	T_1	13.60 ± 14.57	14.84 ± 12.26	$F(1, 44) = 10.98$, $p = .002^{**}$, $\eta_p^2 = .20$	$F(1, 44) = 0.33$, $p = .57$, $\eta_p^2 = .01$	$F(1, 44) = 0.00$, $p = .97$, $\eta_p^2 = .00$
	T_2	6.76 ± 4.03	8.18 ± 7.55			
Beverage (times per week)	T_1	12.10 ± 11.12	14.44 ± 14.10	$F(1, 44) = 11.34$, $p = .002^{**}$, $\eta_p^2 = .21$	$F(1, 44) = 1.16$, $p = .29$, $\eta_p^2 = .03$	$F(1, 44) = 0.03$, $p = .86$, $\eta_p^2 = .00$
	T_2	8.04 ± 6.84	6.58 ± 5.51			
Unhealthy beverage (times per week)	T_1	9.74 ± 10.50	10.00 ± 8.97	$F(1, 44) = 16.83$, $p < .001^{***}$, $\eta_p^2 = .28$	$F(1, 44) = 0.16$, $p = .69$, $\eta_p^2 = .00$	$F(1, 44) = 0.54$, $p = .47$, $\eta_p^2 = .01$
	T_2	5.24 ± 5.62	3.54 ± 3.30			
DEBQ emotional eating (1–5)	T_1	2.26 ± 0.85	3.03 ± 0.93	$F(1, 44) = 10.44$, $p = .002^{**}$,	$F(1, 44) = 7.16$, $p = .010^{**}$,	$F(1, 44) = 1.40$, $p = .244$, $\eta_p^2 = .03$
	T_2	2.00 ± 0.80	2.47 ± 0.96			

TABLE 2 (Continued)

Measures	Time point	M ± *SD*				
		E-MBI group ($n = 21$)	**E-MBI + Planning group ($n = 25$)**	**Time**	**Group**	**Time × Group**
				$\eta_p^2 = .19$	$\eta_p^2 = .14$	
DEBQ external eating (1–5)	T_1 T_2	3.44 ± 0.62 2.76 ± 0.64	3.74 ± 0.85 2.94 ± 0.78	$F(1, 44) = 36.19$, $p < .001^{***}$, $\eta_p^2 = .45$	$F(1, 44) = 1.87$, $p = .18$, $\eta_p^2 = .04$	$F(1, 44) = 0.26$, $p = .61$, $\eta_p^2 = .01$
C-MEQ-R mindful eating (1–4)	T_1 T_2	2.53 ± 0.39 2.87 ± 0.40	2.43 ± 0.42 2.89 ± 0.41	$F(1, 44) = 29.10$, $p < .001^{***}$, $\eta_p^2 = .40$	$F(1, 44) = 0.21$, $p = .65$, $\eta_p^2 = .01$	$F(1, 44) = 0.72$, $p = .40$, $\eta_p^2 = .02$
FCQ-T food craving (15–90)	T_1 T_2	40.43 ± 13.83 34.33 ± 11.47	43.44 ± 11.98 34.00 ± 9.77	$F(1, 44) = 17.06$, $p < .001^{***}$, $\eta_p^2 = .28$	$F(1, 44) = 0.21$, $p = .65$, $\eta_p^2 = .01$	$F(1, 44) = 0.79$, $p = .38$, $\eta_p^2 = .02$
WEL eating self-efficacy (0–80)	T_1 T_2	50.76 ± 15.97 55.29 ± 12.00	43.36 ± 14.89 53.52 ± 12.31	$F(1, 44) = 10.54$, $p = .002^{**}$, $\eta_p^2 = .19$	$F(1, 44) = 1.79$, $p = .18$, $\eta_p^2 = .04$	$F(1, 44) = 1.55$, $p = .22$, $\eta_p^2 = .03$

Abbreviations: BMI, body mass index; C-MEQ-R, revised Chinese version of the Mindful Eating Questionnaire; DEBQ, Dutch Eating Behavior Questionnaire; E-MBI, mindfulness-based eating intervention; FCQ-T, Food Cravings Questionnaire—Trait; WEL, Weight Efficacy Lifestyle.

* $p < .01$.

** $p < .001$.

$p = .002$, $\eta_p^2 = .20$) and beverages (total beverages: $F(1, 44) = 11.34$, $p = .002$, $\eta_p^2 = .21$; unhealthy beverages: $F(1, 44) = 16.83$, $p < .001$, $\eta_p^2 = .28$), eating styles (emotional eating: $F(1, 44) = 10.44$, $p = .002$, $\eta_p^2 = .19$; external eating: $F(1, 44) = 36.19$, $p < .001$, $\eta_p^2 = .45$; and mindful eating: $F(1, 44) = 29.10$, $p < .001$, $\eta_p^2 = .40$), food craving ($F(1, 44) = 17.06$, $p < .001$, $\eta_p^2 = .28$), and eating self-efficacy ($F(1, 44) = 10.54$, $p = .002$, $\eta_p^2 = .19$); however, no significant interaction was observed between condition and time, suggesting that both interventions were equally effective. To further compare the effects of the two intervention conditions on body weight and BMI, analyses of covariance (ANCOVAs) were performed to control for sex and motivation at baseline. The time–group interactions were not significant after controlling for these factors.

User acceptability—Qualitative outcomes

Sixteen adolescents (6 in E-MBI and 10 in E-MBI + Planning) completed the follow-up interviews. Overall, participants reported positive experiences and high levels of satisfaction of taking part in the intervention. Response categories and indicative quotes regarding perceived changes and barriers are shown in Table S7.

Participants reported improved motivation and ability to regulate their snacking. Specifically, all participants reported a *(i) more awareness and a healthier snack choice* by reading food labels and choosing based on the content of sugar, fat, and calories, for example, "I changed from knowing nothing and being very ignorant about snacking, to snacking in a more scientific way. Every time I buy snacks, or before eating snacks, I read nutrition labels, to see how much sugars and fats, also carbohydrates it contains." (03418jxy, boy, E-MBI + Planning). Ten participants reported *(ii) increased awareness of triggers for snacking*, including bodily sensations of hunger and other triggers such as emotional states and external cues. Many described changing from automatic responses to intentionally evaluating their hunger and observing what was driving their desire to eat, for example, "I used to buy or eat snacks whenever I wanted to, but now I first try to figure out whether I'm really hungry, or it's because my mood, or other reasons [...] Before eating I take a moment to observe whether it's my stomach or other parts of my body that is hungry." (zac123, girl, E-MBI + Planning). Nine adolescents reported *(iii) more mindful eating* and specifically slower eating of snack with mindful awareness, for example, "By eating slowly and put down the snacks between bites, I've been trying to pay attention to the taste of food in my mouth, and the texture of it, and I found they taste different than before—mostly in a good way." (0114cr, girl, E-MBI). Finally, nine reported *(iv) increased perceived control on eating*, for example, "The most useful part for me is 'emotional eating and external eating'. This part particularly helps control myself, as I was more likely to snack in these situations. Now I don't eat much for these reasons." (233adc, boy, E-MBI). The most frequently mentioned intervention components related to these meaningful perceived changes included *nutrition education and mindfully choosing snacks*, *listening to your stomach practice*, and *one bite at a time practice*. Other intervention components such as *six kinds of hunger*, *emotional eating and external eating*, *food cravings*, and *planning* were also mentioned as useful content.

Participants also talked about perceived barriers in participating in the intervention or practicing mindful eating. Six participants reported the lack of self-control as the main barrier they had, six reported not having enough time or proper environment to practice mindful eating in daily life, and five found it difficult to observe and be aware of their bodily sensations. Particularly, participants encountered more barriers doing formal mindful eating practices

(i.e. *exploring your six kinds of hunger* and *urge surfing*), as these practices could be more complicated and demanding on time and environment, for example, "I rarely do the urge surfing practice, because I need to really calm myself and be very focused, but I find I don't have time for that, and can hardly have a good environment to do that." (0114cr, girl, E-MBI).

DISCUSSION

This study aimed to test the feasibility and preliminary effects in a pilot randomized trial of an mHealth mindful eating intervention for Chinese adolescents living with overweight. Feasibility thresholds were met or exceeded, that is, high recruitment rate high retention rate, and high satisfaction and usefulness, with no adverse events and only a minor technical problem (i.e. the passwords for intervention videos were too complicated). User feedback showed good understanding and usage of the intervention.

Only a few studies have examined the preliminary effects of E-MBIs for weight loss among adolescents (Barnes & Kristeller, 2016; Daly et al., 2016), and the present study outcomes compared favorably to these. The sample exhibited significant pre- to post-intervention weight loss. Participants in both conditions lost an average of 1.42 and 1.79 kg, constituting 1.86 and 2.41 percent mean loss of initial body weight, respectively. This is relatively low compared with other studies of MBIs for weight loss, although most of those targeted adults living with obesity with an average baseline BMI above 30 kg/m^2 (Carrière et al., 2018). Participants in the present study had a lower baseline BMI and therefore might be less likely to lose weight fast in the short term. Additionally, the duration and intensity of this intervention (considered important to be acceptable to a stressed high school population) were lower than most published MBIs for weight loss (Carrière et al., 2018; Mason et al., 2016).

Our study outcomes contribute to the growing body of evidence for the effects of E-MBIs on improving dietary intake in populations affected by overweight/obesity (Mason et al., 2016; Timmerman & Brown, 2012). The results also extend understanding of the effects of E-MBIs on eating styles (Carrière et al., 2018), eating self-efficacy (Kidd et al., 2013; Timmerman & Brown, 2012), and reducing food cravings (Mason et al., 2016) in adults. This study found a large and significant post-intervention effect on mindful eating assessed using a revised version of the MEQ (Zhang et al., 2022), which contradicts previous studies that did not find significant post-intervention changes in the MEQ scores (Dibb-Smith et al., 2019; Kidd et al., 2013; Mason et al., 2016). However, it should be noted that the MEQ has been criticized for not being a valid measure of mindful eating as it failed to adhere to mindfulness theory and concepts (Carrière et al., 2022; Mantzios, 2021). Future studies should explore the role of mindful eating in the E-MBIs outcomes using more valid and reliable measures (e.g. Carrière et al., 2022).

In the follow-up interview, participants described increased eating regulation using mindfulness skills, and predominantly increased awareness of food sensory properties and bodily sensations without judging, to better regulate eating in response to hunger and satiety cues. This feedback supports improved awareness as a key mechanism of action of E-MBIs (Tapper, 2017; Warren et al., 2017). Overall, the qualitative findings showed that the principles and practices of mindful eating and mindful decision-making around eating were accessible to adolescents, despite the short duration and low intensity of the intervention. These findings encourage future interventions for adolescent weight loss to incorporate brief sessions on mindful eating and mindful decision-making around eating to enhance effectiveness.

Consistent with previous studies (Barkan et al., 2016; Ribeiro et al., 2018), our participants showed high usage of and preference for brief mindfulness practices (e.g. *listening to your stomach* and *one bite at a time*). Compared with formal practices, brief practices can be done throughout routine activities and can have immediate and tangible effects on the person. Meanwhile, some adolescents described difficulties in observing bodily sensations and finding time/environmental opportunities for formal mindful eating practice. The meditative elements of mindful eating practices could be highly complex to beginners, especially youth. When developing or adapting E-MBIs for adolescents, it might be beneficial to consider better incorporating mindful eating within adolescents' daily activities. In addition, future mHealth mindful eating program for adolescents can incorporate group practice and enquiry components by combining offline events or live streaming sessions, which might promote participants' grasp of mindful eating and therefore positive outcomes.

The combination of mindfulness-based healthy eating skills and planning components appeared conceptually feasible for this adolescent group. Although low adherence to planning instructions (i.e. do form plans) has been consistently observed (Mistry et al., 2015; Skår et al., 2011; Wiedemann et al., 2011), we found full adherence, with all participants in the E-MBI + Planning group forming good quality plans. One possible explanation is that the rationale for the listed situational cues ("if" statements) and mindfulness-based solutions ("then" statements) has been explained to the participants during the intervention; therefore, participants may find it easier and feel more motivated to form plans. However, contrary to our hypothesis, the E-MBI + Planning group did not show greater weight loss, snacking, or any other eating-related outcomes compared with the E-MBI group. This may have been due to the short time lapse between the planning component and intervention end (1 week). Although the interview data suggest that participants from both groups had been motivated and able to apply mindful eating strategies in key contexts, longer term follow-ups are needed to determine whether if–then plans help participants to sustain their use of mindfulness strategies over time. In addition, the active adherence to the if–then plans (i.e. whether participants integrated their plans into daily life) was not measured, which should be addressed in future research.

Evaluation and conclusions

The findings of this study need to be considered in the context of its aims and limitations. This was a pilot randomized study with a small and homogeneous sample. Although sufficient to examine our research questions, the intervention should be further tested with a larger and more diverse sample, with longer term follow-up, via a robust trial design (e.g. including active control). Although body weight, dietary intake, and eating behaviors were all self-reported, these are appropriate to mHealth studies and could be more user-friendly for upscaling. There is acceptable correlation between self-report and objective measures on our key outcomes (He et al., 2017; Neuhouser et al., 2009; O'Malley Olsen et al., 2014). However, more specific instructions (e.g. in morning or night, before or after a meal, and with similar weight of clothing/accessories) should be applied in future studies to ensure that participants self-report their weight before and after intervention under the same conditions. In addition, due to the video-sharing platform's privacy policy, it was impossible to track how long or how many times that each participant viewed the videos. Finally, the interviewer was neither independent nor blind to condition, and future evaluations should address this.

In conclusion, to our knowledge, this is the first study testing an mHealth E-MBI program in Chinese adolescents living with overweight. This study provided strong evidence for the feasibility of the intervention with potential to improve snacking and promote weight loss. Qualitative findings suggested improved awareness, self-regulation, and self-efficacy as potential mechanisms of action. Although feasible, the combination of mindful eating strategies with planning did not exhibit greater effects in the short study duration; follow-up evaluation is needed to investigate its long-term effects. These findings add to very limited evidence for the feasibility and effectiveness of E-MBIs for weight loss among adolescents.

CONFLICTS OF INTEREST

None.

ETHICS STATEMENT

The work described was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the University of Leeds Research Ethics Committee (Faculty of Medicine and Health; reference number: PSC-325). Informed consent was obtained from all individual participants included in this study.

DATA AVAILABILITY STATEMENT

Data supporting the quantitative results are available via https://doi.org/10.17605/OSF.IO/BG27Q.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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