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Is decreasing problematic mobile phone use a pathway for alleviating adolescent depression and sleep disorders? A randomized controlled trial testing the effectiveness of an eight-session mindfulness-based intervention

QINGQI LIU[1,5] , XIUJUAN YANG[2,3*] ,
CHENYAN ZHANG[4] and JIE XIONG[5,6]

[1] Department of Psychology, Faculty of Arts and Sciences, Beijing Normal University, Zhuhai 519087, China

[2] Shenzhen Mental Health Center/Shenzhen Kangning Hospital, Shenzhen 518118, China

[3] State Key Laboratory of Chemical Oncogenomics, Guangdong Provincial Key Laboratory of Chemical Genomics, Peking University Shenzhen Graduate School, Shenzhen 518055, China

[4] Department of Neurology, Tongji Hospital, Tongji Medical College, Huazhong University of Science and Technology, Wuhan 430030, China

[5] School of Psychology, Central China Normal University, Wuhan 430079, China

[6] Center of Mental Health Education, Wuhan University of Technology, Wuhan 430000, China

ABSTRACT

Objective: The present study aimed to evaluate the efficacy of a mindfulness-based cognitive therapy (MBCT) intervention in reducing problematic mobile phone use, depression, and sleep disorders among adolescents. Additionally, it sought to investigate whether the decrease in problematic mobile phone use acted as a mediator in the relationship between the MBCT intervention and adolescent depression and sleep disorders. *Methods:* In a randomized controlled trial, a total of 104 adolescents were randomly assigned to the mindfulness group ($n = 52$) or the wait-list control group ($n = 52$). The mindfulness group students completed eight 45-min sessions of mindfulness training in four weeks. The outcomes were measured at baseline, postintervention, and at the 2-month follow-up. *Results:* Compared with the control group, the mindfulness group had significantly greater levels of mindfulness and lower levels of problematic mobile phone use, depression, and sleep disorders postintervention. The intervention effects were maintained at the 2-month follow-up. In addition, decreased problematic mobile phone use significantly mediated the association between the MBCT intervention and decreased depression and decreased sleep disorders. *Conclusion:* The findings suggest that MBCT could improve adolescent depression and sleep disorders and that decreasing problematic mobile phone use is an effective pathway accounting for the MBCT intervention effect on adolescent depression and sleep disorders.

*Corresponding author.
E-mail: yxj@skh.net

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INTRODUCTION

Children face high risks of physical and mental problems as they move into adolescence (Rapee et al., 2019). Studies have revealed that the prevalence of elevated depressive

symptoms among adolescents from 2001 to 2020 was 34% (Shorey, Ng, & Wong, 2022), and the prevalence of depressive symptoms among Chinese adolescents was 23.77% (Ma & Gu, 2023). Moreover, the overall pooled prevalence of sleep disturbances in Chinese adolescents was 26% (Liang, Guo, Huo, & Zhou, 2021). Adolescent depression and sleep disorders can reduce academic performance (Owens, Stevenson, Hadwin, & Norgate, 2012; Shochat, Cohen-Zion, & Tzischinsky, 2014), aggravate interpersonal problems (Gordon & Chen, 2014; Triscoli, Croy, & Sailer, 2019), and lead to self-injury (Khazaie et al., 2021; Lan, Jia, Lin, & Liu, 2019) and suicidal behaviors (Lewis et al., 2014; Wang, Cheng, & Xu, 2019). Therefore, it is of great importance to promote research on interventions aiming to tackle depression and sleep disorders in adolescents.

Problematic mobile phone use and depression and sleep disorders

With the development of information technology, mobile phones have become a necessity for daily life. Adolescents, as the main group of mobile phone users, are susceptible to problematic mobile phone use (Lopez-Fernandez, Honrubia-Serrano, Freixa-Blanxart, & Gibson, 2014; Nikhita, Jadhav, & Ajinkya, 2015). Problematic mobile phone use refers to one's uncontrolled or excessive use of mobile phones, which eventually leads to negative consequences (Billieux, 2012). Extensive theoretical and empirical research has been conducted on the detrimental effects of problematic mobile phone use on physical and mental health, including sleep quality and well-being.

The displacement hypothesis of mobile phone use (Kushlev & Leitao, 2020) posits that mobile phone use occupies individuals' time and attention that could otherwise be devoted to other activities such as sleep, physical exercise, and offline interpersonal interaction, thereby impacting their physical and mental health. Numerous studies have provided support for the displacement hypothesis. Research has demonstrated that phubbing behavior, which involves snubbing someone in a social setting by focusing on one's phone rather than engaging in direct conversation with the person present, can have a detrimental impact on individuals' relationships with their significant others (Chotpitayasunondh & Douglas, 2018; Roberts & David, 2016). Higher levels of problematic mobile phone use are associated with greater levels of sleep interference (procrastination in bedtime scheduling), leading to more significant sleep disorders (e.g., Correa-Iriarte, Hidalgo-Fuentes, & Martí-Vilar, 2023; Cui et al., 2021; Hamvai et al., 2023).

Moreover, the interference hypothesis of mobile phone use proposes that the negative impact of mobile phone use, particularly problematic use, on well-being is due to its disruption of cognitive and interpersonal processes (Kushlev & Leitao, 2020; Sbarra, Briskin, & Slatcher, 2019). Previous research has confirmed the crucial role of disruptions in cognitive and interpersonal processes in the connection between problematic mobile phone use and psychological adaptation, thereby providing empirical evidence for the interference hypothesis. First, mobile phone use can impair attention (Byun et al., 2013; Zheng et al., 2014), preventing individuals from adequately focusing on positive emotional stimuli and potentially leading to an excessive focus on negative emotional stimuli (Hu et al., 2020; Zu, 2017), which might result in more negative emotions. Second, mobile phone use can interfere with interpersonal communication, leading to interpersonal problems (Bi, Kou, Xie, & Dong, 2022; Chen et al., 2016), thereby exacerbating psychological maladjustment such as depression.

In addition to these theoretical hypotheses and empirical studies, recent systematic reviews and meta-analytic studies have also demonstrated that adolescents with problematic mobile phone use are at high risk for depression and sleep disorders (Yang, Fu, Liao, & Li, 2020; Zhang et al., 2022). These findings suggest that decreasing problematic mobile phone use may be a pathway for alleviating adolescent depression and sleep disorders.

Effects of mindfulness-based intervention training

Mindfulness refers to focusing attention on the present moment in a conscious and nonjudgmental way (Williams & Kabat-Zinn, 2013). Mindfulness can be conceptualized as a momentary state, a stable trait (the tendency to be mindful in daily life; Brown & Ryan, 2003), or an intervention method (e.g., mindfulness-based stress reduction). Studies have shown that mindfulness skills and trait mindfulness can be significantly improved through mindfulness-based intervention (MBI) training (Khoury, Sharma, Rush, & Fournier, 2015; Spinhoven, Huijbers, Ormel, & Speckens, 2017). Mindfulness-based cognitive therapy (MBCT) is one of the most widely used and evidence-based MBI methods. MBCT integrates MBI training with traditional cognitive therapy and is generally performed in eight sessions of manualized group exercises (Segal, Williams, & Teasdale, 2018; Sipe & Eisendrath, 2012). Originally designed to prevent the recurrence of severe depression (Segal et al., 2018), MBCT is now commonly employed to promote cognitive development, regulate negative emotions, improve interpersonal relationships, and enhance psychological well-being (Crane, 2017). For example, Quan, Wang, Chu, and Hou (2018) reported that seven days of MBCT training significantly enhanced attention orientation, executive control, and positive coping style scores, indicating that MBCT can effectively improve individuals' attentional subsystems and coping styles in a short time. Querstret, Morison, Dickinson, Cropley, and John (2020) conducted a recent systematic review and meta-analysis and reported that individuals who underwent MBCT exhibited significantly lower levels of rumination, stress, depression, and anxiety than did those in a passive control group.

Many studies have demonstrated the effectiveness of MBCT in reducing depression (Goldberg et al., 2019; Simonsson, Bazin, Fisher, & Goldberg, 2021) and sleep disorders (Javadi & Ghorbani, 2019; Nikkhah, Haghani, & Aghaali Tari, 2019). For instance, meta-analytic studies have demonstrated the efficacy of MBCT in reducing depression

in patients in remission (Kuyken et al., 2016) and preventing depression relapse in the long term (McCartney et al., 2021). Moreover, there is growing evidence indicating that MBCT is effective in improving subjective sleep quality, sleep latency, sleep duration, and sleep disturbances in patients with generalized anxiety disorder (Javadi & Ghorbani, 2019) and college students with depression disorder (Nikkhah et al., 2019). Empirical research has also confirmed the positive effects of MBCT on problematic behaviors, including substance use disorders (Hamonniere & Billieux, 2023; Hoppes, 2006) and, specifically, problematic mobile phone use (e.g., Lan et al., 2018; Li et al., 2018). For example, Lan et al. (2018) reported that college students' problematic mobile phone use decreased significantly during an 8-week mindfulness-based cognitive-behavioral intervention and six weeks after the intervention. Zhang and Zhu (2014) revealed that compared with the control group, college students who received four weeks of MBCT had significantly greater levels of trait mindfulness and lower levels of problematic mobile phone use.

However, most of these studies on problematic mobile phone use have focused on adult groups, especially college students aged 18–25 years, and few studies have focused on adolescents aged 12–18 years. Moreover, few studies have tested whether MBCT can alleviate adolescent depression and sleep disorders by decreasing problematic mobile phone use. As stated earlier, problematic mobile phone use represents one of the key factors that aggravate adolescent depression and sleep disorders (Xie, Dong, & Wang, 2018; Yang, Zhou, Liu, & Fan, 2019; Zhang et al., 2022). Investigating the potential mediating role of problematic mobile phone use linking MBCT intervention to depression and sleep disorders has important implications for improving adolescents' physical and mental health in the mobile internet era. Furthermore, studies have shown that standardized eight-week MBCT or simplified versions of MBCT (less than eight weeks, one or more times per week) can exert positive treatment effects (Burgess, Selchen, Diplock, & Rector, 2021; Shead, Champod, & MacDonald, 2020; Zhang & Zhu, 2014). However, few studies have investigated the effectiveness of a modified MBCT intervention on adolescent depression and sleep disorders and further explored its mechanisms.

Aim of this study

The present study aimed to explore the intervention effects and mechanisms of an MBCT intervention on adolescent depression and sleep disorders. We propose the following hypotheses. The conceptual model is illustrated in Fig. 1.

Hypothesis 1a: Compared with the wait-list control condition, the MBCT intervention will significantly decrease adolescent depression.

Hypothesis 1b: Compared with the wait-list control condition, the MBCT intervention will significantly decrease adolescent sleep disorders.

Hypothesis 1c: Compared with the wait-list control condition, the MBCT intervention will significantly decrease adolescent problematic mobile phone use.
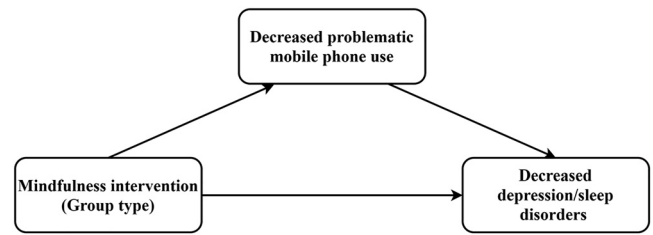

Fig. 1. The conceptual model

Hypothesis 2a: Decreased problematic mobile phone use will play a mediating role in the effect of the MBCT intervention on adolescent depression.

Hypothesis 2b: Decreased problematic mobile phone use will play a mediating role in the effect of the MBCT intervention on adolescent sleep disorders.

METHODS

Trial design and procedure

The present study was part of the research program "Multiple Risk Factors and Effective Intervention of Adolescent Problematic Mobile Phone Use: Comparison of Different Types of Problematic Mobile Phone Use." This program aims to investigate the intricate mechanisms and intervention outcomes of problematic mobile phone use among adolescents, specifically focusing on the interplay between individual factors (including emotional, cognitive, and personality aspects) and environmental factors (such as family, peer group, and school environments). This research project was approved by the Ethics Committee of the authors' university (No. 2018YBZZ095). Informed consent was obtained from all individual participants included in the study.

A two-group randomized controlled single-blind trial (RCT) was conducted to compare the effectiveness of mindfulness training with that of the control group. The mindfulness group received eight group sessions of MBCT training twice a week for 45 min each. The wait-list control group engaged in normal classroom activities without any mindfulness training until all the data were collected. Both groups needed to complete assessments measuring mindfulness, problematic mobile phone use, depression, and sleep disorders at baseline (pre-test), post-intervention (post-test), and at the 2-month follow-up. Adolescents in the control group received eight sessions of MBCT training after the formal study was completed.

The pre-test was administered by psychology graduate students who had undergone training. Each graduate student was entrusted with the task of conducting questionnaire measurements for a specific class. The questionnaire was administered in the classroom during study hall sessions using a pen-and-paper format. The first author performed the post-test and follow-up measurements. On the day
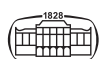
following the completion of the eight mindfulness training sessions, post-tests were conducted on both the experimental and control groups. Two months after the mindfulness training, follow-up measurements were conducted on both the experimental and control groups. Both measurements were conducted during study hall sessions using a pen-and-paper format.

Participants

Participants were recruited from an ordinary high school in South China, where we randomly selected five to six classes in each grade from Grade 7 to Grade 12. A total of 1,320 adolescents participated in our survey and completed questionnaires that measured mindfulness, problematic mobile phone use, depression, and sleep disorders. Participants with high levels of cumulative risk, especially depression and sleep disorders, were eligible for inclusion in the intervention study. Participants who were diagnosed with severe mental disorders, such as personality disorders or schizophrenia, were excluded from this study. Information regarding participants' psychiatric diagnoses was primarily obtained through self-reports and reports provided by teachers. Those who had engaged in mindfulness-related training in the past month were also excluded.

Eligible participants were invited to participate in a four-week training program aimed at enhancing attention. The program consisted of two sessions per week and incorporated a variety of techniques specifically designed to improve attention. Since MBCT itself involves various attention-training activities, participants were less likely to suspect the true purpose of the study. Moreover, by emphasizing the attention-training aspect of the program, we were able to attract more participants, as many high school students believe that attention has a strong connection to academic performance. The participants also received the following information: (1) the training program would be conducted in two phases, (2) each student would be randomly assigned to either the first or second phase, and (3) apart from the difference in timing, all students would receive identical training content. This information facilitated the implementation of a single-blind design by preventing participants in the wait-list control group from speculating about the reasons for the delayed intervention training and ensuring that the subjects remained unaware of their assignment to the experimental or control group.

Sample size

According to convention (Kelley, 1939), the top 27% of participants with the highest scores were classified as the high-scoring group. Given the focus of our study on an intervention for depression and sleep disorders, we defined the top 27% of participants with the highest scores on the depression and sleep disorder measures as the target population. A total of 104 adolescents who scored in the top 27% for both the depression and sleep disorder measures at baseline were invited to participate in our study. These participants were randomly assigned to a mindfulness group

or wait-list control group, with each group consisting of 52 participants. The individuals in the mindfulness training group were further randomly divided into seven subgroups, with each subgroup consisting of 7–8 adolescents. Informed consent was obtained from all participants prior to the formal experiment. Four participants in the mindfulness group were excluded because their daily mindfulness home practice time was less than 6 min. Three participants in the mindfulness group and three participants in the control group were excluded because they did not complete all the subsequent assessments. Thus, the final sample consisted of 94 participants, with 22 boys and 23 girls in the mindfulness group and 22 boys and 27 girls in the control group.

Intervention

The Chinese version (Nie & Xue, 2017) of the Mindfulness-based Cognitive Therapy Workbook (The Mindful Way Workbook: An 8-Week Program to Free Yourself from Depression and Emotional Distress; Teasdale, Williams, & Segal, 2013) was adopted as the MBI guideline. This workbook provides a comprehensive and detailed introduction to the eight specific training courses in the MBCT program. Each training session included a review of weekly homework practices, psychological education, guided mindfulness practices (e.g., sitting meditation, body scan), and an inquiry into and discussion of the participants' experiences during the training. This workbook also provides nearly 300 min of audio materials to help guide participants to better master mindfulness skills. Based on the eight MBCT training sessions in the workbook, we designed eight sessions of an MBCT intervention course suitable for our participants. The MBCT course consisted of eight 45-min sessions, which were delivered twice a week for four consecutive weeks, once on Monday night and once on Thursday night each week. The first author of this study instructed the mindfulness group to practice mindfulness skills in the psychological activity room of the school. At the end of each session, the participants were asked to complete homework that included recording and summarizing their experiences with group practice and self-guided practice to assess whether they complied with the mindfulness training courses.

The specific activities of the eight sessions of the MBI can be found in Appendix 1. The design of the course adhered to the fundamental principles of MBCT, with the training activities centred around the main principles of mindfulness, such as the exercises "Beyond automatic pilot," "Coming home to the present: Gathering the scattered mind," "Allowing things to be as they already are," and "Kindness in action". It is important to note that the effects of mindfulness practice are multifaceted, and each exercise may have positive impacts on several components of mindfulness, albeit with varying emphasis. Of particular importance, considering the targeted intervention, we incorporated activities in the intervention program that address problematic mobile phone use. Through the recall and analysis of scenarios related to mobile phone use, we guided adolescents in examining the relationship between phone use and mind-

wandering, thereby helping them understand that mind-wandering is a contributing factor to the unconscious and uncontrollable use of their mobile phones. Mindfulness exercises were then introduced to mitigate mind-wandering. As adolescents became more focused on the present moment, their cravings and thoughts related to mobile phone use decreased, and they exhibited reduced susceptibility to excessive usage. In the section titled "Kindness in action," adolescents were taught techniques to amplify positive emotions through pleasurable activities and enhanced cognitive styles through mastery activities. As a result, the emotional and cognitive factors contributing to problematic mobile phone use were alleviated. Moreover, the gradual improvement in positive emotions and cognitive styles reduced the likelihood of experiencing withdrawal symptoms associated with addictive behaviors and repaired any impaired psychological functions resulting from problematic mobile phone use among adolescents. In this way, as adolescents' mindfulness levels improved, the symptoms of problematic mobile phone use may have also been alleviated.

Integrity check for the MBI

The integrity of the MBI was assessed by evaluating the participants' completion of group activities and homework practices. Regarding the group activities, participants in the treatment group were considered to have dropped out if they attended less than 75% of the mindfulness intervention sessions (Semple, Lee, Rosa, & Miller, 2010). Regarding the homework practices, we considered both quantitative and qualitative indicators. Previous research has suggested that the average daily practice time, which is considered a crucial quantitative indicator, should be at least six minutes (Hülsheger, Alberts, Feinholdt, & Lang, 2013; Xu, Zhu, & Liu, 2019). To measure compliance quantitatively, we assessed the duration of home practice, considering an average daily practice time of no less than six minutes as satisfactory. Qualitatively, compliance was evaluated based on the specificity and clarity of the insights gained from the training.

Outcome measures

Primary outcome measures

Depression. Depression was assessed by the Depression Subscale of the Chinese short version (Gong, Xie, Xu, & Luo, 2010) of the Depression Anxiety Stress Scale (DASS-21, Lovibond & Lovibond, 1995). Participants answered seven items (e.g., "I felt that I had nothing to look forward to") on a four-point scale (0 = does not apply to me at all, 3 = applies to me very much). The scores of the seven items were summed to calculate the depression values. High scores indicate high levels of depression. Numerous studies have validated the reliability and validity of this scale among Chinese adolescents (e.g., Novak et al., 2021; Yang et al., 2019). The Cronbach's α coefficients for the post-test and follow-up tests were 0.792 and 0.775, respectively.

Sleep disorders. Sleep disorders were assessed by the sleep disorder dimension of the Pittsburgh Sleep Quality Index scale (Buysse, Reynolds III, Monk, Berman, & Kupfer, 1989), as revised by Liu et al. (1996). The scale contains nine items (e.g., "During the past month, how often have you had trouble sleeping because you had bad dreams") rated on a 4-point scale (0 = not during the past month, 3 = three or more times a week), with higher scores indicating greater sleep disorders. The scores of the nine items were summed to calculate the sleep disorder values. The reliability and validity of this scale have been extensively validated through numerous studies in the population of Chinese adolescents (e.g., Ren et al., 2021; Zhou et al., 2020). The Cronbach's α coefficients for the post-test and follow-up tests were 0.814 and 0.747, respectively.

Secondary outcome measures

Problematic mobile phone use. Problematic mobile phone use was assessed by the Chinese version (Cheung et al., 2019) of the Smartphone Addiction Scale-Short Version (Kwon, Kim, Cho, & Yang, 2013). This scale includes ten items (e.g., "Feeling impatient and fretful when I am not holding my smartphone") rated on a five-point scale (1 = never, 5 = always). High scores indicate high levels of problematic mobile phone use. The scores of the ten items were summed. The reliability and validity of the scale have been well established among Chinese adolescents (Chang et al., 2023; Cheung, 2019). The Cronbach's α coefficients for the post-test and follow-up tests were 0.948 and 0.936, respectively.

Mindfulness. Trait mindfulness was assessed by the Chinese version (Liu et al., 2017) of the Child and Adolescent Mindfulness Measure (CAMM, Greco, Baer, & Smith, 2011). This scale consists of ten items (e.g., "I get upset with myself for having certain thoughts") rated on a five-point scale from 0 to 4 (0 = never, 4 = always). After reverse scoring, the scores of the ten items were summed. The scale has shown to have good reliability and validity in multiple studies conducted on Chinese adolescents (e.g., Liu et al., 2017; Liu et al., 2018). The Cronbach's α coefficients for the post-test and follow-up tests were 0.809 and 0.855, respectively.

Randomization

Participants were randomly assigned in a 1:1 ratio to either the experimental intervention group focused on mindfulness or the wait-list control group using a computer-generated randomization sequence. Randomization was performed by an independent statistician after the initial assessment, with no involvement or interaction with the participants.

Statistical analysis

A descriptive statistical analysis was conducted using SPSS 23.0 to show the baseline information about the participants, with a focus on their mental health status and the homogeneity of the experimental and control groups prior to the intervention. Repeated measures analysis of variance
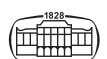
(ANOVA) was conducted to test the immediate and short-to-medium-term effects of the MBCT intervention on adolescent depression and sleep disorders. Effect sizes were described using partial η_p^2 calculated by repeated measures ANOVA. Cohen's d values were employed to illustrate the effect sizes in the analysis of simple effects.

Finally, mediating effect analyses were performed to test whether problematic mobile phone use could mediate the effect of MBCT on adolescent depression and sleep disorders. The mediation analysis was conducted through the bias-corrected percentile bootstrap method using the PROCESS macro for SPSS (Hayes, 2013). The bias-corrected percentile bootstrap allows for direct testing of the mediation effect and provides more accurate confidence intervals (e.g., Edwards & Lambert, 2007; Hayes & Scharkow, 2013; Preacher & Hayes, 2008). As suggested by Preacher and Kelley (2011), we employed the K^2 index as a measure of the effect size for the indirect effects. Although K^2 has limitations as an effect size index for mediating effects (Wen & Fan, 2015), presently, no measures of indirect effects are without limitations (Hayes, 2017). Nonetheless, K^2 can still provide some insight into the magnitude of mediating effects. To control for potential sex and age differences in depression (Salk, Hyde, & Abramson, 2017) and sleep disorders (Auer, Frauscher, Hochleitner, & Hoegl, 2018; da Cunha Silva Santiago et al., 2017), we included sex and age as covariables in the mediation analyses.

Ethics

The present study was part of the research program "Multiple Risk Factors and Effective Intervention of Adolescent Problematic Mobile Phone Use: Comparison of Different Types of Problematic Mobile Phone Use." This program was approved by the Ethics Committee of the authors' university (No. 2018YBZZ095). Informed consent was obtained from all individual participants included in the study.

RESULTS

Participation

Figure 2 displays a CONSORT diagram illustrating the flow of participants throughout the study. Regarding the group activities in the experimental group, all 52 participants attended 6 sessions of the intervention activities. Specifically, 45 adolescents (86.5%) attended 7 sessions of the group intervention activities, while 41 adolescents (78.8%) participated in all 8 sessions. Therefore, the participants in the experimental group all met the minimum requirements for the group intervention. As for the home practice, four participants (7.7%) reported spending less than 6 min per day on mindfulness home practices and thus were excluded from the final analysis. Three participants were excluded from the formal analysis because they did not complete the pre-test and post-test measures. The remaining 45 adolescents in the mindfulness group included in the formal analysis all met the criteria of participating in at least 6 group exercises and

engaging in mindfulness home practices for a minimum of 6 min per day. On average, they engaged in 7.690 group training sessions ($SD = 0.668$), with a daily duration of mindfulness home practice averaging 16.16 min ($SD = 6.564$).

Baseline information

The participants included in the formal analysis were between 12 and 18 years of age ($M = 14.060$, $SD = 1.703$). In terms of sleep disorders, the participants had an average score of 17.851 ($SD = 3.458$), which exceeded the theoretical mean score of 13.50 by approximately one standard deviation, indicating that the participants had relatively high sleep disorder scores. However, it should be noted that the sleep disorders subscale of the Pittsburgh Sleep Quality Index alone is not sufficient for accurately classifying the severity of sleep disorders. Therefore, it can only be cautiously concluded that the overall level of sleep disorders among the participants was moderate. On the depression subscale, the participants had an average score of 13.968 ($SD = 2.559$). Based on the classification of depression severity using the DASS-21 (Lovibond & Lovibond, 1995), 37 participants (39.4%) exhibited mild depression, while 53 participants (56.4%) exhibited moderate depression. Only four participants (4.2%) did not meet the threshold for mild or moderate depression; however, all four of them scored 9 on the depression subscale, indicating their proximity to the threshold for mild depression. The detailed baseline information for both the intervention and control groups is presented in Table 1. The independent-samples t test showed no statistically significant differences between the mindfulness group and the control group in the pre-test scores for trait mindfulness, problematic mobile phone use, depression, or sleep disorders. That is, the mindfulness group and the control group were homogeneous before the mindfulness intervention.

Test for the intervention effect

Repeated measures ANOVAs (2 group types: mindfulness group and control group × 3 study periods: pre-test, post-test, and follow-up test) were conducted to reveal the effects of the MBCT intervention on trait mindfulness, problematic mobile phone use, depression, and sleep disorders. There was a statistically significant group type × study period interaction effect on trait mindfulness ($F(2, 184) = 58.842$, $p < 0.001$, $\eta_p^2 = 0.390$), problematic mobile phone use ($F(2, 184) = 78.960$, $p < 0.001$, $\eta_p^2 = 0.462$), depression ($F(2, 184) = 10.319$, $p < 0.001$, $\eta_p^2 = 0.101$), and sleep disorders ($F(2, 184) = 26.630$, $p < 0.001$, $\eta_p^2 = 0.224$). The simple effect analyses are illustrated in Table 2. In the post-test phase, the experimental group participants exhibited significantly higher scores for trait mindfulness and significantly lower scores for problematic mobile phone use, depression, and sleep disorders than did those in the control group. These differences between the experimental and control groups remained statistically significant during
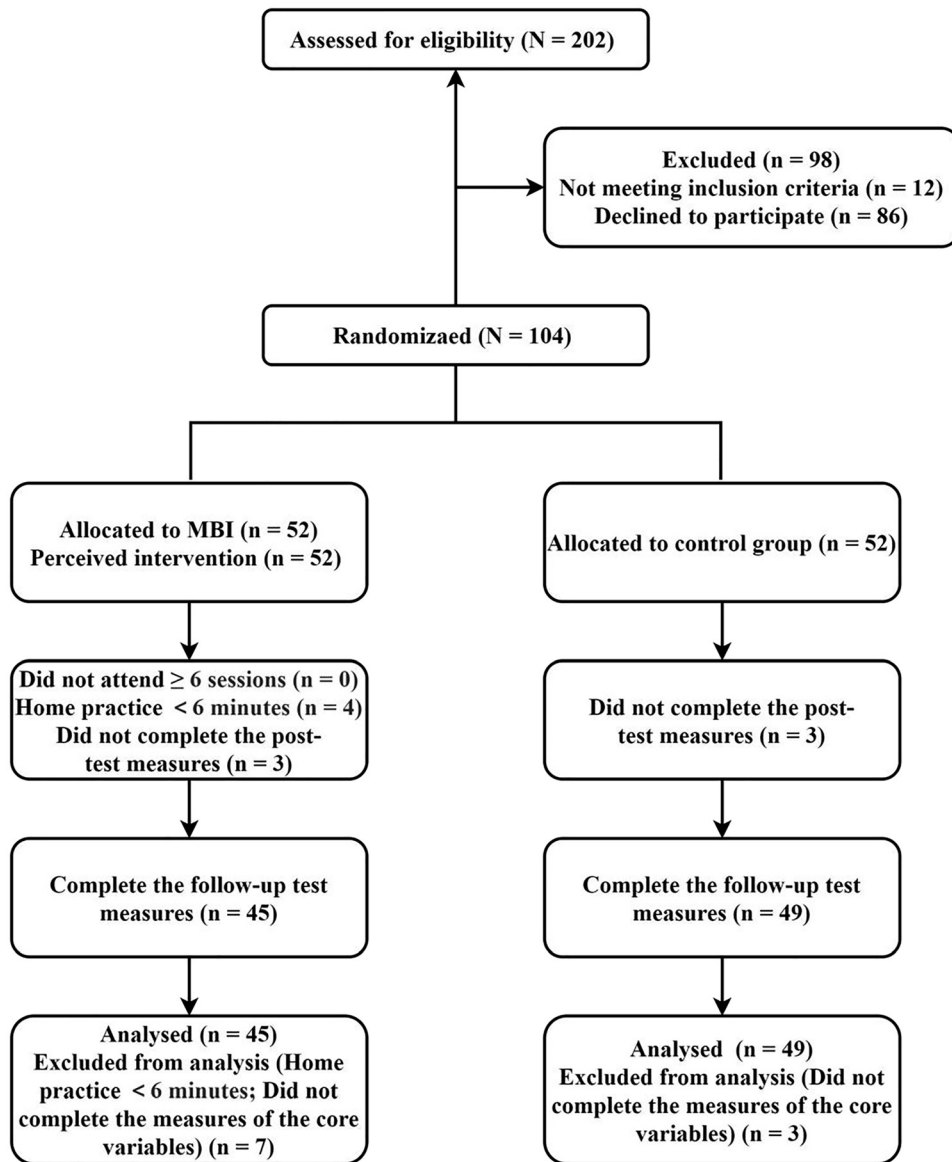
Assessed for eligibility (N = 202)

Excluded (n = 98)
Not meeting inclusion criteria (n = 12)
Declined to participate (n = 86)

Randomizaed (N = 104)

Allocated to MBI (n = 52)
Perceived intervention (n = 52)

Allocated to control group (n = 52)

Did not attend ≥ 6 sessions (n = 0)
Home practice < 6 minutes (n = 4)
Did not complete the post-test measures (n = 3)

Did not complete the post-test measures (n = 3)

Complete the follow-up test measures (n = 45)

Complete the follow-up test measures (n = 49)

Analysed (n = 45)
Excluded from analysis (Home practice < 6 minutes; Did not complete the measures of the core variables) (n = 7)

Analysed (n = 49)
Excluded from analysis (Did not complete the measures of the core variables) (n = 3)

Fig. 2. CONSORT flow diagram of the study

Table 1. Baseline information of the participants included in the formal analysis

|	Intervention group (N = 45)		Control group (N = 49)
Age, mean ± SD	14.18 ± 1.614		13.96 ± 1.791
Male, %	48.9		44.9
Rural region, %	17.8		32.7
Senior high school, %	42.2		32.7
Mild depression, %	35.6		42.9
Moderate depression, %	60.0		53.1
Mindfulness, mean ± SD	14.911 ± 5.672		15.878 ± 5.743
		$t = -0.820$	
Problematic mobile phone use, mean ± SD	39.689 ± 8.045		38.816 ± 8.061
		$t = 0.525$	
Depression, mean ± SD	13.978 ± 2.454		13.959 ± 2.677
		$t = 0.305$	
Sleep disorders, mean ± SD	17.911 ± 3.976		17.796 ± 2.944
		$t = 0.159$	
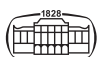
Table 2. Between-group and within-group differences

Outcome variables	Group	Post-test M(SD)	Follow-up test M(SD)	Pre-post difference	Post-follow-up difference	Pre-follow-up difference
Trait mindfulness	Intervention	24.311 (5.672)	20.622 (7.460)	$d = -1.657^{***}$	$d = 0.557^{**}$	$d = -0.862^{***}$
	Control	15.980 (5.282)	16.367 (5.195)	$d = -0.018$	$d = -0.074$	$d = -0.089$
	Between-group difference	$d = 1.520^{***}$	$d = 0.662^{**}$			
PMPU	Intervention	28.289 (7.440)	31.489 (8.457)	$d = 1.471^{***}$	$d = -0.402^{**}$	$d = 0.994^{***}$
	Control	39.980 (7.896)	39.837 (8.068)	$d = -0.146$	$d = 0.018$	$d = -0.126$
	Between-group difference	$d = -1.524^{***}$	$d = -1.010^{***}$			
Depression	Intervention	11.422 (3.917)	9.644 (3.537)	$d = 0.782^{**}$	$d = 0.476^{*}$	$d = 1.424^{***}$
	Control	14.306 (3.709)	13.939 (3.602)	$d = -0.107$	$d = 0.100$	$d = 0.006$
	Between-group difference	$d = -0.756^{***}$	$d = -1.203^{***}$			
Sleep disorders	Intervention	9.422 (6.207)	10.644 (5.839)	$d = 1.629^{***}$	$d = -0.203$	$d = 1.455^{***}$
	Control	17.714 (3.786)	17.653 (3.772)	$d = 0.024$	$d = 0.016$	$d = 0.042$
	Between-group difference	$d = -1.612^{***}$	$d = -1.426^{***}$			

Note. PMPU = Problematic mobile phone use. $^{*}p < 0.05$. $^{**}p < 0.01$. $^{***}p < 0.001$.

the follow-up phase. The findings indicated significant improvements in trait mindfulness, problematic mobile phone use, depression, and sleep disorders, with effect sizes ranging from moderate to large. Furthermore, the analysis of within-group differences revealed that individuals in the mindfulness group exhibited significantly increased trait mindfulness scores at post-test and follow-up compared to at pre-test. Additionally, scores for problematic mobile phone use, depression, and sleep disorders were significantly lower at post-test and follow-up than at pre-test among the mindfulness group participants.

Mediation model analysis

We conducted a mediation model analysis in which group type (control group = 0, mindfulness group = 1) was the independent variable, decreased problematic mobile phone use (pre-test score minus post-test score) was the mediator, and decreased depression (pre-test score minus follow-up score) was the dependent variable. The bias-corrected percentile bootstrap method (Table 3) showed that the mediating effect of decreased problematic mobile phone use was 0.362, and its 95% confidence interval was [0.120, 0.620]. When considering the effect size, the K^2 value

($K^2 = 0.584$) indicated a moderate to large mediating effect. Thus, the MBCT intervention could effectively alleviate adolescent depression by decreasing problematic mobile phone use.

We also conducted a mediation model analysis in which group type (control group = 0, mindfulness group = 1) was the independent variable, decreased problematic mobile phone use was the mediator, and decreased sleep disorders acted as the dependent variable. The bias-corrected percentile bootstrap method (Table 4) showed that the mediating effect of decreased problematic mobile phone use was 0.318, and its 95% confidence interval was [0.073, 0.562]. When considering the effect size, the K^2 value ($K^2 = 0.566$) indicated a moderate to large mediating effect. Thus, the MBCT intervention could effectively improve adolescent sleep quality by decreasing problematic mobile phone use.

DISCUSSION

The present study conducted an RCT to test the effectiveness of an abbreviated MBCT intervention on adolescent problematic mobile phone use, depression, and sleep disorders

Table 3. Total, direct, and indirect effects of MBI on depression

Effects	Coefficient	SE	Bootstrap LLCI	Bootstrap ULCI
Total effect	0.484^{***}	0.090	0.305	0.664
Direct effect	0.122	0.152	−0.180	0.424
Indirect effect	0.362^{**}	0.125	0.120	0.620

Note. Bootstrap sample size = 5,000. SE = standard error. LL = low limit, CI = confidence interval, UL = upper limit. $^{**}p < 0.01$, $^{***}p < 0.001$.

Table 4. Total, direct, and indirect effects of MBI on sleep disorders

Effects	Coefficient	SE	Bootstrap LLCI	Bootstrap ULCI
Total effect	0.564^{***}	0.087	0.392	0.737
Direct effect	0.247	0.149	−0.050	0.544
Indirect effect	0.318^{*}	0.123	0.073	0.562

Note. Bootstrap sample size = 5,000. SE = standard error. LL = low limit, CI = confidence interval, UL = upper limit. $^{*}p < 0.05$, $^{***}p < 0.001$.

and further examined whether decreasing problematic mobile phone use through an MBCT intervention functioned as a pathway for alleviating adolescent depression and sleep disorders. To the best of our knowledge, this is one of the first RCT studies focusing on the mediating role of problematic mobile phone use in accounting for how an MBCT intervention promotes adolescent physical and mental health. The findings can provide empirical support and practical suggestions for interventions for adolescent depression and sleep disorders in the mobile internet era.

First, our results demonstrated the immediate and short-to-medium-term effects of the MBCT intervention on adolescent mindfulness, depression, and sleep disorders. Therefore, Hypotheses 1a and 1b were confirmed. Compared with those in the control group, adolescents in the mindfulness group reported significantly greater levels of mindfulness and lower levels of depression and sleep disorders after eight sessions of the MBCT intervention, and these intervention effects were maintained after two months. Mindfulness does possess a level of stability; however, it is contingent upon various factors and is not considered absolutely stable. Noteworthy factors can still lead to fluctuations in mindfulness. Given the nature of our intervention training, which consisted of an eight-session mindfulness program, its potential impact on altering mindfulness is expected to be noticeable. Previous studies employing the CAMM have provided evidence that mindfulness training significantly improves the levels of mindfulness among adolescents, with effect sizes ranging from small to moderate (e.g., Bluth & Eisenlohr-Moul, 2017; Bluth, Roberson, & Gaylord, 2015; Tan & Martin, 2013). In addition, the results coincide with those of meta-analytic studies on the effects of MBCT on depression (Goldberg et al., 2019; Kuyken et al., 2016; McCartney et al., 2021) and RCTs on sleep disorders (Camino et al., 2022; Javadi & Ghorbani, 2019). Although the effects of MBCT interventions on depression and sleep disorders have been well established, these studies have mainly focused on adults, especially patients who were clinically diagnosed with depressive disorder, generalized anxiety disorder, or sleep disorders (e.g., Javadi & Ghorbani, 2019; Nikkhah et al., 2019). Our findings add to prior research by documenting the efficacy of an MBCT intervention in reducing depression and sleep disorders among general adolescents.

Second, consistent with Hypothesis 1c, our results confirmed the immediate and short-to-medium-term effects of the MBCT intervention on problematic adolescent mobile phone use. Compared with those in the control group, adolescents in the mindfulness group reported lower levels of problematic mobile phone use after eight sessions of the MBCT intervention, and the intervention effect remained significant at the two-month follow-up. These results are consistent with previous research revealing the intervention effect of MBCT on problematic mobile phone use among young adults, such as college students (Lan et al., 2018; Zhang & Zhu, 2014). Previous research has established that MBCT can improve individuals' mindfulness (Gu, Strauss, Bond, & Cavanagh, 2015), which is a salient protector of

problematic mobile phone use (Kim, Milne, & Bahl, 2018). Individuals with high levels of mindfulness can better regulate negative emotions (Guendelman, Medeiros, & Rampes, 2017; Teper, Segal, & Inzlicht, 2013), reappraise negative thoughts (Garland, Hanley, Farb, & Froeliger, 2015; Troy, Shallcross, Davis, & Mauss, 2013), and control behavioral impulses (Elkins-Brown, Teper, & Inzlicht, 2017). Therefore, they are less likely to be addicted to their mobile phones due to negative emotions, negative cognitive styles, or a lack of self-control. Our research suggests that mindfulness interventions are also efficacious in reducing problematic mobile phone use in adolescents. These findings may encourage more researchers to apply mindfulness-based training for the prevention and intervention of technology addiction in children and adolescents.

Third, our study further confirmed the mediating role of problematic mobile phone use underlying the intervention effect of MBCT on adolescent depression and sleep disorders. That is, the MBCT intervention could significantly alleviate adolescent depression and sleep disorders by reducing problematic mobile phone use. Therefore, Hypotheses 2a and 2b were also supported. Existing studies have shown that problematic mobile phone use is a critical risk factor for adolescent depression (Seo, Park, Kim, & Park, 2016; Yang et al., 2019) and sleep problems (Xie et al., 2018; Zhang et al., 2022). These findings indicate that decreasing problematic mobile phone use may help enhance adolescents' physical and mental health. Thus, alleviating adolescent depression and sleep disorders by reducing problematic mobile phone use is highly important. Our research findings not only align with previous empirical studies but also support the displacement hypothesis and interference hypothesis of mobile phone use (Kushlev & Leitao, 2020; Sbarra et al., 2019). The present study supports the advancement of innovation by confirming that an eight-session MBCT intervention effectively reduces depression and sleep disorders by addressing problematic mobile phone use. In our study, the research design meets the general requirements of a mediation model in a time series. Specifically, we conducted three wave tests at different time points (baseline, postintervention, and 2-month follow-up) and used the decrease in problematic mobile phone use scores from the pre-test to post-test as the mediating variable and the decrease in depression and sleep disorder scores from the pre-test to follow-up tests as the dependent variable. Thus, the results confirmed that decreased problematic mobile phone use played a critical mediating role in the association between the MBCT intervention and decreased depression and sleep disorders in adolescents. The findings highlight that decreased problematic mobile phone use functioned as a pathway through which the MBCT intervention alleviated adolescent depression and sleep disorders in practice.

One notable result that warrants further discussion is the moderate to large effect sizes observed in our study using a mindfulness intervention. Some studies on a mindfulness intervention for adolescents have found significant effects, with small to moderate effect sizes (Ames, Richardson,

Payne, Smith, & Leigh, 2014; Borquist-Conlon, Maynard, Brendel, & Farina, 2019; Lee, Chen, & Lin, 2022), but there are also studies on adolescents that have reported moderate to large effect sizes (Hilt & Swords, 2021; Tan & Martin, 2013). When individuals other than adolescents are included, a greater number of studies have reported significantly large effect sizes (Hofmann, Sawyer, Witt, & Oh, 2010; Jain et al., 2007; Newland & Bettencourt, 2020). Moreover, the effect size of the mindfulness intervention in our study is consistent with previous research conducted on Chinese university students (Dai, 2018; Zhu & Zhang, 2014). Although some studies may not have directly reported effect sizes, it is possible to calculate these effect sizes by utilizing critical indicators from both the experimental group and the control group (such as the means and standard deviations or t values and degrees of freedom). For instance, Zhu and Zhang (2014) observed a significant increase in mindfulness levels (Cohen's $d = 2.432$), a decrease in anxiety (Cohen's $d = -1.733$), and a reduction in mobile phone dependence (Cohen's $d = -3.064$) among students who participated in a 4-week MBCT group training program consisting of 8 counselling sessions. Similarly, Dai (2018) found that the mindfulness group experienced a significant decrease in the levels of problematic mobile phone use compared to the control group (Cohen's $d = -1.581$) after four weeks of mindfulness intervention training for university students.

Individual differences among participants and program characteristics can have an impact on the receptivity and effectiveness of mindfulness training (Carsley, Khoury, & Heath, 2018). Previous research has indicated that MBCT tends to have more pronounced effects than does mindfulness-based stress reduction (Querstret et al., 2020). Moreover, individuals with depression typically exhibit more noticeable effects than adolescents in general (Reangsing, Punsuwun, & Schneider, 2021). In terms of outcomes, significantly larger effect sizes were observed for psychological symptoms than for other types of symptoms (Zoogman, Goldberg, Hoyt, & Miller, 2015). The intervention program in our study utilized an adapted version of mindfulness-based cognitive therapy and predominantly involved adolescents with varying degrees of depression. These factors allowed us to observe moderate to large effect sizes in the outcomes. Therefore, the moderate to large effect sizes observed in our study do not significantly deviate from previous research findings. Nevertheless, we should still exercise caution when evaluating the magnitude of the effects of mindfulness interventions. The varying sizes of the effects of mindfulness interventions suggests that researchers should further explore the boundary conditions of mindfulness intervention effectiveness to better understand when the practical effects of mindfulness training are stronger or weaker.

The absence of mood variation in the control group is also a notable observation. Typically, adolescents' moods tend to vary depending on the academic year and season. However, it is important to recognize that our study participants might not have experienced significant changes in academic pressure or seasonal variations. The stability of the psychosocial adaptation indicators in the control group is also in line with the findings of some previous studies (e.g., Ebrahiminejad, Poursharifi, Roodsari, Zeinodini, & Noorbakhsh, 2016; Li, Song, Lian, & Feng, 2019; MacDonald & Neville, 2023; Poli, Maremmani, Gemignani, & Miccoli, 2022). In our study, we conducted three rounds of data collection during the middle of the autumn semester and at the beginning of the spring semester, avoiding the period of highest academic pressure (the end of the semester). Moreover, Chinese high school students generally face consistently high levels of academic pressure regardless of the timing during the semester. Hence, for Chinese high school students who already experience high levels of academic pressure, the influence of pressure changes due to semester timing may be minimal. Additionally, the participants attended a school in Guangdong Province in South China, which is located in a subtropical climate zone. This region is known for mild and humid winters with minimal temperature fluctuations throughout the year. Consequently, the impact of seasonal changes on the emotional state of our participants may have been negligible.

LIMITATIONS AND IMPLICATIONS

This study has several limitations. First, all the data in this study were obtained from self-reports and thus were susceptible to subjective bias. More objective data need to be obtained through scientific measurement tools. For instance, evaluating sleep disorders through physiological indicators, such as respiration, electroencephalogram (EEG), and electrocardiogram (ECG), can provide objective data and ensure the accuracy of the research results (Matthews et al., 2018). Second, we cannot specifically analyze the changes in different dimensions of mindfulness because of the single-dimension mindfulness scale used in this study. Future research could use a multidimensional mindfulness scale such as the Five Facet Mindfulness Questionnaire (Baer et al., 2008) to explore the functions of specific components of mindfulness. Third, the generalizability of the sample may be limited since all participants were from the same school in a single city. Future researchers could verify the effect of mindfulness-based interventions on problematic mobile phone use, depression, and sleep disorders in more diverse groups. Fourth, it is infeasible to eliminate experimenter bias (e.g., expectation bias) and subject bias (e.g., allegiance bias) during the data collection process. In this study, both mindfulness training and the measurement of the variables after training were carried out by the first author, potentially introducing experimenter bias. Moreover, questionnaire surveys conducted within the school context might elicit a desire to "succeed" in post-intervention evaluations. In future research, we will address these issues by having individuals other than the mindfulness training instructors perform the variable measurements, thereby reducing potential experimenter bias. We will also consider modifying the questionnaire measurement environment or employing non-self-report methods to gather data, thus mitigating subject bias.

Although limitations were observed, this study still has important theoretical and practical significance. From a theoretical perspective, this study explored the mediating effect of an MBCT intervention on adolescent depression and sleep disorders, which contributes to illuminating how mindfulness training improves adolescent physical and mental health in the mobile internet era. From a practical perspective, the present study focused on an early-onset population with problematic mobile phone use (i.e., adolescents), which helps provide empirical support for the early prevention and intervention of problematic mobile phone use in adolescents. In addition, this study provides strong empirical support for the positive effects of an MBCT intervention on adolescent problematic mobile phone use, depression, and sleep disorders. The findings may encourage parents and educators to apply formal and informal mindfulness interventions in adolescents' daily lives. The present study can also provide scientific guidance and practical suggestions for the design of intervention plans and the implementation of intervention activities.

Authors' contribution: QL: study design, methodology, statistical analysis, writing–original draft, writing–review & editing. XY: supervision, writing–review & editing. CZ: resources, statistical analysis, writing–review & editing. JX: data curation, writing–review & editing.

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SUPPLEMENTARY MATERIALS

Supplementary data to this article can be found online at https://doi.org/10.1556/2006.2024.00034.

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Appendix 1. Content of the Eight-Session MBI

Topics	Intervention Targets	Group Activity	Homework Practices
Session 1: Beyond automatic pilot	1. Understanding what mindfulness is 2. Perceiving the present moment 3. Weakening automation reaction mode	1. Explanation of mindfulness 2. Mindfully eating a raisin 3. Bring awareness to routine activities	1. Mindful eating 2. Body scan meditation
Session 2: Another way of knowing	1. Differentiating between thinking and awareness 2. Reducing excessive rumination 3. Enhancing direct experience	1. Explanation of ruminant 2. The "working down the street" exercise 3. Body scan 4. Mindfulness of breathing	1. Bring awareness to routine activities 2. Pleasant experiences calendar
Session 3: Coming home to the present: Gathering the Scattered mind	1. Identifying mind wandering 2. Evaluating mobile phone usage and mind wandering 3. Integrating a fragmented mind	1. Time travel of the mind: Past, present, and future 2. Analysis of situational memory: Mind wandering and mobile phone use 3. Three-minute breathing space 4. Mindful movement meditation	1. Combined stretch and breath meditation 2. Unpleasant experiences calendar
Session 4: Recognizing Aversion	1. Identify environmental risk factors 2. Identifying avoidance reactions 3. Confronting negative experiences	1. Explanation of ecological model of human development 2. Scenario recall analysis: Avoidant responses under environmental risk 3. Sitting meditation 4. Three-minute breathing space: Regular 5. Mindful walking	1. Sitting meditation 2. Mindful walking
Session 5: Allowing things to be as they already are	1. Accepting environmental risk factors 2. Allowing negative emotions to arise 3. Objectively experiencing changes in emotions	1. Explanation of coexisting with difficulties 2. Sitting meditation: Working with difficulties 3. Three-minute breathing space: Regular 4. Three-minute breathing space: Responsive	1. Sitting meditation 2. Three-minute breathing space
Session 6: Seeing thoughts as thoughts	1. Distinguishing between thoughts and facts 2. Separating emotions from thoughts 3. Weakening the connection between emotions and thoughts	1. Psychophysical exercises: Stimulating thoughts through emotions 2. Sitting meditation: with a focus on relation to thoughts as mental events 3. Three-minute breathing space: Regular 4. Three-minute breathing space: Responsive	1. Sitting meditation 2. Three-minute breathing space
Session 7: Kindness in action	1. Improving positive emotions through pleasure activities 2. Improving cognitive style through mastery activities 3. Replacing mobile phone usage with beneficial activities	1. My list of pleasure activities 2. My list of mastery activities 3. Sustainable mindfulness practice 4. Three-minute breathing space: Regular 5. Three-minute breathing space: Responsive	1. Sustainable mindfulness practice 2. Three-minute breathing space

(continued)

Continued

Topics	Intervention Targets	Group Activity	Homework Practices
Session 8: What now	1. Summary 2. Reflection 3. Plan	1. Intervention summary: What did we practice? 2. Insight sharing: What mindfulness brings 3. Future Planning: The Real Eighth Time is Life After	1. Some daily formal mindfulness practice 2. Some everyday informal mindfulness practice