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A mindfulness-based mobile health (mHealth) intervention among psychologically distressed university students in quarantine during the COVID-19 pandemic: A randomized controlled trial

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Abstract

This randomized controlled trial evaluated the effect of a mindfulness-based mobile health (mHealth) intervention, tailored to the pandemic context, among young adult students ($N = 114$) with elevated anxiety and/or depressive symptoms during quarantine in China, compared to a

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The study was registered as a clinical trial (www.chictr.org.cn; trial identifier: ChiCTR2100042726).

Data will be made available upon request.

time- and attention-matched social support-based mHealth control. At baseline, post-intervention (1-month), and 2-month follow-up, participants completed self-reports of primary outcomes (anxiety and depression), secondary outcomes (mindfulness and social support), and emotional suppression as a culturally-relevant mechanism of change. Feasibility and acceptability were also evaluated. Using intent-to-treat (ITT) analysis, linear mixed effects models showed that compared to social support mHealth, mindfulness mHealth had superior effect on anxiety ($p = .024$, between-group $d = 0.72$). Both conditions improved on depression (baseline-to-FU d s > 1.10 , between-group difference not significant, $d = 0.36$ favoring mindfulness). There was an interaction of emotional suppression reduction X condition in improvement of anxiety and depression. Further, mindfulness mHealth was demonstrated to be more feasible and acceptable in program engagement, evaluation, skills improvement, and perceived benefit. Retention was high in both conditions ($> 80\%$). Difference in self-reported adverse effect was non-significant (3.9% in mindfulness and 8.7% in social support). Results of this pilot trial suggests that both mindfulness and social support, delivered via mHealth, show promise in reducing distress among young adults in quarantine, with mindfulness being particularly effective in addressing anxiety. Successful implementation and dissemination of this mHealth intervention approach has potential for addressing the psychological consequences of the pandemic.

Keywords

COVID-19; young adults; psychological distress; mindfulness; clinical trial

Large-scale quarantine measures (e.g., lockdowns, shelter-in-place) have been implemented across the globe to contain the spread of and protect the public from the coronavirus-2019 (COVID-19) (Han et al., 2020). In China, the first country to experience this public health crisis, the government applied strict, nation-wide quarantine policies to curb the outbreak. However, one of the unintended consequences of quarantine is its adverse psychological impact. A recent meta-analysis of 25 empirical studies found those in quarantine had increased odds for anxiety ($OR = 2.0$) and depression ($OR = 2.8$) (Henssler et al., 2020).

In particular, young adult university students may be a vulnerable population to psychological distress during quarantine. Mental health challenges among young people has long been recognized as a global public health issue (Patel et al., 2007). Further, the pandemic has caused mass disruption in education resulting in a transition to internet-based learning, social isolation, and increased uncertainty about the future for young adults. Extant evidence indeed suggests elevated anxiety and depression among young adult students during quarantine (Sun et al., 2021; Tang et al., 2020; C. Wang & Zhao, 2020). Left unaddressed, mental health symptoms may worsen with time (Canet-Juric et al., 2020), resulting in increased adverse educational and health outcomes for impacted young adults (Arnett et al., 2014; Patel et al., 2007). However, despite the high need for mental health promotion, evidence-based interventions addressing elevated psychological distress (i.e., anxiety and depression) during quarantine are scarce. In fact, although various guidelines for improving psychological well-being have been proposed (Liu et al., 2020), to our knowledge, no known empirical research has examined the efficacy of an intervention tailored to young adults in the pandemic context.

Both dispositional mindfulness and social support appear to protect against psychological distress in a survey of 1,912 university students during the COVID-19 pandemic quarantine (Sun et al., 2021). Mindfulness is defined as “paying attention, on purpose, in the present moment and non-judgmentally” (Kabat-Zinn, 1994). Mindfulness-based interventions (MBIs), such as Mindfulness-based Stress Reduction (MBSR) and Mindfulness-based Cognitive Therapy (MBCT), have shown to be effective in reducing psychiatric symptoms such as anxiety and depression including in young adults (Dawson et al., 2020; Kuyken et al., 2015). Tailored to the pandemic context, a mindfulness-based intervention could help young adults in quarantine cope more effectively (e.g., enhance emotion regulation) and reduce psychological distress. Enhancing social support may be another effective pathway for improving psychological health among young adults. Social isolation is a major risk factor for development of anxiety and depression (Beutel et al., 2017; Matthews et al., 2016). Evidence suggests that quarantine and social distance measures have also created a “loneliness pandemic.” A recent survey found that compared to their elder peers, young adults experience higher loneliness during the pandemic, which was linked to depressive symptomology (Lisitsa et al., 2020). Loneliness can be particularly detrimental to young adults developmentally, given that social support is crucial for psychological health, motivation, and academic success (Hefner & Eisenberg, 2009; J. Song et al., 2015). Social support interventions for young adults have shown to be effective to improve psychological health (Griffiths et al., 2009; Hogan et al., 2002), and this approach might also mitigate the psychological sequelae of the COVID-19 pandemic.

Mobile health (mHealth) modalities offer promise for reaching and engaging distressed young adults in quarantine in psychological care. Reports of service providers and organizations have documented the transition from in-person to internet and phone-based mental health care during the pandemic, though efficacy of such programs has largely not been evaluated (Chen et al., 2020; Liu et al., 2020). In addition, scholars have argued for the need for smartphone-delivered, evidence-based mHealth interventions that can reduce the burden of care for providers and successfully address psychological symptoms as a public health strategy to mitigate long-term mental health consequences of the pandemic (Figueroa & Aguilera, 2020). Despite over 10,000 mental health apps available to consumers, most are not evidence-based (Wasil et al., 2019). Further, although highly scalable, engagement and adherence to treatment remain issues for mHealth interventions. Research suggests low rates of engagement and continued use after downloading (Baumel et al., 2019). A meta-analysis of mHealth-based randomized controlled trials (RCTs) suggested that approximately one quarter of participants drop out at follow-up (8 weeks from baseline) (Linardon & Fuller-Tyszkiewicz, 2020). For young adults in quarantine, engagement to an mHealth intervention could be higher due to increased time spent on mobile phones (Sun et al., 2021), although to our knowledge this has not been demonstrated.

The Current Study

The research highlighted above demonstrates the need for development and empirical evaluation of feasible and scalable mental health interventions that can effectively engage vulnerable populations such as young adults during a global pandemic. Through a randomized controlled trial (RCT), the current study examines the efficacy, mechanism,

feasibility and acceptability of a mindfulness-based mHealth intervention compared to a time- and attention-matched social support-based mHealth control among Chinese university students in quarantine with elevated anxiety and/or depressive symptoms. Like many other low-and middle-income countries (LMIC), demand for mental health services in China is high while available resources are insufficient and stigma for seeking professional treatment remains prevalent (X. Song et al., 2019; World Health Organization, 2017). The COVID-19 outbreak was officially announced on January 20th, 2020, during the winter break time when university students typically return home city to spend Chinese New Year with family. The Spring semester was initially suspended, followed by transition to internet-based learning (Ministry of Education of China, 2020). Given the critical need for scalable, mHealth-based interventions to reduce the burden of psychological distress during the COVID-19 pandemic, we rapidly developed a multi-component, app-based mindfulness intervention tailored to a distressed young adult population in the pandemic context (intervention development process is described in Method).

Aims of this randomized controlled trial were threefold. First, the primary aim was to examine the effectiveness of a mindfulness-based mHealth intervention in reducing symptoms of anxiety and depression for young adults in quarantine compared to a rigorous active control (social support mHealth). Primary outcomes were anxiety and depression, and secondary outcomes were mindfulness and perceived social support. Meta-analysis found MBIs to be similar to or slightly superior compared to controls intended to be therapeutic in reducing psychiatric symptoms (Goldberg et al., 2018). Thus, we hypothesized we would see slightly more improvement in symptoms of anxiety and depression in the mindfulness versus social support condition. As secondary outcomes, we expected the mindfulness condition to produce larger effects on mindfulness and the social support condition to produce greater increases in perceived social support. Secondly, we aimed to examine emotional suppression, a culturally-relevant emotion regulation strategy, as a potential intervention mediator. Social psychology and neuroscientific evidence suggest that people in East Asian cultures, compared to their peers of Western/European cultures, are more likely to adopt emotional suppression as a regulatory strategy in accordance with cultural values that prioritize self-control and interpersonal harmony (Butler et al., 2007; Murata et al., 2013; Su et al., 2017). Emotion regulation has long been hypothesized as a mechanism of mindfulness (Farb et al., 2014; Gu et al., 2015; Shapiro et al., 2006). Yet instead of suppressing emotions, mindfulness training emphasizes observation of emotional experiences without changing them, and it has been conceptualized that such awareness itself leads to emotional regulation and symptoms reduction (Ludwig et al., 2020; Shapiro et al., 2006). Thus, we anticipated that reduction in emotional suppression in the mindfulness condition would be associated with greater improvement in anxiety and depressive symptoms, while the opposite would be found in the social support condition (i.e., increase in emotional suppression would be associated with greater symptoms improvement) due to its greater emphasis in the interpersonal context. The third aim was to evaluate the feasibility and acceptability of the mindfulness mHealth in comparison to social support mHealth. We anticipated that young adults in the mindfulness condition, compared to their peers in the social support condition, would report higher feasibility and acceptability of the intervention, such that they will show greater intervention engagement, lower attrition,

and report the intervention to be more acceptable, relevant, beneficial, with a lower rate of self-reported adverse effect.

Method

Participants

We recruited 114 Chinese university students during the emerging COVID-19 pandemic in March and April 2020. Recruitment took place online via WeChat-based flyers and websites targeting college students. Potentially interested participants completed a brief online screening survey to determine eligibility. Specifically, eligible participants needed to (a) identify as Chinese; (b) currently enrolled as an undergraduate or graduate level university student; (c) age 18 or older; (d) can read, speak, and write Mandarin Chinese; (e) self-report as currently in quarantine due to the pandemic without physically attending school; (f) have daily personal internet access; (g) have access to a smartphone or device that allows for Zoom video conferencing and WeChat, a widely used social media app in China; (h) experiencing elevated psychological distress, such that their depression or anxiety symptoms at or above the mild cutoff on the Patient Health Questionnaire-9 (PHQ-9; Chinese version) (Kroenke et al., 2001; W. Wang et al., 2014) and the 7-item Generalized Anxiety Disorder Scale (GAD-7; Chinese version) (Spitzer et al., 2006; Zeng et al., 2013). Participants were excluded if they (a) were taking psychotropic medication; (b) were receiving or planning to receive other professional psychological treatment; (c) unable to attend weekly meetings due to scheduling conflict; and (d) indicated imminent risk of self-harm (see Figure 1 for participant flow).

Participants were 22.21 years old ($SD = 2.67$) on average. The majority were female (73.7%). Participants resided in 27 various provinces out of the total 34 provinces in China (79.4%), representing a wide geographical reach. The majority were undergraduate (67.5%). Most participants (59.6%) reported they perceived their family income to be at a similar level compared to their peers, whereas 28.9% reported family income as lower and 11.4% reported family income to be higher than their peers.

Procedure

The study protocol was reviewed and approved by the Institutional Review Board at Beijing Normal University. The study was registered as a clinical trial (www.chictr.org.cn; trial identifier: ChiCTR2100042726).

Internet-based screening and assessment.—The study advertisement posted on social media platforms indicated that enrolled participants will be randomly assigned to two “psychological interventions” to address distress during quarantine without specifying details. Interested individuals contacted a research assistant (RA) by WeChat to communicate their interest. The RA then further described the study, including random allocation to one of two mHealth conditions, and asked participants to complete an eligibility screening questionnaire online. Prior to answering screening questions, participants were asked to indicate their consent to the screening survey and subsequent contact with a study RA if they were eligible. All eligible participants then met with a study

RA individually via videoconferencing to confirm their interest and eligibility, including showing their national identification as proof of age. Both verbal and written consent were obtained from participants. For participants who indicated suicidal risk (e.g., ideation), an RA who is also a licensed counselor provided further screening to determine if suicide risk was imminent and provided relevant resources (e.g., local therapists) for those excluded from the study. Following confirmed eligibility, participants completed an internet-based baseline assessment via SoJump, a widely used survey tool in China.

Experimental design.—Upon completing the baseline assessment, participants were randomized to either a mindfulness-based mHealth condition or a social support-based mHealth condition. Both conditions were matched in duration and session length. A priori randomization sequence was generated (via the RANDBETWEEN function in Excel), and both the RA and participants were blinded to condition until the allocation was revealed.

Mindfulness-based mHealth intervention.—A 4-week intervention, “Mindfulness for Growth and Resilience,” was developed for this study. It was adapted from established evidence-based MBIs, including Mindfulness-based Stress Reduction and Mindfulness-based Cognitive Therapy. The intervention was tailored for our target population (university students), the context (distress during the COVID-19 pandemic), and platform (app-based delivery). Prior to the RCT, we conducted a focus group with Chinese university students who met the study criteria ($n = 14$) to inform rapid intervention development and adaptation, as gathering input from target populations can enhance interventions’ relevance and responsiveness (Nastasi et al., 2007). Specifically, we inquired students in the focus group regarding challenges related to mental health in the pandemic context and asked them to try three brief mindfulness exercises (5–10 minutes), including focused attention, body scan, and loving-kindness meditation. Students were then asked about their experiences with these exercises and how such exercises might assist in coping with their distress. Further, a brief video example was provided to gather participants’ feedback. Thematic analysis of the focus group revealed three themes: (a) common experiences of psychological distress, including excessive worries related to health and school, severed belonging and loneliness, and sadness; (b) experiencing mindfulness exercises as grounding, clarifying, and beneficial; and (c) preference for a brief intervention duration (brief, 2–4 weeks), short instructional videos (~ 3 minutes), and delivery via widely used existing platforms (e.g., WeChat).

The first author, who is a licensed psychologist and an MBSR teacher, developed the intervention content. A course outline was shared with experts in mindfulness and university students’ mental health for further feedback. We employed multiple widely used platforms to deliver the intervention. First, videoconferencing via Zoom was used to provide weekly one-hour meetings for experiential and group learning of mindfulness. Second, a WeChat-based mini-program was developed for (a) didactic learning regarding mindfulness and (b) audio-based daily practice. As a ubiquitous communication tool, WeChat offers the potential for scalability (e.g., over 1.2 billion monthly active users), multiple interactive features, and capacity for rapid, affordable development of mini-programs embedded within the app (Luan et al., 2020). Specifically, our mini-program included a total of 20 videos (~ 3 minutes each, ~ 5 videos per week), which participants could review in a designated order (i.e.,

reviewing the first video unlocks the next video), followed by session-specific questions to which participants could provide a text response. Further, the mini-program included audio recordings for mindfulness practice (~ 2 per week, which varied from 5 to 40 minutes each), followed by the option of journaling about one's experience of the practice. Four study RAs with experiences in mindfulness received further training from the first author and provide individually tailored responses to participants who submitted questions or difficulties arose in their daily practice journaling. Figure 2 provides snapshots of the mini-program. Supplemental Materials Table S1 also provides detailed information on content of each week's videos, audios, and examples of tailoring to the experience of psychological distress among university students in the pandemic context (e.g., discussing the impact of and normalizing pandemic-related stress, promoting self-knowledge on how to cope with pandemic-related stress). Third, a messaging-based group via WeChat that allows for text, picture, and audio-based messages, was used for asynchronous group communication and discussion (e.g., sharing of practice experiences, group-based practice feedback).

Week 1 provided participants an orientation to the program, including an understanding of what mindfulness is, the potential benefits of mindfulness in addressing common psychological symptoms in the COVID-19 pandemic context, and brief mindfulness exercises including focused attention and mindful walking (audio recordings of these two practices were also provided). Week 2 further emphasized awareness on bodily experience, including noticing physical sensations throughout the day and its connection with emotional states, encouraging awareness of various mental states (e.g., "being vs. doing"), and practicing the body scan and mindful eating (audio recordings of these two exercises were also provided). Informal homework of "pleasant event calendar" (derived from MBSR & MBCT) was provided: participants were asked to notice their bodily sensations, thoughts, emotions, and impulses during a pleasant event in their day. Week 3 focused on habitual patterns of the mind, reviewed the concept of experiential avoidance, with practices focused on awareness of thoughts and working with difficult emotions through recognition and acceptance (audio recordings of these two exercises were also provided). An informal homework of "unpleasant event calendar" was provided and participants were encouraged to notice and record their bodily sensations, thoughts, emotions, and impulses during an unpleasant event in their day. Week 4 focused on understanding self-care, reviewed skills that participants developed during the program, and encouraged ongoing application to future challenges in the emerging infectious disease context and various difficulties in participants' lives. The first author, a PhD-level psychologist who has experience working with psychiatric populations and teaching mindfulness, delivered the intervention, including didactic videos, audio recordings, and weekly videoconferencing.

Social support-based mHealth.—We chose to use a rigorous, active, time- and attention-matched comparison condition to maximize comparability, as well as for ethical considerations regarding the unprecedented psychological health consequences of the emerging pandemic and the need for intervention. A social support-based condition was employed based on research on psychological health during the COVID-19 pandemic and our focus group findings highlighting high loneliness and the protective value of social support (Lisitsa et al., 2020; Sun et al., 2021). Similar to the mindfulness-based

mHealth intervention, the social support mHealth condition was delivered via Zoom and WeChat. Participants met via Zoom for four weekly, hour-long sessions aimed at discussing shared experiences and promoting peer support. As the number of participants was higher than a typical support group, participants were randomly divided into groups of 4–5 individuals for further, more focused peer support via videoconferencing when small group activities occurred (e.g., discussion). WeChat-based groups were also used to provide ongoing support and peer interaction outside of the weekly sessions. Session 1 focused on establishing ground rules; introductions; understanding how to best seek, provide, and receive interpersonal support; and sharing one’s current experiences related to the pandemic. Session 2–4 discussed topics and experiences identified by participants as a useful focus of each session, such as family relations, isolation, school-related stress, and coping strategies. An RA, who is a licensed counselor in China and has extensive experience leading psychotherapy groups, delivered the social support mHealth intervention. Supplemental Materials Table S2 provides a summary of how both intervention conditions utilized various platforms and functions.

Measures

At baseline, participants provided demographic information. Primary and secondary outcomes and potential mediator were assessed at baseline (prior to randomization), immediate post-intervention (1 month), and at follow-up (2-month post-baseline). Feasibility and acceptability assessment took place at post-intervention only.

Primary Outcomes.—*Generalized Anxiety Disorder-7* (GAD-7; Chinese version) was used to assess anxiety symptoms (Spitzer et al., 2006; Zeng et al., 2013). The GAD-7 is a widely used measurement for common anxiety disorders (Generalized Anxiety Disorder, Social Phobia, and Panic Disorder). The scale has shown good reliability and validity among Chinese people in outpatient settings (Zeng et al., 2013). Participants rated their symptoms of anxiety in the past week on a 4-point Likert scale, from 0 (*not at all*) to 3 (*nearly every day*). Sample items include “feeling afraid, as if something awful might happen” and “not being able to stop or control worrying”. Recommended clinical cut-off values are 5–9 (mild), 10–14 (moderate), and 15 (severe) (Spitzer et al., 2006). Higher scores indicate more severe anxiety symptoms. Cronbach’s α in this study were .88, .92, and .93 at baseline, post-intervention, and follow-up, respectively.

Patient Health Questionnaire-9 (PHQ-9; Chinese version) measured depressive symptoms (Kroenke et al., 2001; W. Wang et al., 2014). Each item reflects one of the nine DSM-IV criteria for major depressive episode (e.g., “feeling down, depressed, or hopeless”) (American Psychiatric Association, 1994). PHQ-9 is widely used in clinical and university settings in China and has demonstrated good reliability and validity (Du et al., 2017; W. Wang et al., 2014). Participants rated on each item regarding their experience in the past week on a 4-point Likert scale from 0 (*not at all*) to 3 (*nearly every day*). Recommended clinical cut-off values are 5–9 (mild), 10–14 (moderate), 15–19 (moderately severe), and 20 (severe) (Kroenke et al., 2001), with higher scores indicating more severe symptoms. Cronbach’s α were .75, .88, and .87 at baseline, post-intervention, and follow-up, respectively.

Secondary Outcomes.—*Mindful Attention Awareness Scale* (MAAS; Chinese version) measured participants' level of dispositional mindfulness, defined in this scale as receptive awareness and attention to their experience in the present moment (Brown & Ryan, 2003; Deng et al., 2012). The MAAS has demonstrated good reliability and validity among Chinese young adults (Deng et al., 2012). Participants indicated the frequency of their experience on a 6-point Likert scale from 1 (*almost always*) to 6 (*almost never*). Sample items include "It seems I am 'running on automatic,' without much awareness of what I'm doing" and "I find myself preoccupied with the future or the past." Higher scores indicate higher levels of mindfulness. Cronbach's α were .85, .89, and .92 at baseline, post-intervention, and follow-up, respectively.

The Multidimensional Scale of Perceived Social Support (MSPSS; Chinese version), which has shown good reliability and validity among Chinese young adults (Chou, 2000), was adapted to measure perceived social support among participants (Zimet et al., 1988). The original scale measured three sources of support including family, friends, and significant other. As not all young adults are in a romantic relationship, eight items from the scale assessing perceived social support from family and friends were used (e.g., "my family really tries to help me"). Participants rated each item on a 5-point Likert scale from 1 (*strongly disagree*) to 5 (*strongly agree*). Higher scores indicate higher perceived social support. Cronbach's α were .84, .84, & .89 at baseline, post-intervention, and follow-up, respectively.

Potential Mediator.

Emotional Suppression.: The Emotional Suppression subscale on Emotion Regulation Questionnaire (Chinese version) was used to assess suppression of emotions as a culturally-relevant emotion regulation strategy (L. Wang et al., 2007). The scale has demonstrated good reliability and validity among Chinese young adults (L. Wang et al., 2007; Zhang & Bian, 2020). Participants rated on a 7-point Likert scale from 1 (*strongly disagree*) to 7 (*strongly agree*). Sample items include "When I dislike someone or something, I often suppress my feelings and not show it." Higher scores indicate higher levels of emotional suppression. Cronbach's α at baseline and post-intervention were .85 and .93.

Feasibility and Acceptability.—*Feasibility* was indicated by attendance to videoconferencing sessions and retention rates assessed in both conditions.

Acceptability was indicated by evaluation of four domains assessed via structured surveys and open-ended questions. First, an 8-item questionnaire adapted from the Session Evaluation Form (Harper et al., 2003) assessed participants' **overall experience of the intervention**, such as "I can apply what I learned in this program to my life," "The topics of this program are relevant to me," and "I would recommend this program to others." Participants rated each item from 1 (*strongly disagree*) to 4 (*strongly agree*). Cronbach's alpha for this scale was .92. Second, a structured, self-developed survey inquired about participants' perceived **skills improvement** garnered through the program on domains relevant to both conditions (e.g., better coping, improved emotion regulation, self-care). Participants rated each statement from 1 (*strongly disagree*) to 10 (*strongly*

agree). Cronbach's alpha for this scale was .95. Third, participants rated on a single-item regarding the perceived *overall degree of benefit* of the program they received. Lastly, a single item assessed potential *adverse effects*. Participants in both conditions indicated whether the intervention they received had caused any negative, adverse impact for them (yes/no). If answered yes, participants were asked to describe in detail, as much as they can, such adverse effects.

Analytic Plan

We first used independent t-tests and χ^2 tests to determine whether there were significant demographic differences between the mindfulness mHealth and social support mHealth conditions at baseline. As there were no significant demographic differences between conditions, no covariates were controlled for in efficacy analysis. To investigate intervention efficacy, we utilized an intent-to-treat analysis, including all randomized participants ($n = 114$). Regarding the primary aim, we employed linear mixed modeling with maximum likelihood estimation in the 'lme4' package in R which is robust to data that are missing at random (Snijders & Bosker, 2012). We assessed intervention condition, time, and condition X time interaction effects for all outcome variables (i.e., measures of anxiety, depression, mindfulness, and perceived social support). Consistent with guidelines for adjusting for multiple comparisons in RCTs with multiple primary outcomes (Vickerstaff et al., 2019), false discovery rate (FDR) correction, using the Benjamini-Hochberg procedure of p -value correction, was applied for primary outcomes (anxiety and depression). In addition, we calculated the effect sizes of each outcome, using Cohen's d , to quantify the between-group difference from baseline to follow-up and the relative efficacy of mindfulness mHealth versus social support mHealth (i.e., Becker's d , 1988). Cohen's d and Becker's d can both be interpreted according to Cohen's (1988) conventions as small (0.20), medium (0.50), and large (0.80). As an exploratory pilot, the study was likely underpowered to detect between-group differences: power analysis in R ('pwr' package) suggests that with 57 participants in each arm, the study had 80% power to detect a medium or larger between-group effect size ($d = .53$). We captured clinical significance of change by the proportion of participants endorsing clinically significant symptoms from baseline to follow-up in both conditions.

Second, we examined emotional suppression as a mechanism of change whose impact may differ across intervention and control conditions by the MacArthur approach (Kraemer et al., 2008), which modified the Baron & Kenny criteria by providing more clarity and is considered as more suitable for intervention research (Agler & De Boeck, 2017). Specifically, to establish mediation: (1) T (treatment condition; i.e., mindfulness vs. social support) must precede M (mediator; i.e., change in emotion suppression during intervention), (2) there is an association between T and M, and (3) there must be either a *main effect* of M or an *interaction* between T and M in predicting O (outcome; i.e., improvement in psychiatric symptoms). As recommended (Kraemer et al., 2008), all continuous variables were mean-centered.

Third, we reported descriptive statistics of feasibility and acceptability measures (e.g., *Mean*, *SD*) and examined between-group differences using independent *t*-tests and χ^2 test for continuous and categorical variables, respectively.

Results

Primary Mental Health Outcomes

Condition comparisons.—Using multi-level modeling, intent-to-treat analysis (Table 1, Figure 3), we found that both groups improved over time on primary outcomes ($p < .001$). Both groups reduced anxiety symptoms from baseline to follow-up ($d_s = 1.40$ and 0.68 for mindfulness and social support, respectively), with the mindfulness mHealth yielded greater improvement, condition X time $B = -1.08$, 95% $CI = [-2.01, -0.15]$, $p = .024$ ($p = .048$ after FDR correction), between-group $d = 0.72$. Both conditions had large reductions in depression ($d_s = 1.46$ and 1.10 , for mindfulness and social support, respectively), and magnitude of depressive symptoms reduction over time did not differ significantly by condition (between-group $d = 0.36$).

Clinical significance.—To understand clinical significance, we calculated the reduction in the proportion of participants, from baseline to follow-up assessment, meeting or exceeding clinical significance of anxiety and depression (at least moderate symptoms, indicating presence of symptoms indicative of clinical diagnosis and continued need for intervention) (Manea et al., 2012). In terms of anxiety, stronger reduction was found in the mindfulness mHealth condition from baseline to follow-up (proportion reduced from 63.2% to 9.6%), which was superior to the social support mHealth condition (57.9% to 27.7%), $p = .020$. Reduction of depressive symptoms in mindfulness mHealth from baseline to follow-up (73.7% to 17.3%) compared to the social support mHealth condition (71.9% to 34.0%) was not statistically significant, $p = .056$.

Secondary Outcomes

Both conditions improved in secondary outcomes over time (time effect $p < .01$). The mindfulness mHealth condition had a large effect size from baseline to follow-up in improving mindfulness ($d = 1.17$), and compared to control condition ($d = 0.67$), its relative efficacy was medium in size ($d = 0.50$). Both conditions had small effect sizes in enhancing perceived social support ($d_s < .40$), and the relative efficacy of mindfulness mHealth condition in improving social support was small and negative ($d = -0.23$). Condition X time in secondary outcomes were not significant, though there was a trend of improvement on mindfulness in the mindfulness mHealth condition (compared to social support condition), $B = 1.97$ $[-0.11, 4.06]$, $p = .065$, whereas there was a trend of improvement in perceived social support in the social support mHealth condition (compared to mindfulness condition), $B = -0.76$ $[-1.61, 0.98]$, $p = .084$ (see Table 1, Figure 3).

Exploratory Analysis: Emotional Suppression as a Potential Mechanism of Change

Table 2 provides a summary of mediation analysis (also see Supplemental Material Figure S1 for an illustration of models). As shown, there was no between-group difference in change of emotional suppression during the course of the intervention, $p = .091$. Thus,

emotional suppression did not meet the criteria as a mediator (Kraemer et al., 2008). However, there was a significant emotion suppression reduction (from baseline to post-intervention) X condition effect in the reduction of both anxiety ($b = 0.44 [0.05, 0.84]$, $p = .029$) and depressive ($b = 0.54 [0.13, 0.94]$, $p = .010$) symptoms from baseline to follow-up. Specifically, reduction in emotional suppression during the course of the intervention (baseline to post-intervention) was linked to reduction of both depression and anxiety symptoms from baseline to follow-up in the mindfulness condition, whereas an opposite direction was found in the social support control (see Figure 4).

Evaluation of Feasibility and Acceptability

Intervention Feasibility.—Engagement and attrition were examined as indicators of intervention feasibility. Compared to the social support mHealth condition (average attendance $M = 2.39$, $SD = 1.16$), participants in the mindfulness mHealth condition had significantly higher attendance in weekly videoconferencing sessions (average attendance $M = 3.39$, $SD = 1.10$), $F = 24.00$, $p < .001$. Retention did not differ from baseline to post-intervention (91.2% for both conditions) and follow-up (91.2% vs. 82.5% in mindfulness and social support conditions, $p = .166$).

Intervention Acceptability.—Table 3 presents descriptive and comparative outcomes of four domains of intervention acceptability for both conditions. The mindfulness mHealth condition outperformed social support mHealth control in their overall experience of the program ($p < .001$, between-group $d = 1.05$) and skills improvement ($p < .001$, between-group $d = 0.95$). Participants in the mHealth condition rated the program as significantly more beneficial than their peers in the social support, $p < .001$, $d = 1.13$. There was no group difference in the report of adverse effect (3.9% in mindfulness vs. 8.7% in social support control). Those indicating adverse effect were asked to explain what these negative impacts of the program are for them. Two participants in the mindfulness condition (3.9%) noted adverse effect responded that “I learned to better regulate my emotions”, and “Everything needs to be balanced,” indicating potential misunderstanding of the question. Four participants in the social support control (8.7%) who noted adverse effect responded that “I don’t feel well-responded when I disclosed myself,” “Listening to others’ stress and negative emotions gave me more stress,” “Because I already have friends that I can discuss difficulties with, the activities in our social support group did not feel that helpful to me. In addition, it took me time to complete these questionnaires,” and “Recognizing individual differences in our experiences made me more stressed and anxious”.

Discussion

In this randomized controlled trial, we examined the relative efficacy, mechanism, and feasibility and acceptability of a mindfulness-based mHealth intervention to reduce anxiety and depression among young adults in quarantine compared to a social support mHealth control. Both groups showed overall reductions in anxiety and depression and increased mindfulness and social support. A few potentially meaningful between-group differences emerged. Participants randomized to the mindfulness mHealth condition showed significantly greater reduction in anxiety. Anxiety symptoms in the mindfulness

mHealth condition also showed a clinically significant improvement using established clinical cutoffs. Reduction in emotional suppression was associated with symptoms improvement in the mindfulness condition while the opposite was true for the social support condition. Participants showed greater engagement to the mindfulness mHealth and reported significantly higher ratings across most acceptability indicators. As a relatively brief psychological intervention, the mindfulness-based mHealth program represents a promising and scalable public health approach to reduce the highly prevalent experience of psychological distress among young adults in quarantine during the COVID-19 pandemic.

Several strengths of the mindfulness mHealth intervention and this randomized controlled trial are worth noting. First, the intervention was based on other established evidence-based MBIs yet was also novel, insofar as it was tailored to the context of pandemic-related stress among young adults. Qualitative formative data was gathered to ensure the adapted intervention content was grounded in the experiences of young adults and capture their unique challenges during quarantine. Second, instead of creating a new smartphone app, we responded to the urgent nature of the public health crisis by employing multiple existing platforms (Zoom, WeChat) and their built-in functions, including developing a mini-program embedded in WeChat, a widely used social media app. This significantly reduced time for platform and program development and may have facilitated engagement and retention due to participants' familiarity with these platforms. Third, we used an active control for a more rigorous understanding of relative efficacy, feasibility and acceptability of the mindfulness intervention as well as due to ethical considerations concerning a distressed sample and the unprecedented nature of the pandemic.

While the mindfulness mHealth intervention improved anxiety, its effect on depression was not superior to the social support condition. As the effect sizes were in expected directions, the lack of stronger statistical between-group difference could be due to a lack of power. In addition, although mindfulness is considered as a transdiagnostic approach to reduce a broad spectrum of symptoms, its differential effect on anxiety and depressive symptoms in this trial might be explained by the study population, mHealth delivery format, the pandemic context, and previous research findings of MBIs in comparison to other active controls. Overall, meta-analytic evidence suggests that the effects of web-based psychological interventions for university students (including a majority of cognitive behavioral therapy trials) were not superior to active controls in reducing anxiety or depressive symptoms (Davies et al., 2014). Specific to mindfulness, our findings are consistent with a recent meta-analysis of 51 mindfulness RCTs for university students which found that compared to active controls, MBIs significantly improved anxiety, but not depression, mindfulness, or emotion regulation (Dawson et al., 2020). Mindfulness-based mHealth trials are relatively new in development compared to web-based mindfulness programs, and interestingly, meta-analysis on web-based mindfulness RCTs yielded similar findings: these programs were effective in reducing anxiety but not in depression in clinical populations (Sevilla-Llewellyn-Jones et al., 2018). Specific to this trial, it is worth noting that the baseline to follow-up effect sizes for anxiety ($d = 1.40$) and depression ($d = 1.46$) were both similarly large in magnitude in the mindfulness mHealth intervention, yet social support mHealth control had a considerably lower effect on anxiety ($d = 0.68$) compared to depression ($d = 1.10$). It is possible that the emphasis on interpersonal connection in the social support mHealth

condition was effective in reducing depressive symptoms for young adults in quarantine via reduced loneliness, while treatment for anxiety in this population might benefit from a more skills-focused approach.

In accordance to the guidelines on criteria, findings, and interpretations of the MacArthur approach to treatment mechanism analysis (Kraemer et al., 2008), intervention condition had a *moderating* effect on the role of emotional suppression on treatment outcome. Successful regulation of emotions is considered to be crucial for adjustment and psychological well-being. According to Gross's process model of emotion regulation, suppression is involved in the second part of emotion regulation in response modulation, following reappraisal (Gross, 2002). In Western psychology, emotional suppression is often viewed as unhealthy. A meta-analysis found emotional suppression to be strongly associated with psychopathology including depression and anxiety ($r = .34$, aggregated from 51 studies) (Aldao et al., 2010). However, country-level evidence consistently shows that suppression is a widely used emotional regulation strategy in cultures where social order and group harmony are strongly valued, such as in East Asia (Matsumoto et al., 2008; Wei et al., 2013). Indeed, meta-analysis found that suppression was associated with mental health issues in Western samples but not in East Asian samples (Hu et al., 2014). Similarly, in our sample's baseline data, post-hoc analysis suggests that emotional suppression was not associated with anxiety or depression ($r_s = -.09$ and $.13$, respectively, $p_s > .10$). Thus, it is likely that for some young adults, suppression might be a helpful and culturally-relevant coping strategy, while for others it represents an unhealthy form of avoidant coping. However, reduction in emotional suppression during the intervention had opposite roles in symptom improvement in the mindfulness and social support conditions, suggesting differing mechanisms of change. As teachings of mindfulness emphasize observing and accepting one's emotional experience without trying to control or change them, it might offer a potentially different strategy to cope with emotions for those habitually suppress their emotional experience. In the social support condition, however, suppression might represent a sense of self-control and for some, increased emotional suppression could be part of the cost for interpersonal connection and group cohesion.

The mindfulness mHealth intervention outperformed the social support mHealth control in various aspects of feasibility and acceptability. For a brief mHealth intervention with no monetary compensation, the rates of retention in both conditions are exceptional (91% and 82% at 8-week follow-up, for mindfulness and social support, respectively), compared to meta-analytic finding of 75.9% retention in mHealth RCTs overall at short-term follow-up (8 weeks), including even lower retention (56.6%) for trials where enrollment took place entirely online (Linardon & Fuller-Tyszkiewicz, 2020). Success in retention in this trial might be due to a variety of factors, including the use of widely popular platforms embedded in young adults' daily life, the group component via WeChat and weekly Zoom meetings in both conditions, and a brief Zoom-based screening (5–15 minutes) prior to enrollment to confirm age, interest, and oral consent. Participants in the mindfulness condition showed higher engagement in weekly videoconferencing¹. Regarding acceptability, it is worth

¹Post-hoc sensitivity analysis revealed that Zoom session attendance as an engagement factor was not a significant covariant ($p_s > .10$) in linear mixed-effects models on primary outcomes (anxiety and depression).

noting that there was no group difference in item, “I felt supported and cared for during the program”, suggesting that participants in both conditions received similar levels of attention and care as intended. However, those in the mindfulness mHealth condition reported better experiences in all other ratings regarding their experience of the program, improvement of skills, and overall benefit of the program, providing support for the relevance and potential utility of mindfulness-based skills via a tailored mindfulness mHealth program for young adults to cope with psychological distress during quarantine. There was no significant group difference in reported adverse effects, though the proportion was numerically higher in the social support condition (8.7% vs. 3.9%). Qualitative data of these adverse effect suggests that interpersonal disclosure in the social support condition (by self and others) may have led to some stress and discomfort for some participants.

Limitations and Directions for Future Research

Study findings should be interpreted in light of several design limitations. First, although participants completed assessment via the internet and thus blinded from interviewer bias, measures were subject to bias related to self-report (e.g., social desirability) and limited to the brief and non-diagnostic nature of the mental health scales. Future research should use more comprehensive mental health assessments, ideally including diagnostic assessment by a clinician. Second, with the preliminary support of efficacy from this pilot, future trials should aim for a larger sample size and include longer follow-up periods (e.g., 6 months or longer). This would enhance statistical power as well as our understanding of the effectiveness of the intervention in preventing relapse of psychiatric symptoms and effect on other more distal health and educational outcomes. Another methodological limitation is that although a mixed model approach is the standard practice for intent-to-treat analysis in clinical trials (Chakraborty & Gu, 2009), we cannot be certain that data are missing at random. Thus, estimates of effect sizes could be biased by data missing not at random. Third, although using an active control was a design strength, consistently recommended by mindfulness researchers (Goldberg et al., 2021), and ethically important during the pandemic, the lack of passive control hinders our knowledge on the efficacy of both interventions in comparison to passage of time alone. A control condition using another evidence-based treatment such as cognitive behavioral therapy would also have provided information on the relative efficacy of the mindfulness program compared to another frontline treatment. Fourth, although our study demonstrated that change in emotional suppression is a relevant mechanism in distress symptoms reduction, we did not select participants who were necessarily experiencing comorbid emotion regulation difficulties in addition to anxiety/depression. It is possible that we may see a stronger effect of mindfulness on emotional suppression in these subsamples, such as individuals with persistent patterns of emotional avoidance. As emotion regulation strategies differ culturally, future clinical research with East Asian populations may want to further understand how interventions such as mindfulness may facilitate emotion regulation in a healthy and adaptive way congruent with people’s cultural values. Fifth, although viewed as not a major component of the social support intervention (i.e., the bulk of both interventions occurred in a single large group meeting), unmodeled nesting with smaller groups may have downwardly biased standard errors (Baldwin et al., 2005). As group assignment data was not retained following the study, we were unable to model this nesting. Sixth, although

the rapid intervention development and use of everyday platforms was a strength given its cost-effectiveness and responsiveness to the public health emergency, it also limited collection of complex user engagement data such as user log-in and practice time. Future research should consider collecting comprehensive data to further uncover what type of mHealth engagement may be most crucial for symptoms improvement. Finally, findings of the current study indicate potential benefits of an mHealth-based, tailored intervention approach to engage vulnerable populations and reduce the burden on mental health providers during a public health crisis in the LMIC context. However, this does not guarantee the uptake and effectiveness of both interventions in the real world. Future research employing implementation and dissemination science can advance our understanding of facilitative factors and barriers in the adoption and integration of such intervention approach in clinical practice (McHugh & Barlow, 2010).

Conclusions

A rising epidemic of mental health issues during the COVID-19 pandemic — including increased need for psychological services and limited staff resources and access to care — demand innovative, cost-effective, and scalable solutions to reduce the burden of psychological distress in the general public. Focused on Chinese young adults with elevated anxiety and/or depressive symptoms in quarantine, the current randomized controlled trial demonstrated the feasibility and acceptability of a tailored mindfulness mHealth program in comparison to a time- and attention- matched social support mHealth control, along with some indications of relative efficacy on anxiety. Mobile health may be a feasible approach to reach young adults with elevated psychiatric symptoms during the pandemic and coupled with a mindfulness approach, it may facilitate learning of effective coping skills in face of various psychosocial and educational challenges. Further, the mixture of self-learning, practice, and group component could significantly reduce the workload of providers. If implemented and disseminated successfully, this may represent a promising means to address the psychological fallout of the pandemic and ultimately move the population's "mental health bell curve" in the direction of well-being.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Public Significance Statement:

This study provides initial empirical support for a tailored, mHealth approach in the application of both mindfulness and social support-based interventions to mitigate psychological distress among young adults in the pandemic context. Successful implementation and dissemination of this or similar approaches have potential to improve access to psychological services, reduce provider burden, and enhance public mental health.

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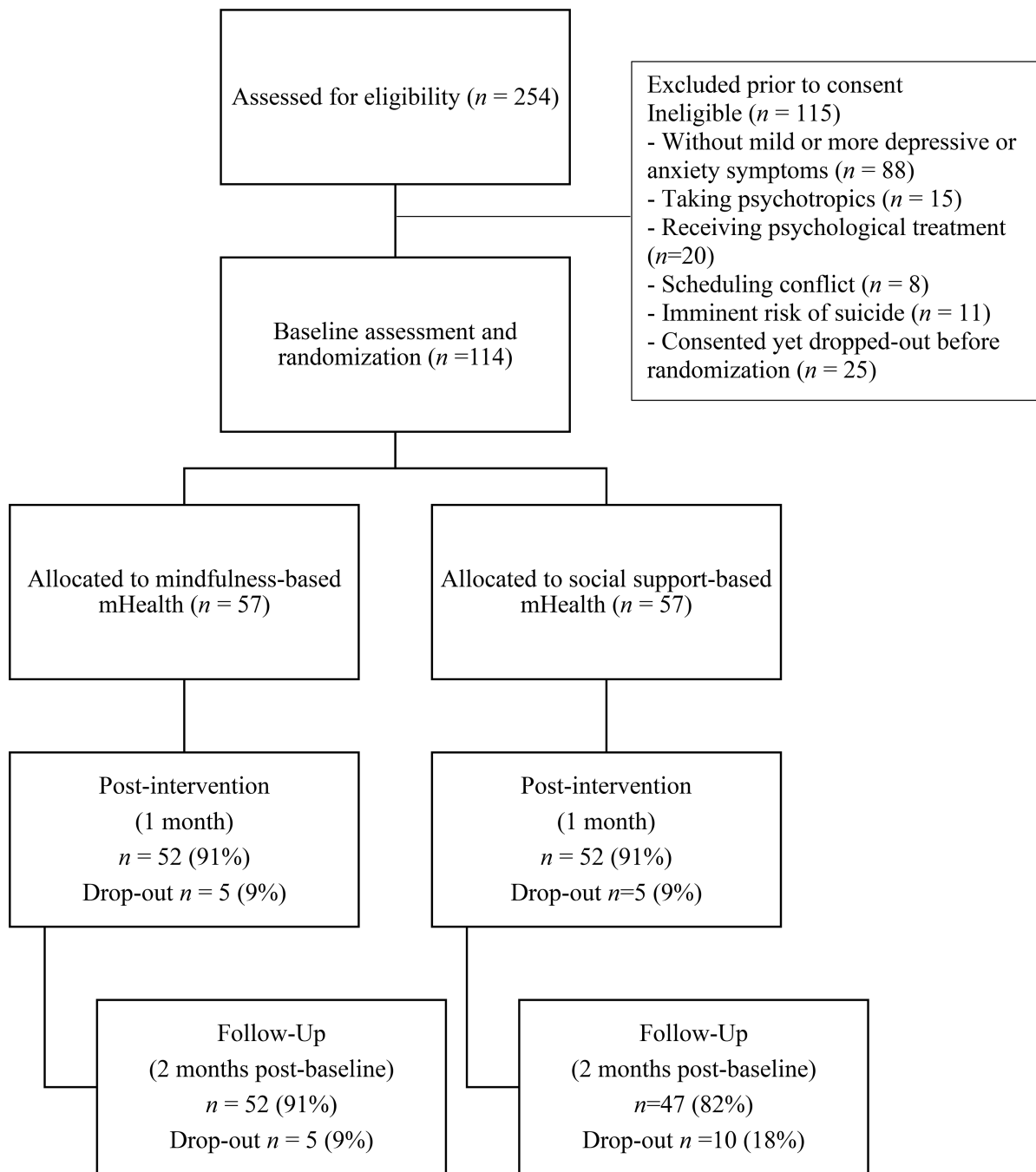


Figure 1.
Participant flow through study procedures

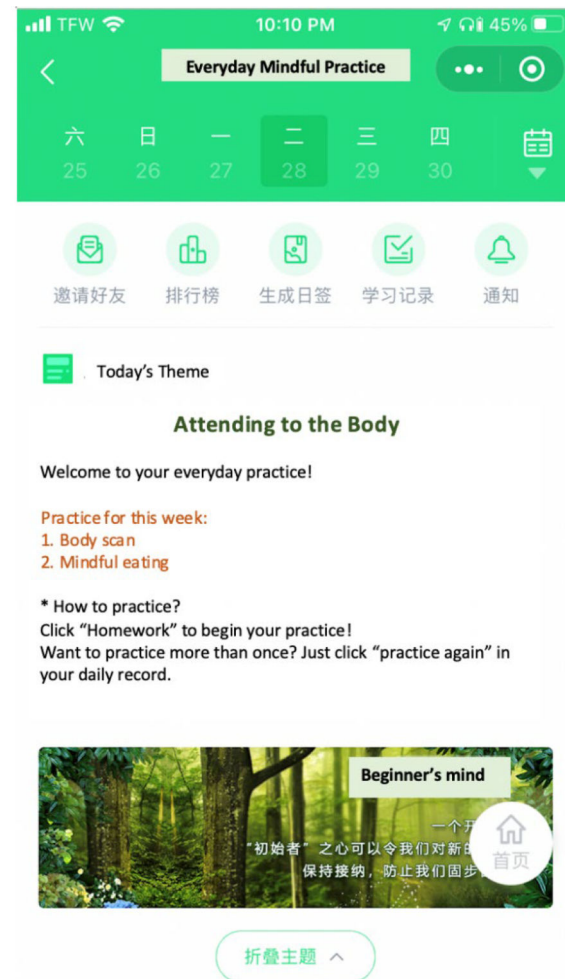
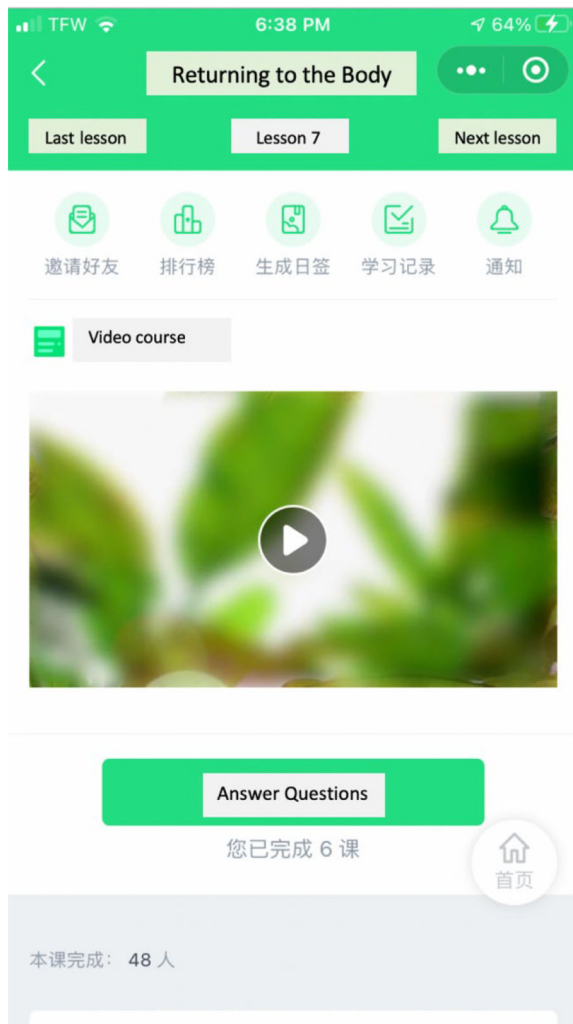


Figure 2.

Snapshots of the WeChat-based mini-program.

Note. Image on the left represents the interface for video-based didactic learning, and image on the right shows the interface for daily practice. Parts of the content are translated to English in this figure for ease of understanding.

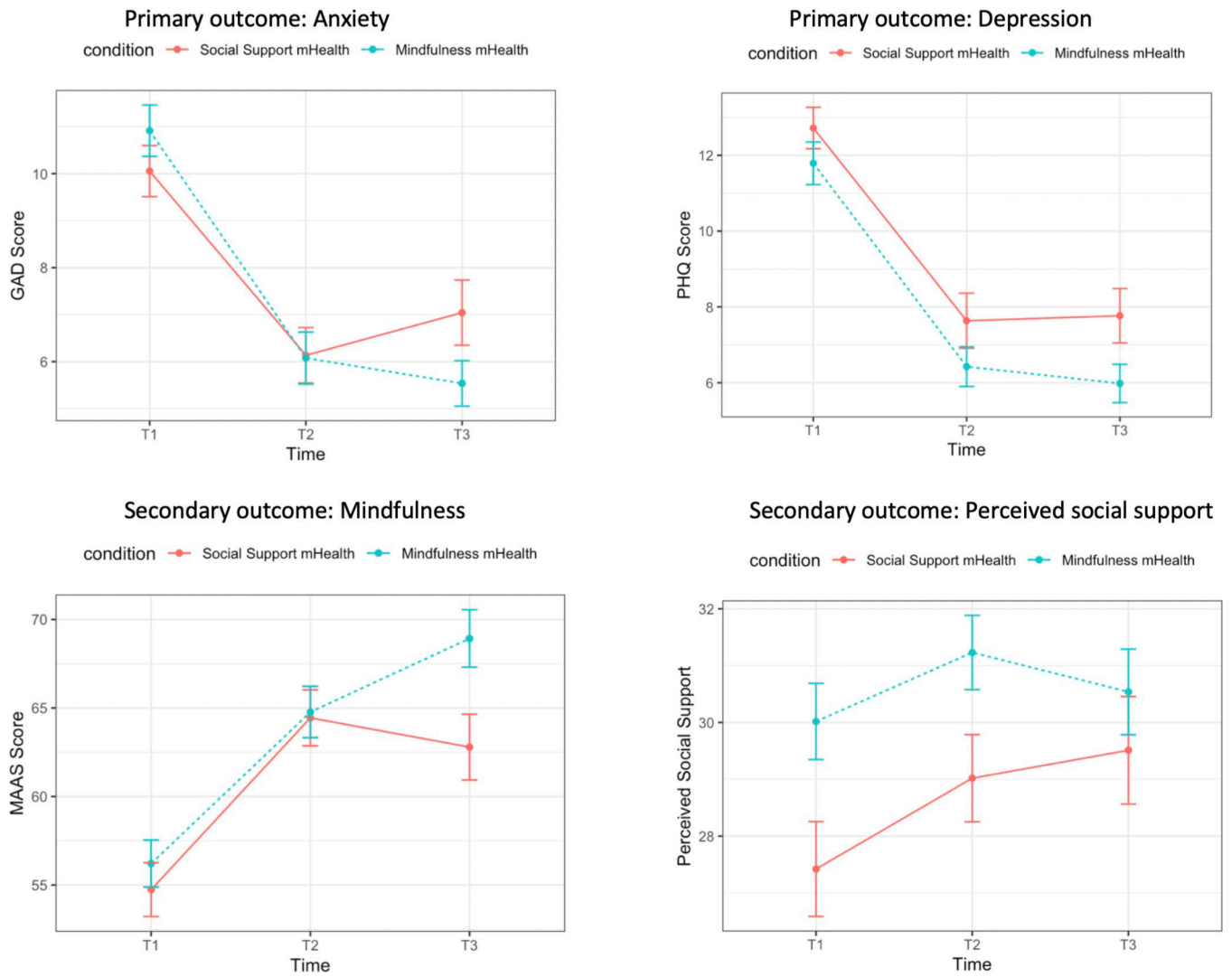


Figure 3. Trajectory of change for intervention and control conditions over time
Note. T1 = Baseline; T2 = Post-Intervention (1-month); T3= 2-month Follow-Up; Error bars indicate Mean ± 1 SE

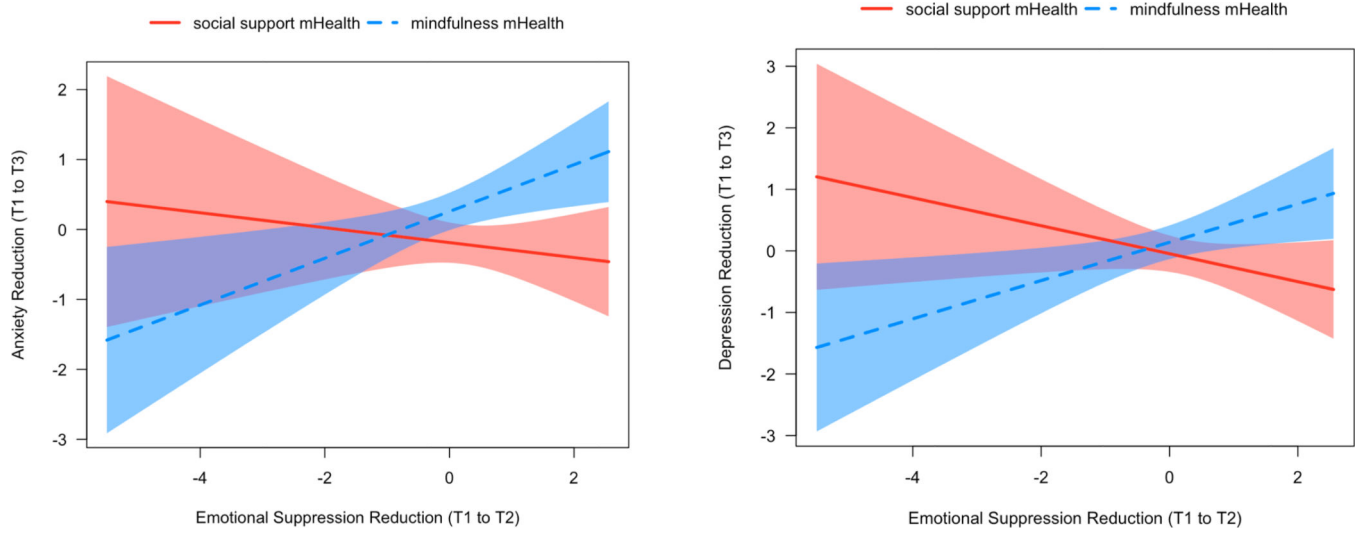


Figure 4. Interaction effect of emotional suppression reduction X condition in predicting symptom reduction (anxiety and depression)

Table 1.

Between-group effects on primary and secondary outcomes

Variable	Support		Mindfulness		Time			Condition X Time			Effect size (T1 to T3)		
	Mean	SD	Mean	SD	B	95%CI	p	B	95% CI	p	d ₁	d ₂	d _{2-d1}
Primary outcomes													
Anxiety					-1.59***	[-2.25, -0.92]	<.001	-1.08*	[-2.01, -0.15]	.024	0.68	1.40	0.72
T1	10.05	4.10	10.91	4.12									
T2	6.13	4.26	6.08	3.99									
T3	7.04	4.75	5.54	3.48									
Depression					-2.52***	[-3.17, -1.86]	<.001	-0.37	[-1.23, 0.54]	.430	1.10	1.46	0.36
T1	12.72	4.13	11.79	4.25									
T2	7.63	5.24	6.42	3.76									
T3	7.77	4.91	5.98	3.64									
Secondary outcomes													
Mindfulness					4.45***	[2.95, 5.94]	<.001	1.97	[-0.11, 4.06]	.065	0.67	1.17	0.50
T1	54.74	11.45	56.21	10.04									
T2	64.44	11.39	64.77	10.43									
T3	62.79	12.75	68.92	11.7									
Social support					0.97**	[0.35, 1.58]	.002	-0.76	[-1.61, 0.98]	.084	0.33	0.10	-0.23
T1	27.42	6.30	30.02	5.06									
T2	29.02	5.53	31.23	4.71									
T3	29.51	6.48	30.54	5.44									

Note. The main effect of condition was controlled in all models to account for potential baseline between-group differences. The effect of time represents improvement of symptoms regardless of intervention condition assignment. Condition X time represents differences in improvement of symptoms over time depending on intervention condition assignment. T1 = Baseline; T2 = Post-Intervention (1-month); T3= 2-month Follow-Up; CI = confidence interval; d₁= Cohen's d for social support mHealth condition; d₂= Cohen's d for mindfulness mHealth condition; d_{2-d1} = relative efficacy of mindfulness mHealth condition compared to social support mHealth condition

* p < .05

** p < .01

*** p < .001

Table 2.

Summary of mediation analysis

	<i>b</i>	95% <i>CI</i>	<i>SE</i>	<i>t</i>	<i>p</i>
Outcome: Anxiety Reduction (T1 to T3)					
Model 1. O (anxiety reduction) regressed on T (condition)					
Condition	0.44*	[0.04, 0.83]	0.19	2.20	.030
Model 2. M (ES reduction; T1 to T2) regressed on T (condition)					
Condition	-0.33	[-0.72, 0.05]	0.19	-1.71	.091
Model 3. O (anxiety improvement) regressed on T (condition), M (ES reduction; T1 to T2), and interaction TxM					
ES reduction	-0.11	[-0.42, 0.20]	0.16	-0.68	.497
Condition X ES reduction	0.44*	[0.05, 0.84]	0.20	2.21	.029
Outcome: Depression Reduction (T1 to T3)					
Model 1. O (depression reduction) regressed on T (condition)					
Condition	0.14	[-0.26, 0.54]	0.20	0.69	.491
Model 2. M (ES reduction; T1 to T2) regressed on T (condition)					
Condition	-0.33	[-0.72, 0.05]	0.19	-1.71	.091
Model 3. O (depression reduction) regressed on T (condition), M (ES reduction; T1 to T2), and interaction TxM					
ES reduction	-0.23	[-0.54, 0.09]	0.16	-1.42	.159
Condition X ES reduction	0.54*	[0.13, 0.94]	0.20	2.64	.010

Note. *CI* = Confidence Interval; T1 = Baseline; T2 = Post-Intervention (1-month); T3 = 2-month Follow-Up; ES = Emotional suppression; O = Outcome; T = Treatment; M = Mediator

* $p < .05$,

** $p < .01$

*** $p < .001$

Table 3.

Acceptability of mindfulness mHealth and social support mHealth conditions

	Social Support		Mindfulness		Comparison	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>t</i>	<i>p</i>
Domain 1: Overall Program Evaluation (item range = [1, 4])						
Total program evaluation (range = [8, 32])	22.8.9	4.21	27.29	3.37	-5.73***	<.001
<i>Evaluation by item</i>						
1. I learned a lot from this program.	2.67	0.70	3.42	0.57	-5.82***	<.001
2. I can apply what I learned from this program in my life.	2.74	0.74	3.38	0.53	-4.99***	<.001
3. I was able to do the activities.	2.93	0.71	3.35	0.48	-3.39**	.001
4. The program was well-organized.	2.98	0.58	3.48	0.50	-4.60***	<.001
5. The topics in the program were interesting.	2.63	0.61	3.42	0.50	-7.08***	<.001
6. The topics of the program were relevant to my life.	2.93	0.74	3.40	0.50	-3.72***	<.001
7. The program was enjoyable.	3.09	0.63	3.35	0.48	-2.31*	.023
8. I would recommend this program to others.	2.91	0.69	3.48	0.54	-4.54***	<.001
Domain 2: Improvement of skills (item range = [1, 10])						
Total skills improvement (range = [8, 80])	49.93	16.66	64.13	9.78	-5.21***	<.001
<i>Evaluation by item</i>						
1. I learned how to unwind my body and mind through the program.	5.76	2.21	8.38	1.36	-7.16***	<.001
2. My lifestyle behaviors have improved since participation of this program.	5.85	2.32	7.60	1.64	-4.35***	<.001
3. I have learned how to regulate my emotions through this program.	6.67	2.48	8.00	1.34	-3.35**	.001
4. I have become more accepting of myself through this program.	5.91	2.52	8.12	1.35	-5.48***	<.001
5. I have learned how to cope with stress through this program.	5.80	2.25	7.94	1.45	-5.66***	<.001
6. I have learned how to better care for myself through this program.	5.91	2.53	8.27	1.42	-5.78***	<.001
7. I can cope with difficulties better now.	6.33	2.29	7.52	1.55	-3.05**	.003
8. I felt supported and cared for during the program.	7.70	2.22	8.31	1.50	-1.61	.110
Domain 3: Overall Benefit (range = [1, 5])						
How beneficial do you think the program has been for you?	3.20	0.81	4.06	0.61	-6.02***	<.001

	Social Support			Mindfulness			Comparison		adj <i>p</i>
	<i>M</i>	<i>SD</i>	%	<i>M</i>	<i>SD</i>	%	<i>t</i>	<i>p</i>	
Domain 4: Adverse Effect (Yes/No)									
Has the program caused any negative impact in your life? (Yes)	4	8.70	2	3.85	0.99	.318			.318

Note. adj *p* = adjusted *p*-value for multiple testing after false discovery rate correction via the Benjamini-Hochberg method

* *p* < .05,

** *p* < .01

*** *p* < .001