

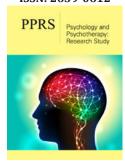


Digital Health and Mindfulness: Current Applications and Emerging Evidence

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Abstract

Digital health encompasses the use of digital, mobile and wireless technologies to support and enhance health-related objectives. The practice of mindfulness has become a relevant topic due to evidence of its effectiveness in treating many health conditions, especially mental health conditions, which has sparked interest among clients and psychotherapists regarding its clinical application. The main aim of this study was to review recent scientific reports on digital mindfulness applications. A search was conducted on PubMed using the advanced search function, with the terms "mindfulness" and "digital" in the title field and the full text was available. The search resulted in the identification of a diverse range of applications of digital mindfulness within different contexts and populations. Recent scientific evidence indicates that digital mental health interventions, particularly mindfulness-based approaches, show promising outcomes across diverse contexts and further research should be encouraged to deepen the understanding of their applications and benefits.

Keywords: Mindfulness; Online health; Mental health; Well-being; Neuroscience; Psychiatry; Psychology

Introduction

Digital health refers to the application of digital, mobile and wireless technologies to promote health-related goals [1]. Digital mental health interventions employ tools such as smartphone applications, virtual reality, wearable devices and generative artificial intelligence for their delivery [2]. These technologies can improve access to timely, evidence-based mental health care and help reduce health disparities [3].

It is estimated that about 6% to 7% of the global population experiences mental disorders. According to the World Health Organization (WHO) nearly 1 in 7 people in the world live with a mental disorder [4]. Following the COVID-19 pandemic, there was a significant worldwide increase in mental health issues. However, many individuals still face barriers to accessing mental health services, including financial constraints, geographic isolation, stigma and lack of information. The rise of online mental health services may help address some of these challenges, as they are more accessible regardless of location, cost-effective and can lessen the fear of judgment or labelling [5]. In most studies in the literature, the primary outcome measure focused on symptoms of depression. Additionally, reports mention studies that measured anxiety, stress, well-being, burnout, occupational/work-related stress and perceived stress. There are also publications focusing on resilience, sleep and mindfulness [6]. Considering the global growth of the digital health field, as well as the recent expansion in the fields of psychiatry and psychology, this study becomes relevant. The main aim was to conduct a literature review focused on the most recent scientific reports on applications of digital mindfulness. A search was conducted on PubMed using the advanced search function, with the terms "mindfulness" and "digital" in the title field and the full text was available. The search, limited to articles published in the last year and aligned with the central focus of this review, resulted in 17 articles, which formed the basis for achieving the objective of

this literature review. Of these, one was excluded because it was a retraction. However, it is important to mention that the 16 main foundational articles were not the only sources consulted; other supplementary sources were added for a better analysis.

Mindfulness: Concept and Foundations

Mindfulness is defined as a form of conscious and deliberate attention, in the present moment and without judgment. This definition has been widely accepted in the scientific community, although it can lead to multiple interpretations and therefore lacks sufficient clarity in the study of the neurophysiological basis of mindfulness practices. Training is a central element in mindfulnessbased programs. Repetition of structured exercises can improve basic functions such as attention, emotional regulation and decentration, which are associated with functional and structural variations in the nervous system [7]. Initially adapted from religious contexts by Buddhist, Hindu and Taoist traditions, meditation and mindfulness eventually broke free from these spiritual roots to become a very familiar component of contemporary mental health [8]. The incorporation of mindfulness into psychological science demanded the adaptation of its original definition, stemming from the Buddhist context. Thus, contemporary conceptualizations have moved away from Buddhist principles to better suit academic, skills training and psychotherapeutic fields [9]. In psychology, most definitions of mindfulness follow the proposal of Jon Kabat-Zinn [10], widely recognized as the main pioneer responsible for introducing mindfulness approaches into health and psychological science, which describes it as "the awareness that emerges from paying attention, intentionally, in the present moment and without judgment, to the unfolding of experience moment by moment" (p. 145). The practice of mindfulness enables individuals to cultivate a heightened presence in the moment, fostering greater sensitivity, flexibility and adaptability to their surroundings. It also promotes openness to new information, enhancing the ability to recognize and integrate diverse perspectives in problem-solving. This process is not merely a detached cognitive activity; rather, the development of new distinctions engages the individual as a whole, encompassing environmental awareness, a sense of presence and an expanded consciousness of multiple viewpoints [11].

Mindfulness and Neuroscience

There is evidence supporting the wide-ranging benefits of MBSR (Mindfulness-Based Stress Reduction) across neuroanatomical, psychological and social domains. Studies show that MBSR programs, including their shorter versions, can increase cortical thickness in regions such as the right insula and lead to positive psychological effects, including reductions in anxiety, depression and alexithymia. In addition, mindfulness meditation has a specific influence on pain reduction and enhanced emotional awareness, activating neural pathways different from those engaged by placebo treatments. It has also shown potential in aiding smoking cessation, particularly among women, by lowering brain reactivity to smoking-related cues [12]. While mindfulness does not consistently alter impulsivity, it appears to enhance social interactions by promoting

greater interbrain synchrony during communication [10,13-15]. Interventions like MBSR have demonstrated the capacity to produce neurobiological adaptations that can support neurorehabilitation. The increased cortical thickness observed, notably in the right insula and somatosensory regions, suggests improved sensory and interoceptive processing. Such effects may be particularly beneficial in neurorehabilitation contexts, as patients often experience sensory impairments or altered body consciousness, such as in stroke or traumatic brain injury [16,17].

This is especially significant given that the modulation of pain by mindfulness through mechanisms distinct from placebo underscores its potential in managing chronic pain conditions [12]. Furthermore, mindfulness has been shown to modulate both high and low daytime cortisol levels, indicating improved regulation of the hypothalamic-pituitary-adrenal axis [18]. Neuroimaging studies, such as that by Kral et al. [19], examined the effects of both short- and long-term mindfulness meditation training on the amygdala's response to emotional stimuli in a healthy, nonclinical adult population, using functional magnetic resonance imaging. The authors conclude that the affective response can be enhanced by meditation training through increased connectivity between the amygdala and the prefrontal cortex and reduced amygdala reactivity, as this has a beneficial effect on the ability to regulate emotions [20,21]. Consistent with these neuroimaging findings [21] summarized in their review that several magnetic resonance imaging studies have demonstrated structural brain changes associated with mindfulness training. For instance, 8-week mindfulness programs have been shown to increase hippocampal gray matter density in healthy individuals [22] and to reduce hippocampal atrophy in adults with mild cognitive impairment after training. Cross-sectional studies corroborate these results after mindfulness training, indicating a greater amount of gray matter in the hippocampus among long-term meditation practitioners compared to non-practitioners [23].

Digital Mindfulness-based Interventions (MBIs): Recent Research

Advances in technology have progressively increased the prominence of digital mental health services. The search resulted in the identification of a diverse range of applications of digital mindfulness within different contexts and populations. Compared to traditional face-to-face formats, smartphone apps and online platforms offer greater advantages in terms of accessibility, standardization, degree of personalization and effectiveness of mindfulness training. Furthermore, mindfulness practices based on digital technology have shown promising results [24]. A randomized controlled pilot study investigated the feasibility and preliminary effects of a self-administered digital MBI in 15 patients with COPD (Chronic Obstructive Pulmonary Disease) with elevated levels of anxiety and/or depression. Self-administered digital practice, including brief 10-15-minute meditations, has proven viable. The results indicate the feasibility of the intervention and its preliminary effects point to improvements in anxiety symptoms

and emotional functioning after 8 weeks, as well as reductions in momentary subjective stress, anxiety and dyspnoea immediately following daily mindfulness practice [25]. Accumulating evidence indicates that MBIs may represent a promising adjunctive approach for managing insomnia symptoms. In the study by Wang et al. [26], a single-blind randomized controlled trial conducted between October 2021 and February 2023, with 160 eligible pregnant participants demonstrated significant short-term improvements in prenatal insomnia. These effects occurred through reductions in sleep-related worry and presleep arousal, suggesting that MBIs may constitute a practical, accessible and early-stage intervention for pregnant individuals at elevated risk for insomnia.

A study systematically examined the impact of a digital mindfulness intervention on perceived stress and anxiety among university students through a randomized controlled trial. The clinical design involved 310 participants aged 18 to 22 years, who were randomly assigned to either an intervention or control group. Upon completion of the intervention, participants in the program group exhibited significantly reduced levels of perceived stress and anxiety [25]. Two separate nonrandomized pilot studies were conducted. In the first, 27 physicians received digital mindfulness training delivered via podcast, whereas in the second, 29 physicians and nurse practitioners accessed the same program through a free app-based platform. The primary outcome measure was cynicism, representing one dimension of burnout. Secondary outcomes included emotional exhaustion (the second burnout dimension), anxiety, depression, intolerance of uncertainty, empathy (assessed through personal distress, perspective taking and empathetic concern subscales), self-compassion and mindfulness (evaluated through nonreactivity and nonjudgment subscales). In the second study, additional variables, worry, sleep disturbances and emotion regulation difficulties, were also assessed. Outcome changes were measured through self-report questionnaires administered at baseline, post-intervention and at a 1-month follow-up. Mindfulness therapy led to a reduction in burnout syndrome, anxiety, intolerance to uncertainty and personal suffering, as well as promoting increased self-compassion and mindfulness, with effect sizes ranging from medium to large. Furthermore, the second study revealed additional worry, sleep disturbances and difficulties in emotional regulation [27].

According to Ross et al. [28], mindfulness-based treatment demonstrates substantial potential as a continuous care strategy to support multidimensional recovery from substance use disorder. The authors aimed to iteratively design and evaluate the feasibility and initial acceptability of Mindful Journey, an innovative digital mindfulness-based intervention intended to facilitate recovery in individuals with substance use disorder. Participants were encouraged, through app narrators and telephone instructors, to prioritize completing the 15 digital lessons, averaging approximately three lessons per week and to engage with supplementary resources as needed to apply mindfulness skills in real-time and formal practice settings. Upon post-trial evaluation, participants assigned mean ratings of 4 or higher ("agree") across all

dimensions of acceptability, including usability, comprehensibility, engagement level, visual appeal, overall usefulness, perceived skill acquisition and confidence in skill application. Collectively, the quantitative and qualitative findings from phases 1 and 2 demonstrated high acceptability of the intervention. However, the authors acknowledged that the small sample size (n=10) limited the generalizability of the results, underscoring the need for further research with larger participant cohorts.

Mangelsdorf et al. [29] have an interesting proposal: A digital, cognitive, social and mindfulness-based intervention for relapse prevention in young people with depression in Australia: a study protocol for a randomized clinical trial of Rebound. A moderated online social therapy platform (called Rebound) was developed, integrating:

- a) Peer social networks.
- b) Personalized third-wave therapeutic content, focusing on mindfulness, self-compassion and rumination.
- c) Three types of human support (clinicians, peers and career counsellors) grounded in self-determination theory. The clinical trial includes a 48-month recruitment period and an 18-month treatment phase, with completion expected in 5.5 years.

Positive psychology underscores the association between mindfulness and enhanced well-being, self-awareness and adaptive functioning, emphasizing its potential to mitigate maladaptive behaviours such as problematic smartphone use [30,31]. From this standpoint, mindfulness is conceptualized as a psychological resource that supports intentional behaviour and healthier patterns of technology engagement [32]. Self-regulation theory provides further insight into the mechanisms connecting mindfulness with problematic smartphone use. Mindfulness improves attentional control, emotional regulation and reflective awareness, essential components of self-regulated learning [33]. These processes allow students to plan, monitor and assess their actions more effectively, thereby reducing the propensity for compulsive smartphone use [34].

A cross-sectional study examined the association between dispositional mindfulness and smartphone addiction, while also testing the mediating role of digital life balance in 1,241 Chinese university students. Dispositional mindfulness showed a negative correlation with smartphone addiction and a positive correlation with digital life balance [35,36] contextualized mindfulness for endometriosis. MY-ENDO (Mind Your Endometriosis) is a mindfulness- and acceptance-based endometriosis self-management intervention designed to teach women with symptomatic endometriosis how to manage and reduce the negative physical, psychological and social consequences of the disease. This study aimed to involve women with endometriosis in the co-development process of a digital version of MY-ENDO to investigate their experiences and attitudes toward the intervention. 35 interviews were conducted with seven women who reported

having a diagnosis of endometriosis, based on a semi-structured interview guide. Each participant completed the first four sessions of the intervention and was interviewed before the first and after each of the four sessions (five times in total) during participation. The program appears to be a viable, acceptable and relevant intervention for women with symptomatic endometriosis. The study indicated that participants experienced several benefits upon completing the first four sessions, related to better management of difficult thoughts and emotions and a more positive pain experience. Participants considered it an advantage that the program was specifically targeted at endometriosis and was developed in conjunction with the patients. Researchers examined how older adults integrate mindfulness into their daily routines, investigated their design preferences for digital mindfulness tools and explored whether and how such interventions can enhance self-perceived well-being. The study involved 15 older adults in Sweden who used a voice-guided mindfulness application at home for three weeks. After the intervention, individual semi-structured interviews were conducted with all participants. Overall, participants acknowledged mindfulness training as beneficial for supporting mental health and reducing of stress. However, some participants reported negative experiences, including frustration and discomfort, indicating that experiences and preferences related to digital mindfulness among older adults are highly diverse and varied, emphasizing the need for personalized approaches to achieve effective engagement [37].

Also involving elderly individuals, another study is underway in China. It is a clinical trial, a protocol for a feasibility trial of digital mindfulness and cognitive-motor exercise for subclinical depression. Participants will undergo an 8-week intervention that combines mindfulness practices and cognitive-motor exercises [38]. Still within the context of mindfulness for the elderly, a study conducted in Germany employed Patient-Centred Design and Development (PCD) methods to translate the experiences of key stakeholders into the design of a hybrid, in-person and digital Intensive Mindfulness Intervention for health promotion in nursing homes, called silBERN. The PCD process incorporated multiple stakeholders, including members of the target group, their families, nurses, other nursing home professionals, health plan representatives and application developers. Although complex and demanding, this initial step proved valuable in guiding future research. The authors emphasized the need for a randomized controlled clinical trial to evaluate the usability and effectiveness of the silBERN intervention. They also highlighted the range of positive outcomes of mindfulness interventions, already proven in the literature, such as improvements in stress perception, awareness, self-reflection, self-acceptance, mood, relaxation, interpersonal connection, immune function and cognition, emphasizing the solid scientific basis and relevance of these new research initiatives [39,40] describe the application of the person-centred approach in the development of a digital MBI to reduce risk factors for eating disorders in young people. The findings demonstrate a rigorous and transparent approach to intervention development, integrating theory, evidence and user-centred design. It also presents new primary evidence addressing gaps in the literature on MBI

interventions, particularly with regard to older adolescents and the application of mindfulness to body image. The development of a logical model aided in the identification of proposed mediating variables and guided the selection of process measures for evaluation. This work offered a transferable model for researchers developing person-centred psychological interventions.

Sanjivini et al. [41] report that 30 to 40% of individuals with insomnia do not benefit from first-line treatments, making it important to consider viable alternatives. They are developing a protocol detailing a clinical trial to investigate the feasibility and effectiveness of a digital mindfulness intervention in improving sleep and well-being in 106 people aged 55 or older recruited for the trial, randomly allocated to a sleep hygiene program (n=53) or a mindfulness intervention program (n=53). Participants in both programs will participate in self-directed digital programs lasting 6 weeks. They will be assessed for sleep and well-being through self-report questionnaires. There will be a comparison after the intervention and at a 3-month follow-up to assess effectiveness.

In France, a clinical trial is underway to investigate the usability and acceptability of a mindfulness-based digital intervention designed to complement standard smoking cessation treatment and enhance its effects. All participants will receive a combination of transdermal and oral nicotine replacement therapy and will be introduced to a digital health app that offers a digital equivalent of an 8-week mindfulness training program. The acceptability of the initial version of the app will be assessed based on frequency of use and usability will be evaluated using the Mobile App Rating Scale. This is a pilot study to explore the usability and acceptability of the proposed app, making necessary adjustments to its content and functionality based on participant feedback. Following this, a large randomized controlled clinical trial will be conducted to evaluate the app's potential to improve the effects of standard treatment [42].

Conclusion

In general, the evidence analysed indicates that digital mindfulness-based interventions represent a promising approach for promoting mental health in different contexts and populations. These interventions broaden access, promote standardization and allow for greater personalization, maintaining or even surpassing the effectiveness observed in face-to-face formats. Several studies report significant benefits in reducing stress, anxiety, insomnia and symptoms associated with chronic conditions, as well as promoting improved emotional self-regulation and overall well-being. However, methodological limitations, such as small sample sizes and lack of long-term follow-up, still restrict the generalizability of the findings. Therefore, future investigations should prioritize more robust clinical trials and the improvement of user-centred approaches, ensuring the effectiveness, adherence and sustainability of these digital mental health care tools.

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