Internet-Based and Mobile-App-Based Mental Health Interventions among Adults: A Best Evidence Synthesis of Rigorous Randomized Controlled Trials

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Table of Contents

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Abstract

Compared to in-person mental health interventions, programs delivered through mobile applications or the internet might be more cost-effective, scalable, demand less training, and are more acceptable and accessible among populations. In the aftermath of the pandemic, the use of online mental health interventions has increased significantly. However, there is limited understanding of the conditions and populations for which these interventions are most effective. To address this gap, we conducted a meta-analysis to synthesize findings from existing randomized controlled trials and expand our knowledge on this topic. Research plans were pre-registered before analyzing the data. We conducted a meticulous search strategy including database queries, handsearching, forward and backward citation tracking and retrieved 8944 studies. After double blinded screening, 64 studies and 247 effect sizes (total sample sizes = 17,388) were eligible to be included in this systematic review and meta-analysis. Results showed that these online interventions were effective (ES = -0.80, $p < .001$) while holding all moderators fixed at their mean. Specifically, online interventions were effective at reducing anxiety, depression, stress, and psychological distress. However, studies on average showed no impacts on suicidal ideation. Moderator analysis showed that online interventions targeting anxiety outcomes are more effective than interventions targeting psychological distress; internet-based interventions are more effective than mobile-app-based interventions, although both modalities showed effectiveness. These findings provide valuable insights for policymakers and practitioners in developing cost-effective technology-based mental health interventions. While technology can be a double-edged tool, this review highlighted its benefits for improving adult well-being, particularly in the treatment of mental health symptoms.

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Abstract

Compared to in-person mental health interventions, programs delivered through mobile applications or the internet might be more cost-effective, scalable, demand less training, and are more acceptable and accessible among populations. In the aftermath of the pandemic, the use of online mental health interventions has increased significantly. However, there is limited understanding of the conditions and populations for which these interventions are most effective. To address this gap, we conducted a meta-analysis to synthesize findings from existing randomized controlled trials and expand our knowledge on this topic. Research plans were pre-registered before analyzing the data. We conducted a meticulous search strategy including database queries, handsearching, forward and backward citation tracking and retrieved 8944 studies. After double blinded screening, 64 studies and 247 effect sizes (total sample sizes = 17,388) were eligible to be included in this systematic review and meta-analysis. Results showed that these online interventions were effective (ES = -0.80, $p < .001$) while holding all moderators fixed at their mean. Specifically, online interventions were effective at reducing anxiety, depression, stress, and psychological distress. However, studies on average showed no impacts on suicidal ideation. Moderator analysis showed that online interventions targeting anxiety outcomes are more effective than interventions targeting psychological distress; internet-based interventions are more effective than mobile-app-based interventions, although both modalities showed effectiveness. These findings provide valuable insights for policymakers and practitioners in developing cost-effective technology-based mental health interventions. While technology can be a double-edged tool, this review highlighted its benefits for improving adult well-being, particularly in the treatment of mental health symptoms.

Keywords: Mobile-app-based interventions; Internet-based interventions; Depression; Anxiety; Systematic Review; Meta-analysis

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Introduction

Mobile phones and the internet have shaped the way people communicate, interact, and access information. While plenty of online interventions address physical health-related outcomes such as cancer [1, 2], sexual health [3], and behavioral issues like suicide prevention [4] and cyberbullying [5, 6], there is a lack of interventions focusing on psychological well-being [7]. In light of the current shortage of counselors [8] and the growing national crisis in mental health [9], there is a pressing need to investigate cost-effective interventions to improve mental health.

Online mental health interventions delivered through mobile-app-based or internet-based programs can potentially help with the mental health crisis. These interventions are attractive because they can be delivered at scale [10], with a low cost [11], and request no extensive training [12]. These features facilitate people's access to mental health resources and alleviate the burdens of healthcare workers. What's more? In conservative societies with mental health stigma, the anonymity feature makes online intervention more acceptable and accessible [13]. Yet, evidence on internet and mobile based interventions are so far limited and inconclusive [14].

Recognizing the immense potential of self-help digital interventions, there is an urgent need to identify key features associated with treatment outcomes. For future researchers and practitioners, it is a million dollar question to answer: which types of intervention content, dosage, and modality work best? Through rigorous meta-analysis of randomized controlled trials, this paper seeks to conduct a comprehensive examination of internet-based and mobile-app-based mental health interventions among adults. The results of the meta-analysis will give us a clear picture of the best ways we can utilize the technology to benefit our mental health.

Addressing adult mental health has immense economic implications in the post-pandemic world. The World Health Organization estimated that depression and anxiety in adults result in a $1 trillion loss in productivity annually [15]. Compared to children and adolescents, adults particularly experience time poverty, i.e. the chronic lack of time due to balancing work, family, and other responsibilities [16]. This extended lack of time not only significantly reduces adults' overall well-being, but also makes it difficult for them to prioritize their mental health and seek treatment [17, 18]. Reports found a huge gap in the number of adults screened positive for mental health problems and those who receive treatments in countries such as the United States [19], India and China [20]. As a result, the ratio of working-age adults who suffer from mental disorders reaches an alarming 15% globally, according to the WHO estimates [15]. As the global societies navigate pandemic recovery, addressing adult mental health to ensure a healthy and productive workforce becomes an urgent necessity.

Past meta-analyses

Up till the time of this study, there are around 10 prior meta-analyses that examined online mental health interventions. Among these meta-analyses, many included a limited number of studies and reported a relatively high risk of bias for studies identified [21, 22, 23, 24], which is not an ideal representation of existing randomized-controlled-trial (RCT) studies. The limited scope of the meta-analyses can be explained by the relatively narrow range of searched databases and publication years. Several meta-analyses were conducted before and in 2018 and therefore could not attend to the rocketing internet use and mental health problems due to the pandemic [25, 26]. Not all studies included the range of publication years in their search criteria description, but the majority of their included studies were published between 2014-2022 [27, 28]. Concerning databases, most previous reviews tended to search on several specific databases such as PsycINFO and PubMed [25, 27, 29, 26, 21, 22, 28].

Previous reviews hold conflicting views on the effectiveness of internet-based interventions in reducing symptoms such as depression and anxiety when features of the interventions vary. For example, Christ and colleagues [29] included 24 studies and found that in terms of anxiety

symptoms, iCBT interventions were beneficial compared to active treatment controls, but the effect was not evident in favor of depressive symptoms. This is challenged by Alrashdi and colleagues [30], who included 26 studies and found that there were no statistically significant benefits in favor of anxiety reduction for online interventions compared to active controls. A possible explanation for the inconsistent findings is a lack of moderator analysis in previous reviews to explain the heterogeneity of effect sizes [29, 21, 31, 23]. While several reviews conducted subgroup analyses [27, 26, 28], the moderators examined were overwhelmingly focused on factors such as intervention duration and technique.

Meta-analyses should aim not only at presenting single average effect sizes but also examining features that affect effect sizes [32]. As preference for online delivery of mental health services continues to grow, it is pertinent to examine the generalizability of online interventions via different modalities for mental health treatment of different age groups. Therefore, this study is conducted based on a large number of rigorous RCTs via a comprehensive database search, taking into account the moderating factors relevant to the effect sizes [33]. This study assesses a range of potential moderators, including outcome domains, sample demographics, recruitment type, and control group type, to account for the inconsistent correlations between internet-based interventions and mental health.

Potential moderators in interventions

Outcome Domains

Most online mental health interventions targeted the alleviation of negative mental health symptoms, among which anxiety, depression, psychological distress, stress, and suicidal ideation stood out as the outcome domains mostly examined. Anxiety is an emotion characterized by a fear of an imminent threat or misfortune and often involves physical tension [34]. Depression is characterized by a serious mood disorder, causing severe symptoms that affect a person's daily life [35]. Stress refers to a state of mental tension or worry triggered by challenging situations [15]. Psychological distress is broadly defined as a state of emotional pain characterized by symptoms of depression and anxiety [36]. Suicidal ideation is defined as having the thought of killing oneself [37].

Past meta-analyses revealed conflicting views on the effectiveness of internet-based mental health interventions as the targeted outcome domains vary. For example, Harrer et al. [26] reported small effects of such interventions on college students' depression, anxiety, and stress symptoms. The heterogeneity of effect sizes was moderate for depression and anxiety, and high for stress. Zhang et al., [38] found a similar disparity in the effects of e-mental health interventions. Specifically, they found a significant alleviation of stress and anxiety among healthcare workers, but only a small to moderate reduction in depression symptoms. The variability of intervention effects across different mental health outcomes requires examining each outcome domain individually, which motivated this paper to present a more nuanced view on outcome domains.

Recruitment Type

Recruitment type can be categorized into universal or targeted. The universal approach of recruitment recruited participants from the general population (e.g., the general public, all healthcare workers, etc.) regardless of their mental health conditions. The targeted approach selects participants based on a pre-screening process of elevated mental health symptoms after recruitment. Harrer et al. [26] found that internet-based interventions had a greater impact on college students when the samples were pre-selected based on symptom cut-offs or risk factors. However, an earlier systematic review of studies on eHealth intervention among the general population showed that universal and selective interventions have similar effect sizes [39]. The conflicting conclusions drawn from prior meta-analyses necessitate a holistic reexamination of the role recruitment types play in differentiating intervention effects.

Sample Demographics

Mental health interventions that restrict their sample to individuals over 18 often include

university students as their participants. University students, as emerging adults, exhibit unique demographic and behavioral characteristics compared to older adults, including more unstable residential status and more risk behaviors [40]. As a result, university students may engage with and respond to online mental health services differently from older adults, leading to distinct outcomes. For example, Harrer et al. [26] found that the effect sizes of internet-based interventions on university students' depression, anxiety, and stress were smaller than that of adults with or without diagnosed depression or anxiety disorder. Distinguishing the results of university students from non-student participants is therefore important in understanding the nuances of intervention effects.

Control Group Type

Different randomized control studies examining the effect of mental health interventions often use different control groups to compare their experimental results. The most commonly used control groups are categorized as either active control or passive control. In active control groups, participants receive an alternative intervention, whereas in passive control groups, there are no interventions given. Harrer et al., [26] examined the effects of interventions having both passive control groups (e.g. waitlists, psychoeducational materials with no behavioral instructions, and no controls) and active control groups (e.g. placebos, diaries, behavioral recommendations) as comparison groups. The meta-analysis showed that intervention effects were reported to be higher when passive controls were used in the studies. In Zhang [38], there was no significant difference found between the treatment effects between having non-active control groups (e.g. no treatment, waiting list, treatment-as-usual) versus having active control groups (placebos or relaxation sessions) as the comparison group. It is worth noting that Zhang [38] categorized treatment-as-usual as non-active control, whereas in other studies it was considered active control "treatment as usual" (i.e. sometimes referred to "care as usual") [41].

Intervention Technique

Cognitive Behavioral Therapy (CBT) is a well-researched psychological treatment. CBT is found to be effective in treating symptoms including depression and anxiety disorders [42]. CBT typically focuses on changing thought and behavioral patterns, with an emphasis on empowering individuals to manage their own challenges. Previous meta-analyses have found that interventions based on CBT principles yielded stronger effects [26]. Heber et al. [43] also revealed that web- and computer-based stress-management interventions grounded in CBT demonstrated small-to-moderate effect sizes, whereas non-CBT interventions produced only small effect sizes. Therefore, the intervention technique of CBT is an important moderator to be included when examining the effectiveness of online interventions.

Intervention Channel

The most common intervention channels of online mental health interventions are web pages and smartphone apps, or a combination of the two. Prior meta-analysis identified that interventions carried out through a combination of web pages and mobile apps were outnumbered by mobile app-only interventions [44]. In a review examining 145 mobile phone-based interventions, overall there were no moderate to high effect sizes on any of the psychological outcomes examined, with a few of the studies showing weak evidence [45]. The null results are perhaps due to an overall poor quality of existing pediatric health apps downloadable from the app stores [46]. To our knowledge, no study has yet compared the effects of internet-based interventions with mobile app-based ones, highlighting the need for further research. Our study addresses this gap by including intervention channels as moderators.

Intervention Delivery

Internet-based and mobile-app-based mental health interventions are either delivered with no human guidance or with different levels of guidance from personnel such as therapists, coaches, or research assistants. Prior research has mixed opinions on whether human guidance would affect

intervention outcomes. Wang et al. [47] reviewed that there was no notable difference between guided online self-help interventions led by coaches, therapists, or through emails and unguided online self-help interventions. Findings from Harrer et al. [26] yielded similar conclusions, indicating that human guidance, either with a reminder mechanism or human feedback, did not moderate intervention effects. This conclusion, however, was in conflict with earlier reviews. For example, Heber et al., [43] found that web- and computer-based stress-management interventions with guidance were more effective than unguided interventions. Given the mixed research evidence on the intervention effects by delivery channels, this paper includes intervention delivery as a moderator.

Intervention Intensity

Intervention intensity is usually measured through the duration of the intervention. Past systematic reviews on internet-based mental health interventions have not reached agreement in whether different lengths of program duration differentiate intervention effects. Wang et al. [47] found that interventions longer than eight weeks had a significant impact on mental health symptoms, while those shorter than four weeks did not show statistical significance. This finding contrasts with prior reviews, which reported either no significant differences among interventions of different durations [48] or significantly stronger effects for interventions lasting between four to eight weeks [26, 43]. In Zhang et al., [38], intervention duration only affected anxiety outcomes but not stress or depression outcomes. While the result from Zhang et al. [38] is partially due to the small sample size and in turn high heterogeneity of some subgroups, the contrasting findings on intervention duration among studies suggest that other aspects of intervention intensity may influence the overall effects. Indeed, the duration of the interventions does not determine the length of the actual dosage participants will be exposed to. Instead, the total number of sessions the intervention includes, or the length of each session, might play a bigger role in the total time of intervention exposure. To our knowledge, prior research has not fully examined intervention effects with the number of sessions included in the calculation of intervention intensity.

Current Study

Research questions

RQ1: What are the overall impacts of mobile-app-based and internet-based randomized-controlled-trial interventions on the alleviation of negative mental health outcomes (anxiety, depression, psychological distress, stress, and suicidal ideation)?

H1: We hypothesize that mobile-app-based and internet-based randomized-controlled-trial interventions can effectively alleviate negative mental health outcomes.

RQ2: To what extent do intervention outcomes differ according to methodological criteria, such as sample size and program duration; and intervention criteria, such as recruitment type (targeted vs. universal); intervention delivery (self guided vs. human guidance); intervention technique (CBT vs. non-CBT); control group type (waitlisted vs. non-waitlisted), intervention intensity, and age group (university adult students vs. older adults), intervention channel (mobile-app-based vs. internet based)?

H2: We hypothesize that effect sizes will be larger in studies examining relatively less severe mental health outcomes, such as stress and anxiety, when compared to more severe outcomes, such as depression psychological distress, and suicidal ideation. We also hypothesize larger effect sizes in studies with targeted recruitment, non-student adult samples, passive control groups, CBT embedded techniques, internet-based interventions, guided support, or higher intervention intensity.

Methods

Registration

This meta-analysis was pre registered at <link blinded for review>.

Literature search

To ensure comprehensive literature coverage, the first author conducted a meticulous search strategy encompassing database queries, handsearching, and backward citation tracking. Employing a predefined set of keywords on social media, intervention method, and mental health (detailed in Table 1 of the Appendix), the first author systematically scoured databases including the Education Resources Information Center, PsychINFO, Scopus, PsychArticles, Communication and Mass Media Complete, and Proquest (shown in Table 2 of the Appendix). Supplementary to the database search, targeted handsearching was performed through <blinded for review> [49] across select reputable journals specific to the field (as outlined in Table 3 of the Appendix). Finally, forward citation tracking and backward citation chasing were performed using *CitationChaser* on relevant systematic reviews and meta-analyses (shown in Table 4 of the Appendix). All literature searches were concluded by March 2024, yielding a total of 8944 studies, and subsequently imported into Covidence for screening. Covidence, chosen for its functionality in facilitating full-text review and availability of software licenses through the authors' affiliated institutions [50], was utilized for both title/abstract screening and full-text review via a double-blinded approach. We resolved any conflicts through weekly group discussions and reached a consensus with 100% agreement. We conducted double-coding in Google spreadsheet.

Eligibility criteria

1) Studies must be randomized controlled trials. A control group must be present in research design. We excluded quasi-experimental study designs.

2) Studies must have at least 30 participants per experimental condition at the baseline measurement [51].

3) Interventions must be delivered through websites or mobile apps. We excluded e-mail reminders or text-messaging or chatbot interventions. We also exclude social media abstinence interventions.

4) Difference between conditions at baseline on mental health measure must be less than 0.25 standard deviations.

5) Differential attrition between treatment and control groups must be less than 15%.

6) Intervention or instruction should be delivered by non-researchers. Treatments delivered by researchers might be more challenging to sustain or replicate in the real world.

7) Outcomes of interest measurements must include quantitative measures of mental health outcomes

8) Focus populations must be adults including and above 18 years old.

9) Full-text must be available on the Internet and written in English.

10) Articles must be published on or after January 1st, 2005.

11) Studies must be primary studies not secondary analysis.

12) We exclude studies that use one-item measures.

13) We exclude interventions that only have a single session.

14) We exclude interventions that recruit from special medical populations with existing medical diagnoses, such as cancer patients, HIV positive men, pregnant women with depression or patients diagnosed with depression in clinical settings. We include studies that focus on general populations.

Analytical plan

We used the R statistical software, specifically employing the *metafor* package for analysis [52]. This study utilized weighted mean effect sizes and meta-analytic tests such as Q statistics. Weights were assigned to each study based on inverse variance [53] and were adjusted according to Hedges' [54] recommendations. A random-effects model in meta-regression was employed due to the presence of a range of effect sizes dependent on various factors [55]. For cluster randomization, adjustments were made based on methods adapted from the What Works Clearinghouse [56].

The analysis included eight sets of moderators and examined differential effects by incorporating interaction terms. All moderators and covariates were grand-mean centered to aid interpretation. Mean effect sizes were derived from the meta-regression model, which accounted for potential moderators and covariates. To assess publication bias, selection modeling was utilized instead of traditional methods due to their limitations [57]. This involved a weight function model developed by Vevea and Woods, implemented using the *weightr* package [58]. In adherence to the principles of open science, the complete dataset and code will be made publicly available.

Moderators

Outcome Domains

In this study, outcome domains of the interventions were coded according to the corresponding scales they used to measure the outcomes. For anxiety, the most commonly used scales include anxiety scales such as the Beck Anxiety Inventory (BAI) [59], the Depression Anxiety Stress Scales (DASS) [60], and the Generalized Anxiety Disorder-7 item scale (GAD-7) [61]. The outcomes were coded as depression if they were measured by scales such as the self-rating DASS depression scale, the Beck Depression Inventory (BDI-II) [62], and the 9-item Patient Health Questionnaire for depression (PHQ-9) [63]. We coded intervention outcomes to be stress if they were measured by the DASS scale [64] and the Perceived Stress Scale (PSS) [65]. The outcome domain of psychological distress was coded if the outcome measures used scales such as the DASS scale [64], the Kessler-10-question scale (K-10) [66], and the Clinical Outcome in Routine Evaluation–Outcome Measure (CORE-OM) [67]. Suicidal ideation was coded if the severity of having suicidal thoughts was measured through scales including the Suicidal Ideation Attributes Scale (SIDAS) [68].

Recruitment Type: Universal vs. Targeted

Interventions were coded as universal if the participants were recruited from the general public or a specific subgroup of the general public (e.g. health workers, college students) without a pre screening process for mental health symptoms. On the other hand, interventions were coded as targeted if participants were selected based on specific criteria, such as people who passed a certain threshold for symptoms of depression, anxiety, or stress, or people who were referred based on their mental health clinical records.

Sample Demographics: Students vs. Non-Students

The sample demographics of the interventions were coded as students if participants were enrolled in postsecondary education, including university students and graduate students. Otherwise, the sample demographics of the interventions were coded as non-students.

Control Group Type: Waitlist vs. Other Types

Control groups type was coded as waitlist if the studies used waitlist control groups. It was

coded as other types if the control groups of the studies involved other types, such as treatment as usual, care as usual, or receiving an alternative treatment such as a similar mobile app, a website content review, or an online forum discussion.

Intervention Technique: CBT vs. Non-CBT

Interventions were coded as CBT if they were specifically designed to follow the principles and techniques of CBT, which could typically involve activities like cognitive restructuring, behavioral activation, and problem-solving to help participants manage mental health symptoms. All other interventions that do not follow a strict CBT framework or are designed with CBT principles are coded as non-CBT.

Intervention Channel: Mobile App based vs. Non-App Based

Interventions were coded as mobile app-based if interventions were primarily delivered through a mobile application accessed on smartphones or tablets for progress tracking. All other interventions that were not delivered via mobile apps were coded as non-app based, including interventions delivered through websites.

Intervention Delivery: Self-Guided vs. Guided by Others

Interventions were coded as self-guided if participants were given access to the program but did not receive any support or guidance from personnel such as clinicians or research assistants. On the other hand, interventions were coded as guided by others if they involved some kind of human help, ranging from email reminders, to meetings with therapists, coaches, or research assistants who could give feedback, advice, or support.

Intervention Intensity

To have a more accurate measure of the actual exposure time of intervention on participants, intervention intensity was calculated by dividing the number of sessions by the program duration (converted to weeks).

Results

Descriptive results

The review retrieved a total of 8,944 published studies. Figure 1 presents the PRISMA screening process conducted in Covidence. A total of 1,505 studies were removed as duplicates. After title and abstract screening, 720 studies went through full-text review, and 613 were excluded. Each study was independently assessed by two reviewers. When conflicts arose, we discussed and reached consensus in weekly meetings. The top five reasons for exclusion were: studies not being randomized controlled trials (n = 321), fewer than 30 participants per condition (n = 72), lack of a mental health outcome (n = 50), differential attrition greater than 15% (n = 38), and interventions focusing on social media abstinence (n = 35). Ultimately, 64 qualified studies with 247 effect sizes (total sample sizes = 17,388) were included in this meta-analysis. Table 1 presents main characteristics of included studies.

Figure 2 presents the increasing trend of number of studies over the past decade. Internet-based studies have a slow and stable presence and increase over years while mobile-app-based studies started to emerge around 2018 and experience a sharp increase in the past five years. There is a diverse distribution across different countries, with the UK (n = 11), Australia (n = 10), US (n = 8), Sweden (n = 7), and Germany (n = 5) providing the most studies. Recruitment methods primarily included social media and online platforms (n = 20), university and academic channels (n = 14), flyers, posters, and direct communication (n = 11), mass media and outreach (n = 10), and healthcare and professional networks (n = 9). Regarding the study sampling, 53 studies (82.8%) did not involve students, while 11 studies (17.2%) included student samples. We also coded for percentage of female

participants. On average, females constitute 66.12% of all participants across 64 studies. In terms of intervention design, 14 programs (21.9%) utilized mobile/app-based interventions, while 50 programs (78.1%) used social media-based (n = 8) or web-based (n = 42) interventions. Among these studies, 49 (76.6%) incorporated CBT components and 15 (23.4%) reported using non-CBT strategies. Most interventions (75%) targeted patients with mental health issues, while 16 studies (25%) were universal. In terms of guidance, 36 studies (56.2%) were self-guided, while 28 studies (43.8%) were guided by therapists, technicians, clinicians or coaches.

This review analyzed 247 effect sizes across various mental health issues:105 (42.5%) related to anxiety, 98 (39.7%) related to depression, 23 (9.3%) related to stress, 18 (7.3%) related to psychological distress, and 3 (1.2%) related to suicidal ideation. For control groups, 138 studies (55.9%) used a waitlist control, while 109 studies (44.1%) used other types of controls such as care/treatment as usual, attention control, information control, or active control. Table 2 provides a summary of descriptive statistics of these categories.

Meta-analysis results

As shown in Table 3, the overall mean effect size for these 64 programs is -0.80 ($p < .001$) while holding all moderators fixed at their mean. The 95% predictive interval ranges from -3.30 to 1.71 and confidence interval ranges from -1.08 to -0.50. The prediction interval means that there is a 95% probability that a future observation will be contained within the prediction interval of -3.30 and 1.71. The confidence interval means that we are 95% certain that the true average effect lies between -1.08 to -0.50. Since the confidence interval does not contain 0, we are more confident that internet-based and mobile-app-based mental health interventions reduce adult negative mental health outcomes.

Outcome Domain: Psychological Distress vs. Anxiety vs. Depression vs. Stress vs. Suicidal Ideation

Overall, outcomes using anxiety-related measurements had a significant weighted mean effect size (ES = -0.77, $p < .001$, Table 4), as well as depression (ES = -0.83, $p < .001$), psychological distress-related (ES = -0.55, p = .004) and stress (ES = -0.82, p = .002). But no significant mean effect size was found in outcomes measuring suicidal ideation (ES = -0.82, p = .783)

No statistically significant difference was found between intervention effects on anxiety and depression (p = .724), anxiety and stress (p = .843), or anxiety and suicidal ideation (p = .649). The difference between anxiety outcomes and psychological distress outcomes was 0.24 SDs on average, which is marginally significant (p = 0.086).

Recruitment Type: Universal vs. Targeted

Intervention type was not a significant moderator of intervention impact. The mean effect size for interventions focused on targeted populations was -0.83 (p = .001), while the mean effect size for interventions focused on universal populations was -0.58 (p = .056).

Sample Demographics: Students vs. Non-students

No significant difference was found between the mean effect size of students and non-students. On average, students group had a statistically significant mean effect size (ES = -1.1, p = .016), while non-students group had a significant mean effect size of -0.71 ($p < .001$).

Control Group Type: Waitlist vs. Other Types

Control group type was not a significant moderator. Waitlist control had a significant average effect size of -1.02 ($p < .001$), while the mean effect size for other control group types was -0.46 (p = .077).

Intervention Technique: Cognitive Behavioral Therapy vs. Others

Intervention design was not a significant moderator of effect sizes. CBT programs had a mean effect size of -0.86 ($p < .001$), while the effect size for programs without CBT elements was -0.46 (p

= .118).

Intervention Channel: Mobile App Based vs. Others

Intervention channel was a marginally significant moderator of impact. On average, non mobile app based interventions had significantly higher effect sizes than those mobile app based interventions (p = 0.056). Non mobile app based interventions had a mean effect size of -0.86 ((p < .001), while mobile app based interventions had a mean effect size of −0.43 (p = 0.015).

Delivery personnel: Self Guided vs. Others

Delivery personnel were not a significant moderator of impact. Delivery personnel by others, on average, had a significant mean effect size of -0.53 (p = 0.001) while programs that were self-guided had an average significant mean effect size of -0.99 (p = 0.004).

Intervention Intensity

Intensity was not a significant moderator of effect size. As intensity increases one unit (one more session per week), effect size increases 0.0005 standard deviation (p = .972).

Interactions (Students X Outcomes)

Significant differential effects were identified for outcome types by age group (β = -0.57, p = 0.015). Interventions with outcomes on psychological distress in student group have a significantly larger effect size (ES = -1.24, p = 0.023) compared to those in non student group (ES = -0.55, p = 0.004). However, interventions with outcomes on depression and stress in the student group were not significant compared to those in the non-student group.

Discussion

This pre-registered meta-analysis examined online mental health interventions targeting adults from the general population. Descriptive statistics showed a surge in the number of high-quality RCTs on mobile app- and internet-based mental health interventions over the past five years, especially in the year of 2020 and 2022. Notably, rigorous mobile-app-based studies emerged around 2018 and surged in the past five years, indicating real-world and research attention on this modality. Considering the relatively flat trend prior to 2019, this surge may be attributed to the growing accessibility of digital technologies and the increased need for remote mental health support, especially during and after the COVID-19 pandemic. The pandemic has accelerated the adoption of digital health solutions, highlighting their potential to provide scalable and accessible mental health care.

The pooled effect sizes analysis of this meta-analysis found that online interventions were effective at reducing anxiety, depression, stress, and psychological distress, but not effective at reducing suicidal ideation. There could be two reasons for the null finding in reducing suicidal ideation. First, our screening process yielded only three eligible studies on suicidal ideation. While we understand that RCTs on suicidal ideation are constrained by ethical concerns, a lack of rigorous studies on this outcome domain limits future researchers' ability to design effective interventions. Furthermore, the null effect may also be explained by the high complexity of suicidal thoughts, which may require more intensive and potentially in-person interventions.

Several of the findings about pooled effect sizes are different from prior meta-analyses. Compared to Christ et al. [29], we found a higher pooled effect size on depression (ES = -0.83) than their findings (ES = -0.51), higher pooled effect size on anxiety (ES = -0.77) than their findings (ES = -0.44). This difference could be attributed to two reasons. Firstly, Christ et al. [29] focused on CBT interventions while this paper includes both CBT and non-CBT interventions. Our findings indicate that non-CBT based interventions are also promising in treating negative mental health symptoms. Secondly, Christ et al. [29] only included young adults between 12 to 15 years old while this paper

included adults above 18 years old, who may respond differently to interventions due to developmental and life stage differences. The difference in pooled effect sizes between two meta-analyses suggests that a comparison between non-adult and adult population might be needed for future research.

Similarly, compared to Alrashdi et al. [30], we also found a higher pooled effect size on depression (*ES* = -0.83) than their findings (*ES* = -0.41); higher pooled effect size on stress (*ES* = -0.82) than their findings (*ES* = -0.40); higher pooled effect size on anxiety (*ES* = -0.77) than their findings (*ES* = -0.45); and similar pooled effect size on psychological distress (*ES* = -0.55) than their findings (*ES* = -0.54). One plausible explanation for this difference could be that Alrashdi et al. [30] focused on mindfulness-based interventions while this paper includes a broader range of interventions. The complete description of the intervention characteristics will be made available together with the data and R code in the following link <link blinded for review>.

In addition to pooled effect sizes, our moderator analysis showed that these online interventions targeting anxiety outcomes were more effective than interventions targeting psychological distress, although interventions were effective on both outcomes. This finding was marginally significant and suggests a need for further research. Although there are no clear reasons to explain this finding, it is important to note that there are many more effect sizes (*n* = 105) related to anxiety compared to psychological distress (*n* = 18). This comparison shows that current rigorous RCTs have devoted more efforts in evaluating interventions on more specific and common mental health conditions such as anxiety. In contrast, psychological distress is a broader construct that may include a wider range of symptoms, making it harder to address uniformly and tailor target interventions.

Moreover, moderator analysis also showed that non mobile app based interventions, such as internet-based interventions or others (e.g., Zoom, Youtube), had significantly higher effect sizes than those mobile app based interventions (e.g., meditation and well-being apps). To the best of our knowledge, there is no prior evidence that compared mobile-app-based interventions with non-mobile-app-based ones. Yet, this result is not surprising, given that Goldberg et al. [45] found a lack of strong evidence on the effect of mobile phone-based interventions for mental health. Although the prevalence of mobile phone possession means that such interventions are quite accessible to the majority of populations, more science-based mobile well-being apps or mobile-based interventions are necessary. The difference in effects between the two modalities might be explained by the more dimensional and interactive capabilities of internet-based platforms, which can include video sessions, live interactions, and extensive modules that mobile apps may not support as robustly.

Implications for practice

The results of this meta-analysis provide several important implications for public health policymakers, mental health practitioners, and the developers of digital mental health interventions. As internet-based and mobile-app-based mental health interventions grow in prevalence, translating these findings into practice can significantly enhance the provision of mental health services globally.

Increased Adoption of Online Interventions

This study demonstrated that internet-based and mobile-app-based interventions can be effective in reducing anxiety, depression, stress, and psychological distress among adults. Given the benefits of scalability and cost-effectiveness of such approaches, mental health services should consider integrating online interventions into routine practice. These interventions are especially beneficial for individuals facing barriers to traditional therapy, such as those in geographically isolated areas or those unable to afford in-person care. Policymakers should prioritize the integration of these interventions into public health systems, promoting equitable access to mental health care through digital platforms.

Preference for Internet-Based Over Mobile App-Based Interventions

While both internet-based and mobile-app-based interventions are effective, this meta-analysis revealed that internet-based platforms could demonstrate greater efficacy. This finding is consistent with previous research indicating the higher therapeutic value of structured, internet-based interventions over app-based solutions that may lack depth [45]. Practitioners and developers should consider prioritizing web-based interventions while continuing to enhance the design and functionality of mental health mobile apps. Investing in the improvement of mobile platforms could extend the accessibility of mental health services while ensuring effectiveness.

Efficacy of Self-Guided Interventions

A key finding in this meta-analysis is that self-guided interventions are as effective as those with therapist support, aligning with previous studies [26]. This has significant implications for public health and mental health systems, especially in settings with limited resources or a shortage of trained mental health professionals. Self-guided interventions can be deployed at scale, offering a cost-effective solution to meet the increasing demand for mental health services. Practitioners and policymakers should promote the adoption of these interventions, which could reduce the workload on mental health professionals while expanding access to evidence-based mental health care.

Suitability for Broader Public Health Initiatives

The effectiveness of internet-based and mobile-app-based interventions for universal adult populations suggests that these tools can be scaled for public health initiatives, including prevention programs. Public health campaigns, schools, workplaces, and community organizations can adopt these interventions as part of a broader effort to promote mental well-being. These tools can be deployed to address mental health needs early, potentially reducing the incidence of clinical mental health conditions and alleviating the burden on mental health services.

Expanding Accessibility in Low- and Middle-Income Countries

The concentration of studies in high-income countries highlights the need to expand internet-based mental health interventions to low- and middle-income countries (LMICs). Prior research has emphasized the potential of digital interventions to overcome barriers to mental health care in resource-constrained settings [69]. Policymakers and international organizations should invest in the development and dissemination of culturally appropriate internet-based interventions that can be deployed in LMICs. By expanding access to these interventions globally, public health systems can address critical gaps in mental health care and reduce global mental health disparities.

Limitations

There are several limitations worth readers' attention in interpreting results. For example, we amended several plans listed in the pre-registration. Firstly, we originally planned to compare social-media-based interventions with internet-based interventions. However, during data analysis, we modified this moderator to mobile-app-based intervention and internet-based interventions because of the severe lack of social-media-based mental health interventions (12.5%) that meet our inclusion criteria. Secondly, we planned to include both positive outcomes (e.g., well-being, life satisfaction, happiness) and negative outcomes. However, we realized that reversing positive mental health outcomes was not the same as negative outcomes. For instance, the interventions that can effectively increase happiness are very different from interventions that can effectively reduce anxiety. Therefore, we removed this research question and only focused on interventions targeting negative mental health outcomes, such as anxiety, stress, and depression.

In addition, we did not collect enough information on racial distribution, which could be a valuable moderator to investigate the equity issue in the design and application of high-quality interventions. Although we planned to code for racial distribution, most studies did not report race. Even among studies that did report relevant information, they might have reported nationality instead of race or used very different racial categories than the commonly used US. racial buckets (White, Black, Hispanic, and Asian).

It is also worth noting that during the moderator analysis, there are a few subgroups of moderators that have small sample sizes. For example, we only found three effect sizes on suicidal ideation and 11 effect sizes on adults who are students that met our criteria. The small sample sizes not only revealed a lack of intervention studies on the specific moderators, but also reminded us to view the results with caution.

Recommendations for Future Research

Although we did not place any geographical restrictions, most RCTs included were conducted in the UK, Australia, US, and Sweden. This indicates that more research resources were available among high-income countries compared to low- and middle-income countries. Therefore, more online mental health interventions are needed in low- and middle-income countries to ensure global accessibility and equity in mental health care.

There is a severe lack of online interventions targeting management of safety-related crises (e.g., suicidal ideation). In this meta-analysis, among 247 effect sizes, we only found two studies with three effect sizes on this outcome. This significant gap highlights the urgent need for more research focused on developing and evaluating effective online interventions for managing safety-related crises.

Conclusion

Internet-based and mobile-app-based mental health interventions provide an important modality to deliver treatment with various benefits, including accessibility, cost-effectiveness, scalability, and acceptability. This meta-analysis synthesized best evidence on this topic and found that, overall, high-quality randomized controlled trials were effective in reducing anxiety, stress, depression, and psychological distress among adults. Moderator analysis showed that internet-based interventions were more effective than mobile-app-based interventions, although both modalities showed effectiveness. The lack of studies among low- and middle-income countries as well as the lack of reporting on race call for future researchers to devote more attention and efforts on these gaps to improve equity of robust mental health RCTs.

Figure 1
PRISMA Diagram

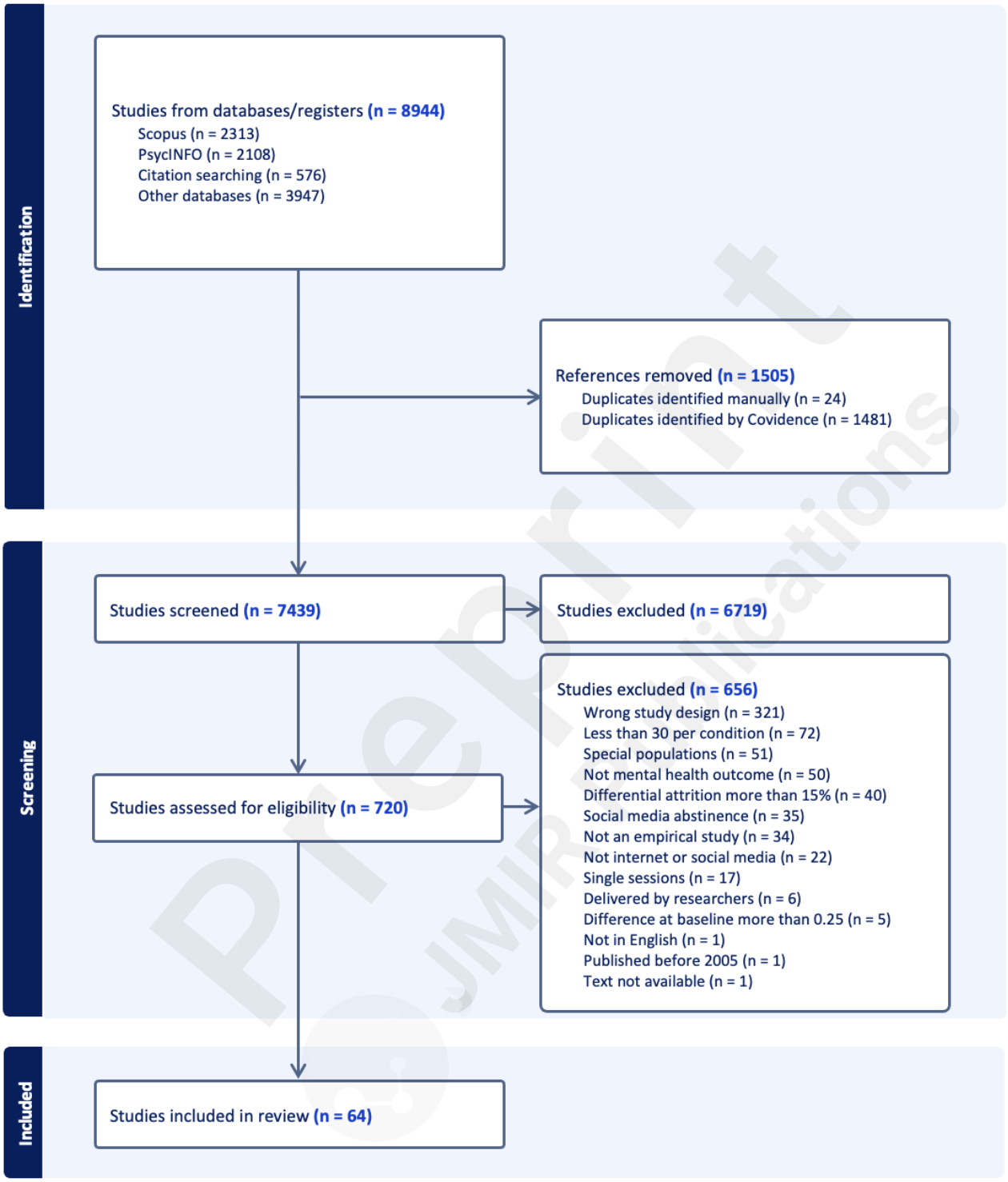
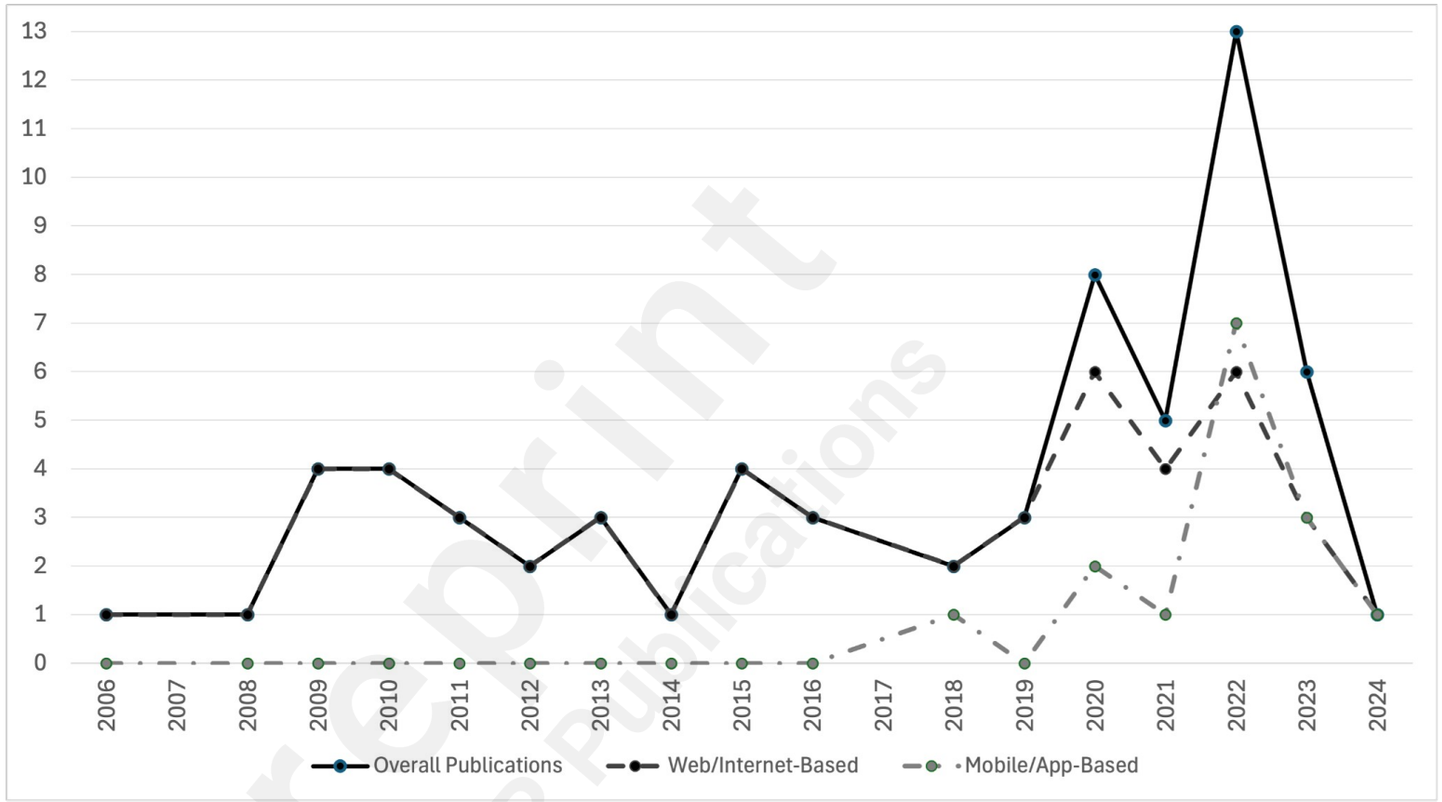


Figure 2
Distribution of Included Studies by Year



Note: The literature search was completed in March 2024, which explains the limited coverage of studies published in 2024, as only one publication from this year is included. The black dotted line represents internet-based studies while the gray dotted line represents mobile-app-based studies. For studies that are delivered both through internet and mobile applications, they were coded as both. In 2018, two publications were identified, with one utilizing solely web/internet-based interventions and the other using both web/internet-based and mobile/app-based interventions. Similarly, a publication in 2024 employed a combination of both web and mobile/app-based interventions.

Table 1

Study Characteristics Table

Study	Phone/ Website	CBT	Self Guided	Age Mean	Students	Country/Region	Sample Size	Universal	Duration Weeks	Number of Sessions
Throuvala et al., 2020	Phone	1	1	20.72	0	UK	261	0	0.34	1.5
Yu et al., 2020	Facebook	0	1	20.53	1	Taiwan	122	1	3	3
Deady et al., 2016	Web-based	0	1	21.74	0	Australia	104	0	4	4
Torok et al., 2022	Phone	0	1	21.50	0	Australia	455	0	6	7
Heim et al., 2021	Phone app	1	0	27.27	0	Lebanon	138	0	8	5
Batterham et al., 2021	Web-based	1	1	41.46	0	Australia	1986	0	4	12
Rubel et al., 2024	Web-based	1	0	35.20	0	Germany	156	0	12	12
Lin et al., 2023	WeChat	1	0	30.82	0	Mainland China	84	0	8	7
Levin et al., 2013	Web-based	1	1	18.37	0	US	76	1	3	2
Li et al., 2022 Insomnia	WhatsApp	0	0	42.13	0	Hong Kong	333	0	3	21
Li et al., 2022 Pain	WhatsApp	0	0	41.35	0	Hong Kong	235	0	3	21
Study	**Phone/ Website**	**CBT**	**Self Guided**	**Age Mean**	**Students**	**Country/Region**	**Sample Size**	**Universal**	**Duration Weeks**	**Number of Sessions**
Tay et al., 2022	Web-based	1	0	21.00	1	Singapore	174	0	2	4
Lambert et al., 2018	Web-based	0	0	38.10	0	UK	62	0	8	13

Prestin & Nabi, 2020 Underdog	Youtube clips	0	1	19.54	1	US	126	1	0.17	5
Prestin & Nabi, 2020 Comedy	Youtube clips	0	1	19.54	1	US	122	1	0.17	5
Prestin & Nabi, 2020 Nature	Youtube clips	0	1	19.54	1	US	120	1	0.17	5
Hussain et al., 2023 mindfulness	Phone	0	1	20.97	1	UK	110	1	6	6
Hussain et al., 2023 SNS	Phone	0	1	20.97	1	UK	110	1	6	6
Thabrew et al., 2022	Well-being app	1	1	23.80	0	New Zealand	90	0	4	7
Hedman et al., 2012	Internet-based	1	1	39.05	0	Sweden	81	0	12	12
Abedishargh et al., 2021	WhatsApp	1	0	34.40	0	Iran	90	0	24	42
Ebert et al., 2016	Internet-based	0	1	42.00	0	Germany	264	1	24	7
Study	**Phone/ Website**	**CBT**	**Self Guided**	**Age Mean**	**Students**	**Country/Region**	**Sample Size**	**Universal**	**Duration Weeks**	**Number of Sessions**
Christensen et al., 2016	Web-based	1	1	*NA*	0	*NA*	1149	0	6	6
Koelen et al., 2023 computer-guided	Web-based	1	1	18+	1	*NA*	801	0	8	7
Koelen et al., 2023 human-guided	Web-based	1	0	18+	1	*NA*	801	0	8	7
Weisel, et al.	Web-based	1	1	42.60	0	Germany	791	1	7	7

2018										
Ebenfeld et al., 2021	Hybrid web-based	1	0	38.00	0	Germany	92	0	8	6
Stuart et al., 2022	Web-based	1	1	47.20	0	US	302	0	5	31
Morriss et al., 2019	Web-based	1	0	32.20	0	UK	156	0	48	9
Clark et al., 2023 (iCBT)	Web-based	1	0	32.20	0	UK	68	0	14	24
Clark et al., 2023 (CBT)	Web-based	1	0	32.20	0	UK	68	0	14	24
Mullarkey et al., 2019	Web-based	1	1	31.60	0	US	295	0	8	10
González-Robles et al., 2022	Web-based	1	0	38.64	0	Spain	200	0	48	12
Study	**Phone/ Website**	**CBT**	**Self Guided**	**Age Mean**	**Students**	**Country/Region**	**Sample Size**	**Universal**	**Duration Weeks**	**Number of Sessions**
Newman et al., 2020	Phone App	1	0	21.40	1	US	100	0	12	40
Schure et al., 2019	Internet-based	1	1	42.90	0	US	343	0	8	31
Currie et al., 2022	App-based Yoga of Immortals	0	1	44.72	0	US	445	1	12	12
Hwang et al., 2022	Phone app	1	1	37.95	0	Korea	126	1	10	600
Hechanova et al., 2023 Zoom	Zoom	0	0	20.90	1	Philippines	262	1	6	6
Robinson et al., 2010 Clinician	Internet-based	1	0	48.43	0	Australia	95	1	10	6
Robinson et al., 2010 Technician	Web-based	1	0	47.60	0	Australia	98	1	10	6

Study	Phone/ Website	CBT	Self Guided	Age Mean	Students	Country/Region	Sample Size	Universal	Duration Weeks	Number of Sessions
Hallgren et al., 2015	Web-based	1	1	41.80	0	Sweden	946	0	12	13
Gilbody et al., 2015 Beating the Blues	cCBT programme (“Beating the Blues”)	1	1	40.09	0	UK	449	0	48	8
Gilbody et al., 2015 MoodGYM	cCBT programme (MoodGYM)	1	1	39.97	0	UK	481	0	48	5
Andersson et al., 2006	Web-based	1	0	37.30	0	Sweden	64	0	9	11
De Graaf et al., 2009 (CCBT without support)	Web-based	1	1	44.30	0	The Netherlands	100	0	9	9
De Graaf et al., 2009 (CCBT & TAU combined)	Web-based	1	1	45.20	0	The Netherlands	100	0	9	9
Titov et al., 2010 Technician	Web-based	1	0	44.00	0	Australia	41	0	8	6
Titov et al., 2010 Clinician	Web-based	1	0	40.00	0	Australia	46	0	8	8
Kessler et al., 2009	Web-based CBT program	1	0	34.90	0	UK	297	0	16	10
Van Ballegooijen et al., 2013	Web-based	1	0	36.60	0	The Netherlands	126	0	12	6
Paxling et al., 2011	Web-based	1	1	39.30	0	Sweden	89	0	8	8

Study	Phone/ Website	CBT	Self Guided	Age Mean	Students	Country/Region	Sample Size	Universal	Duration Weeks	Number of Sessions
Kivi et al., 2014	ICBT program	1	1	36.60	0	Sweden	90	0	12	7
Titov et al., 2008	Shyness program	1	1	38.13	0	Australia	105	0	10	6
Farrer et al., 2011 counselor call	BluePages	1	0	41.53	0	Australia	155	0	6	6
Furmark et al., 2009 trial 1 ICBT	Web-based	1	0	35.00	0	Sweden	40	0	9	9
Andersson et al., 2012	Web-based	1	0	38.20	0	Sweden	204	0	9	9
Tulbure et al., 2015	Web-base	1	0	28.82	0	Romania	76	0	9	9
Jelinek et al., 2020 Active control	Web-based	1	1	45.84	0	Germany	104	0	4	5
Jelinek et al., 2020 Care as usual	Web-based	1	1	45.84	0	Germany	104	0	4	5

Note. CBT = Cognitive Behavior Therapy; ICBT = Internet-based Computer Cognitive Behavior Therapy ; UK= United Kingdom; US=The United States of America

Table 2

Descriptive Statistics

Category	Level	Overall (%)
Study Level		
Total Studies		64
Students	No	53 (82.8%)
	Yes	11 (17.2%)
Mobile App Based	No	50 (78.1%)
	Yes	14 (21.9%)
CBT	No	15 (23.4%)
	Yes	49 (76.6%)
Universal	No	48 (75.0%)
	Yes	16 (25.0%)
Self Guided	No	28 (43.8%)
	Yes	36 (56.2%)
Outcome Level		
Total Effect Sizes		247
Outcomes	Anxiety	105 (42.5%)
	Depression	98 (39.7%)
	Psychological Distress	18 (7.3%)
	Stress	23 (9.3%)
	Suicidal Ideation	3 (1.2%)
Control Wait List	No	109 (44.1%)
	Yes	138 (55.9%)

Note. CBT = Cognitive Behavior Therapy.

Table 3

Model Results

Coef	beta	SE	t	df	P value
Null Model					
Intrcpt	-0.79	0.15	-5.32	53.66	.000
Meta-Regression					
Intrcpt	-0.80	0.16	-5.13	31.98	.000
Control Waitlist	-0.54	0.33	-1.67	5.56	.149
Students	-0.24	0.54	-0.45	7.15	.665
Outcomes Depression	-0.04	0.11	-0.36	24.27	.724
Outcomes Psychological Distress	0.24	0.17	2.07	5.79	.086
Outcomes Stress	-0.03	0.13	-0.26	7.14	.843
Outcomes Suicidal Ideation	1.85	3.09	0.6	1.08	.649
Mobile App Based	0.47	0.22	2.08	14.43	.056
CBT	-0.38	0.28	-1.36	6.80	.217
Universal	0.28	0.41	0.68	9.98	.509
Self Guided	-0.46	0.39	-1.16	25.94	.256
Intensity	0.00*	0.01	0.04	1.60	.972
Students X Outcomes Depression	-0.38	0.42	-0.89	5.56	.410
Students X Outcomes Psychological distress	-0.57	0.18	-3.11	7.82	.015
Students X Outcomes Stress	0.11	0.47	0.23	4.54	.832

Note. SE = standard error; df = degrees of freedom; CBT = Cognitive Behavior Therapy.
*The beta here is 0.0005, but was shortened for formatting reasons.

Table 4

Marginal Means

Moderator	Group	beta	SE	t	P value	df
Universal	Targeted	-0.83	0.22	-3.79	.001	25.01
	Universal	-0.58	0.26	-2.20	.056	8.75
CBT	Not CBT	-0.46	0.26	-1.79	.118	6.76
	CBT	-0.86	0.17	-5.06	.000	34.42
Students	Not Students	-0.71	0.17	-4.08	.000	24.25
	Students	-1.10	0.37	-3.01	.016	8.44
Self Guided	Not Self Guided	-0.53	0.14	-3.67	.001	21.45
	Self Guided	-0.99	0.32	-3.12	.004	26.54
Mobile App Based	Not Mobile App Based	-0.86	0.18	-4.80	.000	35.43
	Mobile App Based	-0.43	0.15	-2.84	.015	12.17
Control Waitlist	Not Control Waitlist	-0.46	0.24	-1.94	.077	11.78
	Control Waitlist	-1.02	0.21	-4.86	.000	20.02
Students X Outcomes	Not Students X Anxiety	-0.76	0.17	-4.56	.000	23.59
	Not Students X Depression	-0.74	0.23	-3.15	.004	23.55
	Not Students X Psychological Distress	-0.43	0.16	-2.66	.023	10.34
	Not Students X Stress	-0.80	0.22	-3.61	.006	8.58
	Not Students X Suicidal Ideation	1.10	3.02	0.36	.764	1.38

	Students X Anxiety	-1.00	0.50	-2.01	.091	6.00
	Students X Depression	-1.36	0.46	-2.95	.024	6.33
	Students X Psychological Distress	-1.24	0.47	-2.63	.055	4.21
	Students X Stress	-0.94	0.29	-3.19	.059	2.63
Outcomes	Anxiety	-0.77	0.15	-5.07	.000	35.38
	Depression	-0.83	0.21	-4.02	.000	35.50
	Psychological Distress	-0.55	0.15	-3.59	.004	11.60
	Stress	-0.82	0.19	-4.25	.002	9.62
	Suicidal Ideation	1.03	3.04	0.34	.783	1.27

Note. SE = standard error; df = degrees of freedom; CBT = Cognitive Behavior Therapy.

Declarations

Ethical Approval and consent to participate
Not applicable

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Not applicable

Availability of data and materials
Data and R code in the following link <link blinded for review>.

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Supplementary Files