

Suicide prevention using self-guided digital interventions: a systematic review and meta-analysis of randomised controlled trials



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Summary

Background Digital interventions that deliver psychological self-help provide the opportunity to reach individuals at risk of suicide who do not access traditional health services. Our primary objective was to test whether direct (targeting suicidality) and indirect (targeting depression) digital interventions are effective in reducing suicidal ideation and behaviours, and our secondary analyses assessed whether direct interventions were more effective than indirect interventions.

Methods In this systematic review and meta-analysis, we searched online databases MEDLINE, PubMed, PsycINFO, and Cochrane CENTRAL for randomised controlled trials published between database inception to May 21, 2019. Superiority randomised controlled trials of self-guided digital interventions (app or web based, which delivered theory-based therapeutic content) were included if they reported suicidal ideation, suicidal plans, or suicide attempts as an outcome. Non-inferiority randomised controlled trials were excluded to ensure comparability of the effect. Data were extracted from published reports, and intention-to-treat data were used if available. The primary outcome was the difference in mean scores of validated suicidal ideation measures (Hedges' g) with the associated 95% CI for the analysis of digital intervention effectiveness on suicidal ideation. We also present funnel plots of the primary outcome measure (suicidal ideation) for direct and indirect interventions to assess for publication bias. We calculated I^2 (with P CI) values to test heterogeneity. We used random-effects modelling for the meta-analyses to assess the primary and secondary outcomes. This study is registered with PROSPERO, CRD42018102084.

Findings The literature search yielded 739 articles (including manual searching) for suicidality and 8842 articles for depression. After screening, 14 papers reporting on 16 studies were included in the narrative review and meta-analysis. The 16 studies (ten on direct interventions and six on indirect interventions) provided baseline data for 4398 participants. The primary outcome of overall post-intervention effect for suicidal ideation was small but significant immediately following the active intervention phase (Hedges' g -0.18 , 95% CI -0.27 to -0.10 , $p < 0.0001$; $I^2 = 0\%$, I^2 CI 0.0 – 47.9). The secondary objective, comparing direct and indirect interventions, showed that direct interventions (targeting suicidality) significantly reduced suicidal ideation at post-intervention (g -0.23 , 95% CI -0.35 to -0.11 , $p < 0.0001$; $I^2 = 17.6\%$, I^2 CI 0.0 – 58.6), but indirect interventions (targeting depression) failed to reach significance (g -0.12 , 95% CI -0.25 to 0.01 , $p = 0.071$; $I^2 = 0\%$, I^2 CI 0.0 – 30.7).

Interpretation Self-guided digital interventions directly targeting suicidal ideation are effective immediately post-intervention. Indirect interventions were not significant for reducing suicidal ideation. Our findings suggest that digital interventions should be promoted and disseminated widely, especially where there is a lack of, or minimal access to, health services.

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Introduction

An estimated 817 000 people die by suicide each year, accounting for 1.4% of deaths globally.¹ Psychological treatment is effective in reducing suicidality, but many individuals who die from, or attempt, suicide do not seek help from health services. A 2015 review² reported that, of 12 006 individuals with suicide ideation, plans, or attempts in the past year, the weighted average proportion of individuals seeking or engaging with mental health services was 29.5%. The proportion of individuals seeking help ranged from 30% to 70%, with lower

frequencies of help seeking associated with being younger (12–18 years), male, and from diverse cultural backgrounds.^{2,3} Among individuals least likely to seek help, perceived stigma, difficulty expressing concerns, and a preference for self-reliance have been identified as barriers to accessing care and support.⁴

Self-guided digital interventions, designed to be used without professional guidance and delivered through web-based programmes or mobile applications, have proved to be successful in preventing and reducing depression and anxiety.^{5,6} In the past 5 years, digital interventions have

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See [Comment](#) page e4

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Research in context

Evidence before this study

Self-guided digital interventions are increasingly being promoted as a way to assist individuals at risk of suicide who will not seek professional face-to-face help. As many as 70% of individuals who are thinking of or planning suicide do not seek help or access care. Digital interventions have the potential to increase help seeking and provide earlier access to care, and thus reduce the frequency and intensity of suicidal ideation. However, important questions remain regarding the effect of digital interventions on suicidality and depression because previous reviews have not directly compared digital interventions that specifically target suicidality with those that target depression. We searched MEDLINE, PubMed, PsycINFO, and Cochrane CENTRAL, from database inception to May 21, 2019, for randomised controlled trials using the search terms: "(suic\$ or self?harm* or self?inj* or self-poison* or attempted?suic*)" and "(randomis* or randomiz*)" and ("web* or 'online' or 'internet*" or "mobile" or "smartphone" or "cell phone" or "phone" or "app" or "mhealth" or "ehealth"). Self-guided interventions had to deliver theory-based therapeutic content digitally (web or app based), and studies had to report suicidal ideation, suicidal behaviour, or both as an outcome. 14 studies (16 unique comparisons) adhering to our eligibility criteria were identified.

Added value of this study

The number of published randomised controlled trials targeting suicide has increased since the last relevant review, warranting an updated review of the evidence. To our knowledge, this meta-analysis is the first to examine whether digital interventions that specifically target suicidality are superior to those that target depression in reducing suicidal ideation. We found that, overall, digital interventions are effective for reducing suicidal ideation, and we found encouraging evidence for the superior effectiveness of digital interventions targeting suicidality over those targeting depression.

Implications of all the available evidence

Digital interventions that directly target suicidality can, and should, be widely promoted through the internet and digital distribution platforms, such as app stores, as part of suicide prevention efforts. Although the overall effect size of these interventions is small, the population impact could be substantial if uptake is widespread. Evidence suggests that a range of interventions including dialectic behaviour therapy, cognitive behaviour therapy for insomnia, and therapeutic evaluative conditioning are likely to be more effective than general cognitive behavioural therapy alone, reinforcing the importance of direct suicide prevention content within apps and online programmes, and the need to examine promising novel treatments.

been developed to prevent suicide.⁷ Their ability to provide high-fidelity therapeutic support, at the users' discretion and pace, both anonymously and cost-effectively, means that digital interventions might overcome barriers associated with accessing traditional care, while also offering a sustainable, scalable solution. In 2012, it is estimated that 75·5% of suicides occurred in low-income to middle-income countries,¹ where professional health resources are scarce but where digital technologies are prevalent.

There is now increased international interest in finding immediate, technology-based solutions focusing on suicide ideation and mental health, particularly in countries without adequate mental health services and in those where access is insufficient. It has become a global public health priority to determine whether these novel solutions will work.

There is a growing body of evidence for the effectiveness of digital interventions in reducing suicidal ideation.⁷ An updated review of this evidence is, however, warranted because new trials of digital interventions specifically targeting suicidality have been published in the past 3 years with stronger research designs than used previously, specifically randomised controlled trial designs. Accordingly, the primary purpose of this review was to examine the effectiveness of digital interventions on suicide ideation and suicidal behaviours, relative to control conditions at post-intervention and follow-up. Our primary hypothesis is that digital interventions are

effective in reducing suicide ideation and suicidal behaviours relative to control conditions. This analysis builds on previous reviews, which have been limited by several factors, including treating intervention types (self-guided, clinically supported, and aftercare) as comparable despite elevated risk in clinical compared with community samples, including observational studies or non-randomised trials with pre-post assessment,⁷ combining superiority and non-inferiority trials,⁷ and inattention to subpopulations or settings across studies.

As a secondary outcome, we also investigated the effectiveness of interventions that specifically address suicidal thoughts and behaviours (direct) against those that target depression (indirect) in reducing suicidal ideation. Depression is a risk factor for suicidality but not a causal one,⁸ and suicidality can occur in the absence of depression.⁹ There is evidence in support of depression and suicidality having independent latent trajectories,⁹ suggesting that changes in suicidality might occur independently of changes in depression. Accordingly, people with suicidality and those with depression might respond differentially to different treatments.¹⁰ Yet, the effect of digital interventions designed to address suicidality versus those that address depression has yet to be explored in a meta-analysis. We postulated that direct interventions would be effective at reducing suicidal ideation while indirect interventions would not, on the basis of a previous meta-analysis of face-to-face interventions that found that treating depression did not

statistically improve suicidal ideation.¹¹ We also postulated that direct interventions would not reduce depression, given potential differences in underlying mechanisms of suicide and depression phenomena.⁹

Methods

Search strategy and selection criteria

This systematic review and meta-analysis adheres to the PRISMA guidelines.¹² Four online bibliographic databases were searched from inception to May 21, 2019: MEDLINE (from 1946), PsycINFO (from 1806), PubMed (from 1996), and Cochrane CENTRAL (from 1996). We used an empirical approach to derive an objective primary search strategy for identifying randomised controlled trials of digital interventions that included suicidal outcomes (ideation, plans, and attempts).¹³ In the first step, we identified a test set of critical papers meeting our inclusion criteria (six on direct interventions and three on indirect interventions). The search strategy was developed in MEDLINE using article identification numbers, and the search strategy was iteratively improved to maximise the sensitivity and specificity for identifying relevant articles. This search strategy achieved 100% sensitivity against these initial test sets. Following this step, key search terms derived from the medical subject heading terms used in the test papers were established, which included four primary sets of terms pertaining to suicide, depression, randomised controlled trials, and digital interventions. A variety of terms related to each of these terms were entered into each database. References of relevant sources, which were manually examined to identify any additional relevant studies, are included in the appendix (p 1).

After the removal of duplicate records, two reviewers (MT and JH), early-to-mid career research fellows trained in this method, independently screened the titles and abstracts for relevance, and then extracted and selected relevant full-text records. Discrepancies were resolved through discussion at each stage, and consensus was achieved with acceptable inter-rater reliability ($\kappa=0.84$; $p<0.01$). A third author (IW) verified the eligibility of included studies.

No restrictions were placed on the target population, setting, intervention type (indicated, selective, or universal), or language. Only one potential paper was not published in English, and this paper was read by a reviewer competent in that language. Eligible studies were any superiority randomised controlled trials, involving treatment as usual, waitlist, or attention placebo comparison conditions, of interventions that were delivered digitally (web or app based) and self-guided (used self-reliantly without a coaching or support component delivered by a clinical supervisor or health professional). Interventions had to deliver theory-based therapeutic content (eg, cognitive behavioural therapy [CBT] and dialectical behaviour therapy [DBT]), and studies had to report suicidal ideation, suicidal plans, or suicide attempt outcomes.

Interventions had to be directed towards an individual, and interventions directed towards caregivers and people in positions of trust were excluded. Interventions delivered by other digital means, such as text messaging or DVD, were excluded to enhance comparability. Interventions that did not explicate that the intervention delivered therapeutic content (eg, intervention restricted to digital journaling or diary keeping) were also excluded. Non-inferiority randomised controlled trials were excluded to ensure comparability of the effect, and one study (Wagner et al)¹⁴ was excluded on this basis. After eligible studies had been identified, MT and MEL were responsible for classifying studies as direct or indirect intervention studies. The protocol is available online.

Data analysis

Three authors (MT, JH, and AW-S) extracted data using a custom spreadsheet to record the study design, study sample (adults or youths, age, and sex), the intervention name and therapeutic model, comparison conditions, and study outcomes (suicidal ideation, suicidal plans, attempts, or depression). If reported, intention-to-treat data were used. If data were missing or unclear, or we could not determine the nature of the intervention, we contacted the corresponding author of the publication by email for clarification. Three studies were excluded through this process: one because the author could not be reached and two because the interventions did not fit criteria.

We analysed quantitative data using random-effects meta-analyses based on the Hedges' *g* statistic,¹⁵ which is used to estimate the effect size for the difference between means of continuous measures between the intervention and the control conditions. Our primary analyses included four separate a priori meta-analyses: the effect of digital interventions on symptoms of suicidal ideation (thoughts of, or plans for, suicide, as measured by the presence, frequency, or intensity of suicidal thoughts); the effect of digital interventions on suicidal behaviours (plans and attempts); the effect of digital interventions on targeting suicidality on depression symptoms; and the effect of digital interventions on targeting depression on suicidal ideation.

Other subgroup analyses were planned a priori and included comparisons of the therapeutic model of intervention (CBT vs other), the effectiveness of the delivery model (app based vs web based), control conditions, and subpopulations (adolescents vs adults; appendix p 3).

Because most studies were expected to report on suicidal ideation, the primary outcome was the difference in mean scores of validated suicidal ideation measures (Hedges' *g*) with the associated 95% CI for main and subgroup analyses. We did meta-analyses for all studies combined, and for direct and indirect interventions separately, to test our hypotheses. Negative effect sizes indicate superior effects of the intervention versus the control condition (waitlist, attention placebo, or treatment as usual). In cases in which studies reported suicidal ideation as a

For the protocol see https://www.cr.d.york.ac.uk/PROSPERO/display_record.php?RecordID=102084

See Online for appendix

dichotomous outcome (odds ratio [OR]) between intervention and control conditions, we transformed results into a Hedges' *g* effect size. For the primary analysis (digital intervention effectiveness on suicidal ideation), we did a planned leave-one-out sensitivity analysis¹⁶ to test whether a single study had a disproportionately large effect. We did an additional planned sensitivity analysis to examine whether the effects of interventions remained robust when only studies with low risk of bias ratings were retained in the analysis. Where available, follow-up data for suicidal ideation were extracted and analysed in respect to the longest follow-up period post-intervention for which data were available. Waitlist randomised controlled trials that made the intervention available to the comparison condition immediately after the post-intervention assessment were excluded from the long-term follow-up analysis. For depression symptoms, the Hedges' *g* and associated 95% CI values were pooled for continuous measures. Forest plots are presented for each meta-analysis along with the *I*² statistic, which is used to evaluate

heterogeneity.¹⁷ This statistic indicates whether variation is more likely due to chance or study heterogeneity. Negative *I*² values are put equal to zero, and values range between 0% and 100%.¹⁷ 0% indicates no heterogeneity, whereas 25%, 50%, and 75% indicate low, moderate, and high heterogeneity, respectively. We calculated CIs for *I*² according to the formulas provided by Borenstein and colleagues.¹⁸ We present funnel plots of the primary outcome measure (suicidal ideation) for direct and indirect interventions to assess for publication bias,¹⁹ with imputed studies generated by the trim-and-fill procedure²⁰ to correct for effect variance and provide a best estimate of the unbiased effect size. We assessed publication bias using Egger's test for asymmetry. We used Comprehensive Meta-Analysis (version 3)²¹ for all statistical analyses.

The Cochrane Collaboration's tool for assessing risk of bias (version 1.0) was used to evaluate the risk of bias of included studies (appendix p 2).²² Each of the seven risk criteria was scored against a three-point rating scale, corresponding to a high, low, or unclear risk of bias. The risk of bias appraisal was done independently by two reviewers (MT and IW), with good inter-rater agreement ($\kappa=0.74$; $p<0.001$) and consensus achieved through discussion.

This study is registered with PROSPERO, CRD42018102084.

Role of the funding source

The funder of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report. The corresponding author had full access to all the data in the study and had final responsibility for the decision to submit for publication.

Results

The literature search yielded 739 articles (including manual searching) for suicidality and 8842 articles for depression. After removal of duplicates and excluding studies on the basis of their abstracts or through examining their full text, 14 were identified as eligible for inclusion (figure 1).

The 14 papers describe 16 unique comparisons (Franklin et al²³ included three substudies with different participants), and studies were classified on the basis of their intent (ten direct and six indirect; table). The 16 studies contained baseline data on 4398 participants (mean age range from 14.7 years [SD 1.4] to 42.5 years [12.2]). The sex distribution was skewed towards females (range 49–86% female), and 13 (81%) studies recruited adults. The studies included participants from three continents; most studies were done in Australia and North America (table). Baseline sample sizes ranged from 50 to 1149 participants (mean 280.19 participants [SD 288.15]), and ten (63%) studies had sample sizes of less than 200 participants.

Adherence data were reported in 11 (69%) studies, with moderate completion of the programme (at least half of

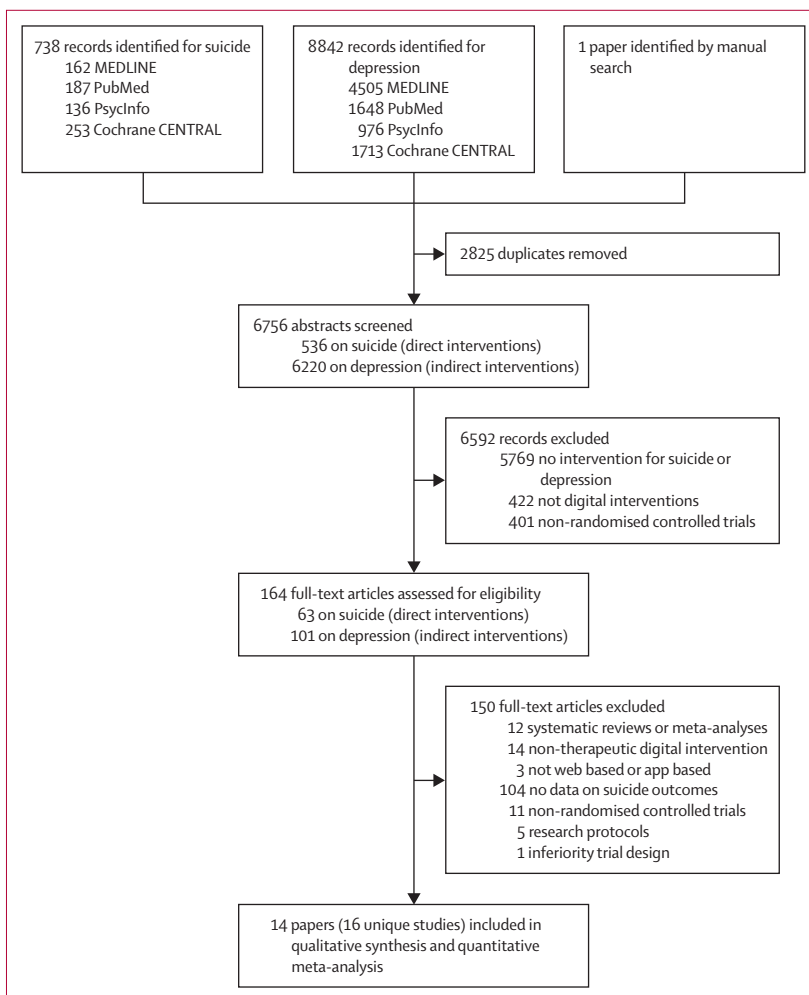


Figure 1: Study selection

Intervention type	Recruitment	Delivery mode	Baseline sample size	Target population	Intervention	Control condition	Duration of intervention	Primary outcome measures	Post-intervention assessment timepoints	Proportion completing post-intervention or follow-up assessment, n (%)
Direct (suicide) interventions										
De Jaegere et al (2019), ²⁴ Belgium	Community based, online	Online	724	Adults, mean sample age 35.7 years (SD 3-6)	Think Life (CBT for insomnia, DBT, and mindfulness)	Waitlist (available after completion of post-survey)	6 modules over 6 weeks	Beck Scale for Suicidal Ideation	Immediate post-intervention, 12 weeks post-baseline	Post-intervention: 267 (37%); follow-up: 247 (34%)
Franklin et al substudy 1 (2016), ²³ USA	Community based, online	App	114	Adults, mean sample age 23.0 years (SD 5.5)	Therapeutic evaluative conditioning	Attention placebo therapeutic evaluative conditioning	Unlimited access for 1 month	Self Injurious Thoughts and Behaviors Interview; number of days suicidal ideation occurred	Weekly during treatment month, immediate post-intervention	Post-intervention: 79 (69%)
Franklin et al substudy 2 (2016), ²³ USA	Community based, online	App	131	Adults, mean sample age 22.9 years (SD 5.0)	Therapeutic evaluative conditioning	Attention placebo therapeutic evaluative conditioning	Unlimited access for 1 month	Self Injurious Thoughts and Behaviors Interview; number of days suicidal ideation occurred	Weekly during treatment month, immediate post-intervention	Post-intervention: 94 (72%)
Franklin et al substudy 3 (2016), ²³ USA	Community based, online	App	163	Adults, mean sample age 24.5 years (SD 6-6)	Therapeutic evaluative conditioning	Attention placebo therapeutic evaluative conditioning	Unlimited access for 1 month	Self Injurious Thoughts and Behaviors Interview; number of days suicidal ideation occurred	Weekly during treatment month, immediate post-intervention, 2 months post-intervention	Post-intervention: 90 (55%)
Hetrick et al (2017), ²⁵ Australia	Schools	Online	50	Youth, mean sample age 14.7 years (SD 1-4)	Reframe-IT (CBT for insomnia) and treatment as usual	Treatment as usual	8 modules over 10 weeks	Suicidal Ideation Questionnaire	Immediate post-intervention, 12 weeks post-intervention	Post-intervention: 39 (78%); 12 weeks: 30 (60%)
Hill and Pettit (2019), ²⁶ USA	Community based, online	Online	80	Youth, mean sample age 16.9 years (SD 1-7)	LEAP (CBT for insomnia)	Attention placebo (psychoeducation)	2 modules and planned activity (active learning) over 2 weeks	Interpersonal Needs Questionnaires; Beck Scale for Suicidal Ideation	Immediate post-intervention, 6 weeks post-intervention	Post-intervention: 71 (89%); 6 weeks: 69 (86%)
Tighe et al (2017), ²⁷ Australia	Community based, online	App	61	Adults, mean sample age 26.3 years (SD 8-1)	ibobbly (acceptance and commitment therapy)	Waitlist (available after completion of post-survey)	3 content modules, 3 self-assessments over 6 weeks	Depressive Symptom Inventory Suicidality Subscale	Immediate post-intervention	Post-intervention: 59 (97%)
van Spijker et al (2014), ²⁸ Netherlands	Community based, online	Online	236	Adults, mean sample age 40.9 years (SD 13-7)	Leven onder Controle (CBT, DBT, and mindfulness)	Attention placebo (psychoeducation)	6 modules over 6 weeks	Beck Scale for Suicidal Ideation	2 weeks into intervention, 4 weeks into intervention, 6 weeks post-intervention	6 weeks: 215 (91%)

(Table continues on next page)

Intervention type	Recruitment	Delivery mode	Baseline sample size	Target population	Intervention	Control condition	Duration of intervention	Primary outcome measures	Post-intervention assessment timepoints	Proportion completing post-intervention or follow-up assessment, n (%)
(Continued from previous page)										
van Spijker et al (2018), ²⁹ Australia ³⁹	Community-based, online	Online	418	Adults, mean sample age 40.6 years (SD 11.9)	Living with Deadly Thoughts (CBT, DBT, and mindfulness)	Attention placebo (psychoeducation)	6 modules over 6 weeks	Columbia-Suicide Severity Rating Scale (suicidal ideation subscale)	Immediate post-intervention, 6 months post-baseline, 12 months post-baseline	Post-intervention: 192 (46%); 6 months: 273 (65%); 12 months: 277 (66%)
Wilks et al (2018), ³⁹ USA	Community based, online	Online	59	Adults, mean sample age 38.0 years (SD 10.4)	iDBT-ST	Waitlist plus weekly screening for suicidal ideation or alcohol use (available 8 weeks post-baseline)	8 modules over 8 weeks	Scale for Suicidal Ideation	1, 2, 3, and 4 months post-baseline	Immediate post-intervention: 30 (100%); 1 month: 24 (80%)*
Indirect (depression) interventions										
Batterham et al (2017), ³¹ Australia	Community based, online	Online	194	Adults, 50% younger than 25 years	FitMindKit (behaviour activation, CBT, and mindfulness)	Attention placebo (psychoeducation)	10 modules over 2 weeks	Custom composite mental health measure	Immediate post-intervention, 3 months post-baseline	Post-intervention: 75 (39%); 3 months: 61 (31%)
Christensen et al (2013), ³⁴ Australia	Community based, online	Online	155	Adults, mean sample age 41.5 years (SD 12.4)	BluePages+ MoodGym (CBT) (programme only vs programme and LifeLine Callback vs Callback only)	Waitlist (available after 6-month follow-up)	5 modules and 1 psychoeducation module (BluePages) over 6 weeks	Center for Epidemiological Studies-Depression	Immediate post-intervention, 6 months post-baseline	Post-intervention: 107 (69%); 6 months: 92 (59%)
Christensen et al (2016), ³³ Australia	Community based, online	Online	1149	Adults, mean sample age 42.5 years (SD 12.2)	SHUTi (CBT for insomnia)	Attention placebo (psychoeducation)	6 modules over 6 weeks	Patient Health Questionnaire-9; Bergen Insomnia Scale	Immediate post-intervention, 6 months post-baseline	Post-intervention: 581 (51%); 6 months: 504 (44%)
Guille et al (2015), ³⁴ USA	Medical interns, online	Online	199	Adults, mean sample age 25.2 years (SD 8.1)	MoodGYM (CBT for insomnia)	Attention placebo (psychoeducation)	4 modules over 4 weeks	Patient Health Questionnaire-9; Beck Depression Inventory-II	At 3, 6, 9, and 12 months of intern year	Overall follow-up: 165 (83%)
Moritz et al (2012), ³⁵ Germany	Community based, online	Online	210	Adults, mean sample age 38.6 years (SD 13.3)	Deprexis (CBT)	Waitlist (available after completion of post-survey)	10 modules over 8 weeks	Beck Depression Inventory-II	Immediate post-intervention	Post-intervention: 170 (81%)
Perry et al (2017), ³⁶ Australia	School	Online	540	Youth, mean sample age 16.7 years (SD 13.3)	SPARX-R (CBT)	Attention placebo (psychoeducation)	7 modules over 5 weeks	Major Depression Inventory	Immediate post-intervention, 6 months post-baseline, 18 months post-baseline	Post-intervention: 406 (75%); 6 months: 341 (63%); 18 months: 104 (19%)

CBT=cognitive behavioural therapy, DBT=dialectical behaviour therapy, iDBT-ST=iDBT skills training intervention. *intervention group only (n=30).

Table: Study characteristics

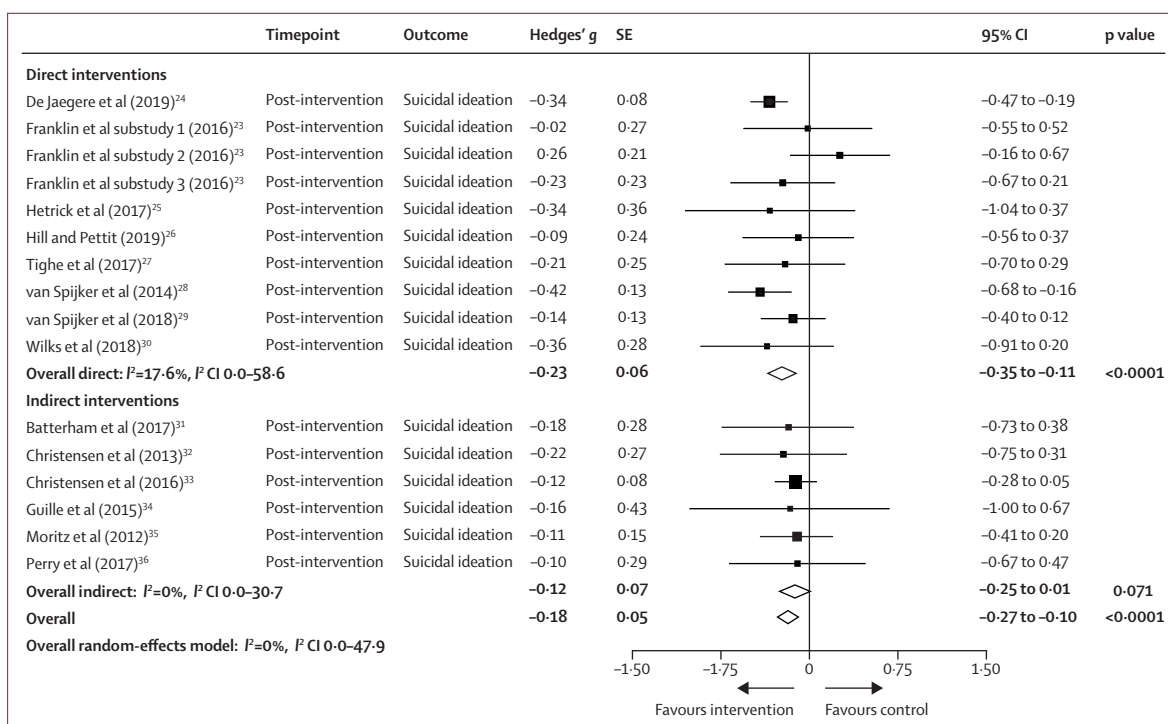


Figure 2: Effect of direct and indirect digital interventions on suicidal ideation at post-intervention

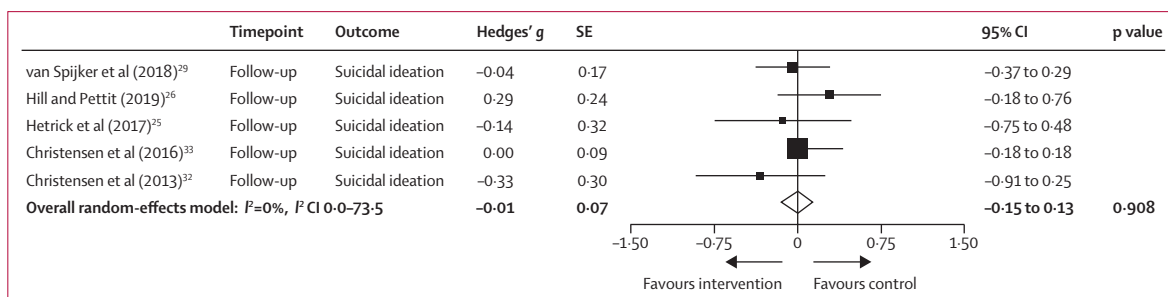


Figure 3: Effect of digital interventions on suicidal ideation at longest follow-up timepoint

the intervention modules) ranging from 34%³¹ up to 93%.²⁶ Seven (64%) of these 11 studies had moderate completion of less than 60%. All 16 studies reported immediate post-intervention data for suicidal ideation, and seven (44%) studies provided follow-up data for suicidal ideation, although two were excluded from the meta-analysis for using waitlist designs. Of the seven studies with follow-up data, the mean duration of follow-up was 13.28 weeks (SD 6.60) post-intervention, and for the five eligible studies it was 15.60 weeks (SD 6.39) post-intervention. Six studies^{25,26,32,34-36} delivered interventions based primarily on CBT, and the other studies included interventions delivered mixed therapeutic approaches (blended CBT, DBT, and mindfulness),^{24,28,29,31} therapeutic evaluative conditioning,²³ primary DBT,³⁰ acceptance and commitment therapy,²⁷ and CBT for insomnia,³³ which included sleep diaries, sleep

restriction, and stimulus control alongside CBT. Ten (63%) of the trials included attention placebo control conditions.

For the total comparisons (n=16), suicidal ideation scores were significantly reduced at post-intervention compared with control conditions (Hedges' g -0.18, 95% CI -0.27 to -0.10, p<0.0001; $I^2=0%$, P^2 CI 0.0-47.9; figure 2). The outlier was substudy 2 in Franklin et al,²³ in which the intervention condition reported a worsening of suicide ideation symptoms (figure 2). Leave-one-out analysis showed that no single study rendered the random-effects model non-significant if omitted from the model. Omitting De Jaegere et al²⁴ had the largest effect reduction, increasing the Hedges' g value from -0.21 to -0.16 (appendix p 4). When only studies with low risk of bias were included (n=11), the effect size was similar to that of the total comparisons (Hedges' g -0.22, 95% CI -0.33 to -0.10,

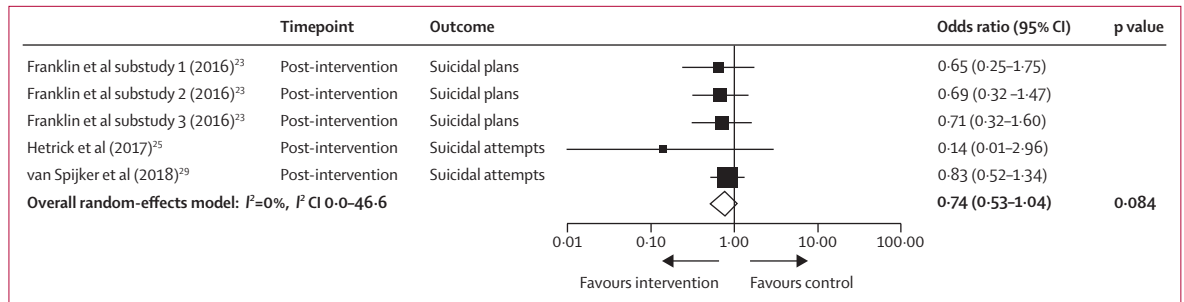


Figure 4: Effect of digital interventions on suicidal behaviours at post-intervention

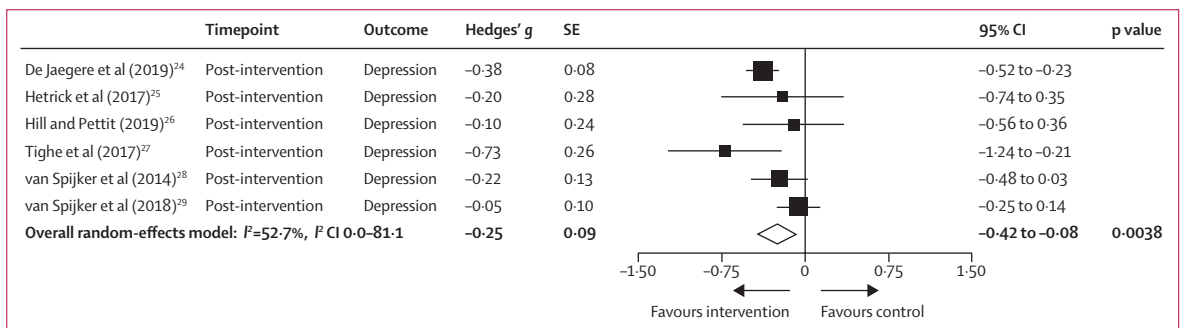


Figure 5: Effect of direct interventions on depression outcomes at post-intervention

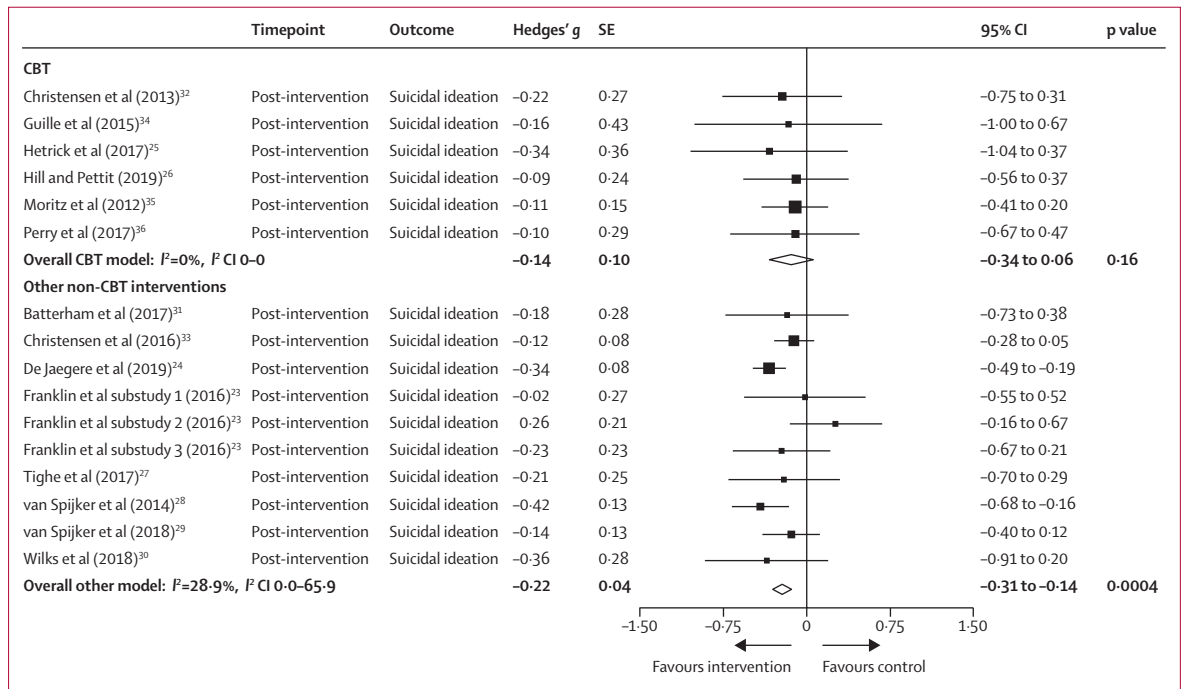


Figure 6: Effect on suicidal ideation of CBT versus other therapeutic approaches at post-intervention

CBT=cognitive behavioural therapy.

$p=0.0002$; $I^2=20.9%$, I^2 CI 0.0-60.2; appendix p 5). There was a small effect in favour of direct interventions on suicidal ideation scores at post-intervention (Hedges' g -0.23, 95% CI -0.35 to -0.11, $p<0.0001$; $I^2=17.6%$,

I^2 CI 0.0-58.6), which was not evident for indirect interventions (Hedges' g -0.12, 95% CI -0.25 to 0.01, $p=0.071$; $I^2=0%$, I^2 CI 0.0-30.7; figure 2). As indicated by the I^2 values and associated CIs, we found no evidence of

significant heterogeneity in the overall, direct, or indirect models. No effect was detected at follow-up of suicidal ideation outcomes for studies in which such data were available ($n=5$; Hedges' g -0.01 , 95% CI -0.15 to 0.13 , $p=0.908$; $I^2=0\%$, I^2 CI $0.0-73.5$; figure 3).

For the five studies that compared the effects of the digital interventions on suicidal behaviour (plans or attempts), the odds were not significantly lower at post-treatment (OR 0.74 , 95% CI $0.53-1.04$, $p=0.084$; $I^2=0\%$, I^2 CI $0.0-46.6$; figure 4). However, the treatment effect favoured the intervention condition. The effect for direct interventions on depression outcomes was small yet significant ($n=6$; Hedges' g -0.25 , 95% CI -0.42 to -0.08 , $p=0.0038$; $I^2=52.7\%$, I^2 CI $0.0-81.1$; figure 5), and was at a magnitude similar to the effects of direct interventions on suicide ideation.

Comparison of the therapeutic approach showed that non-CBT interventions were associated with significant improvements in reducing suicidal ideation ($n=10$; Hedges' g -0.22 , 95% CI -0.31 to -0.14 , $p=0.0004$; $I^2=28.9\%$, I^2 CI $0.0-65.9$) and CBT interventions were not ($n=6$; Hedges' g -0.14 , 95% CI -0.34 to 0.06 , $p=0.16$; $I^2=0\%$, I^2 CI $0-0$; figure 6).

Examination of the funnel plots (figure 7) suggest that no publication bias existed for direct interventions, as indicated by the one-tailed p value ($p=0.43$). The trim-and-fill method post-intervention suggests that three studies with significant effects might be missing from the current literature for direct interventions (figure 7), with an imputed effect estimate of -0.31 (95% CI -0.40 to -0.22).

On the basis of the Cochrane Risk of Bias tool,²² the methodological quality of the studies was found to vary markedly (appendix p 2). We identified the largest source of potential bias as resulting from incomplete data resulting from attrition (attrition bias), with 11 (69%) of 16 studies reporting 20% or more attrition at post-treatment or follow-up, followed by failure to clearly describe blinding procedures (performance bias; 68.75%). Nine (56%) studies did not report enough information to rule out selective reporting, which is largely contingent on publication of a study protocol to ensure authors report on a priori defined outcomes, or detection bias (43.75%; appendix p 2).

Discussion

In this systematic review and meta-analysis, two of our a priori hypotheses were supported: digital interventions are effective in reducing suicidal ideation, and direct interventions produce more favourable effects than do indirect interventions. Our main analysis showed that, collectively (direct and indirect) self-guided digital interventions yielded small, significant effects on suicidal ideation immediately following the active intervention phase. The magnitude of our effects, particularly for direct interventions (-0.23), is not substantially different from the effect sizes identified in meta-analyses of

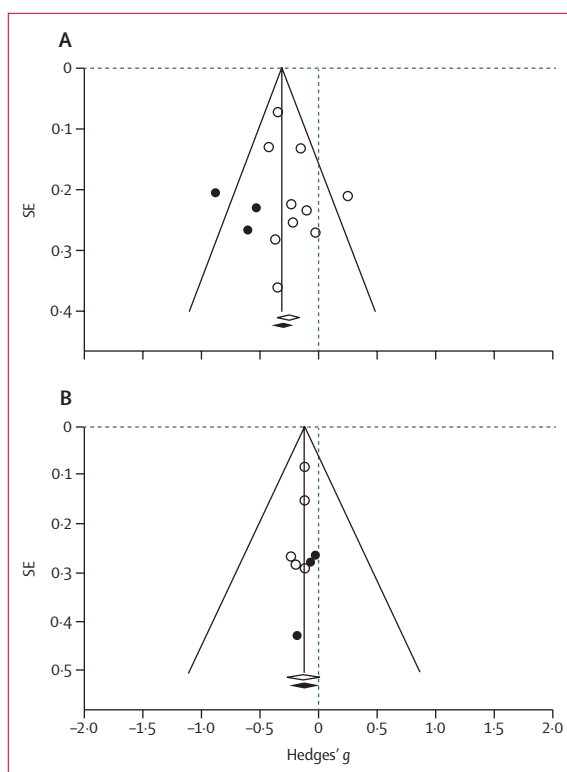


Figure 7: Funnel plot of studies reporting post-intervention suicide ideation data for direct interventions (A) and indirect interventions (B)

Studies inside the triangle have non-significant effect sizes; studies outside the triangle are significant at the $p=0.05$ level. Open circles depict the studies included in the analysis. Black circles depict imputed studies estimated by the trim-and-fill method.

face-to-face interventions for suicide prevention (effect sizes -0.24 ,³⁷ -0.25 ,³⁸ and -0.28 ³⁹). These similarities suggest that digital and face-to-face interventions might be similar in their effectiveness.

Although the effects reported are small, which is in part to be expected by the low incidence of suicidal ideation and behaviour in the population, variability in these effects might be explained by differences in symptom thresholds for suicidal ideation, the intensity of treatment, or trial characteristics (ten [63%] of 16 studies had baseline samples sizes of <200 , 69% reported attrition of $\geq 20\%$). Studies with larger sample sizes are needed. Adherence, or lack of it, is also likely to be a factor in the magnitude of the effects observed. Where adherence information was available, almost two-thirds of studies reported that participants completed less than 50% of the treatment modules. A meta-analysis by Karyotaki and colleagues⁴⁰ has identified similarly high levels of non-adherence (70% dropout before completing 75% of modules) among self-guided digital interventions for depression. Despite the enormous potential of digital interventions, engagement is clearly a major barrier to realising optimal effectiveness. Improved user design approaches, adaptiveness, gamification, and personalisation of interventions should

be explored as ways to improve engagement,⁴¹ as the static design of current interventions might act as limitations to their practicality, usefulness, and appeal.

Improvements in suicidal ideation were most evident in studies directly targeting suicide, whereas indirect interventions targeting depression did not reduce suicidal ideation, consistent with findings from the literature on face-to-face interventions. For example, Cuijpers and colleagues⁴¹ reported no association between depression interventions and suicidality in a large meta-analysis of psychotherapies. Similarly, Meerwijk and colleagues⁴² investigated the idea that direct interventions might be more effective in preventing suicide and suicide attempts than indirect interventions. Meerwijk and colleagues⁴² examined 44 studies and found that indirect interventions did not significantly reduce suicide in the short term. It is perhaps unsurprising that depression interventions have little effect on suicidality considering that suicidal behaviour is a rare outcome even among people with depression (estimated 15–20% prevalence).⁴³ We also acknowledge that there are likely to be differences in the composition of suicidal and depressed symptoms in direct and indirect studies that might affect these findings.

Although we did not expect to see an effect for direct interventions on depression, they were found to be effective in reducing depression symptoms at post-intervention (effect size -0.25). Psychological autopsies⁴⁴ indicate that depression is implicated in up to 91% of suicide deaths, and although there is evidence that suicidal ideation and depression are relatively independent constructs,⁹ they are likely to share latent risks⁴⁵ that might tie them together in complex ways. These findings simply reinforce the usefulness of direct interventions as a way forward for achieving important transdiagnostic outcomes.

Most direct interventions for suicidality used non-CBT approaches, whereas approximately 70% of the depression-targeted interventions used CBT models. CBT interventions did not yield significant effects on suicidal outcomes, suggesting that alternative therapeutic approaches, such as DBT, acceptance and commitment therapy, therapeutic evaluative conditioning, or mixed component approaches, should be explored as new opportunities for achieving a clinical effect. Moreover, although the use of therapeutic evaluative conditioning has not been replicated, its efficacy was associated with non-suicidal self-injury not suicidal ideation.²³ There is consensus that capability for suicide is needed to facilitate progression from suicide ideation to attempts,⁴⁶ and non-suicidal self-injury might be a proxy indicator for capability for suicide.⁴⁷ This potential link between non-suicidal self-injury and future suicide attempt suggests that there are distinct ideation-to-action processes that can be targeted⁴⁶ and pursuing further research on best-fit digital interventions for ideation versus behaviour is warranted. Research into the treatment of insomnia is also indicated in the context of suicidality, given its

potential as a less stigmatised intervention and its involvement in the biology of suicide risk.

Our study has several limitations. First, the included studies were diverse, differing in therapeutic approach, delivery, and outcome measures. Suicidal ideation was measured in various ways, including psychometric scales, self-report, and hospital or medical records, which might make it difficult to compare. However, the heterogeneity in suicidal ideation was 0%, suggesting that variation in outcome measure was low. Second, few studies assessed suicidal outcomes beyond 3 months post-intervention, indicating that longer follow-up is needed. Third, although most studies included in the analysis had an attention placebo control condition, some studies used waitlist or treatment-as-usual controls, increasing between-study variation. Variability in the control condition is a rarely investigated source of heterogeneity in meta-analyses of digital interventions.

Future studies of digital interventions to reduce suicidality might standardise suicide outcome measures (eg, ideation, non-suicidal self-injury, plans, and attempts) to compare with other interventions, and trial longitudinal designs, taking measurements over various timeframes (minutes, hours, days, weeks, or months)⁴⁸ to evaluate and elaborate ideation-to-action theories of suicide and identify new opportunities for intervention. Large implementation trials that iteratively test models of user engagement in real-world settings are now needed to accelerate growth in this area. At scale, such trials can examine factors that mediate efficacy, to understand the conditions required to optimise the completion and potency of these interventions.

Although in their infancy, this review demonstrates the effectiveness of self-guided digital interventions for suicide prevention and reinforces the importance of including direct suicide prevention content within digital interventions. We recommend that digital interventions directly addressing suicidality can, and should, be promoted online and integrated into health systems in those countries where they have been tested, to be made available to those in need, particularly once any safety concerns are ruled out. Although they appear to have small effects, the population impact could be significant if uptake is widespread. There is also the need to extend and test their use in low-income and middle-income countries. This review further indicates that non-CBT approaches might be more effective than traditional CBT for people at risk of suicide, raising important questions about the generalisability of cognitive behavioural models in suicide prevention and the mechanisms underlying change.

Contributors

HC, SB, and MT designed the study. JH and MT planned the statistical analysis. JH analysed and extracted data, with assistance from AW-S. MT, IW, and JH assessed study eligibility and quality. MEL monitored the review process and shared responsibility for coding direct and indirect interventions. MT, HC, and JH wrote the first draft of the manuscript. All authors contributed to the interpretation and subsequent edits of the manuscript. HC is the guarantor.

Declaration of interests

All authors declare support from the Australian Government and NSW Health for the submitted work. MT, JH, SB, AW-S, IW, MEL, and HC are employed by the Black Dog Institute (University of New South Wales, Sydney, NSW, Australia), a not-for-profit research institute that develops and tests digital interventions for mental health.

Data sharing

Extracted data are available on request to the corresponding author.

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