Acceptability and Effectiveness of App-Based Interventions in Managing Symptoms of Depression, Self-Harm and Suicidal Ideation in Youth

[redacted]

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Declaration

This report contains no material which has been accepted for the award of any other degree or diploma in any University, and, to the best of my knowledge, this report contains no materials previously published except where due reference is made.

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Literature review

TITLE: App-based interventions and their application in the self-management of depression, self-harm and suicidal ideation in youth

Abstract

Depression during adolescence has been linked to an increased risk for non-suicidal self-harm and suicidal ideation both preceding risk factors for suicide. However, young people are unlikely to seek help for mental health problems. Given that this group routinely use online services to connect with others and seek information, smartphone applications ('apps') present a possible treatment modality. This review critically examines the development and application of apps in the self-guided treatment of depression, self-harm and suicidal ideation among youth. Findings in this area are promising, although inconsistent. Randomized controlled trials are needed to determine treatment safety and effectiveness.

Keywords: Apps, youth, smartphone, depression, self-harm, suicidal

Introduction

Adolescence and early adulthood the period from 10-24 years of age - is considered to be a stage of critical development (Beardslee, Gladstone, & O'Connor, 2012). During this time, young people are tasked with the responsibility of developing their identities and constructing a stable sense of self, all while navigating a more complex social world (Gibbons & Poelker, 2019; Harter, 2012). Multiple age-specific factors heighten the risk of developing a mental illness during this developmental period - including difficulties at school, conflict with friends and family and a tendency to engage in thrill-seeking or health risk behaviours (Kieling et al., 2011). Depressive or affective disorders, in particular, account for the greatest global burden of disease among young people, influencing both mortality risk and morbidity (Gore et al., 2011; Thapar et al., 2012).

Concerningly, young people report significant barriers to accessing mental health services. Commonly cited barriers include perceived stigma and discomfort discussing mental health problems but also a failure to perceive a need for help (Gulliver, Griffiths, & Christensen, 2010). Mental health smartphone applications ('apps') offer a promising way of delivering interventions for depression in this technologically-savvy group. However, the efficacy of app-based interventions remains unclear. This review appraises the available evidence, commencing with a discussion of depression, self-harm and suicidal ideation in youth, followed by the development of self-guided app-based interventions in the treatment of depression. Feasibility studies suggest high acceptability and good app usage; however, controlled trials are promptly needed.

Youth depression: symptoms, epidemiology and prevalence

Many adolescents and young adults face significant transitional or adjustment challenges that leave them vulnerable to depression, including relationship and/or family breakdowns, bullying, unemployment, coupled with a lack of cognitive maturity (Vajani et al., 2007). These psychosocial and financial stressors can lead to Major Depressive Disorder, with symptoms such as depressed mood or anhedonia (loss of interest or pleasure), weight changes, sleep difficulties, fatigue, diminished ability to think or concentrate, and feelings of worthlessness or excessive guilt significantly impacting daily functioning (American Psychiatric Association; APA, 2013). It is estimated that up to 25% of young people are diagnosed with depression before they reach 18 years of age (Gore et al., 2011), with young women being at heightened risk (Salk, Hyde & Abramson, 2017). Even those that do not meet the criteria for a formal diagnosis can experience clinically significant symptoms, with one in five young people that present to primary care experiencing "subthreshold" symptoms (Lee et al., 2018; Bertha & Balazs, 2013; Wesselhoeft et al., 2013). Subthreshold depression is a key risk factor for the development of a subsequent depressive disorder, while also contributing to functional impairment and reduced quality of life (Bertha & Balazs, 2013; Wesselhoeft et al., 2013).

Self-harm

Numerous studies confirm that young people who report higher levels of psychological distress and depression also engage in self-harming behaviours (Di Pierro et al., 2012, Gonçalves et al., 2012, Gutridge, 2010, Kiekens et al., 2015, Klemera et al., 2017). The term "self-harm" can be described as the direct and deliberate intention to self-poison or self-injure (e.g. cutting, burning, scratching, overdosing), regardless of

motive or suicidal intent (Hawton, Saunders & O'Connor, 2012; National Collaborating Centre for Mental Health, 2011). A broader definition of self-harm, which includes those who inflict harm to themselves without the intention to die, is referred to in the mental health literature as Non-Suicidal Self-Injury (NSSI; Nock, 2010). Non-suicidal reasons for self-harm are broad and serve a variety of functions for young people. In a systematic review of 152 studies, Edmondson, Brennan & House (2016) identified a need to manage distress or relieve '*a terrible state of mind*' as the most commonly reported reason for self-harm. In addition to self-harm as a way to communicate emotional pain, people who self-injure may seek to punish themselves, friends or family (i.e. '*look what you made me do*'), use self-harm to achieve a sense of belonging and group identity, or may even self-harm as an 'experimental' act (Edmondson, Brennan & House, 2016). Self-perceived adaptive functions for self-harm have also been identified, including self-validation and self-mastery, a need to regain sensation and feel 'alive' when in a dissociative state, and a need to generate excitement and exhilaration from the associated adrenaline rush (Edmondson, Brennan & House, 2016).

The presence of self-harming behaviours among young people aged 25 and under is a global health concern (Hawton et al., 2012; Chan et al., 2016). Typical age of onset is between 12-16 years (Kiekens et al., 2018) with a lifetime prevalence ranging from 15 to 46% in the general population and up to 80% among clinical outpatient populations (Brunner et al., 2014; Jacobsen et al., 2008; Plener et al., 2009). Notably, this figure may underestimate the true number of cases, given that many young people prefer to conceal their self-harming behaviours from those around them and that less than 20% of youth who self-harm actually seek treatment (Brophy, 2006; Kidger et al., 2012; Hawton et al., 2002). In addition to financial, school and employment problems, psychiatric morbidity is high among this group, with adolescent self-harm closely linked

to anxiety and substance use up to 20 years later (Borschmann et al., 2017). Self-harm also substantially increases the risk of fatal outcomes: approximately 50% of adolescents who die by suicide have previously self-harmed (NCISH, 2016).

Suicidal ideation

Severe depressive symptoms, such as low mood, anhedonia and poor self-worth, have been identified as risk factors for suicidal ideation in young people (Gould et al., 2003; Wolff et al., 2018). Depressed adolescents who self-harm are also more likely to experience suicidal ideation (Tuisku et al., 2006). Concerningly, 30% of those aged 12-20 years have experienced the belief that life is not worth living (Evans et al., 2005). Of this group, 20% have thought about suicide in the past year (Evans et al., 2005). Suicidal ideation can range from fleeting, self-destructive thoughts to well-thought out plans for a suicide attempt (Grunbaum et al., 2004). Although suicidal ideation alone increases a young person's risk of attempted suicide, when combined with self-harm, the transition from suicidal ideation to action becomes more likely (Mars et al., 2019). Indeed, it has been estimated that 1 in 5 (21%) adolescents who report both suicidal thoughts and self-harm will make a future suicide attempt (Mars et al., 2019). The longer that young people experience depression, self-harm and suicidal ideation, the more likely they are to attempt suicide (Zubrick et al., 2017). In recent years, there has been a rapid increase in suicide rates among adolescents, causing suicide to rank among the five leading causes of adolescent death, globally (Kapka-Skrzypczak, 2019).

Depression treatment in young people

Given that depressive illness greatly increases the risk of self-harm and suicide in young people, early targeted intervention to reduce both incidence and symptom severity is critical (Zubrick et al., 2017). The management of depression depends on a variety of factors, including symptom severity and their subsequent impact on functioning, the presence of past and current suicidal thinking, behaviour and self-harm, in addition to available health services and supports. For example, an adolescent presenting with depression, along with self-harm and suicidal ideation, would typically be considered a 'complex' presentation requiring specialist outpatient or inpatient intervention (Davey & McGorry, 2018). In comparison, a young person presenting with mild depressive symptoms, in the absence of active suicidal ideation and self-harm, might be considered ideal for care in a primary, community-based setting (Davey & McGorry, 2018).

Established clinical practice guidelines developed by the National Institute for Health and Care Excellence (NICE) recommend face-to-face treatment with a trained mental health professional, for at least 3 months duration, as a first-line approach for youth depression (Hopkins, Crosland, Elliott & Bewley, 2015). Cognitive-behavioural approaches, in conjunction with socially or family driven frameworks, have shown the greatest promise for mild to moderate depression (Hopkins, Crosland, Elliott & Bewley, 2015; Iyengar et al., 2018). Providing the young person with psychoeducation and including strategies to promote a healthier lifestyle are also vital components of depression treatment (Hopkins, Crosland, Elliott & Bewley, 2015). For more complex adolescent presentations, interventions that combine individual CBT with aspects of dialectical behavioural therapy (DBT) - including group skills training, problem-solving and mindful awareness - have been deemed effective using the 'gold standard'

randomised controlled trial (Iyengar et al., 2018; Ougrin et al., 2015; Spirito, Esposito-Smythers, Wolff & Uhl, 2011). For young people that do not respond to psychotherapy, multi-disciplinary review is also recommended in order to assess the appropriateness of antidepressant medication (Hopkins, Crosland, Elliott & Bewley, 2015).

E-mental health

Although psychotherapies are an important part of the mental health care of young people with mild to more complex presentations, there remain significant barriers to engagement. Attitudinal beliefs that mental health treatment is unnecessary, or will be ineffective, are especially prominent (Witt et al., 2017). In addition, young people have reported high levels of stigma and shame - especially in regards to their self-harming behaviour (Witt et al., 2017). Those experiencing severe depression with suicidal ideation, in particular, are less likely to access professional support (Sawyer et al., 2012). When young people do decide to seek treatment, they may find it difficult given that many do not have primary care doctors whom they visit regularly (Jorm, Wright & Morgan, 2007). Moreover, when attempting to access mental health support, new barriers related to service cost and accessibility arise - particularly for those residing in outer suburban and rural areas (Black, Roberts & Li-Leng, 2012; Gulliver, Griffiths, & Christensen, 2010; Rickwood et al., 2005). Consequently, many young people are reluctant, or unable, to seek conventional face-to-face mental health supports.

Internet-based and technology-assisted therapy may help overcome the attitudinal and structural barriers young people regularly associate with in-person care. With the rapid development of web-based and mobile technology, the plausibility of delivering effective, targeted mental health interventions online, referred to in the

literature as e-mental health, has become an emerging field of research (Christensen & Petrie, 2013). E-mental health interventions can be developed and utilised on a range of platforms, including smartphones, tablets and computers. Indeed, youth can now access confidential online therapy via telecommunication software such as Skype, as well as individual and peer support through online mental health services and virtual clinics (Farrer et al., 2015; Meurk et al., 2016).

The need for accessible, high quality and integrative health care has been recognised in the literature (Meurk et al., 2016). As this demand increases, so too has the rate of policy-focussed research relating to e-mental health. E-mental health services have proven to be an effective and acceptable means of treatment which should be integrated as an additional layer within the Australian healthcare system (Meurk et al., 2016). Notably, engagement in e-mental health service has shown to later facilitate in-person mental health care for some individuals (Kauer, Mangan & Sanci, 2014). For example, in their community sample of 1214 young adults, Younes et al., (2015) found that those who engaged in e-mental health care sought help from psychologists in their local community more frequently than young adults who did not (66.2% vs 52.4%, p=.03). Over the past decade, the availability of mobile technologies and e-mental health services has also improved, thereby reducing the 'digital divide' that previously characterised online health information access and use particularly among rural and low socio-economic populations (Fairburn & Patel, 2017; Hall et al., 2015).

Importantly, high user acceptability and satisfaction with e-mental health services have been identified across numerous trials (e.g., Crisp & Griffiths, 2016; Klein & Cook, 2010; Perini, Titov, & Andrews, 2008; Proudfoot et al., 2010). Structured and standardized interventions, containing modules based on cognitive behavioural therapy

(CBT) protocols, have produced positive findings (Klein et al., 2013). This includes significant and immediate reductions in self-reported depression severity among adolescents and young adults (10-24 years) enrolled in a web-based program (Valimaki et al., 2017). Recent meta-analytic data also found moderate, high quality evidence for the comparative effectiveness of electronically-delivered and face-to-face CBT for depressive disorders in adults (Luo et al., 2020). It follows that e-mental health may be an acceptable platform for at-risk or vulnerable populations that are unable or unwilling to seek in-person care, including depressed adolescents.

App-based Interventions targeting depression, self-harm and/or suicidal ideation

The success of web-based approaches has led to research examining the feasibility and effectiveness of emerging mobile telephone applications, or 'apps', as an alternative platform for mental health care delivery. App-based interventions offer key advantages over web-based interventions, by allowing users to engage with exercises and monitor their symptoms in real-time - including immediately before and after critical events (Stolz et al., 2018). Mobile apps also have significant reach and are accessible by the user at a time and location of their choice, on a range of handheld devices (e.g., iPhone, android-based smartphone; Stolz et al., 2018). In addition, they do not rely on the synchronous availability of a mental health professional (Stolz et al., 2018; Mohr et al., 2013).

Apps have demonstrated clinical advantages, as both stand-alone self-management tools and adjunctive treatments, likely due to their 24-hour availability (Lecomte et al., 2020). That is, therapeutic app content can be accessed immediately by the user; a feature that is advantageous for those unable or unlikely to seek

conventional care, or for those seeking treatment on a waitlist (Lecomte et al., 2020). With over 5 billion people owning a mobile device, and over 10,000 mental health apps being available for download, mobile phone apps can help expand the general public's access to low-cost, quality mental health care (Statista, 2019; Torous et al., 2018).

However, the quality of available mental health apps has been questioned. Despite the majority being classified as appropriate for users of all ages, many apps are not appropriately designed to suit youth and young adults at their stage of development (Lecomte, 2020; Qu et al., 2020). This can lead to high rates of disengagement, particularly if the app content is not relatable to the target group (Garrido et al., 2019). Importantly, app-based interventions specifically targeting symptoms of depression in youth have been rapidly increasing in their public availability (Shen et al., 2015). Indeed, the apps currently available on mobile marketplaces (i.e. Apple App Store, Google Play Store) provide access to a range of depression interventions, which the user can select and download depending on their preferences and needs. Notably, the majority of available mental health apps are designed as stand-alone, self-guided interventions (Fitzpatrick et al., 2017; Flett et al., 2019; Franklin et al., 2016; Hur et al., 2018; Lee et al., 2018; Levin, Hicks & Krafft, 2020; Qu et al., 2020; Tighe et al., 2017; Stallard et al., 2018).

Concerningly, an overwhelming number of apps may contain content that is harmful for the user (Baumel et al., 2020; Grist, Porter & Stallard, 2017; Radovic et al., 2016; Terhorst et al., 2018). In particular, Baumel et al., (2020) identified negative user experiences associated with all non-evidence-based techniques in their systematic review of depression and anxiety related apps. Of the estimated 10,000 to 20,000 mental health apps available for download, only 3-4% of them incorporate well-

established therapeutic frameworks and/or involved mental health professionals (i.e. psychologists, psychiatrists, and therapists) in the initial app design and development (Baumel et al., 2020; Lecomte et al., 2020; Qu et al., 2020). Upon reviewing 29 of the most popular, top-rated apps available for treating depression, Qu et al., (2020) concluded that approximately half involved a cognitive-behavioural, mindfulness or acceptance-based approach. Alarmingly, only 7% (2/29) could provide peer-reviewed evidence supporting the effectiveness of their app in reducing depressive symptoms.

Of those apps that have received research scrutiny, the most common evidence-based treatment elements for depression and its symptoms include psychoeducation, guided meditation, breathing exercises, thought diaries, mindfulness activities and behavioural activation. The aim of these tasks is to overcome the inertia of depression by scheduling pleasant and achievement-based activities, while mindfulness-based components help to defuse from depressive cognitions by teaching the individual how to be aware of what is taking place in the present moment, without judgement (Fitzpatrick et al., 2017; Flett et al., 2019; Huberty et al., 2019; Hur et al., 2018; Lee et al., 2018; Levin, Hicks & Krafft, 2020; Martinego et al., 2019; Qu et al., 2020). Apps designed to target self-harming behaviours and/or suicidal ideation have also typically involved a combination of CBT skills - including skills to improve distress tolerance and develop healthier coping responses, understand painful feelings, and minimize feelings of worthlessness (Franklin et al., 2016; Tighe et al., 2017; Stallard et al., 2018).

Limitations associated with the practical usability of a smartphone app can, however, limit treatment effectiveness. Commonly reported concerns include screen size, limited battery life, the need for regular system updates, and technology requirements (Bauer et al., 2020). Beyond technical faults, app users also have high

expectations regarding the usability and performance of their app and tend to be unforgiving when an app fails to meet their needs. Commonly cited barriers to app use include slow speed, in-app glitches, unsolicited advertisements and a user interface that is difficult to navigate and understand (Lim et al., 2014). Concerns regarding user privacy and data security, including how information is used, shared and protected, have also been raised (Thornton & Kay-Lambkin, 2018). Identifying barriers to app use is important, as it is estimated that 39% of users will promptly abandon an app for a perceived better alternative when it does not meet their short-term needs (Lim et al., 2014). It should be also noted, however, that the acceptability of app-based interventions can be dynamic in nature, as gauged from participants' qualitative feedback and the extent to which app developers are responsive to that feedback. In particular, young people have reported high levels of satisfaction with app interventions whilst also providing constructive feedback about the technical problems that they encountered during their app use feedback which has subsequently been used to enhance an app's features and development (e.g., Fitzpatrick et al., 2017).

Intervention effectiveness

Although a number of randomized controlled trials (RCTs) and meta-analyses have examined app-based interventions for depression, much of this research has centred on adult populations (e.g. Arshad et al., 2020; Weisel et al., 2019; Witt et al., 2017), or included all web modalities (e.g. internet and mobile phone-based; Perry et al., 2016; Valimaki et al., 2017), limiting conclusions to be drawn about the effectiveness of standalone mental health apps for youth, in particular. In addition, the available evidence for the effectiveness of apps targeted to adolescent depression is mixed. For example, Fitzpatrick et al., (2017) assessed the effectiveness of *Woebot,* an app utilising

a fully automated conversational 'agent' to deliver CBT. Young people that accessed *Woebot* reported significant reductions in depressive symptoms, as measured by the well-validated Patient Health Questionnaire, compared to an information-only control group. Commercially available mindfulness meditation apps, such as *Headspace* and *Smiling Mind,* have also demonstrated beneficial effects (Flett et al., 2019). Despite these promising findings, non-significant or negligible treatment effects for app-based interventions have also been found (Hur et al., 2018; Kauer et al., 2012; Lee et al., 2018; Motter et al., 2018).

The effectiveness of targeted app-based interventions for symptoms of self-harm and suicidal ideation in youth, is less well known. Franklin et al., (2016) published a series of RCTs to evaluate a game-like app, *TEC*, to increase aversion to self-injurious thoughts and behaviours and decrease aversion to the self. Although up to 90% of participants accessed the *TEC* app at least once, there were no significant differences in treatment participation across the intervention and an active control groups who accessed a version of this app without intervention components. Intervention participants did report fewer episodes of non-suicidal self-injury during the treatment month than peers in the control group; however, these treatment effects were not maintained at 1-month follow-up. In a more recent study, Stallard et al., (2018) evaluated a smartphone app, *BlueIce,* which had been co-produced with young people and designed based on principles of DBT and CBT. Almost three-quarters (73%) of those who had recently self-harmed reported reductions in self-harm after using *BlueIce* for 12 weeks. However, given that the study design involved a small feasibility trial of 12 to 17-year-old's (N = 44), and with no comparison group, these findings need to be interpreted with caution. Tighe et al., (2016) also measured changes in suicidal ideation with their *iBobbly* app over a 6-week period. Within-group changes in suicidal

ideation were significant, however these changes were comparable to those reported by waist-listed peers. Similarly, Franklin et al, (2016) found no significant treatment effects for suicidal ideation with their *TEC* app.

Several studies have also been limited by their poor rates of app adherence, with some reporting that control conditions had higher participation than the intervention group. This is consistent with reviews of the digital intervention research in general, with non-adherence levels of up to 70% noted (i.e., study withdrawal prior to the completion of 75% of the treatment modules; Karyotaki et al., 2015). Participation dropout rates are particularly high among unguided web-based interventions for depression in comparison to interventions that involve a clinician or administrator support during the delivery or for post-session feedback (74% vs. 28% respectively, Richards & Richardson, 2012).

Sociodemographic factors may, in part, explain this level of disengagement. There is evidence that being male significantly increases the risk of dropping out before completing a self-guided digital intervention (Karyotaki et al., 2015). Conversely, women have demonstrated a higher effort to cope with depression, enhancing their motivation to pursue digital interventions without guidance (Babwah et al., 2006; Karyotaki et al., 2015). This finding extends beyond digital interventions, with research suggesting that men who are depressed are less likely to access conventional mental health care due to the stigma associated with challenging socially constructed ideals of masculinity (i.e. stoicism and resilience; Rice et al., 2020; Seidler et al., 2018; Seidler et al., 2016). Similarly, it has been suggested that young people with a lower educational attainment may have difficulty understanding the content of a self-guided app-based intervention and, as such, lose motivation to pursue treatment (Waller & Gilbody, 2009). Tailoring interventions to suit an individual's level of understanding (e.g.,.

including more audio-visual components), is therefore essential for maintaining engagement and, in turn, realising optimal effectiveness for many app-based interventions (Karyotaki et al., 2015; Peyrot et al., 2015).

Summary

Young people struggling with depression are at a greater risk of experiencing self-harming behaviours and suicidal ideation, increasing their risk of completed suicide. However, barriers to traditional face-to-face care remain. For those experiencing symptoms of depression, app-based interventions show great promise as a tool for self-management. Available reviews in this area have typically included adult populations (e.g., Arshad et al., 2020; Witt et al., 2017) or all web modalities (e.g. internet and mobile phone-based; Perry et al., 2016; Valimaki et al., 2017), thereby limiting conclusions able to be drawn in relation to app-based interventions for young people, specifically. This calls for a need to systematically appraise and synthesise emerging, high quality-controlled studies in this field, so that young people and professionals can better navigate and benefit from the many app-based interventions already available to them.

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Article

TITLE: Effectiveness of App-Based Interventions in Managing Depression, Self-Harm and Suicidal Ideation in Young Adults: A Systematic Review with Meta-analysis

[redacted]
School of Psychology, The University of Adelaide, Australia

Corresponding author:

[redacted] School of Psychology, University of Adelaide, North Terrace,

Adelaide, South Australia, 5000, Australia

[redacted]

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Abstract

Introduction: Effective treatment of depression in young adults is critical, given its prevalence, impacts, and high comorbidity with self-harm and suicidal ideation. Smartphone applications ('apps') have the potential to improve the scalability of effective mental health interventions; however, evidence for stand-alone apps treating depressive symptoms remains unclear. The present systematic review and meta-analysis provides an up-to-date summary of the current research literature.

Methods: A search of Embase, Cochrane Library, PsycINFO, Pubmed and Scopus identified 11 independent randomised controlled trials, involving a pooled sample of 1141 young people (age range 17.9 to 26.3). The reporting quality of studies was evaluated using the Cochrane Risk of Bias Tool 2.0 (RoB 2.0). Hedges' *g* effect sizes were calculated, along with 95% confidence intervals, *p* values and heterogeneity statistics using a random effects model.

Results: Medium to large significant improvements in depression symptom severity were noted immediately post-intervention (g_{range} = 0.43 1.48, CI: 0.12 to 0.59). Apps targeting self-harming behaviours and/or suicidal ideation symptoms also demonstrated positive, albeit preliminary, findings ($N_{studies}$ = 2). Treatment gains were maintained at 4-week follow up for both depression (*g* = 0.55, CI: 0.22-0.88, *p* = <0.01; *g* = 0.48, CI: 0.14-0.82, *p* = <0.01) and suicidal ideation (*g* = 0.42, CI: 0.08-0.77, *p* = 0.01).

Discussion: There remains a significant gap between the large number of apps available to consumers and the high-quality trials needed to prove their efficacy. Large-scale controlled trials are needed to establish a stronger evidence base for app-based interventions and to translate promising research evidence to clinical practice.

Keywords: Apps, youth, technology, smartphone, depression, self-harm, NSSI, suicidal

Introduction

Depressive disorders account for the greatest global burden of disease among young people aged 10-24: up to 25% are diagnosed with Major Depressive Disorder (MDD) before they reach 18 years of age.[1] Moreover, approximately 20% of youth with depressive symptoms, who do not meet full diagnostic criteria for MDD, present to primary care with clinically significant symptoms and functional impairment.[2 4] Concerningly, depressive disorder and symptoms can both lead to an increased risk for non-suicidal self-harm and suicidal ideation.[5]

Self-harm, or the direct and deliberate intention to self-poison or self-injure, is used by young people primarily as a way to regulate their emotions, communicate their pain, or self-punish, and may or may not include suicidal intent.[6,7] A broader definition of self-harm includes those who inflict harm to the self without the intention to die also referred to as Non-Suicidal Self-Injury (NSSI).[8] Self-harming thoughts and behaviour become established during young adolescence (12-16 years)[9], with lifetime prevalence estimated to be as high as 46% among community groups and 80% among outpatients.[10 12]

Without treatment, NSSI can evolve towards suicide ideation and attempts.[13] Indeed, up to 30% of those aged 12-20 years have experienced the belief that life is not worth living while 20% have thought about suicide in the past year.[14] These beliefs can range from fleeting, self-destructive thoughts to well-considered plans for a suicide attempt.[15] When combined with self-harm, the transition from suicidal ideation to action becomes more likely: 1 in 5 (21%) adolescents who report both suicidal thoughts and self-harm will make a future suicide attempt.[16]

Depression, self-harm and suicide ideation are, therefore, important issues for adolescent mental health care. Despite this need, young people are reported to have the worst service access of any age group.[17] On an international scale, less than 40% of adolescents struggling with a mental health problem will be detected by a health service.[18] Similar trends have been reported in Australia: only one third of young persons with a mental health disorder seek formal support from a mental health professional.[19] Concerningly, as suicidal ideation increases in youth, intention to seek help decreases.[20,21]

A number of barriers impede help-seeking in this population. In particular, attitudinal beliefs that mental health treatment is unnecessary, or will be ineffective, are prominent.[22] Young people may also experience shame and perceived stigma in regard to their self-harming behaviour.[22] Structural barriers, including transport and access issues - particularly in rural and remote populations, alongside service cost and competing time commitments have also been noted.[23 25] Consequently, many young people are reluctant, or unable, to seek traditional in-person mental health care.

Internet and communications technology can help transcend the aforementioned barriers that many young people associate with in-person mental health care. Preliminary findings in this area are promising, with significant and immediate reductions in depression severity scores reported by adolescents and young people (10-24 years) enrolled in web-based cognitive behavioural interventions - although longer-term effects remain to be determined.[26] The potential effectiveness of online and social media-based interventions for young people with suicidal thoughts and behaviours has also been demonstrated.[27,28]

The success of web-based approaches has led to research examining the feasibility and effectiveness of emerging mobile telephone applications or 'apps' as an alternative platform for mental health care delivery. Not only do mobile apps have significant reach, they are accessible by the user on a range of handheld devices (e.g., iPhone, android-based smartphone), and do not rely on the synchronous availability of a mental health professional.[29] Apps have clinical advantages, as both stand-alone self-management tools and adjunctive treatments.[30] With over 5 billion people having a mobile device, and over 10,000 mental health apps being available for download, mobile phone apps can help expand the general public's access to low-cost, quality mental health care.[31,32]

Despite this promise, the quality of available mental health apps has been questioned. Indeed, a large number of apps may not be appropriately designed to suit youth and young adults at their stage of development.[30] This can lead to high rates of disengagement, particularly if the app content is not relatable to the target group.[33] Concerningly, many apps also do not have peer-reviewed research to support their claims of efficacy and may even contain content that can be harmful for the user.[34 37] Of the estimated 10,000 to 20,000 mental health apps available for download, is it suggested that only 3-4% of them incorporate well-established, evidence-based therapeutic frameworks, such as Cognitive Behavioural Therapy (CBT), Acceptance and Commitment Therapy (ACT) and Mindfulness Based Cognitive Therapy (MBCT). [30,34]

Notably, narrative, systematic and quantitative reviews in this area have relied on single group or non-randomized study designs to draw their conclusions.[22,30,38] These designs can lead to inflated effect size estimates and limit a study's ability to draw a causal association between an intervention and an outcome.[39] Furthermore, these

reviews have often included different depressed subpopulations with specific health care needs (e.g. depressed people with chronic illness),[40] various age ranges (15 to 50 years),[22,38] or have examined all web modalities (e.g. internet and mobile phone-based;),[41,42] thereby limiting conclusions to be drawn in relation to app-based interventions for young people, specifically.

The current paper provides an updated, systematic review of mobile phone applications to manage and/or treat symptoms of depression, self-harm and suicidal ideation in young people. With more than 200 new health apps emerging daily,[43] it is important that this literature be frequently reviewed so that consumers and health care professionals can make informed decisions about the use of mobile phone apps in mental health care. The specific aims are to: (1) describe the characteristics of mobile apps targeted to young people; (2) assess the quality of the available literature; and (3) assess both short (pre-post intervention) and longer-term (pre-intervention to follow-up) effectiveness of mobile apps, in comparison to usual care, inactive apps or wait-list control.

Methods

Literature search

The Embase, Cochrane Library, PsycINFO, Pubmed and Scopus databases were searched to identify eligible peer-reviewed articles, from database inception to March 5th, 2020, with email alerts established for each database until April 1st, 2020. A broad search of the Google Scholar web search engine was additionally undertaken using specific key terms ('app', 'depression', 'self-injury'). Search terms were developed with the assistance of an expert research librarian and included a combination of keywords

related to the *population* ('young people'), *intervention* ('app-based'), and *outcomes* of interest ('depression', 'suicidal ideation', 'self-injury'; see Appendix A for complete electronic search strategy). The references of systematic reviews and meta-analyses of psychotherapy studies in the broader internet-technology field were additionally examined to identify records that may have been missed in the electronic database searching (reviews by Arshad,[38] Huguet,[44] Perry [41] and Valimaki[42]). Finally, included studies were examined via Scopus citation searching, to identify any related articles, although no new additional studies were found.

Study eligibility

Eligible studies were screened using Covidence software for systematic reviews.[45] Consistent with the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA),[46] a second reviewer, a postgraduate psychology student (JB), checked a random selection of 100 (33%) potentially eligible articles. Good inter-rater agreement was demonstrated (97.25%, kappa = 0.84). Studies were deemed eligible if they met the following *Population, Intervention, Comparison, Outcome* (PICO) and *Design* criteria:

Population. The sample comprised of young people, aged between 12 and 25 years. In the absence of a targeted age range, studies were included if the mean age minus 3 standard deviations was $\leq$ 25 years (i.e. 'Three Sigma Rule', which assumes that 99.7% of data under a normal curve falls within 3 SDs of the mean).[47]

Intervention. Studies needed to evaluate an app-based intervention that could be accessed using a technological device (i.e. smart phone, tablet). Apps are characterised

by their portable accessibility and the features which allow them to store, organise and retrieve user inputs, as well as push notifications, even when the app is not running.[48] Studies were excluded if they examined a multi-component intervention, whereby the app intervention was used as an adjunct to face-to-face psychotherapy or web-based support not specifically designed for an app (e.g. emails, text-messaging).

Comparison. To be eligible, studies had to include a control condition, whether an active control - in which participants engaged in some task during the study period (e.g., self-monitoring of symptoms, psychoeducation), or an inactive group (e.g., wait-list with no treatment).

Outcome. Studies had to administer a validated self-report or clinician-administered measure of depression (defined as depressed affect or psychological distress), suicidal ideation (with or without suicidal intent), or self-harming behaviour (i.e., measures of NSSI) prior to and post-intervention. Studies that only screened for one or more of the aforementioned outcomes during the participant recruitment process but did not evaluate an app intervention targeting these outcomes, were ineligible.

Design. The database searches were limited to journal articles published in the English language, or with English translation. Study protocols, book chapters, grey literature (dissertations, conferencing proceedings) were excluded, as the focus was on original research that had been peer-reviewed. Only randomised controlled trials (RCTs), a methodological design considered to contribute to a higher quality of evidence,[49] were eligible.

Evaluation of study reporting quality

The quality of included trials was assessed using the Cochrane Risk of Bias Tool (RoB 2.0).[49] The ROB 2.0 uses pre-specified criteria (see Appendix B) to assess five sources of methodological bias seen in randomized controlled trials: 1) bias in the randomisation process (resulting in different baseline characteristics between groups); 2) deviations from the intended intervention (including poor adherence, intervention implementation and/or use of co-occurring interventions); 3) missing outcome data; 4) bias in measurement of the outcome (with self-reported outcomes being prone to bias); and 5) selective reporting of significant results. For each domain, each study is rated as having 'low risk', 'some concerns' or 'high risk'. An overall rating or 'low' (i.e., low risk of bias across all domains), 'some concerns' (i.e. bias in at least one domain - but not a high-risk) and 'high' (i.e., a high risk of bias in at least one domain, or concerns in multiple domains) was also assigned to each study. Risk of bias ratings were conducted by the author and discussed with a senior researcher.

Data collection

A purposely developed Microsoft Excel spreadsheet was used to extract relevant information from each study. Extracted data included: a) sample descriptives (e.g. size, mean age, gender); b) study characteristics (e.g., primary and secondary outcome measures); c) intervention features (e.g., app name, duration of app use, intervention framework, control condition); and d) effect size data for individual measures of depression, self-harm and suicidal ideation (i.e., mean pre- and post-intervention scores and SDs for the 'app' and control groups). Data extraction was conducted by the author and double-checked by a second researcher.

Statistical analyses

Effect size data were entered into Comprehensive Meta-analysis Version 3.0 (CMA 3.0).[50] Hedges' g, which corrects for biases due to smaller sample sizes, was used to represent standardised group mean differences.[51] To calculate between group mean differences (g) a pre-post correlation is required. As studies did not provide this information, an estimate of .77 was used based on established test-retest reliability values for the individual measures used by studies in this review. The direction of each effect size was standardised so that a positive g reflected greater improvement (i.e. reduction in symptom severity) among participants that accessed an app intervention. Hedges' g was interpreted according to Cohen's guidelines, with values of 0.2, 0.5 and 0.8 reflecting small, medium and large intervention effects.[52] To determine the precision of g, 95% confidence intervals were calculated, with (p) values then used to determine statistical significance.

Individual effect sizes were grouped by the construct they represented (depression, suicidal ideation, self-harm) and pooled. Before being pooled, each g was weighted by that study's inverse variance (g_w). Where studies provided multiple effect estimates per construct (e.g., use of multiple control conditions), effect sizes were averaged beforehand to ensure that data were independent.[53] As considerable heterogeneity was expected, a random effects model was utilised. Heterogeneity was interpreted based on the I^2 statistic, which represents the overall percentage of between-study variance,[54] and tau - or the SD of a mean effect.[50]

To address potential publication bias, fail-safe N's (N_{fs}) were calculated. This estimated the likelihood of overestimating a treatment effect due to a bias towards publishing studies that report significant results.[55] The N_{fs} reflects the hypothetical number of unpublished or unidentified studies reporting no effect which would need to

exist to render a calculated effect size as meaningless (i.e., $g < 0.2$).[56] The higher the N_{fs} value, the more robust the result.

Results

Study selection

As shown in the PRISMA flow chart (Figure 1), 1515 potentially relevant records were retrieved upon initial database searching. Of these, 403 duplicates were removed, and 810 off-topic records (i.e. not app-based intervention, did not examine target sample or outcomes of interest) were excluded, based on title and abstract screening. A further 302 full-text records were re-assessed for eligibility, with a final sample of 11 independent RCTs identified for inclusion. The single article by Franklin and colleagues contained three independent studies with no sample overlap, all assessing the effectiveness of the *Therapeutic Evaluative Conditioning (TEC)* app.[57]

Study characteristics

The majority of published studies included in this review originated from the United States ($N_{studies}$=4) and Australia ($N_{studies}$=2), with single studies from New Zealand, Korea and Canada (see Table 1). All utilised an independents groups design, with one study comparing two guided meditation and mindfulness apps, *HeadSpace* and *Smiling Mind* with the same active control condition: a note-taking app, *Evernote*.[58]

Seven well-validated measures of depression symptom severity were used, most commonly the Patient Health Questionnaire-9 (PHQ-9),[59 61] and Centre for Epidemiological Studies Depression Scale (CES-D).[58, 62] Motter[63] incorporated a clinician-administered measure, the Hamilton Depression Rating Scale (HDRS).[64] Self-

harm and suicidal ideation were assessed using either the 4-item Depressive Symptom Inventory Suicidality Subscale (DSI-SS),[61,65] designed to identify the frequency and intensity of suicidal ideation in the previous week, or The Self-Injurious Thoughts and Behaviors Interview (SITBI).[57,66] The SITBI is a structured clinical interview applied in both school-based and clinical samples that assesses the whole spectrum of self-injurious thoughts and behaviours - including suicidal ideation and non-suicidal self-injury (NSSI).[66,67]

Of the eight active control groups used by studies in this review, seven involved an app-based condition. Specifically, Franklin[57] and Kauer[68] removed the treatment components for their respective interventions but still required participants to use features of their app for 4 weeks. Kauer[68] additionally imposed a frequency of 2 sessions (or 'entries') per day for their control group, with participants monitoring themselves using an abbreviated version of the *MobileType* program to assess current activities, location, companions, quality and quantity of sleep, quantity and type of exercise, and diet. Motter[63] also asked their intervention and control participants to use the same app, *Peak,* each weekday for 8 weeks. However, the content of the cognitive rehabilitation modules differed, with the control group receiving content focused on promoting verbal-ability whereas the intervention group received content focused on executive functioning and processing speed. Control participants in the Hur[69] study used a daily chart app to record their mood state and sleep quality/quantity over a 3-week period, whereas Flett[58] instructed their control group to download a note-taking app, *Evernote,* to write in everything they could remember doing in the previous week, for 10 minutes each day. Fitzpatrick[60] was the only study without an app-based control condition, instead providing participants an eBook developed by the National Institute of Mental Health on *Depression in College Students.* The remaining three studies used a

wait-list control condition, whereby controls were given access to the app on study completion.[61,70,71]

Sample characteristics

The 11 RCTs comprised a total sample of 1141 participants, the majority of which were female university students (68.7%, $N_{participants}$ = 784) with an average age of 22 years (SD = 4.29). Franklin[57] recruited exclusively via web forums specific to self-harm and psychopathology, while Kauer[68] based their community sample on referrals from General Practitioners and Tighe[61] recruited by word-of-mouth, via an Indigenous health professional or mainstream mental health service. This targeted recruitment was supplemented with self-referral, which studies promoted through online advertisements, posters and flyers.

Each study targeted their app intervention for participants with depression, although symptom severity varied. Four studies described their participants as experiencing mild to moderate symptoms,[68 71] while three exclusively focused on those with moderate to severe depression.[60, 61, 63] The single article that measured self-harm and suicidal ideation recruited participants with recent and severe histories of self-injurious thoughts and behaviours.[57]

Study reporting quality

Overall reporting quality based on the Cochrane Risk of Bias tool (RoB 2.0)[72] was satisfactory, with most (90.9%) studies rated as having 'some concern' across particular domains - but none categorised as 'high risk' (See Figures 2 and 3 for between and within-group ratings). More specifically, computerised methods to randomise

participants to an app intervention or control group were detailed (Criterion 1). Studies rated as 'low risk' on this domain used the same app interface for both the intervention and control group, thereby minimising the risk of group allocation being detected.[73] Although researchers were not blinded to the intervention condition,[60,70] there was no evidence to suggest that this had caused a deviation from the intended outcome, hence all studies were categorised as 'low risk' on Criterion 2. Reasons for missing outcome data (i.e., study withdrawals) were reported and statistical analyses to minimise potential attrition bias used (i.e., listwise deletion, intent-to-treat analyses; Criterion 3). The reliance on self-reported data may have contributed to some concerns in the measurement of outcomes (Criterion 4), however all measures were valid and reliable, as per the criteria stipulated this review. Finally, only three studies pre-registered their trial protocols to minimise selective reporting of results (Criterion 5).

Characteristics of App-based Interventions

The majority of the included interventions required participants to engage with the app over a period of four weeks.[57,68,70,71] Relatively brief interventions lasted between 10 days to 3 weeks,[58,60,69] with two interventions involving app participation over a 6 to 8-week period.[61,63] Studies expected participants to engage in a set amount of 'sessions' or 'entries' within the app - ranging from one session per day[58,71] to 2-3 times per day[60,68,69] or 5 days per week.[63,70] Franklin[57] did not impose frequency of time and usage, in an attempt to mimic real world usage of the app, while Tighe[61] expected participants to progress through the app content unprompted.

Therapeutic content within the app-based interventions were guided by evidence-based principles and techniques, namely Cognitive Behavioural Therapy

(CBT) including third wave therapies,[57, 58, 60, 61, 69 71] cognitive rehabilitation[63], and Emotional Self-Awareness (ESA).[68] Key treatment components included psychoeducation, guided meditation and breathing exercises.[58,60,70,71] Self-monitoring of mood and/or dysfunctional thoughts was also a consistently included across apps. For example, the *Woebot* app used an automated conversational agent to prompt mood and cognition monitoring,[60] whereas the *Todac Todac* app contained educational scenarios and pre-programmed advice for cognitive or mood distortions.[69] The *iBobbly* app taught participants how to identify and defuse from their thoughts, with valued activity prompts.[61] The *Peak* app was unique in that it examined whether cognitive tasks of processing speed and executive functioning would reduce depression over an 8-week period.[63] Finally, game-like features - including increasingly challenging trials with points awarded for faster and more accurate performance, were a feature of the *Therapeutic Evaluative Conditioning (TEC)* app. Here, participants were required to match images of positive, neutral or aversive stimuli in order to increase aversion to self-injurious thoughts and behaviours and decrease aversion to the self.[57]

All of the app-based interventions were designed as stand-alone treatments. As a result, participants did not need to rely on the synchronous availability of a mental health professional and could access the app at their own convenience. Data pertaining to app adherence was primarily self-reported and indicated good adherence. The dropout rate across all studies was a relatively low 16%, with Franklin[57] indicating that up to 91% of their participants accessed the *TEC* app at least once. Usage of mindfulness apps was also high: *Smiling Mind* and *Headspace* were accessed by participants at least 8 of the 10 study days,[58] while the mean adherence rating for *DeStressify* was 8 out of 10,[70] and all participants accessed *Stop Breathe Think* at least once over a 7-day period.[71] In regard to 'session' engagement, participants using the

Woebot app engaged with the conversational agent an average of 12 times over a 2-week period,[60] while participants using *MobileType* completed on average of 3 entries each day over 4 weeks.[68] However, mean cognitive training time on the *Peak* app was 363 minutes for the verbal control group and 168 minutes for the intervention group: the control group demonstrated significantly higher engagement with this particular app.

Intervention effectiveness

Depression. Of the nine app-based interventions that targeted depression symptoms, six were associated with significant, moderate to large effects in favour of the app. The pooled mean effect was medium, statistically significant and robust *($N_{fs} > N_{studies}$;* Table 2): app participants reported improved mood in comparison to controls. There was, however, some inconsistency in the effect sizes reported by individual studies (I^2 > 60%). The largest group differences were noted by studies that compared mindfulness (*Stop, Breathe and Think*) or an ACT-based app (*iBobbly*) with wait-list controls.[61,71] Commercially available apps (*Smiling Mind, Headspace*) produced favourable results in comparison to standard care or psychoeducation,[58] as did a CBT-based fully automated and conversational app, *Woebot.*[60]

Two studies examined treatment effects at 4 to 6-week follow-up, with one reporting significant effects (Table 3). Participants who accessed *Smiling Mind* or *Headspace* continued to report medium to large improvements in their mood. However, Motter[63] reported similar group treatment effects: depressive symptoms decreased for both their app-based cognitive training group (*Peak* app) and a control group who used the same app on a less frequent basis.

Self-harm. Three RCTs undertaken by Franklin[57] evaluated the same game-like app, *TEC*, for young adults with a history of self-cutting (Table 2). Similar treatment effects were reported by intervention participants and peers who accessed the app game, but not its treatment features. In two of the three studies, app participants reported fewer NSSI episodes during the treatment month than controls, however these findings did not reach significance. Group differences were also comparable at 4-week follow-up (Table 3). Further research is needed to confirm these findings (i.e., very low N_{fs}).

Suicidal ideation. Two studies, involving four RCTs and producing four effect sizes, examined app-based treatment effects on suicidal ideation.[57,61] The pooled effect size was small and non-significant: those who accessed either the *TEC* or *iBobbly* apps reported no significant changes immediately post-intervention, compared to peers who accessed a control version of the app,[57] or those who were wait-listed.[61] Significant treatment gains with the *TEC* app were, however, noted at follow-up (Table 3).[57] These findings may, however, be characterised by publication bias.

Discussion

The current meta-analysis examined the effectiveness of app-based interventions for depression, self-harm and suicidal ideation in young people. Of the 9 eligible articles, outlining 11 RCTs, six reported significant and positive effects with their app interventions in the short-term. Although follow-up data were limited, two of five studies reported continued gains at 4 weeks post-intervention.[57,61] Importantly, studies minimised their risk of bias by reporting adequate methodological details. While these findings require replication with larger samples, preliminary data suggests that app-

based interventions are a promising approach for young people experiencing depression.

Notably, the largest treatment effects were associated with depression: the symptom typically targeted. Pooled effects were not significant for self-harm and suicidal ideation, although individual studies reported promising findings.[57] The discrepancy noted between these treatment outcomes supports the notion that whilst depression and suicidal behaviours share latent risks, they are relatively independent constructs.[74,75] Indeed, previous research has noted that interventions which yield significant effects on depression, such as CBT, may not be as effective in the treatment of suicidal thoughts and behaviours.[76] Notably, the two apps targeting self-harm and/or suicidal ideation in the present review *TEC* and *iBobbly*, did not include components of Dialectical Behavioural Therapy (DBT) - such as skills training, problem-solving and mindful awareness - which have been promoted as highly effective in the treatment of self-harm and suicidal ideation in youth.[77 79] To date, however, evidence for the efficacy of digital interventions targeting self-harming behaviours remains limited.[22,38] Despite this, commercially available DBT-based apps may hold some promise. This includes the popular clinician-developed app targeted to young people, aged 13 and above - *Calm Harm*. App analytics indicate that *Calm Harm* has been downloaded close to one million times and 93% of users (*N*= 476,723) have self-reported a reduction in the urge to self-harm after completing an activity on the app.[80] However, *Calm Harm* is yet to undergo research scrutiny.

The reliance on self-guided app-based interventions in this review may also explain the non-significant, pooled treatment effects noted for suicidal ideation and self-harm. Perhaps self-guided interventions are not clinically viable for youth with complex clinical presentations. Rather, clinician-guided digital interventions - which

have produced very large and positive effects for adult anxiety may be appropriate.[81,82] In this instance, a mental health professional, who can monitor progress and provide additional support, is available over the app. Future research might therefore explore how to effectively integrate apps as an adjunct to evidence-based treatment, given the promising effects reported by interventions that have blended face-to-face with internet-based psychotherapy.[83,84] Another element of treatment engagement worthy of further investigation, yet relatively understudied in adolescent mental health treatment, is that of parent participation. In particular, concurrent parent-child mindfulness training delivered via technology has demonstrated reciprocal improvements to the mental health of both.[85] Future research might therefore consider how parents can best support at risk adolescents using apps for their mental health.

Importantly, the present results highlight the feasibility of app-based interventions which were typically brief in duration. That is, treatment gains were reported within a relatively short time frame: ranging from 10 days to 6 weeks. In addition, there was ease of accessibility, with potential for participants to access their self-guided apps daily, at their own convenience. These figures are in contrast to conventional face-to-face CBT, which is typically limited to a single weekly session for one hour.[86]

Young people also demonstrated reasonable adherence with their respective app and appeared to engage well with the therapeutic material, as suggested by self-reported app usage. The efficacy of an app is dependent on the long-term adherence.[87] It is, however, possible that some participants miscalculated their app usage or responded in a way that would be considered socially acceptable. In either case, the risk of social desirability and recall bias with self-reported data is high.[88] Future studies

might consider objective assessments of app usage to supplement self-reported data, such as tracking the average number of interactions with the app and/or length of time using the app.[89,90] An objective approach to data collection regarding user engagement and adherence would also allow comparison of results across studies, including the features associated with higher user engagement.[90]

Methodological limitations

The current findings need to be considered in the context of several methodological limitations encountered in this review. First, the small number of included studies prevented subgroup analyses in order to better understand possible causes of heterogeneity in effects, particularly for apps targeting self-harm and/or suicidal ideation. This included variability across the included studies in regard to the control group used and duration. The use of different control conditions has been shown to impact on the magnitude of the treatment effect associated with psychosocial interventions for depression - with the largest treatment effects identified by studies that use a wait-list control.[91] Similarly, larger effect sizes were associated with apps such as *iBobbly* and *Woebot*, which involved longer and/or more frequent use, suggestive of a 'dose-response' effect. There is evidence that digital intervention users who complete a higher number of activities per log-in, report greater treatment effects in comparison to peers with a lower number of logins.[92]

Third, the majority of studies relied on self-referral, thereby limiting the generalisability of the findings in this review to the broader population of young adults. Participants who self-refer may be more motivated or open to treatment and therefore experience greater benefits.[93] Sample characteristics of the included studies may also limit the generalisability of the findings in this review. Studies typically included an

'engaged' group of females with tertiary qualifications and mild to moderate depressive symptoms. Conclusions cannot, therefore, be drawn regarding the effectiveness of these apps for males, those of low socioeconomic backgrounds or more severe and complex clinical presentations; key factors that not only shape mental health but also treatment response.[94,95] Finally, it is possible that a degree of publication and/or language bias may have arisen due to the present review's inclusion criteria: English language articles exclusively published in peer reviewed journals. It should be noted, though, that the rigour of systematic reviews lies in their meticulous and reproducible approach, which may be weakened by the inclusion of grey literature.[96]

Conclusion

Although in their infancy, the current review demonstrates the effectiveness of self-guided app-based interventions for young people experiencing symptoms of depression. Longitudinal research is needed to determine app adherence over time and whether treatment effects are maintained once the intervention ceases before app-based interventions can be readily integrated and promoted within healthcare systems. Clinicians and researchers may need to consider guided interventions in order to increase engagement and treatment effectiveness, particularly for more complex presentations of depression in youth. Further improvements in the technological or persuasive design of the app may also encourage adherence and, ultimately, contribute to widespread uptake with population impact.

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None declared.

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Tables

Table 1. Study characteristics

Lead author (year)	Country	Target Outcome	Total N [I C]	Mean age (SD) years	App based Intervention						
					App name(s)	Framework	Control	Duration (weeks/sessions)	Outcome measure(s)	Dropout (%)	Follow up
Fitzpatrick (2017)	USA	Depression	70 [34 36]	22.2 (2.33)	Woebot	CBT	Psychoeducation	2 weeks 20 sessions	PHQ 9	17.1%	
Flett (2019)	New Zealand	Depression	210 [72 73] 210 [63 73]	20.1 (2.8)	Headspace & Smiling Mind	Mindfulness	Evernote app	10 minutes daily 10 days	CES D	7.7%	40 days
Franklin (2016) Study 1	USA	Self harm & suicidal ideation	114 [59 55]	23.02 (5.5)	Therapeutic Evaluative Conditioning (TEC)	Behavioral conditioning	Alternate version of TEC	4 weeks	SITBI	13.5%	
Franklin (2016) Study 2			131 [62 69]	22.9 (5.0)						9.1%	
Franklin (2016) Study 3			163 [78 85]	24.5 (6.6)						15.5%	
Hur (2018)	Korea	Depression	48 [24 24]	23.7 (3.3)	Todac Todac	CBT	Daily mood chart	3 weeks 3 sessions daily	BDI II	20.8%	
Kauer (2012)	Australia	Depression	114 [68 46]	17.9 (3.2)	MobileType	Emotional Self Awareness	Alternate version of MobileType	4 weeks 2 entries per day	DASS D	14.9%	6 weeks
Lee (2018)	Canada	Depression	163 [77 86]	20.6 ( )	DeStressify	Mindfulness	Wait list	4 weeks 5 days per week	QIDS SR	20.8%	
Levin (2020)	USA	Depression	23 [10 13]	20.4 (2.5)	Stop, Breathe and Think	Mindfulness	Wait list	4 weeks	CCAPS 34	30.4%	
Motter (2018)	USA	Depression	46	21 (3.7)	Peak	Cognitive Training	Alternate version of Peak (verbal)	8 weeks 5 days per week	HDRS	23.9%	
Tighe (2017)	Australia	Suicidal ideation & depression	61 [31 30]	26.3 (8.1)	iBobbly	ACT	Wait list	6 weeks	DSI SS PHQ 9	3.2%	

Abbrev at ons: Tota N: Number of part c pants a ocated to groups at base ne, : ntervent on group, C: contro group, C T: Cogn t ve ehav oura Therapy; ACT: Acceptance Comm tment Therapy; P Q-9: Pat ent ea th Quest onna re-9; CES-D: Centre for Ep dem o og c Stud es Depress on Sca e; D - : eck Depress on nventory- ; DASS-D: Depress on Anx ety Stress Sca es – Depress on Subsca e; Q DS-SR: The Qu ck nventory of Depress ve Symptomo ogy- Se f Report; CCAPS-D: Counse ng Centre Assessment of Psycho og ca Symptoms – Depress on Subsca e; DRS: am ton Depress on Rat ng Sca e; S T : Se f- n ur ous Thoughts and ehav ors nterv ew; DS -SS: Depress ve Symptom nventory - Su c da ty Subsca e, -) data not prov ded

Table 2. Short-term treatment effects of app-based intervention across individual outcomes

Construct	Control	Measure	App name(s)	$N_{participants}$	g	95% CI		p	N_{fs}	I^2	Tau	Lead author (date)	
						Lower	Upper						
Depression	Active	PHQ 9	Woebot	70	0.92	0.43	1.40	<0.01	4			Fitzpatrick (2017)	
	Active	CES D	Headspace	210	0.69	0.36	1.02	<0.01	2			Flett (2019)	
	Active	CES D	Smiling Mind	210	0.63	0.28	0.97	<0.01	2			Flett (2019)	
	Active	BDI II	Todac Todac	48	0.49	0.16	1.16	0.14	1			Hur (2018)	
	Active	DASS D	MobileType	114	0.01	0.36	0.39	0.94	0			Kauer (2012)	
	Wait list	QIDS SR	DeStressify	163	0.43	0.12	0.74	0.01	1			Lee (2018)	
	Wait list	CCAPS D	Stop, Breathe and Think	23	1.48	0.58	2.39	<0.01	6			Levin (2020)	
	Active	HDRS	Peak	46	0.00	0.57	0.57	1.00	0			Motter (2018)	
	Wait list	PHQ 9	iBobbly	61	1.13	0.59	1.66	<0.01	5			Tighe (2017)	
	Total g_w			945	0.59	0.33	0.85	<0.01	18	66.44	.31		
Self harm	Active	SITBI	Therapeutic Evaluative Conditioning (TEC)	114	0.16	0.20	0.52	0.38	0			Franklin (2016)	Study 1
	Active	SITBI		131	0.01	0.32	0.35	0.94	0			Franklin (2016)	Study 2
	Active	SITBI		163	0.03	0.33	0.28	0.86	0			Franklin (2016)	Study 3
	Total g_w			408	0.04	0.15	0.23	0.68	2	0	0		
Suicidal ideation	Active	SITBI	Therapeutic Evaluative Conditioning (TEC)	114	0.01	0.34	0.38	0.92	0			Franklin (2016)	Study 1
	Active	SITBI		131	0.30	0.03	0.65	0.07	1			Franklin (2016)	Study 2
	Active	SITBI		163	0.21	0.09	0.52	0.18	0			Franklin (2016)	Study 3
	Wait list	DSI SS	iBobbly	61	0.29	0.20	0.79	0.25	0			Tighe (2017)	
	Total g_w			469	0.20	0.02	0.38	0.15	0	0	0		

Abbrev at ons: $N_{participants}$ = number of part c pants prov d ng these data; g = edges' g effect s ze est mate w th 95% conf dence m ts); p = s gn f cance va ue for g/g_w N_{fs} = fa -safe N stat st c; P Q-9: Pat ent ea th Quest onna re-9; CES-D: Centre for Ep dem o og c Stud es Depress on Sca e; D - : eck Depress on nventory- ; DASS-D: Depress on Anx ety Stress Sca es – Depress on Subsca e; Q DS-SR: The Qu ck nventory of Depress ve Symptomo ogy- Se f Report; CCAPS-D: Counse ng Centre Assessment of Psycho og ca Symptoms – Depress on Subsca e; DRS: am ton Depress on Rat ng Sca e; S T : Se f- n ur ous Thoughts and ehav ors nterv ew; DS -SS: Depress ve Symptom nventory - Su c da ty Subsca e

Table 3. Long- term treatment effects of app-based intervention across individual outcomes

Construct	Control	Measure	App name(s)	$N_{participants}$	Follow up	g	95% CI		p	N_{fs}	I^2	Tau	Lead author (date)	
							Lower	Upper						
Depression	Active	CES D	Headspace	210	4 weeks	0.55	0.22	0.88	<0.01	2			Flett (2019)	
	Active	CES D	Smiling Mind	210	4 weeks	0.48	0.14	0.82	<0.01	1			Flett (2019)	
	Active	DASS D	MobileType	114	6 weeks	0.00	0.37	0.37	1.00	1			Kauer (2012)	
	Total g_w			534		0.28	0.22	0.79	0.27	1	81.01	.33		
Self harm	Active	SITBI	Therapeutic Evaluative Conditioning (TEC)	114	4 weeks	0.27	0.09	0.63	0.14	0			Franklin (2016)	Study 1
	Active	SITBI		131	4 weeks	0.01	0.32	0.35	0.92	1			Franklin (2016)	Study 2
	Active	SITBI		163	4 weeks	0.16	0.14	0.47	0.28	0			Franklin (2016)	Study 3
	Total g_w			408		0.14	0.04	0.34	0.13	1	0	0		
Suicidal ideation	Active	SITBI	Therapeutic Evaluative Conditioning (TEC)	114	4 weeks	0.19	0.17	0.55	0.30	1			Franklin (2016)	Study 1
	Active	SITBI		131	4 weeks	0.42	0.08	0.77	0.01	1			Franklin (2016)	Study 2
	Active	SITBI		163	4 weeks	0.02	0.28	0.33	0.88	1			Franklin (2016)	Study 3
	Total g_w			408		0.20	0.03	0.44	0.08	0	31.16	.11		

Abbrev at ons: $N_{participants}$ = number of part c pants prov d ng these data; g = edges' g effect s ze est mate w th 95% conf dence m ts); p = s gn f cance va ue for g/g_w N_{fs} = fa -safe N stat st c; CES-D: Centre for Ep dem o og c Stud es Depress on Sca e; DASS-D: Depress on Anx ety Stress Sca es – Depress on Subsca e; S T : Se f- n ur ous Thoughts and ehav ors nterv ew; DS -SS: Depress ve Symptom nventory - Su c da ty Subsca e

Figures

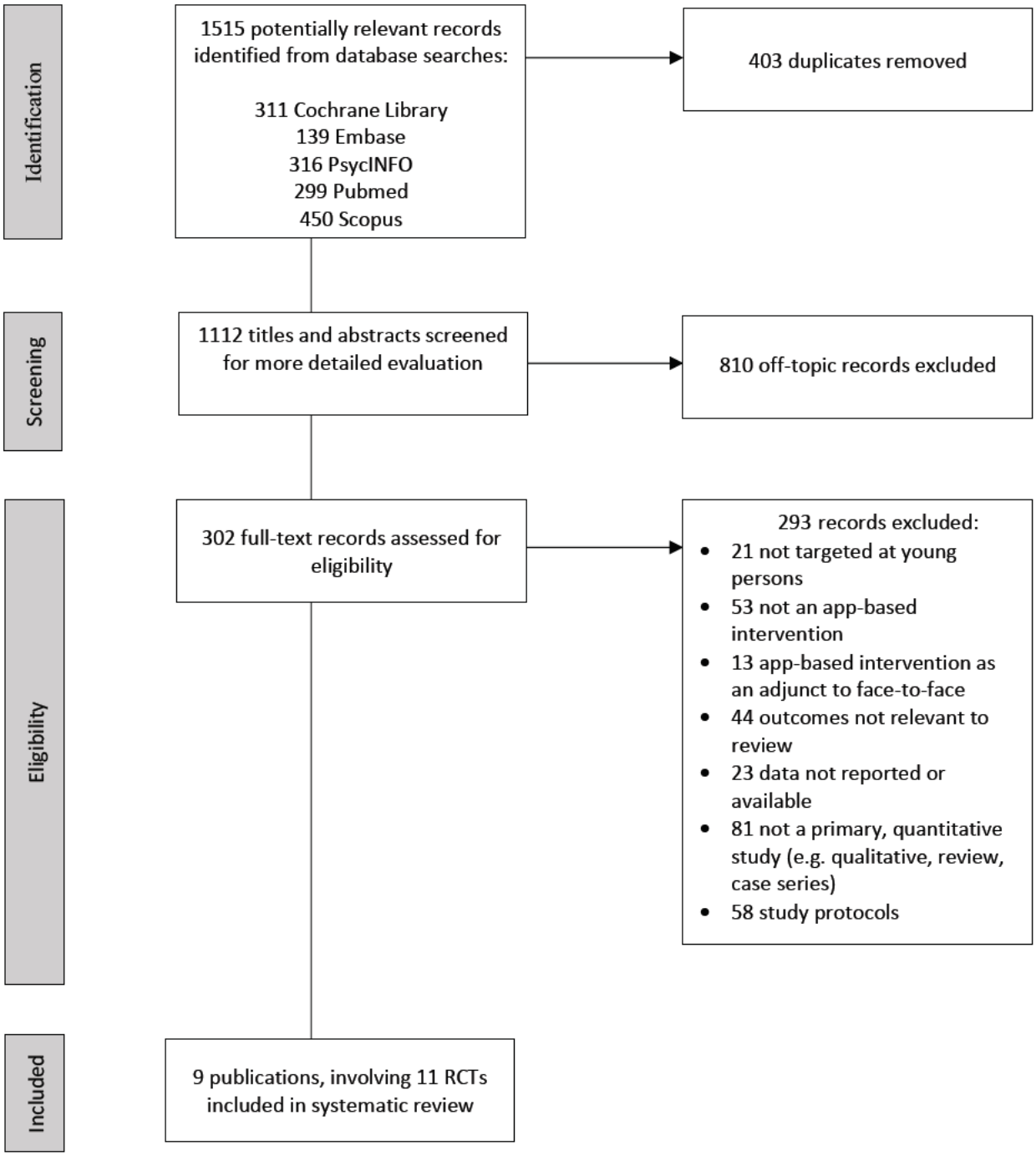

Figure 1. PRISMA flow diagram outlining study selection process[46]

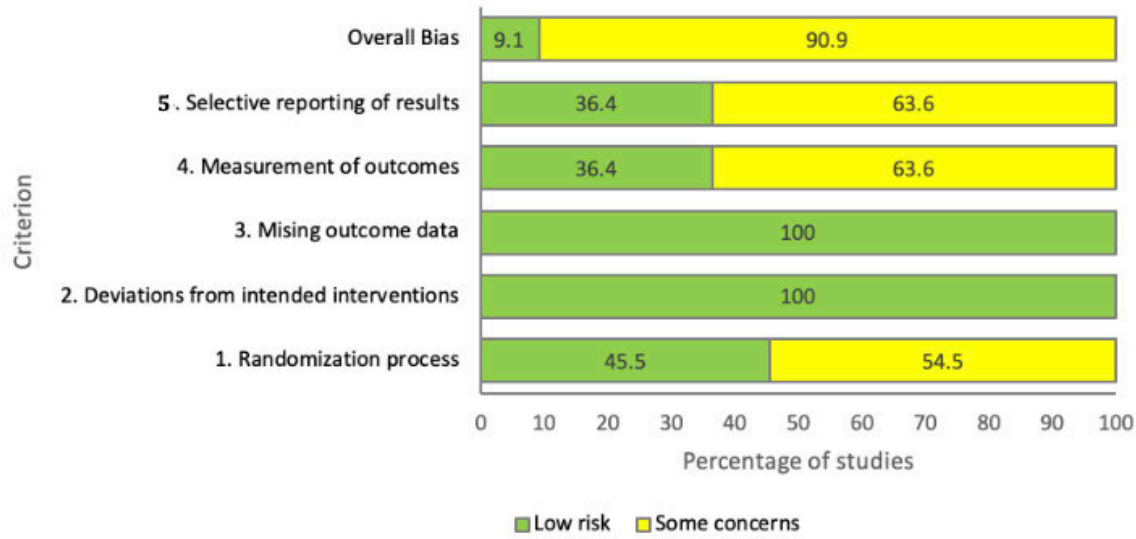

Figure 2. Rob 2.0 ratings across studies

Lead author (date)	1. Randomisation process	2. Deviations from intended interventions	3. Missing outcome data	4. Measurement of outcomes	5. Selective reporting of results	Overall Bias
Fitzpatrick (2017)	🟡	🟢	🟢	🟡	🟢	🟡
Flett (2019)	🟡	🟢	🟢	🟡	🟢	🟢
Hur (2018)	🟡	🟢	🟢	🟡	🟡	🟡
Kauer (2012)	🟢	🟢	🟢	🟡	🟢	🟡
Franklin (2018) – Study 1	🟢	🟢	🟢	🟢	🟡	🟡
Franklin (2018) – Study 2	🟢	🟢	🟢	🟢	🟡	🟡
Franklin (2018) – Study 3	🟢	🟢	🟢	🟢	🟡	🟡
Lee (2018)	🟡	🟢	🟢	🟡	🟡	🟡
Motter (2018)	🟢	🟢	🟢	🟢	🟡	🟡
Levin (2020)	🟡	🟢	🟢	🟡	🟡	🟡
Tighe (2017)	🟡	🟢	🟢	🟡	🟢	🟡

Low risk of bias	🟢
Some concerns	🟡

Figure 3. RoB 2.0 ratings within individual studies

Online supplementary materials

Appendix A. Example of keywords and Boolean (logical) operators used in electronic database searches (Pubmed)

App-based	Depression Suicidal ideation Self-injury	Young people
mobile applications[mh OR App* OR "Smartphone"[mh OR Smartphone*[tiab OR Smart phone*[tiab OR iPhone*[tiab OR Phone app*[tiab OR iPad*[tiab OR app base*[tiab OR App-base*[tiab OR online therap*[tiab OR mobile base*[tiab OR mobile device*[tiab OR handheld device*[tiab OR Hand help device*[tiab OR Distance counseling[mh OR Distance counseling[tiab OR Distance counselling[tiab OR android device*[tiab OR android app*[tiab	"depression"[mh OR Depression[tiab OR Depressive[tiab OR Depressed[tiab OR depressive disorder[mh OR dysthymic disorder[mh OR dysthym*[tiab OR melanchol*[tiab OR suicide[mh OR suicidal ideation[mh OR suicide, attempted[mh OR suicid*[tiab OR self-injurious behavior[mh OR Self-injurious behaviour*[tiab OR self injur*[tiab OR NSSI[tiab OR self harm*[tiab OR Self mutilation[mh OR self mutilate*[tiab	Adolescent[mh OR Juvenile*[tiab OR Minors[mh OR Young adult[mh OR young adult*[tiab OR young person*[tiab OR Schools[mh OR Pre adolesc*[tiab OR Young people[tiab OR "Schools"[mh:noexp OR High school*[tiab OR Secondary School*[tiab OR universit*[tiab

Appendix B. Risk of Bias 2.0 signalling questions across domains

Domain	Signalling question
Bias arising from the randomization process	1.1 Was the allocation sequence random?
	1.2 Was the allocation sequence concealed until participants were enrolled and assigned to interventions?
	1.3 Did baseline differences between intervention groups suggest a problem with the randomization process?
	Risk of bias judgement
Bias due to deviations from intended interventions	2.1.Were participants aware of their assigned intervention during the trial?
	2.2.Were carers and people delivering the interventions aware of participants' assigned intervention during the trial?
	2.3. If Y/PY/NI to 2.1 or 2.2: Were there deviations from the intended intervention that arose because of the experimental context?
	2.4 If Y/PY to 2.3: Were these deviations likely to have affected the outcome?
	2.5. If Y/PY/NI to 2.4: Were these deviations from intended intervention balanced between groups?
	2.6 Was an appropriate analysis used to estimate the effect of assignment to intervention?
	2.7 If N/PN/NI to 2.6: Was there potential for a substantial impact (on the result) of the failure to analyse participants in the group to which they were randomized?
	Risk of bias judgement
Bias due to missing outcome data	3.1 Were data for this outcome available for all, or nearly all, participants randomized?
	3.2 If N/PN/NI to 3.1: Is there evidence that result was not biased by missing outcome data?
	3.3 If N/PN to 3.2: Could missingness in the outcome depend on its true value?
	3.4 If Y/PY/NI to 3.3: Is it likely that missingness in the outcome depended on its true value?
	Risk of bias judgement
Bias in measurement of the outcome	4.1 Was the method of measuring the outcome inappropriate?
	4.2 Could measurement or ascertainment of the outcome have differed between intervention groups?
	4.3 Were outcome assessors aware of the intervention received by study participants?
	4.4 If Y/PY/NI to 4.3: Could assessment of the outcome have been influenced by knowledge of intervention received?
	4.5 If Y/PY/NI to 4.4: Is it likely that assessment of the outcome was influenced by knowledge of intervention received?
	Risk of bias judgement
Bias in selection of the reported result	5.1 Were the data that produced this result analysed in accordance with a pre-specified analysis plan that was finalized before unblinded outcome data were available for analysis?
	5.2 ... multiple eligible outcome measurements (e.g. scales, definitions, time points) within the outcome domain?
	5.3 ... multiple eligible analyses of the data?
	Risk of bias judgement
Overall bias	**Risk of bias judgement**

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-
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Conflicting interests: MS is an employee of XXX. BF has received grants from XXX.
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Ethical approval: The ethics committee of XXXX approved this study (REC number: XXXX)
Guarantor: BF
Contributorship: BF and NP researched literature and conceived the study. MS was involved in protocol development, gaining ethical approval, patient recruitment and data analysis. BF wrote the first draft of the manuscript. All authors reviewed and edited the manuscript and approved the final version of the manuscript

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5.1 Declaration of conflicting interests

It is the policy of DIGITAL HEALTH to require a declaration of conflicting interests from all authors enabling a statement to be carried within the paginated pages of all published articles.

Please ensure that a 'Declaration of Conflicting Interests' statement is included at the end of your manuscript, after any acknowledgements and prior to the references. If no conflict exists, please state that 'The Author(s) declare(s) that there is no conflict of interest'.

For guidance on conflict of interest statements, please see the ICMJE recommendations.

When making a declaration the disclosure information must be specific and include any financial relationship that any of the authors of the article have with any sponsoring organization and the for-profit interests the organization represents, and with any for-profit product discussed or implied in the text of the article.

Any commercial or financial involvements that might represent an appearance of a conflict of interest need to be additionally disclosed in the covering letter accompanying your article to assist the Editors-in-Chief in evaluating whether sufficient disclosure has been made within the Declaration of Conflicting Interests provided in the article.
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DIGITAL HEALTH requires all authors to acknowledge their funding in a consistent fashion under a separate heading. Please visit the Funding Acknowledgements page on the SAGE Journal Author Gateway to confirm the format of the acknowledgment text in

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Medical research involving human subjects must be conducted according to the World Medical Association Declaration of Helsinki.

Submitted manuscripts should conform to the ICMJE Recommendations for the Conduct, Reporting, Editing, and Publication of Scholarly Work in Medical Journals, and all papers reporting animal and/or human studies must state in the methods section that the relevant Ethics Committee or Institutional Review Board provided (or waived) approval. Please ensure that you have provided the full name and institution of the review committee, in addition to the approval number.

For research articles, authors are also required to state in the methods section whether participants provided informed consent for participation in the study and whether the consent was written or verbal.

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Identifying details should be omitted if they are not essential. Complete anonymity is difficult to achieve, however, and informed consent should be obtained if there is any doubt. For example, masking the eye region in photographs of patients is inadequate protection of anonymity. If identifying characteristics are altered to protect anonymity, such as in genetic pedigrees, authors should provide assurance that alterations do not distort scientific meaning and Editors should so note.

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All research involving animals submitted for publication must be approved by an ethics committee with oversight of the facility in which the studies were conducted. The journal has adopted the Consensus Author Guidelines on Animal Ethics and Welfare for Veterinary Journals published by the International Association of Veterinary Editors. When reporting experiments on animals, indicate within the Methods section which guideline/law on the care and use of laboratory animals was followed.

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DIGITAL HEALTH conforms to the ICMJE requirement that clinical trials are registered in a WHO-approved public trials registry at or before the time of first patient enrolment as a condition of consideration for publication. The trial registry name and URL, and registration number must be included at the end of the abstract. For this purpose, a clinical trial is defined as any research project that prospectively assigns human subjects to intervention or comparison groups to study the cause-and-effect relationship between a medical intervention and a health outcome. Studies designed for other purposes, such as to study pharmacokinetics or major toxicity (e.g. phase I trials), would be exempt. Further information can be found at www.icmje.org .

All randomized controlled trials submitted for publication should include a completed Consolidated Standards of Reporting Trials (CONSORT) flow chart. Please refer to the CONSORT statement website at http://www.consort-statement.org for more information.

5.5 Reporting guidelines

The relevant EQUATOR Network reporting guidelines should be followed depending on the type of study. For example, all randomized controlled trials submitted for publication should include a completed CONSORT flow chart as a cited figure and the completed CONSORT checklist should be uploaded with your submission as a supplementary file. Systematic reviews and meta-analyses should include the completed PRISMA flow chart as a cited figure and the completed PRISMA checklist should be uploaded with your submission as a supplementary file. The EQUATOR wizard can help you identify the appropriate guideline.

Other resources can be found at NLM's Research Reporting Guidelines and Initiatives.

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The Guarantor is the person willing to take full responsibility for the article, including for the accuracy and appropriateness of the reference list. This will often be the most senior member of the research group and is commonly also the author for correspondence. Please state this person's name as initials.

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Where an individual who is not listed as an author submits a manuscript on behalf of the author(s), a statement must be included in the Acknowledgements section of the manuscript and in the accompanying cover letter. The statements must:

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Any acknowledgements should appear first at the end of your article prior to your Declaration of Conflicting Interests (if applicable), any notes and your References.

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Where statistical analyses have been carried out please ensure that the methodology has been accurately described. In comparative studies, power calculations are usually required. In research papers, requiring complex statistics, the advice of an expert statistician should be sought at the design/implementation stage of the study.

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As a means of recognising the significant contribution reviewers make to the publication process DIGITAL HEALTH aims to publish the names of the reviewers of accepted articles within the published manuscript itself. The publication of such names is dependent on both parties (authors and reviewers) consenting to these names being published. As part of the submission process you will be asked to opt in or out of having the reviewers names published within your paper.

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6. Publishing policies

6.1 Publication ethics

SAGE is committed to upholding the integrity of the academic record. We encourage authors to refer to the Committee on Publication Ethics' International Standards for Authors and view the Publication Ethics page on the SAGE Author Gateway.

6.1.1 Plagiarism

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7. Preparing your manuscript

- A title page with names and contact details for all authors
- A structured abstract
- The text (usually Introduction, Methods, Results, Discussion, Conclusions)
- Declarations
- References
- Appendix (if any)

7.1 Journal Styles

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7.2 Word processing formats

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Provide full contact details for the corresponding author including email, mailing address and telephone numbers. Academic affiliations are required for all co-authors. These details should be presented separately to the main text of the article to facilitate anonymous peer review.

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Corresponding author:
Professor Joe Bloggs, Department of Digital Health, University of Digital Health, Digital Health Road,
Digital Health, DHJ 2014, UK

Email: JoeBloggs@email.com
Twitter: @profjoebloggs

7.5 Artwork, figures and other graphics

For guidance on the preparation of illustrations, pictures and graphs in electronic format, please visit SAGE's Manuscript Submission Guidelines.

Photographic illustrations should be rendered with at least 300 dpi; please use CMYK color conversion if possible. Graphs made with Office software such as Microsoft Excel, can be provided in their original format to facilitate conversion into printable format with preserved quality. Any other line graphs/illustrations should preferably be provided in EPS format with a resolution of at least 600 dpi to prevent ragged lines when printed. A figure image should be at least 160 mm in width at the appropriate resolution. For further guidance on how to prepare your digital image see http://art.cadmus.com/da/index.jsp.

Graphs and images that are unsuitable may be returned to the author for amendment, causing delay in publication.

7.6 Units of measurement

Units of measurement should be expressed in SI and metric units; older conventional units may be added in parentheses.

7.7 Nomenclature

Use the generic or chemical name of any drug, in lower case; the specific trade name (capitalized) may be given in parentheses after the first text reference.

7.8 Standard abbreviations and symbols

Standard Abbreviations and symbols should be used, then defined in full in the first instance unless they are standard units of measurement. Avoid any use of abbreviations in the article title and abstract.

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This journal is able to host additional materials online (e.g. datasets, podcasts, videos, images etc) alongside the full-text of the article. These will be subjected to peer-review alongside the article. For more information please refer to our guidelines on submitting supplementary files, which can be found within our Manuscript Submission Guidelines page.

7.10 Guidelines for submitting video material as part of an article

Video content can be streamed within the HTML version of your article. If you would like to submit a video as part of your article, please read the below video properties guidelines carefully, ensure that you make a note within your manuscript as to where the video would be placed and upload it under the file type 'Additional Video Content' when you upload your manuscript via the manuscript submission site.

Please note that an audio-visual release form for each individual contributor to the video. This form should be signed, scanned and submitted as 'audio-visual release form'. The form is located here.

Video Properties:

-
  - At least 640 by 480 resolution and at least 20 fps.
  - The video compression should be of high quality. The Journal expects compression technology to evolve and so does not wish to be prescriptive over compression types. Today H.264 codec in an MP4 or AVI contained is a good choice. MPEG-1 and MPEG-2 are portable but have lower quality and larger files than the more modern codecs. We expect videos to be able to play on Windows 8 and back, Linux and Mac so proprietry formats, such as WMV and FLV are discouraged.

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8. Submitting your manuscript

8.1 How to submit your manuscript

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All papers must be submitted via the online system. If you would like to discuss your paper prior to submission, please refer to the contact details below.

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Please supply a title, short title, an abstract and keywords to accompany your article. The title, keywords and abstract are key to ensuring readers find your article online through online search engines such as Google. Please refer to the information and

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Keywords: 2-10 to accompany the abstract. They should, where relevant, be drawn from the MeSH list of Index Medicus and be chosen with a view to useful cross-indexing of the article.

Abstract: The abstract should accurately and concisely reflect the content of the article, and should be limited to 250 words for text articles and 500 words for audio-visual content. Please avoid reference citations and undefined abbreviations in the abstract. Where applicable the abstract should be formatted under the following headings: Objective, Methods, Results, Conclusions.

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