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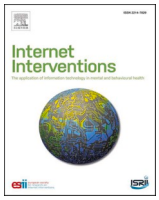

Delivering real-time support for self-injury: A systematic review on ecological momentary interventions

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ABSTRACT

Introduction: Ecological momentary interventions (EMIs) delivered via smartphone apps have gained attention as a potential tool for addressing self-injurious thoughts and behaviors (SITB), particularly non-suicidal self-injury (NSSI). This systematic review aims to assess the efficacy and feasibility of smartphone-based EMIs in reducing SITB and improving mental health outcomes.
Methods: A systematic review was conducted, focusing on smartphone-based EMIs targeting SITB, with particular emphasis on those addressing NSSI. The latest search was made in February 2025.
Results: Sixteen studies featuring smartphone-based EMIs were included. Overall, these studies showed promising evidence for the reduction of SITB. Specifically, several studies reported reductions in NSSI frequency and improvements in emotional regulation among participants. Feasibility and acceptability data showed good results.
Limitations: Key limitations include small sample sizes, study heterogeneity, lack of follow-up, reliance on self-reports, and absence of standardized tools to distinguish NSSI from other self-injurious behaviors.
Conclusions: Results are promising, while the efficacy of smartphone-based EMIs SITB requires further validation through large-scale and well-designed studies. The integration of digital interventions into broader mental health care strategies offers a potential avenue for addressing the treatment gap in at-risk populations, particularly those with limited access to traditional care.

Self-injurious thoughts and behaviors (SITB) are a pressing public health concern, especially among adolescents and young adults. Within this broad category, non-suicidal self-injury (NSSI) refers to deliberate, self-inflicted physical harm carried out without intent to die, typically to

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manage intense emotional distress (Nock, 2010; Vega et al., 2018). In contrast, suicidal behaviors (SIB) involve thoughts (i.e, suicidal ideation, SI), plans, or actions intended to end one's life. Although both NSSI and SIB often co-occur and share risk factors such as emotional dysregulation or impulsivity, they follow distinct developmental pathways and serve different functions (Nock et al., 2008; Nock and Prinstein, 2004). It is noteworthy that NSSI is a strong predictor of future suicide attempts, underscoring the need to treat NSSI and SIB as distinct but related problems requiring different prevention approaches.

There is substantial evidence supporting the efficacy of several psychological therapies preventing SITB, with Dialectical Behavioral Therapy (DBT) being a notable example (DeCou et al., 2019; Kothgassner et al., 2021). However, these therapies are typically costly in terms of resources and the necessity of trained therapists. Furthermore, access to these treatments is globally limited, often resulting in significant delays in their initiation (Kamody et al., 2023; Olfson et al., 1998; Pitkänen et al., 2022). Several factors contribute to this issue, including resource limitations (Kapusta et al., 2010; Kawaguchi and Koike, 2016; Tondo et al., 2006), barriers to help-seeking (Bruffaerts et al., 2011) and a lack of knowledge about mental disorders and stigma (Kohn et al., 2004). Therefore, a large proportion of people engaging in SITB lack access to evidence-based interventions (Hawton et al., 2015, 2016; Hetrick et al., 2016; Jobes, 2012; Mehlum et al., 2019; Turner et al., 2014).

Considering the factors described above, improving access to psychological treatments is a priority in many countries worldwide (Kazdin, 2017; Quinlivan et al., 2023). Given that up to 84 % of European citizens have a smartphone (*Measuring Digital Development:Facts and Figs. 2022*, 2022), smartphone app-based interventions provide a valuable alternative to face-to-face treatments, offering a promising avenue to bridge the mental health treatment gap (Chandrashekar, 2018; Marshall et al., 2019). Additionally, the use of these interventions may offer numerous benefits, such as continuous accessibility, enhanced reach, equitable provision of mental health resources, and potential improvements in service capacity and efficiency (Olff, 2015). Furthermore, previous research has demonstrated their effectiveness in improving symptoms, treatment adherence, and patient satisfaction across psychiatric conditions, including (but not limited to) depression, anxiety, substance abuse disorders, and chronic insomnia (Wang et al., 2018). For instance, Karyotaki et al. (2021) found that smartphone-based interventions reduced depressive symptoms in individuals with major depressive disorder. In substance use disorders, Gustafson et al. (2014) showed that app-based treatment enhanced adherence and lowered relapse rates. Similarly, Ritterband et al. (2009) reported that a digital intervention for chronic insomnia led to sustained sleep improvements and greater patient satisfaction.

Notably, smartphone app-based treatments open the door to integrate interventions into individuals' everyday routines. In this context, Ecological Momentary Interventions (EMIs) offer a novel approach providing instantaneous and personalized feedback based on a given measured state (Patrick et al., 2005). EMIs can deliver tailored therapeutic interventions based on real-time assessments, known as Ecological Momentary Assessments (EMAs), providing psychological support to individuals in their natural environment when needed (Balaskas et al., 2021). Ecological Momentary Assessment (EMA) emerged as a promising method for monitoring daily lives of people with mental disorders in an ecological and momentary manner. This methodology captures real-time data on emotions, behaviors, and physiological states within an individual's natural environment (Shiffman et al., 2008). Unlike retrospective self-reports, EMA provides longitudinal data with high temporal resolution, allowing for a more precise understanding of dynamic psychological processes. It can include self-reported measures (e.g., stress levels) and passive data collection (e.g., physiological signals via wearable sensors).

EMIs have been shown to reduce symptom severity and enhance treatment engagement (Heron and Smyth, 2010; Price et al., 2014). By expanding access to evidence-based care, improving adherence, and offering real-time support, these interventions contribute to more effective symptom management and overall treatment efficacy (Olff, 2015). Additionally, EMIs facilitate self-management, mitigate stigma associated with seeking care, and enhance treatment retention. This kind of intervention may be particularly valuable in addressing SITB, as individuals often face barriers to accessing traditional healthcare services or use previously learned coping skills. Thus, EMIs can reinforce coping strategies by providing reminders, exercises, or crisis tools at critical moments.

While smartphone apps for managing SITB have shown promising findings, studies on this topic are still limited and have important methodological limitations that impede drawing robust conclusions (Arshad et al., 2020; Melvin et al., 2019). To our knowledge, only one previous systematic review has analyzed studies using EMIs in the management and prevention of suicidal thoughts and behaviors (Jiménez-Muñoz et al., 2022). This review reported good rates of effectiveness and feasibility, concluding that EMIs can serve as useful complements to traditional care, especially when face-to-face care is not possible. However, authors excluded studies focusing solely on NSSI.

To address this research gap, the current systematic review aims to explore the effectiveness, acceptability, and feasibility of EMIs targeting SITB, by including studies that specifically examine EMIs designed to address NSSI. Additionally, we reviewed studies utilizing EMIs to address SITB, with a specific interest on extracting results pertaining to NSSI as distinct from SIB. Finally, given the increasing number of studies developing interventions with a smartphone application and the rapid technological advances, we also examined EMAs and EMIs characteristics to expand previous findings in this area.

1. Methods

This systematic review followed the Preferred Reporting Items for Systematic reviews and Meta-Analysis (PRISMA) guidelines (Moher et al., 2009).

1.1. Eligibility criteria

We included studies that met the following criteria, based on the recommended PICOS framework developed from the PRISMA statement (Liberati et al., 2009): (1) *Types of participants*: individuals of any age and gender, clinical or non-clinical samples characterized by experiences of SITB. (2) *Types of intervention*: Studies examining smartphone applications to provide EMIs aimed at preventing SITB. EMIs should provide instantaneous and personalized feedback based on a given measured state (EMAs), following Patrick et al. (2005)'s definition. (3) *Outcome measures*: reports of SITB, and other data related to feasibility and acceptability of the app. 4) *Comparator*: no specific criteria applied. (5) *Study design*: Randomized controlled trials, randomized clinical trials, single-arm trials and case series were eligible for inclusion. Feasibility and acceptability studies were also included in the review. Studies were excluded if exclusively qualitative methodology was used or if they were protocols, reviews, opinion pieces, and design and development papers without user evaluation of EMIs. Grey literature (i.e., dissertations, preregistrations, preprints) was also excluded from the review. Finally, studies had to be original and fully published in peer-reviewed journals.

1.2. Information sources

Studies were identified by searching the following electronic databases: The Cochrane Central Register of Controlled Trials (CENTRAL), PubMed, APA PsycINFO, Web of Science and the Association of Computing Machinery Digital Library (ACMDL). In addition, Google Scholar and citations and reference lists of relevant studies, such as reviews of EMIs for suicide or NSSI, were manually searched to find

relevant articles (forward and backward snowballing searches).

1.3. Search strategy

The database search strategy employed a mix of search terms for four concepts: ecological momentary interventions, suicide, NSSI, smartphone applications. We utilized some relevant search terms used in previous reviews (Arshad et al., 2020; Balaskas et al., 2021; Jiménez-Muñoz et al., 2022; Rodríguez-Blanco et al., 2018; Witt et al., 2017). Although the same search strategy was used for each database, appropriate changes were made to accommodate the different interfaces. To ensure literature saturation we used advanced search techniques such as #Mesh terms from the advanced search in each database. In the first stage of our search, we looked for each group of terms and explored the subject tree to then explode of select related terms. Once combined all terms with the "OR" Booleans function for each group of terms, we then combined it using "AND" in the search history function. Truncation (*) was used to ensure that different combinations of words were obtained. Restrictions were implemented in this search phase, requiring articles to be published in English language and dated from 2005 onwards, given this is the year the term EMI was first coined (Patrick et al., 2005).

To identify additional records, we conducted a manual search across supplementary sources, including Google Scholar, citation tracking, and reference lists of relevant studies. The same inclusion and exclusion criteria applied in the primary search were utilized in this process. In all instances, we had access to the full version of the included papers. Searches were conducted between June and July 2023. An update of the searches was made in July 2024 and 7th February 2025. All the results are presented according to the latest searches from February 2025.

Detailed search strategies are available in Table A.1 in the Appendix.

1.4. Study records

1.4.1. Identification and selection of studies

Studies that were identified by the search strategy were uploaded into EndNote online to save the studies and record the number found. The data screening was done in two steps. Firstly, we identified duplicate records using EndNote and discarded them after recording the number found. Then, titles and abstracts from records obtained from the five databases were screened and studies not fulfilling the PICOS criteria were excluded. When it was uncertain if studies met the inclusion criteria, they were retained for the next stage of screening. Only for relevant studies identified at this stage, the full text was obtained. In the second stage, screening of relevant full-text articles was conducted to determine if they were eligible for our systematic review. When it was uncertain if they met eligibility criteria, a screening table was used in which results were recorded for each study to discuss later with other reviewers.

Both stages of screening were completed in parallel by two independent reviewers (AJ and IJ), and discrepancies were resolved through joint discussions and consensus with the other team members, AG and DV (two active researchers with doctoral level qualifications in Psychology).

1.4.2. Data extraction

Articles that met inclusion criteria were downloaded, and relevant information was added into a data extraction spreadsheet. Extracted information included authors, year of publication, location, app name, topic, study design, sample characteristics, intervention characteristics, EMA and EMI features, outcome measures and results. Quantitative information was extracted independently by two reviewers (AJ, IJ). Any disagreements were resolved after discussion among the team members (DV, AG). Some authors ($n = 6$) were contacted to request further information about their app functionalities to determine whether these met our EMI inclusion criteria. All contacted authors replied and provided information that helped inform our decision. The primary outcomes assessed SITB, feasibility, and acceptability. Acceptability was determined by participant's experiences of using the intervention, with a focus on its perceived helpfulness, utility, likelihood of future use and satisfaction rates. Feasibility was assessed by looking at intervention engagement and usage rates, such as the frequency of accessing the smartphone app during the study period.

1.4.3. Risk of bias assessment

To evaluate the quality and potential biases in eligible studies, the Study Quality Assessment Tools of the National Heart Lung and Blood Institute was used (NHLBI; National Institutes of Health, 2021), which includes six types of studies and specific criteria according to the study design. The total quality scores ranged from 9 to 14 points, depending on the study design. To classify the overall quality of each study, we applied a rating system based on the percentage of questions that received a "Yes" response. Studies in which 70 % or more of the assessed questions were rated as "Yes" were categorized as having good quality. Those with 50 % to 69 % of positive responses were classified as fair quality, while studies with less than 50 % were considered to have poor quality. For the calculation of total percentages, questions marked as "Not Applicable" (NA) were excluded. This classification system provides a standardized approach for researchers to assess and compare the methodological rigor of the included studies. The potential for bias in each study was independently assessed by two reviewers (AJ, IJ), and any discrepancies were discussed with the team (DV, AG) and resolved through constructive discussions.

2. Results

2.1.1. Study selection

Fig. 1 depicts PRISMA flowchart. As shown, the search of Cochrane, APA PsychInfo, PubMed, Web of Science and ACMDL databases provided a total of 1440 articles. Our additional search using Google Scholar and citations, and reference lists of relevant studies produced 4 studies. After adjusting for duplicates 1270 records remained. Of these, 1096 were discarded as they did not meet the criteria after reviewing the title and the abstract. The full text of the remaining 174 records was examined in detail and screened according to our PICOS eligibility criteria, and were excluded if they were a Book chapter, article or a review ($n = 9$), if they were an app design or development ($n = 20$), if the intervention was delivered with something other than an app ($n = 36$), if they did not meet our criteria of EMI ($n = 29$), if they did not target any SITB outcome (n = 9), if it was an non-direct preventive intervention (e.g. to raise awareness) ($n = 8$), if it had a qualitative study design (n = 2), trial registry or protocol ($n = 49$).

2.1.2. Characteristics of included studies

Table 1 depicts the main characteristics of the 16 studies included in the current review, all of which used EMIs to target SITB. These studies examined 10 different apps designed for SITB. Studies were divided into four groups according to their EMIs' target outcome. The first group comprised EMIs specifically for SIB, including BRITE (Goldstein et al., 2024; Kennard et al., 2018), Illumivu (Depp et al., 2023), Jaspr Health (Dimeff et al., 2021), WellPATH (Kiosses et al., 2022), EMMA (Morgiève et al., 2022), and MAPS (Primack et al., 2022; Schatten et al., 2025). The second group involved studies for both SIB and NSSI, including the apps DBT Coach (Rizvi et al., 2016) and CALMA (Rodante et al., 2022). The third group involved Imaginator, an app specifically addressing NSSI (Di Simplicio et al., 2020). Finally, the fourth group involved five studies on unspecified self-injury (i.e., broadly referred to as 'self-harm with or without suicidal intent' or 'deliberate self-harm'). These studies examined BlueIce (Cliffe and Stallard, 2023; Muscara et al., 2020; Stallard et al., 2018; Stallard, Whittle, Moore, Medina-Lara, Morrish, Cliffe,

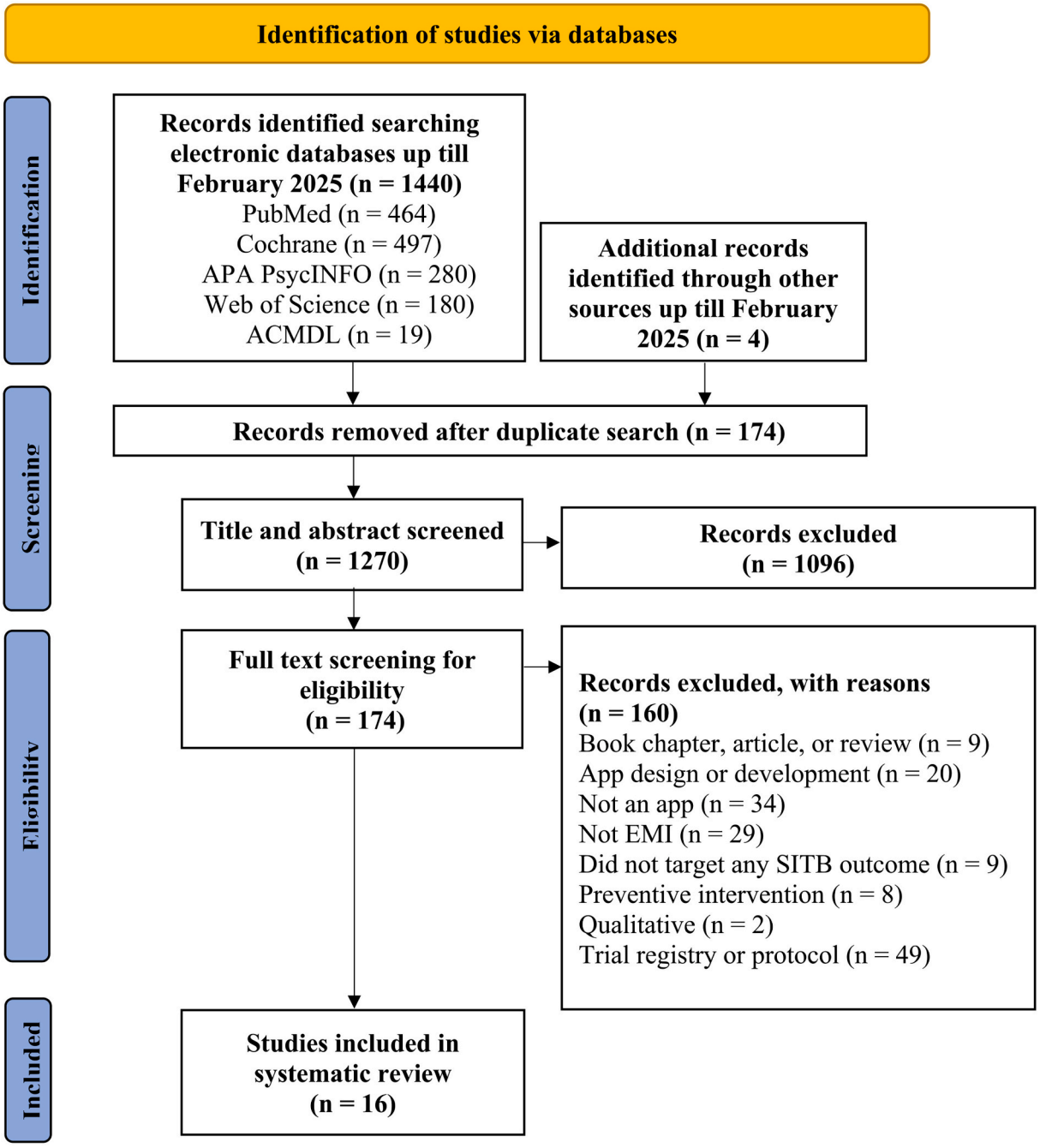

Fig. 1. PRISMA flow diagram.

et al., 2024; Stallard, Whittle, Moore, Medina-Lara, Morrish, Rhodes, et al., 2024). Regarding the type of design, this systematic review included seven RCT studies, five pre-post studies and three cohort and cross-sectional studies.

Sample characteristics varied. Slightly more than half of the samples involved adults (n = 9), while the remaining studies focused on adolescents or university students. Specifically, EMIs for SIB were mostly targeted at adult populations. Studies for SIB and NSSI included adult samples who did not require hospitalization (Rizvi et al., 2016; Rodante et al., 2022). The EMI for NSSI only (Di Simplicio et al., 2020) included adolescents. Finally, EMIs for unspecified self-injury used the same app with both adolescents and university students (Cliffe and Stallard, 2023; Muscara et al., 2020; Stallard et al., 2018; Stallard, Whittle, Moore, Medina-Lara, Morrish, Cliffe, et al., 2024; Stallard, Whittle, Moore, Medina-Lara, Morrish, Rhodes, et al., 2024).

Regarding intervention modalities, these included safety planning (Dimeff et al., 2021; Goldstein et al., 2024; Kennard et al., 2018; Morgiève et al., 2022; Primack et al., 2022; Schatten et al., 2025), CBT and cognitive reappraisal framework (Depp et al., 2023; Kiosses et al., 2022), DBT (Cliffe and Stallard, 2023; Goldstein et al., 2024; Muscara et al., 2020; Rizvi et al., 2016; Rodante et al., 2022; Stallard et al., 2018; Stallard, Whittle, Moore, Medina-Lara, Morrish, Cliffe, et al., 2024; Stallard, Whittle, Moore, Medina-Lara, Morrish, Rhodes, et al., 2024), and functional imagery (Di Simplicio et al., 2020), with DBT and safety planning being particularly prominent.

To assess and quantify the severity and management SITB, the most used method was the Columbia Suicide Severity Rating Scale (Goldstein et al., 2024; Kennard et al., 2018; Kiosses et al., 2022; Morgiève et al., 2022; Primack et al., 2022; Schatten et al., 2025), followed by the Self-Injurious Thoughts and Behaviors Interview (Rizvi et al., 2016; Rodante

Table 1
Main study characteristics.

App name	Ref.	Study design	Participants	Sample	Outcome measures	Primary outcome	Therapeutic model	App role
Group 1 – EMIs for SIB								
BRITE	Kennard et al. (2018)	RCT	Adolescents recently discharged from hospital due to SI with plan, intent, or attempt.	$N = 66$ (I: $n = 34$, C: $n = 32$), Age $M = 15.1$, $SD = 1.5$; 89.4 % female	C-SSRS, Suicidal Ideation Questionnaire–Junior High School Version	Time to suicide attempt and SI	Safety plan and DBT skills	Adjunct
	Goldstein et al. (2024)	RCT	Inpatient adolescents due to SI with plan, intent, or attempt.	$N = 240$ (ASAP = 61, BRITE = 59, ASAP+BRITE = 60, TAU = 61) Age $M = 14.6$, $SD = 1.6$; 80.8 % female	C-SSRS	SI, SB and events, re-hospitalization	Safety plan and DBT skills	Adjunct, stand alone
Illumivu	Depp et al. (2023)	RCT	Adults with bipolar disorder and SI in outpatient mental health system	$N = 78$ I: $n = 38$; Age $M = 48.3$, $SD = 13.7$; 44.7 % female C: $n = 39$; Age $M = 43.7$, $SD = 13$; 56.4 % female	BSSI	SI severity	Suicide-focused CBT	Adjunct
Jaspr Health	Dimeff et al. (2021)	RCT	Acutely suicidal adults in the ED	$N = 31$ Age $M = 34.4$; $SD = 15.2$, 65 % female I: $n = 14$; Age $M = 29$, $SD = 10.76$; 57 % female C: $n = 17$; Age $M = 39$, $SD = 16.92$; 71 % female	Safety and Imminent Distress Questionnaire, SRCS	Feasibility, acceptability, Suicide-related coping ability	CAMS Suicide Status Interview, DBT	Adjunct
WellPATH	Kiosses et al. (2022)	Cross-Sectional & Case Series	Middle-aged and older adults recently discharged from a suicide-related hospitalization.	$N = 12$ Age $M = 63$, $SD = 8.9$; 58 % female	C-SSRS	Feasibility, intensity of negative emotions, cognitive reappraisal for emotions associated with SI	Cognitive reappraisal and emotion regulation	Adjunct
EMMA	Morgiève et al. (2022)	Pre-Post feasibility	Adults with SI or recent suicidal attempt in outpatient psychiatric care	$N = 75$ Age $M = 30$; 75 % female	C-SSRS	Usage and acceptability	Safety plan	Stand-alone
	Primack et al. (2022)	Cohort and Cross-Sectional	Veterans hospitalized for SI or suicidal attempt	$N = 8$ Age $M = 45$, $SD = 15.41$; 25 % female	C-SSRS	Feasibility and acceptability, SI	Safety plan, a mix of coping strategies	Adjunct
	Schatten et al. (2025)	2 open pre-post pilot trials	Adults in psychiatric hospitalization with high risk of suicide	Study 1: $N = 10$ Age $M = 33.2$, $SD = 13.57$; 50 % female Study 2: $N = 10$ Age $M = 19.9$, $SD = 2.08$; 70 % female	C-SSRS	Feasibility and acceptability, SI, SB	Safety plan, a mix of coping strategies	Adjunct
Group 2 - EMIs for SIB and NSSI								
DBT Coach	Rizvi et al. (2016)	Pre-Post	Adults with BPD diagnosis and recent history of repeated NSSI and/or suicide attempts	$N = 16$ Age $M = 27.5$, $SD = 7.1$; 75 % female	SITBI	Distress and suicidal urges	DBT	Adjunct
CALMA	Rodante et al. (2022)	RCT	Adults with SI, plans, attempts or NSSI	$N = 21$ I: Age $M = 31.82$, $SD = 6.94$; 64 %	SITBI	Feasibility and SI, SI with plan, gesture, NSSI thoughts and acts	DBT	Adjunct

(*continued on next page*)

Table 1 (*continued*)

App name	Ref.	Study design	Participants	Sample	Outcome measures	Primary outcome	Therapeutic model	App role
				female C: Age *M* = 27.70, *SD* = 6.60; 100 % female				
Group 3 - EMIs for NSSI only								
Imaginator	Di Simplicio et al. (2020)	RCT	Adolescents with recent NSSI episodes	*N* = 38 I: *n* = 19; Age *M* = 19.7, *SD* = ± 2.5 C: *n* = 19; Age *M* = 19.2, *SD* = ± 2.5; 81.58 % female	Adaptation of NSSI Scale, Self-Efficacy for Control of self-harm, Self-Harm Imagery Interview, SM-SH	Self-harm frequency - NSSI	Functional Imagery	Adjunct
Group 4 - EMIs for unspecified self-injury								
BlueIce	Muscara et al. (2020)	Pre-Post	Former inpatient adolescents due to self-harm or suicidal acts	*N* = 20 Age *M* = 15.5, *SD* = 1.28; 80 % female	Two self-report items to measure self-harm frequency of thoughts and acts of deliberate self-harm	Feasibility, Acceptability, SRI-25, self-harm	CBT and DBT	Stand-alone
	Cliffe and Stallard (2023)	Pre-Post	University students aged 17-52 with self-harm thoughts/ behaviors or other mental health issues	*N* = 27 Age *M* = 21.17, *SD* = 4.39; 74.1 % female	Adapted Self-Harm questions from ALSPAC, coping self-efficacy	Self-harm	CBT and DBT	Stand-alone
	Stallard et al. (2018)	Pre-Post	Young people aged 12 to 17 years old with a history of self-harm	*N* = 44 Age *M* = 16.0, *SD* = 1.4; 91 % female	Non-validated self-report measure of self-harm.	Self-harm	CBT and DBT	Adjunct
	Stallard, Whittle, Moore, Medina-Lara, Morrish, Cliffe, et al. (2024)	RCT	Outpatients aged 12-18 who had self-harmed	*N* = 170 Age *M* = 15.6, *SD* = 1.4; 91 % female	Self-harm scale of the RTSGIA	Self-harm	CBT and DBT	Adjunct
	Stallard, Whittle, Moore, Medina-Lara, Morrish, Rhodes, et al. (2024)	Cohort and Cross-Sectional	Outpatients aged 12-18 who had self-harmed	*N* = 60 Age *M* = 15.6, *SD* = 1.41, 55.92 % female	Self-harm scale of the RTSGIA	Acceptability	CBT and DBT	Adjunct

Abbreviations: SIB = Self-injurious behaviors with suicidal intent; SI=Suicidal Ideation; RCT = Randomized Controlled Trial; I=Intervention group; M = Mean; C = Control condition; SD = Standard Deviation; BSSI = Beck Scale for Suicidal Ideation; CBT = Cognitive Behavioral Therapy; ED = Emergency department; SRCS=Suicide-related coping scale; DBT = Dialectical Behavioral Therapy; CSSRS = Columbia Suicide Severity Rating Scale; NSSI=Non-Suicidal Self-Injury; BPD=Borderline Personality Disorder; SITBI = The Self-Injurious Thoughts and Behaviors Interview; SM-SH = The Strength of Motivation for reducing Self-Harm scale; SRI-25 = Suicide Resilience Inventory; ALSPAC = Avon Longitudinal Study of Parents and Children; RTSGIA = Risk Taking and Self Harm Inventory.

et al., 2022), the Risk Taking and Self-Harm Inventory (Stallard, Whittle, Moore, Medina-Lara, Morrish, Cliffe, et al., 2024; Stallard, Whittle, Moore, Medina-Lara, Morrish, Rhodes, et al., 2024), the Clinician-rated Severity of Non-Suicidal Self-Injury Scale (Di Simplicio et al., 2020), NSSI Scale the Beck Scale for Suicide Ideation (Depp et al., 2023), the Suicide-Related Coping Scale (Dimeff et al., 2021) and the Suicide Resilience Inventory-25 (Muscara et al., 2020). It is important to note that the Suicide-Related Coping Scale and the Suicide Resilience Inventory-25 assess coping capacities and resilience rather than SITB severity itself.

Only three studies explicitly assessed NSSI using standardized measures (Di Simplicio et al., 2020; Rizvi et al., 2016; Rodante et al., 2022), while others relied on unvalidated self-report items that did not distinguish NSSI from other SITB forms (Cliffe and Stallard, 2023; Muscara et al., 2020; Stallard et al., 2024a, 2024b). Additionally, some studies (e.g., Rodante et al., 2022) assessed both SIB and NSSI, leading to overlap across categories, underscoring the challenge of classifying studies by clinical outcomes.

2.1.3. *Clinical symptoms, feasibility and acceptability*

Most studies measuring the effectiveness of EMIs reducing SITB (n = 14) reported improvements in SITB outcomes (Cliffe and Stallard, 2023; Dimeff et al., 2021; Kiosses et al., 2022; Muscara et al., 2020; Primack et al., 2022; Rizvi et al., 2016; Rodante et al., 2022; Schatten et al., 2025; Stallard et al., 2018). One study reported reductions in non-specific self-injury urges but not in non-specific self-injury acts (Cliffe and Stallard, 2023), and five studies (Depp et al., 2023; Di Simplicio et al., 2020; Goldstein et al., 2024; Kennard et al., 2018; Stallard, Whittle, Moore, Medina-Lara, Morrish, Cliffe, et al., 2024) did not demonstrate significant differences in SITB outcome changes between treatment groups. Stallard, Whittle, Moore, Medina-Lara, Morrish, Cliffe, et al. (2024) and Goldstein et al. (2024) did not find differences in improvement regarding SITB between the group which used the app and the group without, but found a reduction on emergency department attendances or admissions, but this was not significant. However, in a posterior study using the same app (Stallard, Whittle, Moore, Medina-Lara, Morrish, Rhodes, et al., 2024), participants reported that the app had prevented

at least one episode of self-harm.

Results among studies delivering an EMI for SIB specifically were mixed. Two studies found that participants in the EMI group (i.e., experimental condition) showed significantly greater improvements in suicide-related outcomes compared to participants in the treatment as usual (TAU) group (Dimeff et al., 2021; Rodante et al., 2022). Goldstein et al. (2024) did not find effects on suicidal ideation and behavior between groups but found that participants who were hospitalized for an attempt and received their app (BRITE) were less likely to have a subsequent attempt. Additionally, one pre-post study reported significant improvement in a scale measuring suicide resilience after using the intervention app (Muscara et al., 2020). A feasibility pilot study also showed an average decrease in suicidal ideation after using an EMI (Primack et al., 2022), while a case study reported a reduction of suicidal severity (Kiosses et al., 2022). Conversely, two other studies found no difference between EMI and TAU (Depp et al., 2023; Kennard et al., 2018), and another study found that EMI use did not predict changes in suicide attempt measures (Rizvi et al., 2016).

Studies examining NSSI generally reported reductions in non-suicidal behaviors. Di Simplicio et al. (2020) found moderate reductions in NSSI over time, while Rodante et al. (2022) showed a high probability of a decrease in NSSI in the DBT plus EMI condition compared to DBT only. Rizvi et al. (2016) found that increased EMI (i.e., 'DBT Coach') use predicted a greater reduction in NSSI instances over the course of treatment, explaining an additional 26.41 % of the within-person variability. Kennard et al. (2018), although focused on feasibility, did not find any significant changes in NSSI. Studies without standard NSSI measurements also reported overall reductions in self-injury (Cliffe and Stallard, 2023; Muscara et al., 2020; Stallard et al., 2018; Stallard, Whittle, Moore, Medina-Lara, Morrish, Cliffe, et al., 2024).

Regarding feasibility, dropout rates to follow-up in studies were an average of 24.36 % (range: 12.8 % to 66 %, excluding the 2 h ED intervention and the case study; Dimeff et al., 2021 and Kiosses et al., 2022) and similar between adult and adolescent samples. While most of participants utilized the apps, there were variations in usage. Available data from studies directly measuring usability of the app revealed overall high adherence rates (Depp et al., 2023; Kennard et al., 2018; Morgiève et al., 2022; Muscara et al., 2020; Schatten et al., 2025). A SIB study examining app usability and participant engagement revealed that higher levels of distress and symptom severity were associated with more frequent app use (Morgiève et al., 2022). Dimeff et al. (2021) reported participants using the intervention app received significantly more best practice interventions for suicidal individuals compared to those who received TAU. In addition, two studies found that participants who engaged more with the app experienced significantly greater improvements in NSSI post-intervention (Di Simplicio et al., 2020; Rizvi et al., 2016).

Satisfaction, reflecting participant reception of the apps, were generally positive (moderate to high) across studies (Depp et al., 2023; Dimeff et al., 2021; Kennard et al., 2018; Kiosses et al., 2022; Morgiève et al., 2022; Primack et al., 2022; Rodante et al., 2022; Stallard et al., 2018). However, several studies found no clear consensus on their helpfulness or effectiveness (Cliffe and Stallard, 2023; Muscara et al., 2020), and there were also neutral evaluations on how enjoyable, interesting, or efficient they were (Rizvi et al., 2016; Rodante et al., 2022).

Findings from RCT studies reflect this variability in user reception. Dimeff et al. (2021) reported that satisfaction ratings significantly favored the app condition over care as usual, highlighting the app's ability to enhance perceived quality of care. However, this effect was observed within an emergency department setting, where immediate access to digital support may have played a distinct role. In contrast, Depp et al. (2023) and Kennard et al. (2018) found no significant differences in satisfaction between the app and control conditions. These results suggest that in studies with unrestricted app access, engagement and perceived usefulness varied, indicating that context influences digital intervention reception.

Regarding acceptability, Muscara et al. (2020) and Stallard, Whittle, Moore, Medina-Lara, Morrish, Rhodes, et al. (2024) found that their app (BlueIce) was considered acceptable and helpful. Participants suggested adding reminders to assess their mood, greater interaction with the therapist or other app users, and customization options for the app background, as well as providing more information on how to use the app.

2.1.4. Utilization of EMAs and EMIs across different apps

Table A.3 in the Appendix summarizes the EMAs and EMIs used in the included studies. We examined the types of EMAs and EMIs the apps used, as well as their interactions.

All apps included EMIs based on EMAs that measured users' current and self-reported emotional status. EMAs consisted of scale ratings (i.e., emotion identification followed by intensity ratings), or warning signs or triggers (specifically, Imaginator, BRITE, CALMA, Illumivu and WellPATH). Some apps included specific EMAs for SITB or suicide risk, suggesting healthy prevention strategies based on user responses and providing emergency contact numbers if needed (i,e Illumivu, Jaspr Health, EMMA and MAPS). Others did not explicitly assess SITB but asked if users found the activity helpful (i.e. BlueIce), guiding them to the "contact section" to reach out to a loved one or a helpline if they did not (i.e. BlueIce, BRITE, CALMA).

All apps included EMIs based on EMAs that measured users' current and self-reported emotional status. EMAs consisted of scale ratings (i.e., emotion identification followed by intensity ratings) (Di Simplicio et al., 2020; Rodante et al., 2022) or warning signs or triggers (Depp et al., 2023; Kiosses et al., 2022). Some apps included specific EMAs for SITB or suicide risk, suggesting healthy prevention strategies based on user responses and providing emergency contact numbers if needed (Depp et al., 2023; Dimeff et al., 2021; Morgiève et al., 2022; Primack et al., 2022; Rizvi et al., 2016; Schatten et al., 2025). Others did not explicitly assess SITB but asked if users found the activity helpful, guiding them to the "contact section" to reach out to a loved one or a helpline if they did not (Cliffe and Stallard, 2023; Muscara et al., 2020; Stallard et al., 2018; Stallard, Whittle, Moore, Medina-Lara, Morrish, Cliffe, et al., 2024; Stallard, Whittle, Moore, Medina-Lara, Morrish, Rhodes, et al., 2024).

Apps also used EMIs to support the skill development of participants. Most apps for SIB delivered EMIs based on DBT such as distress tolerance and emotion regulation skills to manage crises, risk, and provide resources for seeking support (Dimeff et al., 2021; Goldstein et al., 2024; Kennard et al., 2018; Kiosses et al., 2022; Morgiève et al., 2022; Primack et al., 2022; Schatten et al., 2025). Overall, several studies delivered EMIs that covered basic DBT skills, with an emphasis on mindfulness and relaxation (Cliffe and Stallard, 2023; Dimeff et al., 2021; Goldstein et al., 2024; Kennard et al., 2018; Kiosses et al., 2022; Muscara et al., 2020; Rizvi et al., 2016; Rodante et al., 2022; Stallard et al., 2018; Stallard, Whittle, Moore, Medina-Lara, Morrish, Cliffe, et al., 2024; Stallard, Whittle, Moore, Medina-Lara, Morrish, Rhodes, et al., 2024). Additionally, most EMIs encouraged users to engage in specific helpful behaviors (i.e. Depp et al., 2023; Di Simplicio et al., 2020; Primack et al., 2022; Rizvi et al., 2016; Schatten et al., 2025).

The in-app functionalities varied in sophistication. Some Apps included high interactive features such as Artificial Intelligence, algorithms, or iterative branching to deliver customized EMIs (i.e. Dimeff et al., 2021; Morgiève et al., 2022; Rizvi et al., 2016; Rodante et al., 2022). In contrast, other apps had fewer interactive features and functioned more as a digital self-guided toolbox. These apps used automatic routing to respond to indications of low mood and allowed users to personalize the content (Cliffe and Stallard, 2023; Depp et al., 2023; Kiosses et al., 2022; Muscara et al., 2020; Stallard et al., 2018; Stallard, Whittle, Moore, Medina-Lara, Morrish, Cliffe, et al., 2024; Stallard, Whittle, Moore, Medina-Lara, Morrish, Rhodes, et al., 2024).

All EMI apps for SITB delivered the content entirely on demand or

had the option to set up notifications. Only an exception, Rodante et al. (2022), did include weekly reminders to use specific app features. Among apps for SIB, most had daily programmed surveys (Depp et al., 2023; Dimeff et al., 2021; Goldstein et al., 2024; Kennard et al., 2018; Kiosses et al., 2022; Morgiève et al., 2022; Primack et al., 2022; Schatten et al., 2025).

2.1.5. Risk of bias

As detailed in Table A.2 in the Appendix, a comprehensive bias assessment was conducted. The included studies were classified into three categories defined by the National Heart Lung and Blood Institute (NHLBI; National Institutes of Health, 2019): (i) pre-post studies, (ii) cohort and cross-sectional studies, and (iii) controlled intervention studies.

Four out of six investigations classified as pre-post studies had a "good" quality, with percentages of "Yes" responses above 72.72 % (Morgiève et al., 2022; Muscara et al., 2020; Rizvi et al., 2016; Schatten et al., 2025). However, there were shared flaws among studies, such as: (i) small sample size (Morgiève et al., 2022; Muscara et al., 2020; Schatten et al., 2025; Stallard et al., 2018), (ii) loss to follow-up after baseline greater than 20 % and not accounted for in the analysis (Rizvi et al., 2016), and (iii) outcomes measures of interested not taken multiple times pre and post intervention (Muscara et al., 2020; Rizvi et al., 2016; Schatten et al., 2025). The remaining two studies were rated as "fair" quality as they share some of the commented concerns. Additionally, they show additional issues such as participants not being representative for the clinical population of interest (Cliffe and Stallard, 2023), or not used validated measures (Stallard et al., 2018).

For studies classified as a cohort and cross-sectional design, two studies were qualified as "good" (Kiosses et al., 2022; Stallard, Whittle, Moore, Medina-Lara, Morrish, Rhodes, et al., 2024) and one for "fair" (Primack et al., 2022). Common issues included: (i) no sample size justification, (ii) potential confounding variables not measured and adjusted statistically, and (iii) lack of examination of different levels of exposure in relation to the outcome.

Five out of seven studies categorized as controlled interventions were rated as having "good" quality, with total percentages of "Yes" above 71.43 % (Depp et al., 2023; Dimeff et al., 2021; Goldstein et al., 2024; Kennard et al., 2018; Stallard, Whittle, Moore, Medina-Lara, Morrish, Cliffe, et al., 2024). Qualitative flaws identified included a lack of blinding of assessors, participants, or providers as well as missing power or effect size calculations. The remaining two studies were rated as "fair" quality. Both reported insufficient power and did not mask the allocation condition to the providers (Di Simplicio et al., 2020; Rodante et al., 2022). Additionally, Rodante et al. (2022) had issues related to inadequate randomization methods, lack of treatment allocation concealment, and no blinding of assessors. Di Simplicio et al. (2020) reported additional concerns linked to high dropout rates and low adherence to intervention protocols.

3. Discussion

The aim of the current systematic review was to evaluate the effectiveness, acceptability, and feasibility of EMIs targeting SITB. This review extends previous systematic reviews on digital interventions in SITB by including studies using EMIs designed to address NSSI. Sixteen studies using EMIs were identified, showing preliminary and promising results regarding this type of intervention (i.e., EMIs) in individuals engaging in SITB. Moreover, our findings suggest potential differences between EMIs for SIB and those targeting NSSI or unspecified self-injury.

In contrast to prior reviews, we adopted a more stringent criterion for defining EMIs (i.e., Patrick's definition; Balaskas et al., 2021; Patrick et al., 2005). Consequently, studies that did not meet this specific definition were excluded, unlike other reviews (Arshad et al., 2020; Jiménez-Muñoz et al., 2022). Exclusions were based on factors such as the absence of EMAs to deliver EMIs, random delivery of EMIs, lack of interaction between EMAs and EMIs, and insufficient focus on app personalization. Although this resulted in fewer studies being identified, this approach enhances the precision and applicability of our findings.

Prior research utilizing EMAs alone has improved our understanding of NSSI and SIB (Rodríguez-Blanco et al., 2018; Sedano-Capdevila et al., 2021). Combining EMAs with interventions to form EMIs shows significant potential for enhancing existing treatments and making evidence-based interventions more accessible, particularly for NSSI. Findings from this systematic review support this approach, showing EMIs as an effective option to address SITB (Cliffe and Stallard, 2023; Dimeff et al., 2021; Kiosses et al., 2022; Muscara et al., 2020; Primack et al., 2022; Rizvi et al., 2016; Rodante et al., 2022; Schatten et al., 2025; Stallard et al., 2018; see for exceptions: Depp et al., 2023; Goldstein et al., 2024; Kennard et al., 2018). The results are encouraging with more studies showing a decrease in SITB compared to a previous review (9 versus 5; Jiménez-Muñoz et al., 2022), although the overall number of studies is still low. This highlights the need for future trials with larger sample sizes and better methodological quality. It additionally reflects this is an emerging field, with current research primarily focusing on App development to examine feasibility and acceptability before testing effectiveness.

One of the most important findings was that EMIs addressing SIB show mixed results in reducing suicide-related outcomes, whereas EMIs used interchangeably to treat both SIB and NSSI (i.e., group 2 of studies), for NSSI (i.e., one study) and for unspecified self-injury (i.e., group 4 of studies) demonstrate largely positive effects in reducing their target outcomes. A plausible explanation of such findings lies in the setting of application and clinical severity. EMIs designed to prevent SIB were primarily used with patients in emergency psychiatric care or inpatients following (or during) a suicide-related event, often focusing on crisis intervention and safety planning (Chung et al., 2017). In contrast, EMIs for NSSI and unspecified self-injury were mainly used with outpatient or non-clinical participants and employed a broader range of self-regulation strategies. This may be suggestive that EMIs may be more effective in less complex cases and outpatient settings compared to high-risk suicide cases. It also must be noted that the ages of participants differed, with SIB studies mostly involving adults while the rest included both adults and adolescents (from 12 to 52 years old).

Most studies used EMIs in conjunction with face-to-face interventions, with some exceptions (see: Cliffe and Stallard, 2023; Morgiève et al., 2022; Muscara et al., 2020). For studies addressing SIB, the average treatment duration ranged between 4 and 24 weeks, aside for one EMI where participants had access for two hours (Dimeff et al., 2021). Treatment doses varied from prompts to use the app daily (i.e. Primack et al., 2022; Schatten et al., 2025) to on-demand (Dimeff et al., 2021; Kiosses et al., 2022), however all apps incorporated daily programmed notifications. An example of an EMI for SIB is an app that provided access to distress tolerance strategies, emotion regulation skills and personalized safety plan developed with a therapist at the time of discharge to reduce the risk of post-discharge suicidal behavior (Kennard et al., 2018).

Similarly, for studies addressing NSSI or unspecified SITB, treatment duration ranged from 4 weeks to 6 months. Notably, EMIs were primarily delivered on demand rather than through a fixed daily schedule, suggesting a more flexible approach tailored to individual needs. All these EMIs employed strategies based on DBT principles, such as distress tolerance, emotional regulation and mindfulness (see for an exception; Di Simplicio et al., 2020).

NSSI studies demonstrate moderate reductions in self-injurious behaviors. Despite these findings being limited by small sample sizes and lack of active comparison conditions (e.g., control group), the results are encouraging (Di Simplicio et al., 2020; Rizvi et al., 2016; Rodante et al., 2022). Specifically, a recent study showed long-lasting reductions in NSSI episodes, with an overall medium effect size in both immediate and delayed delivery conditions (Di Simplicio et al., 2020). Given the complexity and prevalence of NSSI, these findings are significant for

preventive strategies. The potential of EMIs to effectively reduce NSSI highlights their value as a clinical tool. However, the integration of EMIs with face-to-face interventions raises questions about the impact of the EMI, emphasizing the need for further research to disentangle their individual contributions to traditional treatment outcomes.

Regarding methods to assess SITB, our findings align with Jiménez-Muñoz et al. (2022), which also used similar standardized instruments to assess suicidal thoughts and behaviors (e.g., Columbia Suicide Severity Rating Scale, Beck Scale for Suicide Ideation, Suicide Resilience Inventory). However, measures of NSSI were either absent or particularly varied and unsystematic in some studies (Cliffe and Stallard, 2023; Muscara et al., 2020; Stallard et al., 2018).

All included studies examined the feasibility and acceptability of app-based interventions, with differences in the assessment methodology. Studies addressing SIB mainly relied on satisfaction ratings, whereas the rest of studies measured constructs such as helpfulness and ease of use. EMIs for SIB demonstrated high client satisfaction and were generally well accepted, in consonance with previous reviews in this field of research (Arshad et al., 2020; Jiménez-Muñoz et al., 2022). However, several studies reported mixed results on the perceived helpfulness and effectiveness of the apps. For instance, in two studies using the same EMI, while 47 % of participants felt the App would not help them in crisis, most found it easy to use and would recommend it (Cliffe and Stallard, 2023; Muscara et al., 2020). Other studies reported neutral evaluations on enjoyment and efficiency (Rizvi et al., 2016; Rodante et al., 2022). These mixed findings are congruent with findings from other reviews, which have concluded there is no definitive consensus on whether mobile-based interventions are considered helpful by users (Arshad et al., 2020; Sarubbi et al., 2022).

High dropout rates observed in the studies may indicate a need to improve retention, as app engagement tends to decline after a few weeks. It is of note that the average app access duration ranged between approximately 4 and 24 weeks, excluding a study with only 2-h access (Dimeff et al., 2021). This issue of decreased app use is common in mental health app research (Arshad et al., 2020; Leech et al., 2021). Future studies may consider incorporating persuasive strategies based on behavior change principles to design more effective apps for SIB (see for a review on this topic: Jha et al., 2025). Detailed reporting on users' characteristics, treatment duration and content, dropout rates, engagement levels and acceptability is recommended to improve understanding of app-based EMIs.

The risk of bias assessment showed that overall study quality was acceptable, with over 50 % meeting quality criteria. However, several studies had insufficient statistical power or failed to report it, small sample sizes, or high dropout rates. Some trials did not use validated outcome measures to differentiate NSSI from suicidal self-injury or a suicide attempt. In this regard, future research should incorporate precise, validated questionnaires to improve methodological rigor and facilitate replication and systematic reviews.

3.1. Strengths and limitations

The main strength of this systematic review refers to its comprehensive focus on EMIs for SITB, including NSSI. By addressing both the effectiveness and feasibility of app-based interventions, the review provides a robust evaluation of these digital tools in clinical practice. The rigorous inclusion criteria, focusing on real-time interventions, contribute to the growing body of literature on digital mental health solutions aimed at addressing treatment gaps. In addition, the analysis of EMAs within EMIs provides valuable insight into the potential of these tools to enhance personalized mental health interventions.

Several limitations must be acknowledged. The restrictive inclusion criteria, which focused solely on smartphone-based apps with EMA-EMI functionalities, limited the scope of the review and potentially overlooked other effective digital modalities, such as web-based or text-message interventions. This may have introduced bias into the findings. Furthermore, the lack of standardized and validated tools to distinguish NSSI from other forms of self-injury hinders comparisons across studies and limits the robustness of the conclusions. The absence of a registered study protocol and the relatively small sample sizes in many studies limit the generalizability of the findings and increase the risk of bias.

4. Conclusions

This systematic review highlights the promising potential of smartphone-based EMIs in addressing SITB, particularly NSSI. Despite the scarcity of studies implementing EMI apps for SITB, the available evidence suggests that integrating EMIs with face-to-face interventions and delivering timely, real-time interventions could significantly enhance current strategies for STIB prevention. This review provides the first comprehensive summary of literature on EMIs for NSSI, showing positive outcomes for both EMIs for NSSI and SIB, whether addressed together or separately. Despite encouraging results, their interpretation must be treated with caution due to several limitations including small sample sizes, variability in outcome measures, and methodological inconsistencies. Future studies using standardized assessment tools and including larger and more diverse samples are essential to accurately establish the efficacy of these interventions. Prioritizing the refinement of digital health interventions and integrating them into broader mental health care strategies is crucial to close the treatment gap for at-risk populations.

Author's contributions

DV, AGP and JCP conceived the idea for the review. DV, AJ and IJ collaborated in designing the methodology to be implemented in the study. AJ conducted the systematic literature searches and filtering, quality assessment, and drafted and wrote the manuscript. IJ conducted systematic searches and filtering, quality assessment, and assisted with manuscript revision. DV contributed extensively to the first draft, coordinated and supervised all parts of the review's process. All authors supervised and approved the final version of the manuscript.

Other information

This review was not registered given a protocol was not prepared.

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Declaration of competing interest

The authors declare that they have no conflict of interests.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.invent.2025.100826.

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