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Abstract

Introduction: Suicide is a global health crisis, ranking as the fourth leading cause of death among adolescents. The adolescent phase is marked by numerous challenges, such as increased academic pressures, evolving relationships with parents and peers, and self-identity development. Many of these suicides are preventable, but a significant number of young adolescents succumb to suicide due to a lack of awareness and access to support. Like all other forms of media, digital media can either strengthen or weaken suicide prevention initiatives. **Methods:** A systematic review adhered to the PRISMA guidelines. This systematic review will include randomized controlled trials of suicide prevention among adolescents. Using specific keywords, studies will be retrieved from global databases such as MEDLINE (via Ovid and PubMed), Web of Science, Scopus, CINAHL, Cochrane CENTRAL, Embase, and ProQuest Medical Library. Two reviewers independently screened and extracted the data and critically appraised the included studies. We will compute pooled standardized mean differences and associated 95% confidence intervals. We will assess the risk of bias using the Cochrane Collaboration risk of bias (RoB 2.0) tool. Heterogeneity and publication bias will be estimated, and sensitivity and subgroup analyses will be conducted. **Conclusion:** By synthesizing findings from diverse studies, researchers can identify trends and knowledge gaps regarding the use of digital health interventions for adolescent suicide prevention. This evidence-based approach empowers healthcare professionals, policymakers, educators, and caregivers to make informed decisions about implementing, scaling, or refining digital health interventions to address the challenges of adolescent mental health and suicide prevention. **Protocol registration:** The protocol is registered in the International Prospective Register of Systematic Reviews (PROSPERO - CRD42023479262).

Keywords: Adolescents, digital health, mHealth, eHealth, suicide prevention, suicidal ideation.

Introduction

Suicide, defined as a self-injurious act with the intent to die, is particularly prevalent during adolescence, a phase marked by increased vulnerability (Becker & Correll, 2020). Among adolescents, it ranks as the fourth leading cause of death globally, with the World Health Organization (WHO) estimating an annual mortality rate of 10.7 per 100,000 individuals, exhibiting variations across age groups and nations (Bachmann, 2018)2018. Adolescence, a period of significant growth and transition, presents challenges in preparing for adult roles, encompassing education, employment, relationships, and living circumstances. These transitions can trigger various mental health difficulties, increasing the risk of suicide (Evans et al., 2018). Recognizing the gravity of the issue, the WHO has identified suicide prevention as a crucial public health priority, advocating for the development and implementation of comprehensive national strategies, with a special focus on youth and other vulnerable populations (Henry, 2021).

Rationale for conducting the study

The increasing rate of adolescent suicide is a pressing public health challenge, aggravated by the fact that a

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substantial 70% of young individuals experiencing suicidal thoughts avoid conventional mental health services, primarily due to the stigma and other obstacles associated with seeking help (Rodway et al., 2020). The integration of digital health solutions has significantly improved healthcare quality and accessibility, leading to enhanced health and well-being for individuals (Butcher & Hussain, 2022; Mumtaz et al., 2023). From motivating healthier lifestyles with wearable fitness trackers to providing timely medical consultations through telehealth services, digital health empowers individuals to take a more proactive role in managing their health (Haleem et al., 2021; Kang & Exworthy, 2022). Additionally, it equips healthcare professionals with tools to deliver personalized care and make data-driven decisions, resulting in earlier disease detection, more effective treatments, and improved patient outcomes (Haleem et al., 2022). Digital health has revolutionized the approach to healthcare, granting individuals greater control and access to information while also making healthcare practices more effective and efficient (Abernethy et al., 2022). Digital health, an encompassing term, includes various technologies and innovations aimed at improving healthcare services and patient experiences, such as eHealth (electronic health), mHealth (mobile health), and telehealth platforms (Cascini et al., 2023; Yeung et al., 2023). mHealth, a subset of digital health, utilizes mobile devices such as smartphones and tablets to facilitate healthcare, offering remote patient monitoring, health apps, and telemedicine services, collectively aiming to transform healthcare into a more patient-centered, convenient, and effective system, ultimately leading to better health outcomes and improved accessibility to healthcare services (Bhavnani et al., 2016).

Why it is important to do this review?

Digital health plays a pivotal role in the prevention of suicide in adolescents and the improvement of attitudes towards suicide and suicidal ideation. Its significance is multifaceted, primarily revolving around early detection and intervention (Vahabzadeh et al., 2016). Digital health tools offer the means to identify warning signs of suicidal ideation and related risk factors, enabling timely and tailored support (Chatterjee et al., 2022). Moreover, these technologies are exceptionally accessible to adolescents, who are well versed in digital platforms. By granting them access to mental health resources from the privacy of their devices, digital health helps diminish the stigma

associated with seeking help for mental health issues. It also serves as a valuable educational resource, fostering awareness, reducing stigma, and promoting a deeper understanding of mental health, thereby encouraging open and empathetic conversations around the topic (Bantjes, 2022). Furthermore, digital health platforms often feature crisis helplines and chat support, ensuring immediate assistance during times of crisis. Leveraging data analytics, these tools can provide valuable insights into trends and patterns related to adolescent mental health, enabling more targeted and effective prevention efforts (Thompson et al., 2018; Torous et al., 2021). In essence, digital health serves as a beacon of hope and support, not only in addressing the immediate challenges of adolescent suicide prevention but also in shifting societal attitudes towards a more compassionate and proactive approach to this critical issue (Blattert et al., 2022).

Description of the intervention

Digital health interventions, including mHealth, e-health, web-based, internet-based, telephone, and telemedicine approaches, offer promising avenues for suicide prevention among adolescents aged 13 to 19 years. These interventions leverage technology to provide accessible, confidential, and timely support to vulnerable individuals. Through personalized risk assessment, psychoeducation, crisis management, and counselling services, they address underlying mental health challenges and foster coping skills. Long-term follow-ups enable continuous monitoring of mental health indicators, early detection of warning signs, and timely intervention strategies tailored to individual needs. The convenience and privacy afforded by digital platforms encourage adolescents to proactively seek help, reducing the stigma associated with mental health issues. Moreover, these interventions facilitate collaboration among healthcare professionals, educators, and caregivers, enhancing the holistic support system for adolescents at risk of suicide. With ongoing research and development, digital health interventions hold immense potential to mitigate the burden of suicide and promote mental well-being among adolescents globally. In response to the wealth of literature available, researchers intend to undertake an extensive systematic review aimed at evaluating the efficacy of digital interventions in preventing adolescent suicide. This review recognizes the potential of smartphone-based solutions to provide accessible and convenient mental health support, thereby mitigating

the service access barriers faced by adolescents and potentially delivering a substantial positive impact.

Review questions

How do digital health interventions influence adolescent suicide prevention?

Objectives

- To assess the effectiveness of digital health interventions in reducing depression symptoms, suicidal behavior, and ideation among adolescents.
- To evaluate the influence of digital interventions on improving self-esteem and positive attitudes towards suicide among adolescents.

Methods

This protocol will adhere to the PRISMA-P (Preferred Reporting Items for Systematic Reviews and Meta-Analyses Protocols 2020 Statement) guidelines (Page et al., 2021). The study was duly registered with PROSPERO on November 6, 2023 (CRD42023479262).

Eligibility criteria

The inclusion and exclusion criteria for the studies, as outlined in Table 1, were established in alignment with the Population, Intervention, Comparison, Outcome, Study Design (PICO-TS) model. The rationale behind these criteria is to ensure a comprehensive and all-encompassing evaluation of digital health, mHealth, and eHealth interventions intended for the prevention of suicides among adolescents.

Table 1

Eligibility criteria

Components	Inclusion	Exclusion
Population	Adolescent age between 13-19 years irrespective of gender.	Adolescents diagnosed with chronic mental illness.
Intervention	mHealth, e-Health, telephonic, internet-based, web-based, and digital health interventions.	Direct or indirect counselling interventions by a physician or any other healthcare professional and health education interventions
Comparison	routine care which refers to the standard routine care and support received by adolescents for the prevention of depression and suicidal ideation.	
Outcomes	Depressive symptoms, anxiety, suicidal behavior, self-esteem, suicidal ideation, or self-harm, attitude towards suicidal prevention, and well-being.	
Timeline	Research articles published in English between 2011 and 2023.	
Study design	Randomized Control Trials (RCTs)	Studies other than the RCTs

Information resources and search strategy

We will identify relevant studies through a comprehensive search across electronic databases, including MEDLINE (via Ovid and PubMed), Web of Science, Scopus, CINAHL, Cochrane CENTRAL, Embase, and ProQuest Medical Library, as well as through national and international mental health-related websites. This search approach will be supplemented by manual examination of reference lists in articles and pertinent systematic reviews and meta-analyses related to the topic. Additionally, experts in the field and authors of selected studies will be contacted to enhance the list of included publications. We used comprehensive search terms to find relevant studies in different databases, as outlined in the search strategy in Table 2. Two independent reviewers will conduct database searches, following the PICO-TS model as outlined in the supplementary file, ensuring consistency in the search approach across all databases.

Table 2

Search strategy

Population	Intervention	Outcome
"Adolescent" [Mesh] OR Adolescent* [ta] OR "Early adulthood " [ta]	"Telemedicine"[Mesh] OR digital health [ta] OR mHealth [ta] OR eHealth [ta] OR "mobile application" [ta] OR internet intervention [ta]	"Suicide"[Mesh] OR "Suicide Prevention"[Mesh] "Anxiety" [Mesh] OR "Stress, Psychological"[Mesh] OR "Depression"[Mesh] OR "Attitude"[Mesh] OR "Suicidal Ideation"[Mesh]

Selection of studies

Two independent researchers (NC and UP) will use the Rayyan platform, which was designed for systematic reviews (Ouzzani et al., 2016). Following a database search, researchers exported pertinent studies into Rayyan software and eliminated duplicate entries. Subsequently, the title and abstract were subjected to independent screening by researchers, who excluded studies that did not align with preestablished inclusion criteria. After completing the initial screening, a full-text screening of the remaining records was conducted to determine eligibility for inclusion. Discrepancies will be resolved through discussion and consensus between the two reviewers, with a third independent reviewer involved if necessary. Any remaining questions about study eligibility will be clarified by contacting the corresponding authors (NS). The overall agreement in study selection will be measured using the kappa index (Fleiss et al., 2013). Explanations for the exclusion of specific studies will be detailed in the excluded study tables as part of the reporting process. We will report the process of study selection through the PRISMA flowchart, which is outlined with illustrations (*PRISMA*, 2020) Figure 1.
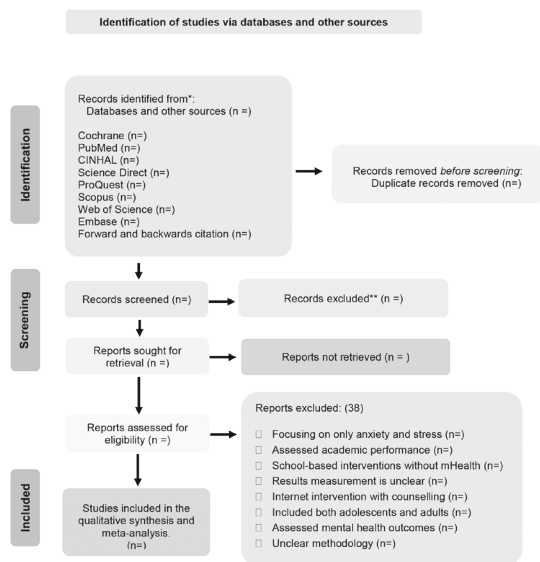

Figure 1: PRISMA flow diagram at each stage of the selection process

Data extraction

Following the selection of studies, a meticulous data extraction process will be carried out by two independent reviewers (NC and UP) utilizing a purpose-designed data extraction sheet. Any discrepancies during this process will be addressed through consensus between the two reviewers or, if necessary, by involving a third independent reviewer (NS). Additionally, to ensure the completeness and clarity of the extracted information, we contacted the authors when needed. The data to be extracted will encompass critical details such as author, publication year, and study origin, as well as comprehensive insights into the target population, including age, educational background, the presence of depressive symptoms, specific difficulties faced, and whether the intervention explicitly targets adolescents with depressive symptoms or a history of depression or suicidal ideation. We will also collect data on the type of intervention, whether it falls under mHealth, eHealth, or other digital health interventions, and detailed exclusion criteria such as participation in counselling sessions and the use of complementary methods for depression and suicidal ideation reduction.

Quality appraisal and risk of bias

To assess article quality, we will employ the risk of bias (RoB-2) criteria as suggested by the Cochrane Collaboration tool for RCTs (Eldridge et al., 2020). Each eligible study underwent evaluation by two independent reviewers, with any discrepancies resolved through discussion with a third reviewer until a consensus was reached. If necessary, we contacted the authors of the original articles for additional information.

Analysis of outcomes

We applied Mantel−Haenszel models for dichotomous outcomes and the inverse variance method for continuous outcomes (Ren et al., 2019) to calculate the mean differences. A random effects model was used to analyse the data, and the results are presented as odds ratios with 95% confidence intervals (CIs) for dichotomous outcomes. RevMan will be used for the meta-analysis. Statistical heterogeneity will be assessed using I^2 values, with $>50\%$ and $>75\%$ indicating moderate and significant heterogeneity, respectively. All p values will be two-tailed and considered significant if < 0.05.

Quality of evidence

We will utilize the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) working group methodology to assess the quality of

evidence (Balshem et al., 2011). We will evaluate the risk of bias, consistency, directness, precision, and publication bias across four distinct categories: high, moderate, low, and very low.

Discussion

Adolescents are often more comfortable with digital technology, making it an ideal medium to engage them in mental health interventions (Wong et al., 2020). The anonymity and privacy offered by these platforms can encourage those hesitant to seek face-to-face assistance to access much-needed support, which can provide evidence-based strategies for suicide prevention (Jain et al., 2021). These interventions can offer psychoeducation, crisis helplines, interactive self-help tools, and therapeutic content tailored to the needs of adolescents. They can equip young individuals with coping mechanisms, emotional regulation skills, and resources to navigate life's challenges (Philippe et al., 2022; Vahabzadeh et al., 2016; Wong et al., 2020). Digital interventions also have the potential to reach a wider audience. Adolescents from diverse backgrounds and geographic locations can access these resources, bridging gaps in mental health care (Borghouts et al., 2021). The scalability and cost-effectiveness of digital solutions make them valuable tools for accessing those who might otherwise be underserved. However, the effectiveness of digital interventions is not uniform, and issues such as adherence and engagement need careful consideration. Personalization, ongoing monitoring, and integration with traditional healthcare services can enhance their impact (Bhavnani et al., 2016; Yeung et al., 2023).

In comparison to existing reviews, our systematic review and meta-analysis on digital health interventions for adolescent suicide prevention offer several unique contributions. While existing reviews have shed light on the efficacy of various digital health interventions, our review specifically targets adolescents aged 13 to 19 years, a critical age group vulnerable to suicide risks. Moreover, our focus extends beyond singular modalities such as mHealth or e-health to encompass a wide spectrum of interventions, including web-based, internet-based, telephone, and telemedicine approaches. For instance, a review conducted by Robinson (Robinson et al., 2018) primarily emphasized the effectiveness of mHealth applications in suicide prevention among diverse age groups but lacked the specificity of interventions tailored specifically for adolescents. Similarly, (Macrinykola et al., 2021) explored web-based interventions for mental health but did not particularly focus on suicide prevention or emphasize the significance of long-term follow-ups in mitigating adolescent suicide risks.

Our review addresses these gaps by synthesizing evidence from a diverse range of digital health interventions, highlighting the importance of long-term follow-ups in sustaining intervention effects and specifically targeting adolescents, a demographic often underserved in the literature. By conducting a meta-analysis alongside a systematic review, we provide quantitative insights into the efficacy of these interventions, facilitating evidence-based decision-making for healthcare practitioners, policymakers, and researchers in adolescent mental health and suicide prevention efforts. Through these efforts, our review aims to inform comprehensive strategies that harness the potential of digital health interventions to mitigate the alarming rates of adolescent suicides worldwide.

Conclusion

Systematic reviews serve as a vital tool for synthesizing existing evidence and informing policymaking, clinical practice, and future research directions. By synthesizing findings from diverse studies, researchers can identify trends, knowledge gaps, and areas of consensus or controversy regarding the use of digital health interventions for adolescent suicide prevention. This evidence-based approach empowers stakeholders, including healthcare professionals, policymakers, educators, and caregivers, to make informed decisions about implementing, scaling, or refining digital health interventions to address the complex and multifaceted challenges of adolescent mental health and suicide prevention.

Strengths and Limitations

This is the first systematic review and meta-analysis including only RCTs employing a comprehensive search across eight international databases that enhances the scope of identifying diverse digital health intervention modalities. Systematic reviews follow

rigorous methodologies, incorporating predefined search strategies, selection criteria, and quality assessment tools alongside meta-analysis, ensuring the transparency, reproducibility, and validity of the findings. This review may have limitations, including a narrow scope of available research, primarily focused on only digital health interventions among adolescents aged between 13 and 19 years. Additionally, the exclusion of studies combining interventions with digital health interventions and adolescents with chronic mental health conditions such as depression may overlook pertinent research in the field.

Clinical Implications

To date, no systematic review has explored the effectiveness of digital health technology interventions that specifically target suicide prevention outcomes among adolescents. This review aims to fill this gap, offering insights for future research, valuable information for clinicians, and aiding in the standardization of practice and policy regarding the utilization of digital health technology for preventing adolescent suicide.

Patient and public involvement

While patients and the public will not be directly involved in the design, execution, or reporting of this study, we will engage with scientific professionals and user organizations for input and guidance on the dissemination plans for this research.

Ethical considerations

Given the nature of this study, no ethical assessment was deemed necessary. The findings from this systematic review and meta-analysis will be shared through presentations at international conferences relevant to the field and disseminated through peer-reviewed publications.

Author Contributions

NS and NKC conceived the study, with input from the other authors on the study design. NC and UP drafted the protocol, and NS reviewed and revised the manuscript. The screening of potential studies, data extraction, risk of bias assessment, and data synthesis will be independently conducted by NKC, UP, SA, and HS. Data analysis will be carried out by RS, BV, and SYN. NKC and NS will be responsible for drafting the final manuscript for this systematic review. All authors participated by reading, offering feedback, engaging in discussions, and providing their approval for the final protocol manuscript.

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