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Effectiveness of smartphone app-based interventions after surgery on quality of recovery among cancer patients: a systematic review and meta-analysis

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ABSTRACT

Background: Postoperative recovery in patients with cancer is a complex process that influences quality of life, functional recovery, and mental well-being. Smartphone app-based interventions have emerged as potential tools for improving various aspects of health and well-being in cancer patients. However, the existing literature lacks a consensus on the efficacy of these interventions, leading to conflicting outcomes.

Methods: We searched multiple databases, including PubMed, Web of Science, Cochrane Library, Scopus, EMBASE, and MEDLINE Complete (EBSCO). We exclusively selected randomized controlled trials meeting the inclusion criteria for our systematic review and meta-analysis. Utilizing a random-effects model, we derived the pooled effect size estimates for the meta-analysis. Where applicable, we calculated the pooled standardized mean difference (SMD) with 95% confidence interval (CI). The Cochrane Collaboration tool (Cochrane ROB) was used to evaluate bias in randomized trials. The primary outcome was the quality of life. The secondary outcomes were psychological symptoms, health conditions, satisfaction, and self-efficacy.

Results: Of 731 screened articles, 15 were included, comprising 1,831 participants. Our meta-analysis revealed that app-based interventions potentially improved quality of life (SMD = −0.58, 95% CI −1.00 to −0.16), alleviated psychological symptoms (SMD = −0.43, 95% CI −0.72,−0.15; p = .003), and enhanced self-efficacy (SMD = 0.90, 95% CI 0.26 to 1.53; p = 0.001). However, there was no statistically significant effect on satisfaction (SMD = 1.25, 95% CI-1.06 to 3.57; p = 0.23).

Conclusions: Our findings suggest that mobile health apps hold promise in improving the well-being of cancer patients after surgery by enhancing their quality of life, health status, and self-efficacy, while also reducing anxiety and depression.

PRÉCIS (CONDENSED ABSTRACT)

Many smartphone apps focus on managing health, particularly for activities such as exercise and preventing diseases such as obesity, diabetes, and mental health; however, there is a noticeable absence of specialized health management apps tailored for cancer patients after surgery. Smartphone app-based interventions have the potential to enhance quality of life, health status, self-efficacy, and decrease feelings of anxiety and depression in adult cancer patients after surgery.

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app; surgery; quality of life; cancer patients; meta-analysis

Introduction

Cancer is a significant public health concern worldwide, affecting both developed and developing nations. The number of new cases is projected to increase to 21.6 million annually by 2030 [1]. Nowadays, the number of cancer patients is increasing, and the significance of survival rate and quality of life after cancer therapy is progressively growing [2]. Postoperative cancer patients worry about disease recurrence, and the fear of recurrence increases anxiety and depression, while reducing their quality of life [3]. The quality of life for

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postoperative cancer patients encompasses several characteristics, such as physical health, psychological conditions, social and spiritual well-being. Modifications in one dimension have an impact on the other dimensions [4].

With the development of the information age, an increasing number of people have smartphones. As of 2022, the United States has one of the highest smartphone penetration rates in the world, with 81.6% of its population using smartphones. In 2023, the number of global smartphone users is expected to reach approximately 6.8 billion, representing an annual growth of 4.2% [5]. More and more mobile applications are increasingly altering behaviours to enhance wellness and manage illness. An increasing number of mobile apps are designed to alter behaviour in order to enhance health and control illness. Presently, there are approximately 325,000 mobile health (mHealth) applications in existence [6]. It is projected that the worldwide health application industry will reach a value of US $236 billion by 2026. More and more fitness and medical applications are being used to collect and track personal health-related data, and to improve the overall health status of patients through the use of smartphones [7]. Furthermore, previous studies have demonstrated the potential benefits and effects of using the smartphone apps as the major intervention for disease prevention or self-care conducted in diabetes, obesity and cancer patients [8]. Mobile health applications are utilized for these objectives; nonetheless, their influence on health results has shown diversity. Information on the feasibility and effectiveness of mobile apps for cancer patients after surgery is limited.

When it comes to cancer treatment, post-surgery and post-chemotherapy or post-RT each pose unique challenges and impacts on patients' lives. Psychological effects like anxiety and fear of recurrence are common [9], though there may be a sense of relief from tumour removal and the possibility of cure. Our study focuses only on postoperative patients with cancer because they have more complications, including physical discomfort, changes in body image, infections, ostomy-related complications and functional impairments.

Most postoperative cancer patients receive follow-up care after treatment, primarily to detect recurrences. Traditional follow-up includes regular visits to cancer experts for examination and testing, which is expensive and may impose a burden on patients [10]. Subsequent strategies involving non-professional nursing providers, surgeries of varying intensities, or the addition of survival care packages have been developed and tested, but their effectiveness is still unclear [11]. The traditional strategy of meeting postoperative needs of cancer patients is not practical, and there is still an urgent need for new technologies that can improve health outcomes. Health education and compliance of postoperative patients are difficult to maintain in the long term.

Patients with cancer need convenient and cost-effective channels for postoperative follow-up and doctor-patient communication. The purpose of this paper is to integrate postoperative smartphone application intervention for cancer patients on quality of recovery and tailor support services to promote physical and psychosocial well-being across the cancer continuum.

Materials and methods

The systematic review and meta-analysis adhered to the PRISMA 2020 guidelines [12]. The review protocol was registered with PROSPERO (CRD42024516470), with its peer-reviewed protocol published online, focused on randomized controlled trials (RCTs) involving in 1846 patients with cancer after surgery. Quality assessment of the RCTs was conducted using the Cochrane Collaboration risk of bias tool [13]. Ethical approval was obtained for all included studies, and participants provided informed consent, either verbally or in writing.

Study selection

One of the authors (L.G.Z) performed a comprehensive search across multiple databases, including PubMed, Web of Science, Cochrane Library, Scopus, EMBASE, and MEDLINE Complete (EBSCO), covering the period from inception to March 3, 2024. Search strategy according to the requirements of each database (Attachment 1). The English literature will be included. According to the Population Intervention Comparison Results (PICO) framework [14] and the eligibility criteria for the study were as follows (Table 1).

Based on the inclusion and exclusion criteria, three rounds of screening were carried out by trained researchers (H.M.Q and C.M.Q), starting with the title, moving on to the abstract, and ending with the complete text. The justifications for eliminating papers in the full-text screening phase are presented. Each paper underwent a thorough evaluation by a minimum of two reviewers, each working independently. The group meetings deliberated on the disparities among the reviewers until a unanimous agreement was achieved. We used EndNote 21 was used to organize the literature database. Following the elimination of duplicate entries, two autonomous researchers (H.M.Q and C.M.Q) evaluated all titles and abstracts. Once the research was determined to satisfy the requirements, they acquired the entire text and proceeded with

Table 1. Study eligibility criteria.

Domain	Inclusion	Exclusion
Population	Postoperative patients diagnosed with tumors.	Minors and elderly individuals over 75 years old; patients have no smartphone or lack smartphone expertise; rapid postoperative disease progression; readmission; severe post-operative morbidity; health condition precluding app use.
Follow-up strategy	Follow up with an intervention time of no less than four weeks.	Follow-up models that do not include app-based interventions.
Study design	Randomized controlled trials (RCTs).	Animal research, literature reviews, case studies, commentary pieces, editorials, and abstracts from meetings or conferences.
Intervention	An intervention using a mobile health application with the goal of modifying behavior to enhance health and illness management (e.g. educational content, goal setting and tracking, reminders and alerts, symptom tracking and communication tools). Mobile applications compatible with all major operating systems (iOS, Android, Windows). Features applicable to mobile applications, including web-based functionality, message reminders (e.g. SMS texts), and video display capabilities.	Not an app for postoperative cancer patients. Mobile applications primarily designed for controlling other technological tools (e.g. robotics devices, functional electrical stimulation devices, virtual reality headsets, telerehabilitation systems, brain-computer interfaces). Mobile applications that are part of larger rehabilitative systems necessitating additional equipment.
Control group	Routine follow-up and usual care.	Blank control.
Outcomes	Measurable health result that can be evaluated for clinical efficacy, such as ratings obtained using a recognized standard instrument (e.g. Self-efficacy Scale, Anxiety and Depression Scale, Short Form Health Survey, Quality of Life Scale and degree of satisfaction).	Outcome measures cannot be calculated using specialized scales.

further screening. A consensus was reached to overcome disagreements.

Data extraction

Data extracting was carried out by two individuals (H.M.Q and C.M.Q) using pre-designed forms. For each trial, we gathered information on the clinical aspects (participants, interventions, and outcome assessments) as well as the specific specifics of the treatments and the findings of each outcome. The quality of the included studies was assessed separately by two reviewers, H.M.Q and C.M.Q. Any discrepancies were addressed by discussion and consensus with a third reviewer, L.G.Z. Each RCT was classified according to its risk of bias in six specific areas: sequence generation, allocation concealment, blinding of participants and outcome assessment, incomplete outcome data, selective outcome reporting, and other conceivable risks. Risk of bias was categorized as low, high, or uncertain. This categorization was based on information obtained from published articles and supplementary materials as well as direct communication with the study authors when necessary.

We extracted the mean (Standard Deviation, SD) and CI (confidence interval), length of follow-up, and characteristics of the interventions. We collected data on the impact of app-based treatments across all the age groups. Two reviewers (H.M.Q and C.M.Q) independently conducted data extraction and risk of bias assessment using a structured Excel spreadsheet. Discrepancies among reviewers were resolved by conversation, and if needed, a third reviewer (L.G.Z) was consulted. Articles that were unable to retrieve numerical values were omitted.

Data synthesis

Statistical analysis was performed using RevMan (version 5.4; The Cochrane Collaboration) and the R meta package (version 4.3.1; R Project for Statistical Computing). Our assessment of outcomes employed standardized mean difference (SMD) along with a 95% confidence interval (CI), considering a P value less than 0.05 as statistically significant. Heterogeneity was assessed using the I^2 test.

Risk-of-bias assessment

Assessing the potential for prejudice and the level of research excellence: Two unbiased evaluators used the Cochrane Collaboration tools [15] to evaluate the likelihood of prejudice in the following domains: generation of randomization sequences, concealment of allocations, participants and investigators, assessors of outcomes, blinding of data assessors, integrity of outcome data, and selective reporting of outcomes. The assessment of bias was conducted using RevMan v5.4. If any differences arose, they were resolved *via* a group discussion or by seeking the input of a third party who is well-informed and impartial.

Bias in the results report is an unrecognized issue that affects a significant portion of the conclusions of the Cochrane review. Individuals conducting system reviews need to clearly address the issue of missing result data to consider their review as a reliable source

of evidence. Extra caution is required during data extraction. Reviewers should determine when the test reports measured results, but do not report results or observe events and encourage contact with the test personnel [16].

Assessment of reporting biases: If more than ten studies were qualified for a quantitative analysis (meta-analysis), a funnel plot [17] was utilized with RevMan v5.4 to examine reporting biases.

Statistical analyses

Meta-analysis

Heterogeneity was examined using the χ^2 test ($\alpha = 0.1$) and the I^2 test. If the *p*-value of the χ^2 test was less than 0.1 and the I^2 was more than 50%, the randomized effect model was employed. If the *p*-value of the χ^2 test was more than 0.1 or I^2 was less than 50%, the fixed effect model was applied. When faced with heterogeneity, we conducted a subgroup analysis to investigate clinical heterogeneity, especially intervention time (Intervention time < 6 months or Intervention time ≥ 6 months). The random-effects approach produces more uniform study weights than the fixed-effects model does. In comparison to the fixed-effects model, large studies are awarded less relative weight, whereas small studies are assigned a greater relative weight [18].

We used a random-effects model to obtain pooled effect size estimates, and study heterogeneity was examined using I^2. Due to the inconsistent evaluation scales for outcome indicators, such as the EORTC-QLQ-C30, QLQ-CR29, EORTC-QLQ-PAN26, and EORTC-QLQ-BR23 scales used for QOL outcome indicators. Standardized mean differences (SMDs) were also computed. If standard deviations (SDs) were missing from the retrieved data but other statistical information such as t values, P values, and confidence intervals (CIs) were available, we utilized these parameters to compute effect sizes following the guidelines outlined in the Cochrane Handbook [19].

Sensitivity analyses

We conducted sensitivity analyses by excluding trials with a high or unknown risk of bias and those with similar risks in other aspects. We also excluded RCTs with follow-up durations of < 4 weeks. Additionally, to evaluate the impact of individual studies on our pooled outcomes, we performed a sensitivity analysis, systematically omitting one study at a time and confirming the robustness of our findings. Publication bias was assessed using funnel plots for asymmetry when at least ten trials were available.

Patients did not participate in formulating the research question or determining outcome measures, nor were they involved in designing or executing the study. Their input did not seek to interpret or phrase the findings. The results will be disseminated widely through social media and professional networks, reaching a diverse audience including the general public, patients, healthcare providers, and experts in the field.

App feature analysis

We selected a minimum effect size of 0.2 or higher as the criterion for a successful app. This value was used as the dependent variable in a logistic regression model. Statistical analyses were conducted using R 4.3.1 [20,21] (R Core Team 2019) and Review Manager5.4.

Results

Through the process of conducting database searches, 731 records were discovered. Of these, 15 satisfied the inclusion criteria and were included in the present review. Refer to Figure 1 for the PRISMA flowchart [12] illustrating the process of research selection, which also provides reasons for excluding full-text publications. The rationale for excluding literature after completing the book is shown in Attachment 2.

Attachment 3 summarizes the characteristics of these studies.

Study characteristics

Participants

The sample sizes ranged from 24 to 339, with a total of 1 831 participants across 15 studies. On average, the age of the participants varied from 45.75 (SD 12.63) to 69 (SD 3) years. The most common condition was breast cancer [22–25] (4/15, 26.7%). Other types of cancer include: pancreatic cancer [26], colon cancer [27], oesophageal cancer [28], colorectal cancer [29], oral cancer [30], gastric cancer [31], thyroid cancer [32], non-small cell lung cancer [33] and bladder cancer [34]. Only three articles [24,25,35] (3/15, 20%) limited the maximum age of the included patients. Two [35,36] (2/15,13.3%) of the articles did not impose restrictions on tumour types.

Interventions

The intervention duration ranged from four weeks to two years. The citation applications' functions (Figure 2) can be categorized as follows: delivering health education and guidance(12/15,80%); facilitating physician-patient

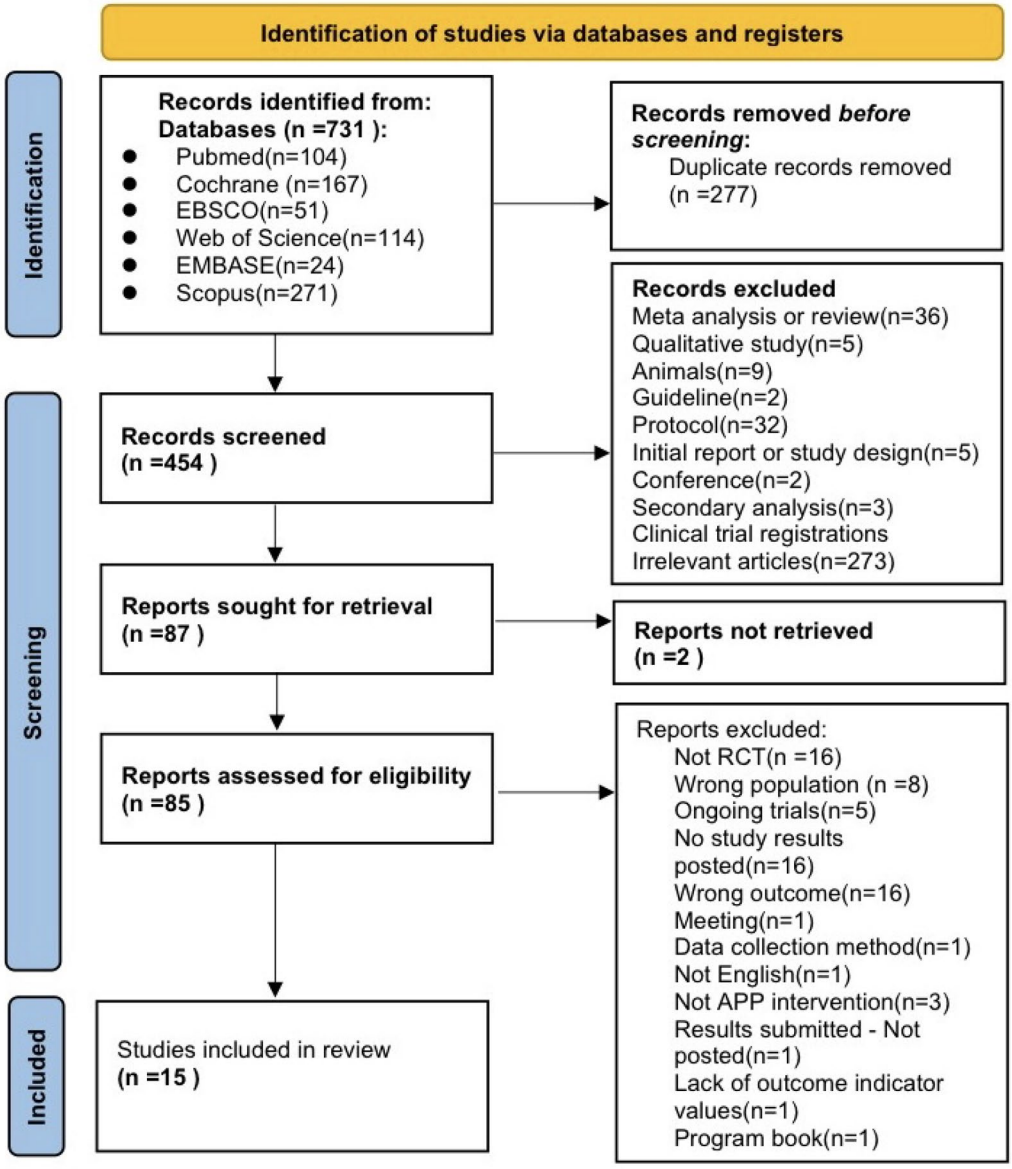

Figure 1. PRISMA Flow diagram of study selection.

communication(11/15,73.3%); data management pertaining to self-management habits of cancer patients(6/15,40%) (including data upload, visualization, and reminders); pain management(1/15,6.7%); side-effect management and drug complications(4/15,26.7%); nutritional education(3/15,20%); psychological education and support(5/15,33.3%); physical activity tracking(6/15,40%); and medication adherence(4/15,26.7%). The numbers of these nine functions in each article are shown in the following figure. The interaction between physicians and patients occurs *via* two methods: the application creates automatic feedback using predesigned individualized input, and medical professionals provide interactive assistance based on personalized data supplied by the patient. The majority (12/15, 80%) of these trials included tailored advisory services offered by healthcare experts that assessed patient data and talked with patients *via* SMS text messages, phones, or videos. Most of the mHealth apps (11/15, 73%) can provide patients with an online channel for direct communication with healthcare professionals.

Risk of bias

The Cochrane Risk of Bias tool for RCTs (Figure 3) was used to assess the risk of bias in all studies. The randomization approach (random sequence generation) for the majority (12/15, 80% low risk of bias) of the experiments was deemed sufficiently explained. More than half of the studies provided information on

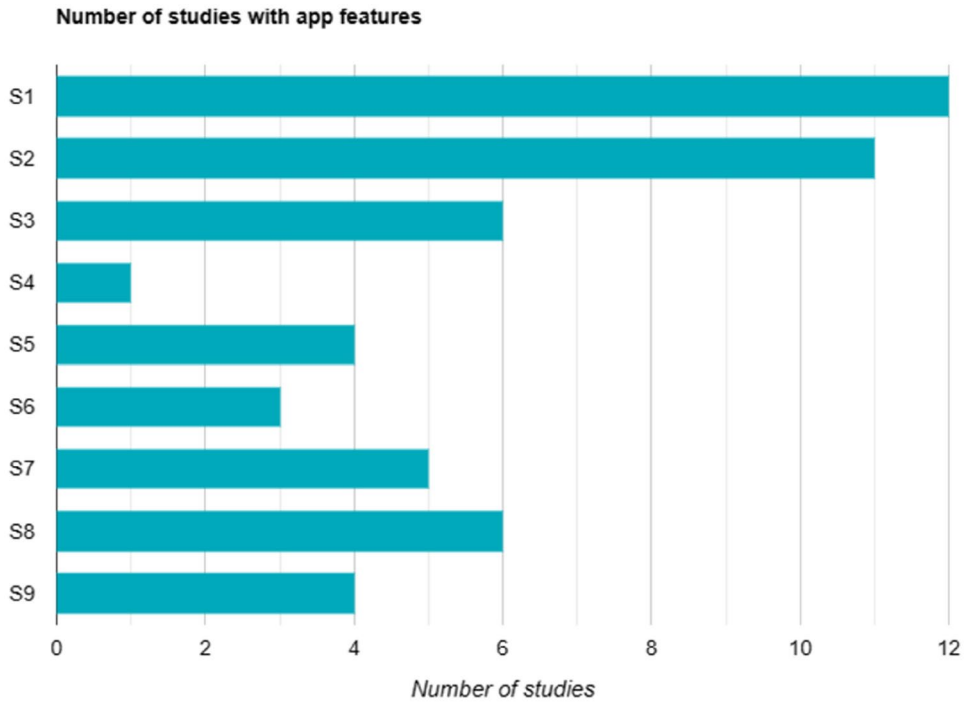

Figure 2. Number of studies with app features. S1: Delivery of health education and guidance; S2: physician-patient communication; S3: Data management pertaining to self-management habits of cancer patients; S4: Pain management; S5: Side-effect management and drug complications; S6: nutritional education; S7: Psychological education and support; S8: Physical activity tracking; S9: Medication adherence.

allocation concealment (10/15, 66.7% indicating low risk of bias), while the description of blinding for participants and personnel was less comprehensive (5/15, 30% indicating low risk of bias). All the included articles had no missing values and have fully reported the values of the corresponding outcome indicators. The attribution bias and reporting biases were low. Other biases in most studies were unclear (14/15,93.3%). Only two [28,31] articles describe how to evaluate or control confounding factors.

Utilizing the GRADE [37] summary of evidence, the evidence quality for the main outcome was deemed to be high. The articles included were RCTs with a low risk of bias, good consistency, and a large number of included patients. In the final rating of quality for each outcome, anxiety and depression (four RCT), physical health (three RCT) and self-efficacy (three RCT) were classified as high quality. Satisfaction (three RCT) was classified as moderate due to the small number of studies included and the wide confidence interval quality.

Sensitivity analysis

One study [34] was excluded because the Chinese version of the Stoma-QOL Quality of Life Scale for Stoma Patients was used instead of the global universal scale for tumour patients to explore potential sources of heterogeneity. After removing this literature, heterogeneity was removed from 'Tau^2 = 0.39; Chi^2 = 105.86, df = 9 ($p < 0.00001$); I^2 = 91%' becomes 'Tau^2 = 0.07; Chi^2 = 25.55, df = 8 (p = 0.001); I^2 = 69%'

Publication bias was assessed using funnel plots (Figure 4) for asymmetry when at least ten trials were included.

Forest plot displaying the random-effects model of the primary analysis. Each white dot represents an individual study included, and the white diamonds indicate the computed effect size. The larger the sample size, the more reliable the result, the smaller the variance, the smaller the standard error, and the more concentrated the small points are in the narrow area at the top of the funnel plot. A large sample size and high research accuracy were distributed at the top of the funnel plot and concentrated towards the middle. Three articles outside the funnel plot indicate heterogeneity [38]. In addition, the appearance of the funnel plot was asymmetric, and there was a blank space at the bottom corner of the graph indicating publication bias. The effect calculated by the meta-analysis may overestimate the efficacy of the intervention measures.

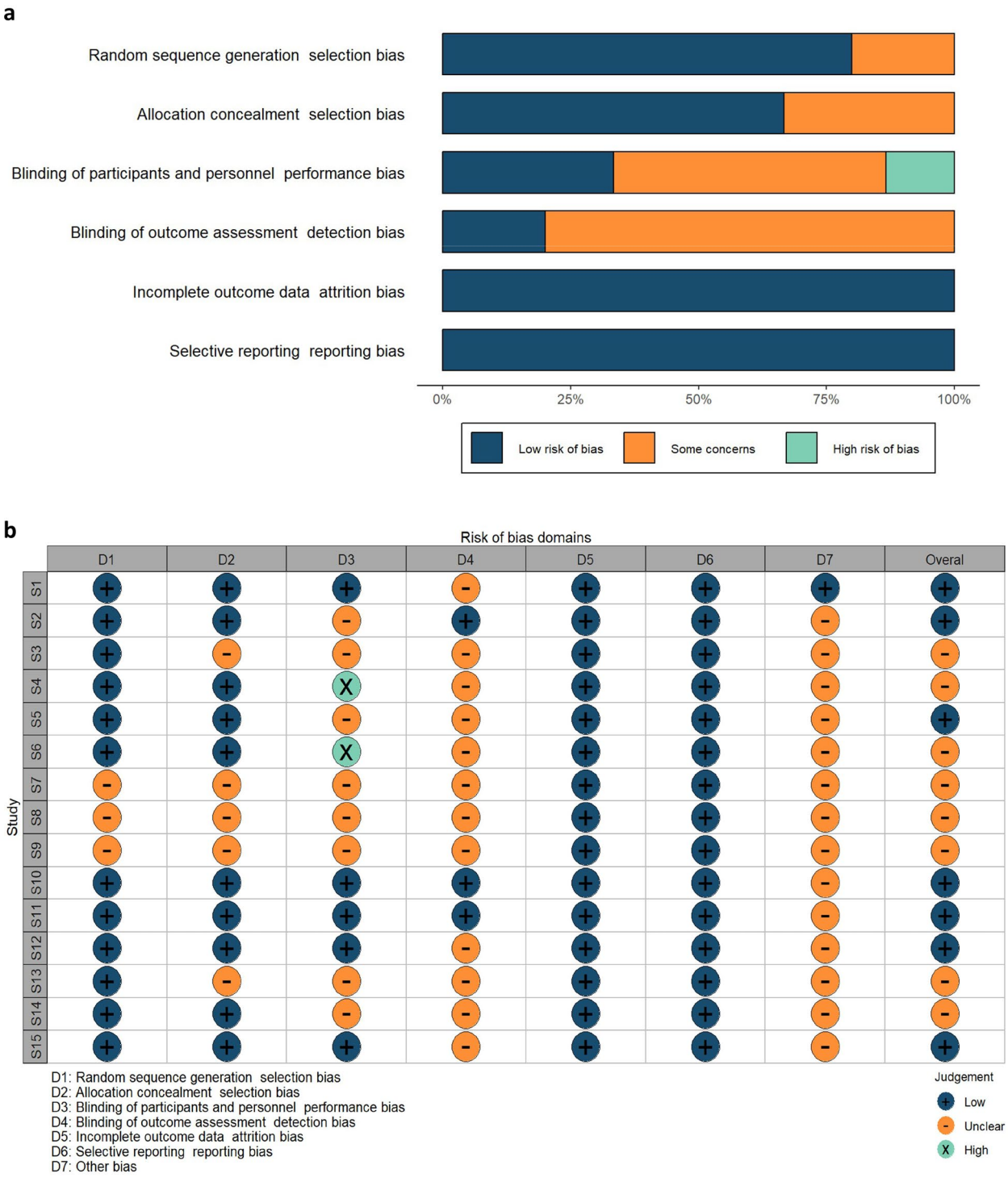

Figure 3. Risk of bias assessment. Overall summary (a) and individual bias assessment (b) for included randomized controlled trials assessed using the Cochrane collaboration tool.

Meta-analysis

Effects on QOL

A total of 67% (10/15) [22,24,26–28,30,31,33–35] of the studies involving 1545 participants utilized different scales to report QOL outcomes. Due to substantial variability among the studies (p<.001; I^2 = 91%), the findings were aggregated using a random-effects model. Owing to slight differences in the selected scales, SMD was chosen for effect size consolidation. Overall, interventions through mHealth applications enhanced scores related to QOL (SMD = -0.58, 95% CI −1.00 to −0.16; p = 0.007; Figure 5).

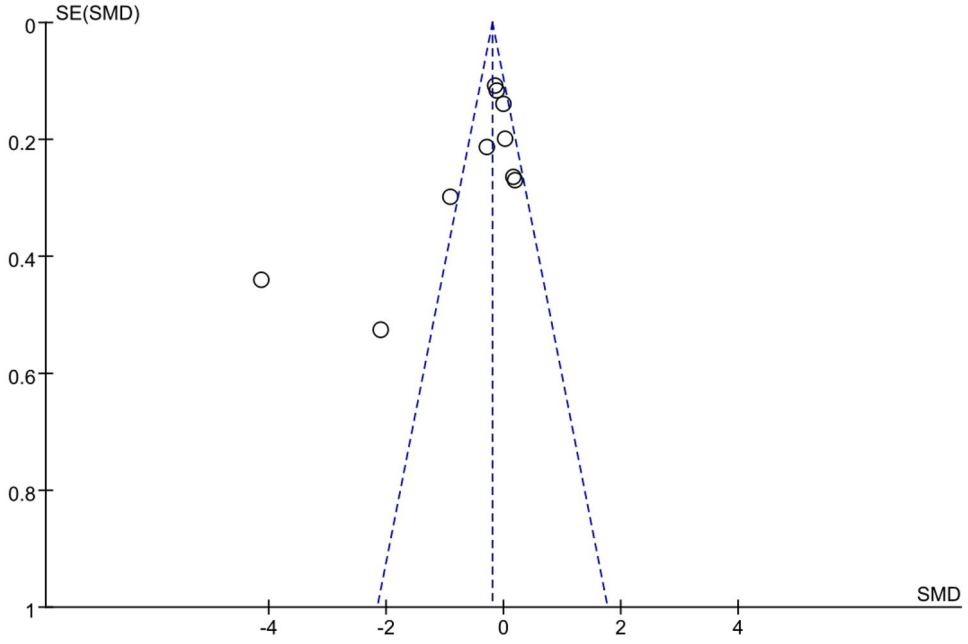

Figure 4. Forest Plot.

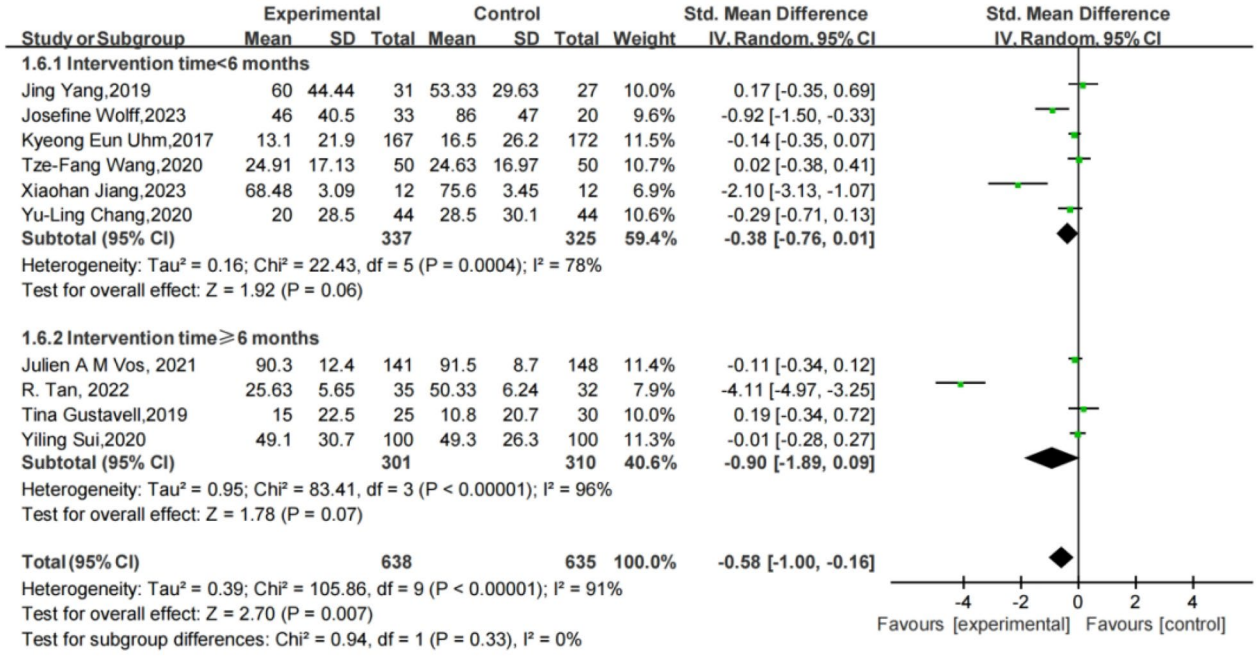

Figure 5. Effect size for quality of life.

The subgroup analysis test revealed no statistically significant subgroup effect ($p = 0.33$), indicating that the duration of the intervention did not alter the impact of intervention outcomes. The test for subgroup differences $I^2 = 0\%$ showed no differences between the subgroups. Since the results from all trials included in this analysis were relatively homogenous, it is unlikely that this analysis would have been performed to investigate the sources of heterogeneity. The sample size of the study population between the two subgroups was similar: Intervention time < 6 months (662 people) and intervention time ≥ 6 months (611 people). As no significant subgroup effects were observed, conducting this subgroup analysis may not be important. It is important to consider the distribution of covariates before drawing conclusions based on the results of subgroup analysis [39].

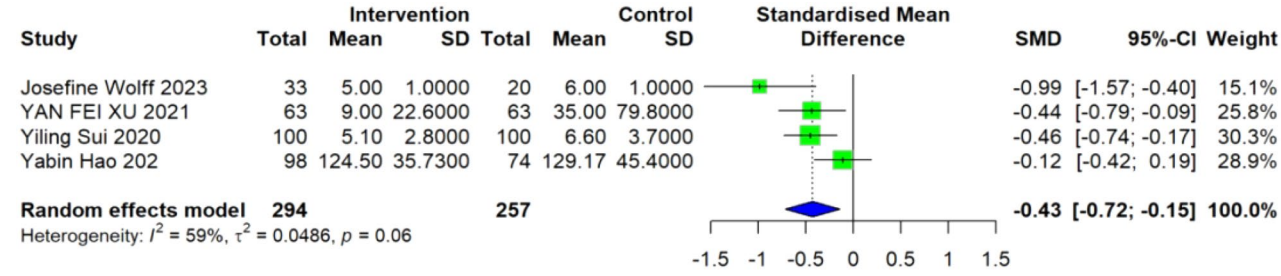

Figure 6. Effect size for anxiety and depression.

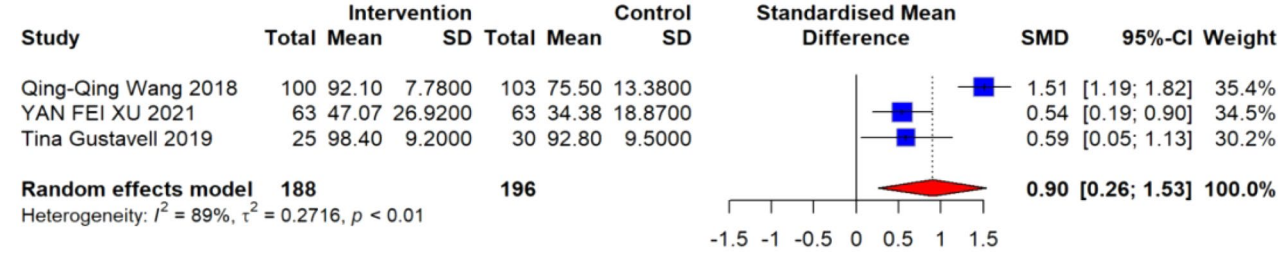

Figure 7. Effect size for self-efficacy.

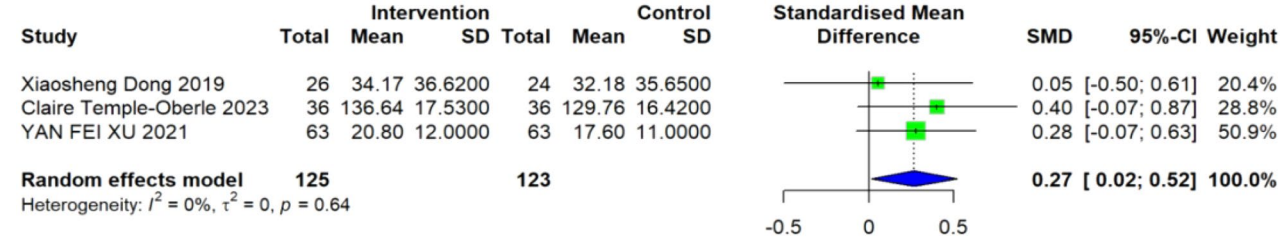

Figure 8. Effect size for health condition.

Effects on anxiety and depression

The meta-analysis of anxiety and depression covered 27% (4/15) [22,25,32,33] of the studies, which included 551 patients with cancer. Owing to the heterogeneity among the studies (p = .06; I^2 = 59%), a random-effects model was used to combine the data. Overall, the mHealth app interventions significantly alleviated distress and anxiety among cancer patients (SMD = −0.43, 95% CI −0.71, −0.15; p = .03; Figure 6).

Effects on Self-efficacy

A total of 20% (3/15) [25,26,29] of the studies reported self-efficacy as an outcome. These three studies showed that using the mHealth app can significantly improve the self-efficacy of postoperative cancer patients (SMD = 0.89,95% CI 0.21-1.58; p = 0.01; I^2 = 89; Figure 7).

Effects on health conditions

A total of 20% (3/15) [23,25,36] of studies reported health conditions as an outcome. These three studies showed that using the mHealth app could improve the health conditions of postoperative cancer patients (SMD = 0.27,95% CI 0.02-0.52; p = 0.04; I^2 = 0; Figure 8).

Effects on satisfaction

A total of 20% (3/15) [23,25,30] of studies reported satisfaction as an outcome. The pooling of studies showed no statistical difference between the intervention group and control group (SMD = 1.25, 95% CI −0.81,3.32; p = 0.23; I^2 = 98%; Figure 9). Use of mHealth app may not increase patient satisfaction.

Discussion

This systematic review and meta-analysis aimed to describe the development of a smartphone-based interventions to improve the physical and mental health outcomes of patients with cancer after surgery. To our knowledge, this is the first comprehensive review to examine the efficacy of smartphone app-based therapies in postoperative cancer patients. It also includes a thorough evaluation of the current

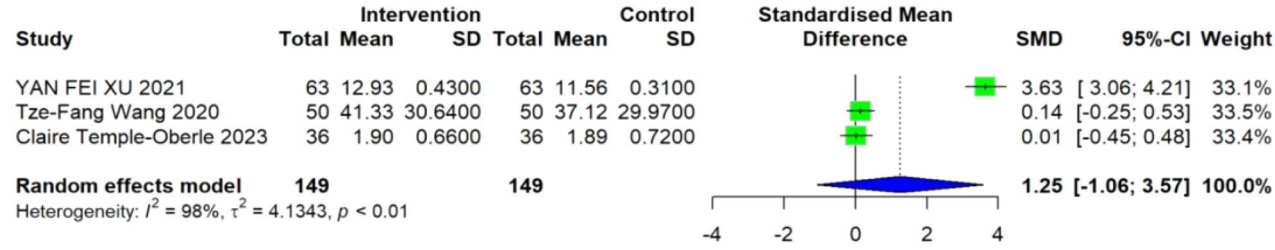

Figure 9. Effect size for satisfaction.

reporting standards. This research examined the use of smartphone applications to enhance traditional postoperative care in 15 different studies. A broad range of patient populations, interventions, and outcome measures had been documented, showing significant variability. We adhered to the guidelines provided by the Cochrane Collaboration and PRISMA Declaration. This study also conducted a thorough evaluation of the credibility of the evidence using the GRADE methodology. Accurate data, particularly trustworthy cancer registries and quality assurance monitoring and assessment systems, are essential for effective cancer control planning [1] The use of mobile data software may provide the possibility for a global cancer patient data sharing platform to be entered in the future. Our study also subdivided and categorized the mobile apps functions used in each included article. Most software covered the two main functions of health education consultation and communication. For cancer patients, pain management is the most lacking module, with only one article [35] involved. In the future, more attention needs to be paid to postoperative cancer pain management for cancer patients. Despite the variety of tumour types included in the studies, common psychological symptoms such as anxiety, depression [40], psychological distress, and fear of cancer recurrence [41] are prevalent among all cancer patients.

However, this study had some limitations. First, masking participants using smartphone app-based interventions is impossible. Although all studies were RCTs, their quality exhibited variance. While some studies explicated specific blinding and random allocation methodologies, others failed to do so. Second, the included studies had qualitative and methodological deficiencies. Several studies did not clarify the methods used for allocation concealment, blinding of researchers or participants, blinding of outcome assessment, or techniques for dealing with inadequate outcome data. Only two [28,31] articles describe how to evaluate or control confounding factors. The data evaluated had limitations, including inherent risks of bias in the original research designs. Hence, future research should prioritize meticulous implementation of allocation concealment, participant blinding, and outcome evaluation to ensure the generation of more reliable and valid results. The third issue pertains to clinical heterogeneity: patients with different types (breast cancer, pancreatic cancer, colon cancer, oesophageal cancer, colorectal cancer, oral cancer, gastric cancer, thyroid cancer, non-small cell lung cancer and bladder cancer) and staging of cancer, inconsistent versions of outcome evaluation scales, or the use of specific and targeted evaluation scales for cancer patients rather than universally applicable scales. Additionally, different groups of people exhibit varying degrees of mobile phone usage. Moreover, disparities in tumour knowledge and comprehensiveness of follow-up content (from 4 weeks to 2 years) across different apps collectively influence variations in efficacy. The sample size and the duration of intervention varied. Each application has subtle differences in intervention measures and functional focus (Figure 2 Number of studies with app features). The fourth point is reflected in the limitations of the research population: the incidence of cancer in patients is still in the middle-aged and elderly populations, who have a relatively low frequency of smartphone usage. At the same time, the coverage of smartphones in this population shows the use of apps, and they are not familiar with the use of smart devices, which affects the effectiveness of the intervention. The population is relatively concentrated and there is a lack of research on the young and middle-aged populations. The young and middle-aged population is proficient in and highly compliant with the use of mobile smart devices, with strong learning abilities, easier acceptance, and better results. In addition, there is a danger of bias if the personnel responsible for measuring the outcomes are not blinded to the allocation, which is the case in almost all trials. The reporting bias may have exaggerated the results. However, any potential overestimation might be balanced by variables, such as incomplete involvement in treatments by the target group or inadequate compliance. Finally, during the literature search process, many registered and ongoing articles that met the inclusion criteria were found, but they

were also excluded due to a lack of experimental results. By confining our search to only English papers, we may have overlooked significant research published in languages other than English. Unpublished studies and gray literature were excluded from the analysis, which may have introduced publication bias.

Mobile phone technology may be a part of transitional care to deliver mental and physical interventions to cancer patients, compensating for the shortcomings of comprehensive post-tumour education among nurses and sharing nurses' work pressure in clinical practice. Utilizing smartphone applications and information technology may enhance medical services to a limited degree, allowing for the specific remote treatment of frequent dangers among postoperative cancer patients with unique needs. Smartphone apps may be used to improve access to healthcare, decrease patient waiting times and expenses, and optimize resource utilization. Nevertheless, the absence of any improvement in patient satisfaction might be attributed to variables such as the asynchronous nature of medical data and inadvertent disclosure of electronic prescription information. In the future, advanced software must adhere to applicable rules such as the Health Insurance Portability and Accountability Act (HIPAA) [42] in the United States and the General Data Protection Regulation (GDPR) [43] in the European Union. Utilizing patient management software with integrated compliance capabilities enables firms to uphold data privacy, fulfill regulatory obligations, and prevent substantial penalties or legal complications. The wide range of perspectives and varying levels of success in implementing patient engagement make it challenging to combine and analyse data. One should be cautious when interpreting the benefits of app treatments because of the significant variation in the definition and scoring of the assessment instruments are defined and scored. This meta-analysis only included RCTs and used random-effects models to combine outcomes, where deemed suitable, to obtain the most cautious estimations. Further rigorous experimentation is necessary to determine the optimal intervention duration and to address the methodological shortcomings observed in prior studies.

Conclusion

This meta-analysis of randomized controlled trial studies showed that smartphone app–based interventions might improve postoperative recovery in patients with cancer. Nonetheless, owing to variations in intervention measures and study designs, cautious interpretation is warranted. Further trials with a randomized, double-blind, and multicentre study design are needed to confirm this effect, considering the small number of clinical trials included.

Attachment 1 Searching strategy.

Attachment 2 Reasons for deleting literature

Attachment 3 Characteristics included in the literature

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Author contributions

Mingqian He: Topic selection, literature search, literature screening, data extraction, software analysis, quality evaluation, and paper writing. **Meiqian Chen:** Conceptualization, literature search, literature screening, and data extraction. **Yue Ji:** Input data checks, paper writing, and polishing. **Guanzhen Lu:** developed retrieval strategies, data checks, article polishing, and editing.

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Data availability statement

Data sharing was not relevant to this study because no new data were generated or evaluated in this investigation.

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