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REVIEW ARTICLE

**Barbara Kopczyńska[1*], Rafał Dyrda[2*], Oliwia Czyżniewska[3], Natalia Wierzejska[1], Mikołaj Domański[1], Karina Otręba[1], Karolina Czupryńska[1], Julia Szałajska[1], Maria Wojcieszek[1]**

[1]Faculty of Medicine, Medical University of Warsaw, Poland
[2]Department of Radiotherapy, Maria Sklodowska-Curie National Research Institute of Oncology, Warsaw, Poland
[3]School of Medicine, Collegium Medicum, University of Warmia and Mazury, Olsztyn, Poland
[*]*Authors contributed equally*

# Mobile applications in treatment of cancer pain — a systematic review

**Address for correspondence:**
Barbara Kopczyńska, MD
Faculty of Medicine, Medical University of Warsaw
ul. Żwirki i Wigury 61, 02–091 Warsaw, Poland
e-mail: kopczynskabasia@gmail.com

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## ABSTRACT

**Introduction.** Chronic pain is often the greatest burden cancer patients experience, impacting their quality of life and daily functioning. Mobile applications are increasingly being utilized in the treatment of chronic diseases. Our review aimed to research whether mobile applications are effective in the treatment of cancer pain.

**Methods.** Searches were conducted at the beginning of April 2024. Relevant studies were identified through databases including PubMed, Embase, the Cochrane Library, and Web of Science. The effects of apps were assessed by meta-analysis and descriptive analysis.

**Results.** In randomized control trials (RCT), the estimated standardized mean difference in pain reduction between combined trial and control groups based on the random effects model was –0.3879 (95% CI from –1.06 to 0.29) and was not statistically significant ($z = -1.13$; $p = 0.26$). The data was heterogenous ($Q = 25.99$; $p < 0.0001$; I2 = 92.49%). In single-arm studies, the estimated average standardized mean difference based on the RE model was –0.4015 (95% CI from –0.59 to –0.22). The outcome was significant ($z = -4.28$; $p < 0.0001$) and the data were homogenous ($Q = 2.16$; $p = 0.54$; $I^2 = 0.00\%$). The results of other studies where we conducted descriptive analysis were statistically significant and showed cancer pain reduction using different scales.

**Conclusions.** Our analysis indicates that applications can be effective in managing cancer pain. Modern apps, with their advanced algorithms, show promise for future cancer pain treatment. However, our analysis was limited by lack of data on pain control prevalence in oncological populations, highlighting the need for more high-quality RCTs on larger patient groups.

**Keywords**: mobile applications, cancer pain, mobile health, pain management

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## Introduction

### The prevalence of cancer and corresponding pain

Cancer remains a significant challenge for society, public health, and the economy in the 21st century. Based on the estimates from the International Agency for Research on Cancer, there were about 20 million new cases of malignant tumors in 2022 and 9.7 million related deaths. Predictions state that cancer morbidity will reach 35 million new cases a year by 2050 [1]. One of the most debilitating symptoms oncological patients experience is pain [2, 3], whose combined prevalence in individuals with cancer reached 44% [2]. Comparing recent data [2] with the literature review from 2016 [4], the pain oncological patients experience is decreasing,

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due to improvements in treatment. Despite this, many patients still suffer from pain that is not effectively controlled, with approximately 40% found to have received inadequate analgesic treatment [5] Another related issue is the phenomenon of breakthrough pain, estimated to afflict 40–80% of the oncological population, particularly those with advanced disease [2, 6]. Insufficient pain control may lead to decreased patient compliance and inadequate management of other aspects of the disease [7]. Pain profoundly impacts the quality of life, hinders recovery, and disrupts daily functioning [8].

## The use of mobile applications

Mobile health (mHealth) encompasses medical practices utilizing smartphones, remote monitoring devices, personal digital assistants, or other wireless tools in service of public health [9]. With the ubiquity of technology in our lives, health-related applications in particular gain popularity. Mobile apps may serve users in many ways — they enhance the patient's memory reminding them about control visits or medication intake. They can help with diagnosis and treatment through education and keeping track of symptoms and side effects [10]. This can promote positive behavior and enable the management of various conditions by the patient himself while keeping healthcare providers updated in real-time on the patient's status [11]. Studies show that applications are already successfully used in the treatment of chronic illnesses such as diabetes mellitus, asthma, hypertension, or cardiovascular diseases [12–15]. They allow for precise medication adjustments, reduce reaction times in emergency cases, and may significantly reduce costs of treatment, which makes questions about their utility in oncology all the more valid [16].

### Mobile apps in cancer pain

The idea of managing pain remotely is not new in oncology [17], and demand for applications increased exponentially in recent years [18]. Many apps appear on the internet to meet these needs, but data indicate that most of them lack the functionality to meaningfully alleviate pain and adequate research assessing their effectiveness [9]. It appears that feedback from oncological patients themselves would be beneficial to the development of such apps [7, 19, 20]. This study aimed to analyze available data on the usage of mobile apps in oncological patients and explore the possibility of their implementation in pain treatment. Thus, the research question of this study is if mobile applications aid in reducing cancer pain.

## Material and methods

### Literature search

Searches were conducted at the beginning of April 2024 and relevant studies were identified through databases including PubMed, Embase, the Cochrane Library, and Web of Science. We performed the search using keywords in titles as shown in Appendix 1. Only articles written in English were considered. There were restrictions placed on the publication date as studies made before 2012 were deemed irrelevant.

### Eligibility criteria

Studies were included if they addressed cancer patients experiencing pain, had an intervention using applications created for an electronic device like a mobile phone or computer intended for cancer pain management. They needed to include assessment of pain before and after the study using a quantifiable rating scale. Patients who were included in the analysis had to use the app for more than a week. All results were reported in English.

Studies were excluded if they were a systematic review, literature review, model study, or conference recap. If the intervention involved a telephone discussion and if the study outcomes were assessed using ordinal scales or did not include pain score reporting at all.

### Study selection

We divided the selected studies into 3 groups based on available data. The first and second were used for forest plot analysis, while the third group consisted of studies that were analyzed descriptively. The first group comprised randomized controlled trials and the second single-arm studies. The studies in these groups addressed the question: do apps help in the treatment of cancer pain? Additionally, these articles presented their results as means and distribution of 1–10 Numerical Rating Scale (NRS) scores, making combined analyses feasible. The third group — "other studies" — included studies that addressed the topic, but their findings could not be easily compared with others.

### Analysis

The main aim of this investigation was to evaluate the difference in average pain perception during the trial between the intervention and control cohorts in randomized controlled trials (RCTs) or the change itself in single-arm studies (SASs). In cases where multiple time points were recorded, emphasis was placed on the final

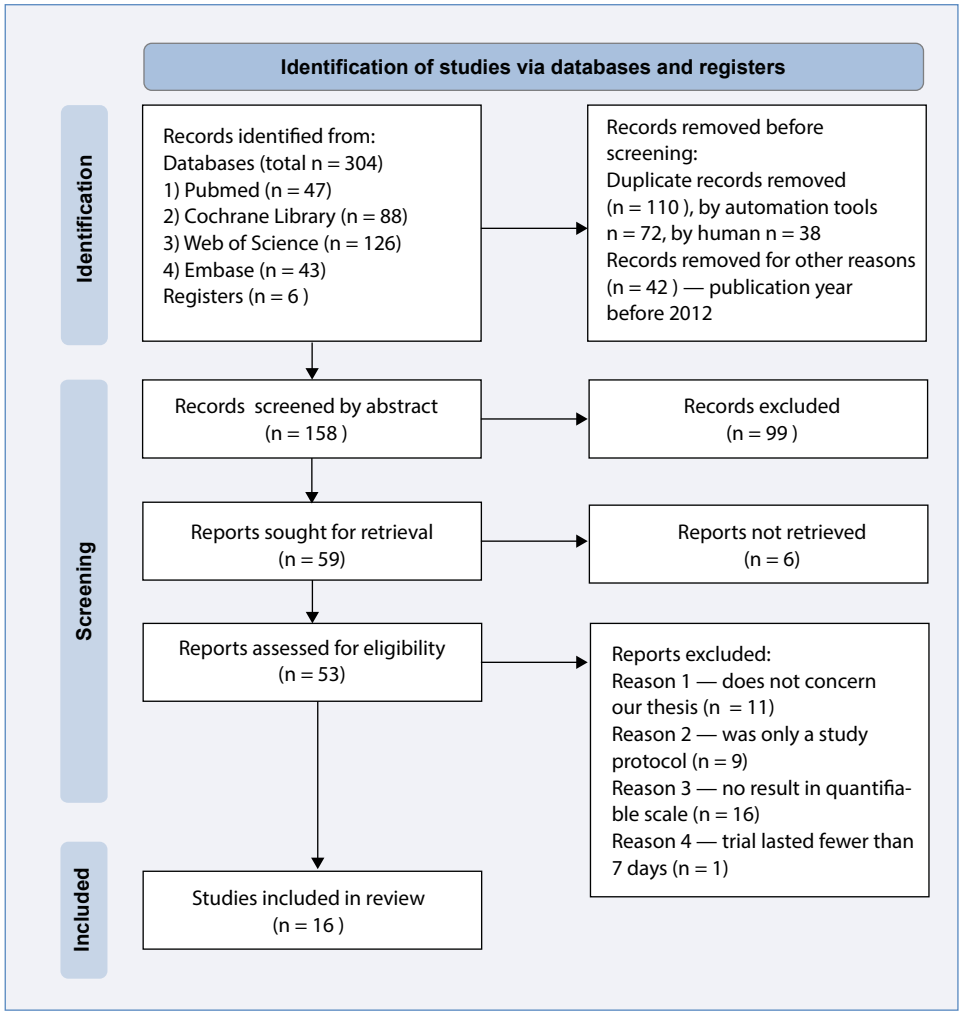


**Figure 1.** PRISMA flow diagram

point of analysis. We performed a meta-analysis in 2 parts, and due to the heterogeneity of the remaining studies, we applied descriptive and comparative approaches to consolidate results across all studies.

## Results

### Study overview

A total of 304 articles were retrieved from databases and 6 articles were retrieved from registers. After a search, using exclusion and inclusion criteria, 16 eligible studies were included (Fig. 1). In total 9 RCTs (Tab. 1 [21–29]), and 7 single-arm/before-after studies (Tab. 2 [30–36]).

### Analysis of available data

**Analysis of randomized controlled trials**

For the eight randomized control trials, we counted differences between start- and endpoint means in both trial and control groups, then counted differences between those cohorts to work out the effect each application had on pain. We excluded a study by Yang et al. (2019) [24], and Weng et al. (2024) [21] due to noncomparable data as these studies utilized QLQ-C30 Score, which cannot be directly translated into NRS 11 scale and a pilot study by Hunter et al. (2020) [23] because of the lack of comprehensible results. We present our results as a forest plot below. The difference in mean NRS scores before and after the study in the combined intervention group was slightly higher

Table 1. Characteristics of the randomized control trials

| RCT characteristics | | | | | | |
|---|---|---|---|---|---|---|
| **Study** | **Study design** | **Number of participants** | **Follow-up [weeks]** | **Age, mean (SD)** | **All functions in the app** | **Instant messaging module** |
| Weng et al. 2024 [21] | RCT | 96<br>Intervention: n = 48<br>Control: n = 48 | 4 | Intervention: 52.12 (8.95)<br>Control: 49.85 (9.74) | 1. Pain self-management<br>2. Online consultation<br>3. Reminders<br>4. Examination report upload function<br>5. Cancer pain science dissemination | Yes |
| Simon et al. 2023 [22] | RCT | 158<br>Intervention: n = 79<br>Control: n = 79 | 4 | Intervention: 7.50 (5.1)<br>Control: 7.50 (5.4) | 1. Education/access to information regarding pain<br>2. Real-time Health Care Professionals' feedback following clinically significant pain scores | Yes |
| Hunter et al. 2020 [23] | Pilot RCT | 48<br>Intervention: n = 20<br>Control: n = 28 | ~8 (60 days) | Intervetntion: 12.25 (3.58) Control: 11.86 (3.44) | 1. Daily pain measurement<br>2. The presence, frequency, and effect of particular symptoms from the time of the last diary entry | Yes |
| Yang et al. 2019 [24] | RCT | 58 Intervention: n = 31<br>Control: n = 27 | 4 | 52.53 (8.78) | 1. Self-evaluations<br>2. Reminders<br>3. Reports<br>4. Records<br>5. Real-time medical consultation<br>6. Music therapy<br>7. Pharmaceutical moments (education) | Yes |
| Kamdar et al. 2019 [25] | RCT | 112<br>Intervention: n = 56<br>Control: n = 56 | 8 | Unknown (minimum 18 years old) | 1. Education<br>2. Pain diary<br>3. Real-time medical consultation | Yes |
| Smith et al. 2018 [26] | RCT | 89<br>Intervention: n = 37<br>Control: n = 52 | 18 | 56.70 (8.7) | 1. Education<br>2. Required activities including attending one online introductory group meeting<br>3. Viewing videos to complete cognitive reframing<br>4. Mind-body exercises | No |
| Sun et al. 2017 [27] | RCT | 46<br>Intervention: n = 25<br>Control: n = 21 | 2 | 67.50 (unknown) | 1. Life quality self-evaluation<br>2. Cancer pain self-evaluation<br>3. Real-time messaging<br>4. Standard medication | Yes |
| Somers et al. 2016 [28] | RCT | 23<br>Intervention: n = 11<br>Control: n = 12 | 1 | 60 (11) | Skype | No |
| Yun et al.2012 [29] | RCT | 273<br>Intervention: n = 136<br>Control: n = 137 | 12 | Unknown | 1. Self-assessment and graphic reports<br>2. Health advice and online education<br>3. Enhanced and short message services<br>4. Caregiver monitoring and support<br>5. Monitoring by a health professional | Yes |

RCT — randomized controlled trial; SD — standard deviation

**Table 2. Characteristics of single-arm and before-after studies**

| Characteristics of single-arm and before-after studies | | | | | | |
|---|---|---|---|---|---|---|
| **Study** | **Study design** | **Number of participants** | **Follow-up [weeks]** | **Age, mean (SD)** | **All functions in the app** | **Instant messaging module** |
| Masiero et al. 2024 [30] | Pilot study | 25 | 13 | 47.12 (8.41) | 1. Pain and psychological well-being assessment section — questionnaires<br>2. Patient's diary<br>3. Educational section<br>4. Decision aid | Yes |
| Bensten et al. 2023 [31] | BAS | 71<br>Treatment group: n = 36<br>Follow-up group: n = 35 | 6 | Unknown* | 1. Symptom and activity diary<br>2. Supportive communication network between app users<br>3. "One-stop shop" information bank with practical information as well as links to patient organizations and other resources | No |
| Mohammadzeh et al. 2022 [32] | BAS | 24 | ~13 (3 months) | Unknown | 1. Education<br>2. Reminders<br>3. Contact | Yes |
| Park et al. 2019 [33] | Prospective SAS | 90 | 12 | 55.10 (8.7) | 1. To-do list<br>2. Individual health<br>3. Information<br>4. In-app chat service | Yes |
| Dorfman et al. 2018 [34] | Pilot SAS | 20 (18 completed) | Unknown (over 5 weeks) | 57.85 (11.72) | 1. Education,<br>2. Relaxation techniques training,<br>3. Weekly individual sessions – clinical psychologists | Yes |
| Oldenmenger et al. 2017 [35] | BAS | 84 (48 completed) | 6 | 59.00 (11.25) | 1. Pain dairy<br>2. Real-time consultations<br>3. Education | Yes |
| Jibb et al. 2017 [36] | BAS | 40 | 4 | 14.20 (1.7) | 1. Questionnaires,<br>2. Real-time self-management<br>3. Recommendations,<br>4. E-mail alerts | Yes |

*For this trial only median age was available: median (range), treatment group M = 24 (18–29), follow-up group m = 23 (18–29); BAS — before-after study; SAS — single-arm study; SD — standard deviation

than in the combined control groups, with the overall difference in NRS pain scores between trial and control shown in the forest plot below. The analysis describes the experience of 587 patients in total with combined trial groups including 288 patients in total. The studies used for analysis lasted from 1 to 12 weeks, which adds to the heterogeneity of data in this group.

The estimated standardized mean difference in pain reduction between combined trial and control groups based on the random effects model was –0.3879 [95% confidence interval (CI) from –1.06 to 0.29] (Fig. 2) and was not statistically significant ($z = -1.13$; $p = 0.26$). The data were heterogenous ($Q = 25.99$; $p < 0.0001$; $I2 = 92.49\%$). The study by Sun et al. (2017) [27] was a clear outlier and after excluding from the analysis, the data became homogenous ($Q = 3.39$; $p = 0.34$; $I2 = 17.23\%$) while the average mean difference dropped to –0.1148 (95% CI from –0.31 to 0.08).

According to Cook's distances, none of the studies could be considered overly influential. Rank correlation and regression test indicated no funnel plot asymmetry ($p = 0.82$ and $p = 0.63$ respectively).

**Single-arm studies included in graph analysis**

The second analysis we performed compared data from available single-arm and before-and-after studies. From 6 studies on the effect of apps on pain, we included 4 studies in forest plot analysis as only these were directly comparable.

This analysis describes the experience of 232 patients in total, all of whom had their pain assessed before and after using applications for periods ranging between 4 and 12 weeks.

A total of 4 studies were included. The estimated average standardized mean difference based on the RE model was –0.4015 (95% CI from –0.59 to –0.22) (Fig. 3).

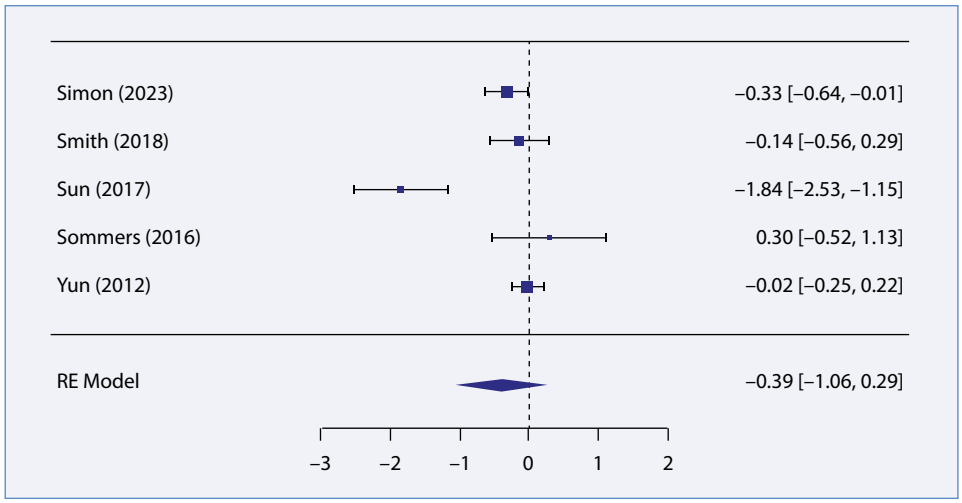


**Figure 2.** Forest plot of the randomized control trials; RE — random effects

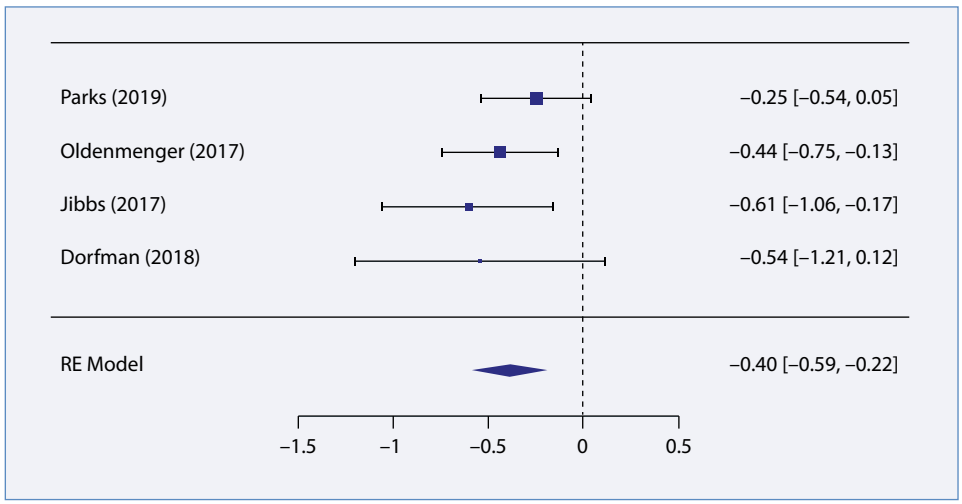


**Figure 3.** Forest plot of single-arm studies; RE — random effects

The outcome therefore differed significantly from zero ($z = -4.28$; $p < 0.0001$). There was no significant heterogeneity in the true outcomes ($Q = 2.16$; $p = 0.54$; $I^2 = 0.00\%$). There were no outliers in the model.

According to Cook's distances, no study was overly influential. There was no funnel plot asymmetry, as indicated by rank correlation and regression test.

**Other studies**

Weng and Yang conducted high-quality RCTs using the OLQ-C30 Score to measure pain — 2 of 30 questions described pain. The pain reduction was presented as median with Interquartile Range (IQR) on an approximate scale of 1–100. The results were positive in reducing cancer pain, with intervention groups from Weng et al. (2024) [21] and Yang (2019) et al. [24] experiencing significantly lower median pain after using respective apps — endpoints shown as (Med, IQR) for control and trial as follows, Weng: [50 (33.33, 66.67), 16.67 (0, 33.33)], Yang: [50 (33.33, 66.67); 33.33 (0, 33.33)]. The initial median levels of pain in both studies were remarkably similar (66.67) with minor differences between IQRs. Both the trial and control groups in Weng et al. [21] included 48 patients each and Yang et al. [24] in his trial studied 31 patients in the trial group and 27 in the control group, making their results statistically significant (both had $p < 0.001$). In the Yang et al. [24] study, the remission rate of pain showed a significant difference between the trial and control groups: Med, IQR (%) [50 (45, 63) *vs*. 0 (0, 25); $p < 0.001$]

Hunter (2022) [37] was a pilot RCT with 20 participants in the intervention group and 28 in the control.

The Adolescent Pediatric Pain Tool (APPT) was used to measure pain, as this scale is validated for children aged 8 to 18 years [37]. Both groups saw significant reductions in average daily pain. However, the intervention group had significantly fewer instances of moderate to severe pain and reported no such pain toward the end of the study.

Bentsen et al. (2023) [31] conducted a before-and-after study on adolescents and young adults (15–29) in Denmark, assessing a smartphone app's impact on quality of life (QoL) in young cancer patients. Participants were allocated to two groups: those starting cancer treatment (n = 36) and those in follow-up (n = 35). Both groups completed the European Organization for the Research and Treatment of Cancer Quality of Life (EORTC QLQ-C30) questionnaire, including pain assessment. After 6 weeks, the treatment group showed significant pain reduction [baseline median — 33.33, IQR (16.67, 50.00) *vs*. 6 weeks median — 16.67, IQR (0.00; 33.33); p = 0.04]. The follow-up group had a lower initial pain level, with an insignificant decrease [baseline — 21.90 (0.00; 41.67) *vs*. 6 weeks — 19.05 (0.00; 33.33); p = 0.37]. Both groups saw significant improvements in other QoL domains like physical, cognitive, role, and social functioning.

In the study by Mohammadzadeh et al. (2022) [32], 24 participants completed the QLACS questionnaire before and after using the app. Four questions concerned the description of pain in a 1–7 range. The average pain level was 6.37 [standard deviation (SD) = 0.637] before using the app and dropped to 4.97 (SD = 0.629) afterward (p < 0.001).

In the Masiero et al. 2024 study [30] 25 patients with breast cancer reported a reduction in pain intensity at 3 month. A repeated measures ANOVA was conducted to identify changes in pain intensity (NRS) from T0 (baseline) to T2 (3 months). The mean decreased from 5 (SD = 1.68) at T0 to 3.72 (SD = 2.59) at T2 (p = 0.04). Additionally, the total number of times the app was accessed showed a positive correlation with pain intensity at 3 months (p = 0.03).

The Kamdar et al. (2019) [25] randomized controlled trial evaluated the ePAL app, which uses AI to manage cancer pain based on patient-reported levels. The AI distinguished between urgent and non-urgent pain, providing real-time education and connecting patients with physicians if necessary. The results showed a significant decrease in pain severity (BPI) and negative attitudes toward cancer treatment (BQ-II) in the ePAL group compared to controls (coeff. –0.09; 95% CI from –0.17 to –0.007; p = 0.034; and coeff. –0.037; 95% CI from –0.072 to –0.001; p = 0.042) [25].

We analyzed 4 RCTs and 3 single-arm studies, all statistically significant. A total of 314 patients from RCTs and 120 from single-arm/before-after studies were included. Weng et al. [21] and Yang's et al. [24] RCTs showed greater cancer pain reduction in the experimental groups using the app, as measured by the median QLQ-C30. Kamdar's et al. [25] study also showed a significant decrease in pain severity (BPI). Hunter's et al. [23] pilot RCT, though small, indicated fewer instances of moderate to severe pain in the intervention group but no difference in mean pain reduction. Two single-arm studies showed significant mean pain reduction, and Bentsen et al. (2023) [31] showed median QLQ-C30 improvement.

## Discussion

### The latest systematic review on the topic

A meta-analysis on the subject, conducted by Zheng in 2020, showed that apps with instant messaging modules may improve pain control in oncological patients. In our opinion, this study had several limitations. It did not include studies performed after 2020, like Weng et al. (2024) [21] and Simon et al. (2023) [22] , which are high-quality RCTs with newer application algorithms and positive results.

The second limitation is that in the 2020 analysis, only endpoint pain levels were used to compare the studies without considering the baseline pain levels. In some of them, the differences between the experimental and control groups before the study were considerable. We believe that it is more appropriate to compare differences in pain caused by the intervention rather than just the final pain outcome in the trial and control groups. Due to the unclear origin of some data used by Zheng et al. (2020) [18] [Yang (2019) — the mean was not available], we cannot precisely calculate this. However, it should be expected that the effect of using applications on pain was overestimated in that analysis because studies on the largest populations — Yun et al. (2012) [29] and Smith et al. (2018) [26] encompassing 230 of 489 patients in total —showed a significant difference in the initial pain level to the disadvantage of the control group (mean differences of –0.23 and –0.20, respectively in both studies).

### Analysis of our study

In summary, the meta-analysis and descriptive analysis of the included studies showed that the applications are quite effective in treating cancer pain. Data from RCTs indicated that apps can be a helpful addition to the treatment of cancer pain (RE = –0.39) although the results are not statistically significant (p = 0.26). It is worth noting that while the Sun et al. (2017) [27] study was the greatest outlier, it was Somers et al. (2016) [28]

study that was most difficult to tackle due to the nature of its intervention — educational seminars conducted *via* Skype barely met our inclusion criteria and explained negative effect achieved in the study in comparison with the control group. Other than that, the study by Yun et al. (2012) [29] had a large effect on our outcomes. It was the oldest and largest of the included studies. Although the program included pain monitoring, its primary objective was to reduce treatment-related fatigue in cancer survivors. The interventions employed differed from those utilized in more contemporary applications, hence relatively poor outcomes were observed in that study.

The effect on pain in single-arm studies was positive (RE = –0.40) and statistically significant ($p < 0.001$), and stronger than in the RCT group. Moreover, data appeared very homogenous (I2 = 0.00%). The reason for this may be that the applications included had similar complex functionalities and were developed rather recently (especially when compared to Yun et al. (2012) [29] — an older study which constituted a large portion of records within our RCT analysis).

The studies excluded from combined analyses also had overall positive results and all of them were statistically significant ($p < 0.001$). The studies included were not older than 2019, and the results of using applications in pain management were assessed using various scales, which made direct comparisons difficult. Even so, it can be clearly seen that the applications tested were quite successful in improving pain control in a group of 322 patients in total.

One has to wonder if a combined analysis is even the right way to acquire the best answer to our research question. It seems more reasonable to look closely at the most effective applications and best-performing algorithms. These studies will indicate the direction in which applications should develop. When we look at the results of more modern studies like those by Weng et al. [21], Simon et al. [22], Masiero et al. [30], Hunter et al. [23], Bentsen et al. [31], or the combined SAS analysis, a trend of improved results can be seen, which offers hope that better algorithms will improve the effectiveness of pain control apps even more in the future.

## Modules and functions

It is worth mentioning that pain management applications were highly diverse in their features, functions, and included modules. More contemporary applications with positive outcomes included real-time contact with healthcare professionals. User feedback highlighted that the most important function for patients was the ability to call a healthcare professional in the case of severe pain [22]. Other appreciated features were pain monitoring, keeping track of side effects, access to information on specific medications, and educational modules. Improved patient involvement in the treatment process and personalization of the application led to greater compliance. Kamdar et al. (2019) [25] utilized AI to quickly tailor instructions sent to patients based on personalized algorithms, guiding how to handle specific situations.

## Application safety

Millions of mHealth apps (both free and paid) are currently accessible in app stores, yet none have undergone evaluation thus far. Developers can create and market mHealth apps via the app store without undergoing any quality checks [10]. Certain scholars [38] propose that impartial and dependable experts assess mHealth apps and then suggest a curated list of reliable apps to healthcare professionals for patient referral. The usability of apps is hindered by their low quality and lack of effectiveness, particularly since most are developed by non-healthcare organizations, raising concerns about their accuracy and reliability [38]. Without standardization and quality control, patients may use applications that are ineffective or can negatively impact the treatment process. Information security and privacy may also be a concern.

## Real-time contact — a solution or inconvenience?

Based on Zheng's et al. (2020) [18] results it may be worthwhile to discuss how much of healthcare professionals' attention is needed for an application to be useful. Instant messaging module entails providing healthcare professionals with immediate feedback on reported pain scores. A prior examination of the advantages of mobile applications demonstrated that digital tools featuring real-time communication were associated with enhanced quality of life and reduced pain catastrophizing. However, it is worth asking if 24-hour availability of healthcare workers does not impose on them an excessive burden. Whether the required financial investments will be too high also warrants consideration. As a result, we see several solutions to these problems. Firstly, through learning while using the application, patients can become more independent in managing their pain, reducing the need for constant contact with healthcare professionals. The Simon et al. (2023) [22] study found that many patients and families eventually felt confident in managing pain independently, leading to fewer pain reports via the app. Therefore, adding a feature that allows families to choose their level of healthcare professional contact could be beneficial. Secondly, involving healthcare professionals in developing more advanced algorithms could further empower patients' pain management.

### Compliance

The data suggest that an intuitive interface and simplicity of use are crucial for the patients to continue to use the app and obtain meaningful results. For most apps to function properly patients need to report their symptoms daily and take time to educate themselves on the nature of their pain and methods of fighting it. The nature of oncological diseases also makes it difficult for many patients to spend time and effort using such a tool, many will get discouraged before gaining any benefit from it. To enhance software usability, involving end-users, specifically patients with chronic cancer pain, in the development process is essential.

There is also a phenomenon of patients reporting more frequent and more severe pain while using electronic reporting tools such as apps [39]. This effect has likely many determinants. Patients reporting through an app are more aware of their symptoms than they attend far less frequent consultations with medical professionals. Also the app, maybe be a constant reminder of pain, which may have an adverse effect on patients' perception of it.

### Use of artificial intelligence

The shortage of palliative care providers is a significant issue in many developed countries. A solution to this could be using artificial intelligence techniques in apps. Through adaptability and machine learning during app usage, AI will become better attuned to each patient's needs. Consequently, it will select more precisely educational content and suggest improved interventions, which may ultimately lead to better pain management. It may even have the potential to replace doctors to some degree. Positive results in Kamdar's et al. 2019 study [25] achieved with their application indicate that such technology may, indeed, see much success in the future.

### Limitations

Our research is subject to several limitations. Firstly, the reviewed literature had relatively small sample sizes and different follow-up durations (from 1 to 18 weeks). Next, our analysis included both children and adults — this was done due to a general lack of data. Given the number of various pain control applications for mobile devices, it is possible that some data on the use of mobile applications for pain management have been gathered but not published when the conclusions appeared unsatisfactory for the developer. High publication bias should be expected, especially as many developers offer their apps as paid services. Furthermore, we compared apps with varying features and functions resulting in heterogenous data.

## Conclusions

Based on our analysis, applications can be effective in treating cancer pain. Modern applications, thanks to their enhanced algorithms and features, offer a promising outlook for the future. In general, our analysis suffered mostly from the lack of data, especially concerning how common the problem of pain control is in oncological populations. More studies, particularly high-quality RCTs on larger patient groups with comparable methodologies are needed to effectively address this question.

## Article Information and Declarations

### Author contributions

B.K.: conceptualization, methodology, analysis, data curation, writing — review and editing, project administration**;** R.D.: conceptualization, methodology, check, analysis, data curation, writing — review and editing, supervision**;** O.C., N.W.: conceptualization, data curation**;** M.D.: check, resources, data curation; K.O.: resources, data curation, visualization**;** K.C., J.S.: resources, data curation; M.W.: investigation, data curation.
All authors have read and agreed with the published version of the manuscript.

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### Conflict of interest

Authors declare no conflict of interest.

### Supplementary material

Search strategy.

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# SUPPLEMENTARY MATERIAL

## Search strategy

**Pubmed, The Cochrane Library, Web of Science, Embase**

| | Searches |
|---|---|
| 1 | (cancer OR oncological OR tumor OR cancerous OR cancer-related OR neoplasm-associated OR neoplasm OR tumor-associated OR tumor-related OR cancer-related OR cancer-associated OR neoplasm-related OR oncology).ti |
| 2 | (pain OR ache OR pains OR aches OR physical suffering).ti |
| 3 | (mobile OR mHealth OR mobile health OR mobile application OR smartphone application OR applications OR smartphone OR apps OR app).ti |
| 4 | 1# AND 2# AND 3# NOT (review OR systematic review OR conference).ti |