

Patient-facing cancer mobile apps that enable patient reported outcome data to be collected: A systematic review of content, functionality, quality, and ability to integrate with electronic health records

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ABSTRACT

Purpose: Enabling cancer patients to self-manage symptoms through mobile applications can result in more informed, autonomous patients who are partners in their care, consequently **reducing the burden** on health services. Electronic patient reported outcomes completed before a clinical review can **increase** the frequency and quality of holistic assessments, while integration into electronic health records can maximise clinical utility. The ability of apps to integrate with electronic health records is key to providing a **real-time interface** between **patient reports and healthcare response**. This review identifies patient-facing cancer apps which can record patient reported outcomes, and explores their purpose, functionality, quality, and ability to integrate with electronic health records.

Methods: A systematic app review and content synthesis was conducted on **patient-facing cancer apps** available in the United Kingdom. Where applicable, the review aligned with the Preferred Reporting Items for Systematic Reviews and meta-Analysis. Two validated scales **assessed functionality and quality**: The IMS Institute for Healthcare Informatics functionality score and the Mobile App Rating Scale. Flesch-Kincaid metrics explored readability.

Results: Apple App and Google Play stores identified 405 apps, of which 12 met the eligibility criteria. All were free to download, 1 (8%) had in-app purchases/subscriptions. Nine (75%) were affiliated with a professional health body/charity. Six (50%) analysed inputted data and provided medical advice based on answers. The average Flesch Reading Ease score was 42.7 out of 100. The apps had an average of 7.3 functions each and a mean MARS score of 4/5. None integrated with electronic health records.

Conclusion: **While many cancer apps exist, few enable patient reported outcomes to be recorded and shared with clinicians in real-time.** Further research is warranted to explore the feasibility of integrating with electronic health records, as this function can improve patient experience and outcomes, and increase efficiency of hospital resources through more proactive care.

1. Introduction

The global cancer burden is predicted to reach 28.4 million cases in 2040, which is a 47 % rise from 2020 [1]. Enabling people with cancer to self-manage their symptoms and quality of life (QOL) can result in more informed, autonomous patients who are partners in their own care, which can consequently reduce the burden on health services by minimising unnecessary hospital attendances [2]. For example, patients receiving systemic anti-cancer therapy (SACT) are informed of

associated toxicities of their treatment based on Common Terminology Criteria for Adverse Events (CTCAE) and educated on when to seek medical attention [3]. Typically, this is done by **phoning a 24-hour hospital hotline** [4], with details of the call recorded on the **patients' electronic health record (EHR)**. Record keeping on the EHR is valuable by promoting communication, productivity, and efficiency, increases quality and data management, and enables symptom tracking and surveillance [5]. Engaging patients and caregivers in technology-enabled structured symptom collection has several benefits, particularly

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related to the early detection of adverse events, which, if acted on, can prevent unnecessary hospital attendances [6]. The use of health-related QOL assessments completed by patients prior to a clinical review has been found to increase the frequency and quality of these holistic assessments, aiding clinicians in identifying patients with moderate-to-severe health concerns [7].

The COVID-19 pandemic has accelerated the prevalence of virtual assessments. The use of electronic patient reported outcome measures (ePROMs) has consequently become more widely utilised, which are validated, digitalised health questionnaires that can promote patient-centred care [8]. PROMs were developed to provide clarity and understanding of the effect of disease and treatments on patients' daily lives, with hundreds of standardised measures developed in the last 30 years [9]. Evidence shows significant benefits of ePROMs regarding patient care, such as greater patient-clinician satisfaction, improved communication, and enhanced efficiency in clinics [10]. However, the integration of ePROMs with the EHR does not happen routinely, which potentially minimises its impact by creating a barrier at the service delivery level through inadequate digital infrastructures [11], causing fragmented and suboptimal use [12].

Mobile phone use has become ubiquitous and could be a facilitator to integrating ePROMs with EHRs. Internet users are growing at an annual rate of 4.8 %, equating to more than 600,000 new users daily, 91 % of which use mobile devices [13]. Technological advances have seen an emergence of smartphones, whose features include powerful computing technology that support third-party applications (apps) [14]. There is an increasing use of mobile health apps aimed at promoting prevention, improving early detection, increasing patient autonomy, and holistic support for living with chronic medical conditions [15]. However, engagement varies for myriad reasons. A population-based survey of 4144 German people aged 35 years or older found that 61 % used a smartphone, with users being younger, more likely to be university educated, working full-time, and more engaged with health-related QOL and health literacy [16]. A cross-sectional survey of 1604 mobile phone users in the USA found that 58 % of users had downloaded a health-related mobile app, but 45.7 % failed to engage in continued use due to high data entry burden, loss of interest and hidden costs [17]. Engagement in an app that focussed on symptom self-management during treatment in patients with breast or prostate cancer found that users who lived with a partner had higher adherence to daily symptom reporting [18]. These socioeconomic, age, and literacy-related factors highlight disparities in the use of mobile technology. Similarly, the quality and credibility of any health-related app is of utmost importance, with evidence-based products being more likely to engage users whilst maintaining safety [19].

Apps are becoming more widely used in oncology, with emphasis placed on positively impacting self-efficacy, empowerment, and improved self-management [20]. However, previous systematic cancer app reviews have highlighted a paucity of content evaluation by health providers and acknowledged that many apps focus on general information for cancer, cancer risk, or content is specific to certain cancer types [20–23]. Additionally, none of the reviews have specifically identified whether any apps that record ePROMs integrate with EHRs. This review aims to identify UK patient-facing cancer apps with the ability to input ePROMs, and to explore their purpose, functionality, quality, and ability to integrate with EHRs.

2. Methods

A systematic app review and content synthesis was conducted on patient-facing cancer apps available in the UK. Where applicable, the review aligned with the Preferred Reporting Items for Systematic Reviews and meta-Analysis (PRISMA) guidelines [24].

2.1. Search strategy and inclusion criteria

Apps were identified from the UK Apple App and Google Play stores from the 11th October until the 15th October 2021. Keywords for the search included: cancer, cancer patient, cancer treatment, cancer management, cancer side effects.

Patient-facing apps that focussed on cancer, enabled patient data to be inputted and were aimed at adults (18 years or older) were included. Apps that were not in English, and those aimed at children, healthcare providers, organisations and students were excluded. Apps that focussed on one cancer type (e.g., breast cancer), or one symptom of cancer (e.g., fatigue), were also excluded. This is because an initial scoping search found these apps to be focussed upon specific disease-related complications, rather than SACT complications, and we wanted to explore symptom reporting more broadly. Apps were also excluded if they required log-in details provided by a healthcare provider, as these were unable to be accessed and thus, evaluated.

2.2. App selection

We selected relevant apps through a two-step process. Two authors (AV and CB) first screened the app markets by reading relevant names and descriptions. Duplicates were removed between the markets and individual searches. Secondly, three authors (NG, AV, and CB) downloaded the apps and screened them for eligibility. Two researchers reviewed each app. Two (AV and NG) reviewed those in the Apple App store using the iPhone 12 Pro (iOS 14.7.1) and iPhone SE (iOS 13.6.1) devices. Two researchers (NG and CB) reviewed those available in the Google Play store using the Samsung Galaxy A41 (Android 10 with One UI 2.0) and Samsung Galaxy S9 (Android 10 with Once UI 2.0).

2.3. Data extraction

Informed by previous app reviews [25,26], a coding sheet was created on Microsoft Excel, into which the three raters (AV, NG, and CB) extracted data from the apps (see Table 1). Descriptive information included the app's name, developer, version number, the app market/s in which it was available, cost to download, whether it was affiliated with a professional health/medical body or charity, average user rating and number of user ratings. We assessed descriptive technical content by determining whether apps contained a privacy strategy, mentioned third-party authorisations, asked to work in the background, worked offline or asked to enable push notifications, and the size of the app. We also assessed whether data could be integrated into the EHR.

Content-related information included the purpose of the app, a short summary and whether it was obviously related to cancer (e.g., the name or icon). Like another app review [26], we determined readability by copying content into a Microsoft Word document and using two Flesch-Kincaid metrics [27,28]. The Flesch-Kincaid Reading Ease score ranged from 0 to 100, with higher scores indicating that material is easier to read [27]. The Flesch-Kincaid Grade Level was also used, with scores referring to the equivalent grade level of education in America [28].

Two validated scales were used to assess functionality and quality of the apps. The IMS Institute for Healthcare Informatics functionality score [29] helped to determine which functions were available. This scale consists of 7 items and 4 subcategories, which correspond with specific functions. Items are rated 1 if the function is present and 0 if it is not. The total score was generated by totaling the items and ranged from 0 to 11. Scores between raters were cross-compared and any disagreement was resolved through discussion. As in other app reviews [25,26,30,31], the Mobile App Rating Scale (MARS) [32] was used to determine the quality of each app. The MARS consists of 19 items across four dimensions (engagement, functionality, aesthetics, and information quality), with each item rated on a 5-point Likert scale: 1. Inadequate, 2. Poor, 3. Acceptable, 4. Good, and 5. Excellent. The apps that have the highest scores are deemed to be of higher quality. The optional subscale

Table 1
Description of the data extraction items.

Items	Description
Descriptive information	
App name	Name of the mobile app
Version number	Version of the app reviewed
Developer	Name of developer
Market/s available	Google Play; Apple App
Cost	Free to download, cost to download (in GBP); in-app purchases
Affiliated with a professional medical/health body or charity	Yes; No
Average user rating	Not rated; Average number of public ratings (maximum 5 points)
Number of user ratings	Total number of user ratings
Privacy strategy	Privacy policy, login, password, two-factor authentication
Third-party authorisations (e.g., data sharing)	Yes; No
Works offline	Yes; No
Works in the background	Yes; No
Asks to enable push notifications	Yes; No
Content	
Purpose	Diagnose, record data/track, educate/inform, instruct, remind, analyse
Description	Summary of the apps content
Obviously about cancer (considering name and icon)	Yes; No
Flesch Reading Ease	Scored 0 to 100
Flesch-Kincaid Grade Level	Score corresponds with USA education grade level
Size of app	MB
Data able to be integrated into HER	Yes; No
Functionality	
IMS Institute for Healthcare Informatics functionality score	Rated 1 (present) or 0 (absent) for the following functions: 1) Inform, 2) Instruct, 3) Record, 3.1) Collect data, 3.2) Share data, 3.3) Evaluate, 3.4) Intervene, 4) Display, 5) Guide, 6) Remind or alert and 7) Communicate.
Quality	
Mobile App Rating Scale	19 items across four dimensions (Engagement, Functionality, Aesthetics, and Information Quality) rated on a 5-point Likert scale. 1 = inadequate, 2 = poor, 3 = acceptable, 4 = good, and 5 = excellent.

for subjective quality was omitted to ensure that quality assessments were only objective [25].

Raters first watched the MARS training video on YouTube [33] and then independently rated each app. They answered the question: “Has the app been trialed/tested?” by searching for published literature on evaluation (e.g., usability, satisfaction, effectiveness). Scores for each dimension were totaled and an overall mean score for quality was calculated. A mean score between the reviewers was then calculated.

2.4. Descriptive analysis

Descriptive summary statistics were generated on applicable items. Inter-rater reliability statistics for the MARS and the IMS Institute for Healthcare Informatics functionality scores were calculated using IBM SPSS Statistics (version 23; IBM, Armonk, NY). Intra-class correlation coefficients (ICCs) on all MARS items were calculated using absolute agreement 2-way mixed-effects, average-measures models [34]. Cohen’s kappa was calculated for the IMS score, given that items are rated categorically (0 = no, 1 = yes). The highest scores across the MARS and IMS measures were identified and cross-compared to identify the best rated apps.

3. Results

We identified 405 apps across Apple App and Google Play stores. Two duplicates were removed. After screening, 190 were excluded as they were not related to cancer or were diagnostic in nature (e.g., algorithm-based apps for skin cancers). A further 151 apps were excluded as they were not patient facing, were a social platform for patients, or did not enable patient data to be inputted. A total of 62 apps were downloaded, after which 50 were excluded as they **only focussed on one disease group (n = 30) or one symptom (n = 2), and thus, did not provide a broad profile of symptoms as was the goal for this review, or were for patients who were treated at a specific cancer centre (n = 5), would not open or were no longer available (n = 4), or did not allow patient inputted data (n = 9)**. Twelve apps were consequently included in the review. Fig. 1 presents the PRISMA flowchart, summarising the search and screening process.

3.1. Descriptive characteristics

Most (n = 8, 67 %) of the 12 apps were available from both the Apple App and Google Play stores, with 3 (25 %) only appearing in the Apple App store, and 1 (8 %) only appearing on the Google Play store. All apps were free to download, with only 1 (8 %) having in-app purchases/subscriptions. Nine (75 %) were **affiliated with a professional health body or charity**. None appeared to integrate with an EHR. Only 2 (17 %) apps worked offline. A privacy strategy was included in all 12 apps, with **100 % asking for a password or login**. **None of the apps enabled third-party sharing**. Of the apps, an average of 45 pre-determined symptoms were available to report (range 2–91), but only 5 apps (42 %) **enabled users to input their own symptoms**. Table 2 summarises some key characteristics.

The average user rating was 4.5 out of 5 (3.4 to 5), however, only 4 apps (33 %) were rated on both stores, 4 apps (33 %) received a rating on one store, and 4 apps (33 %) did not receive any user ratings. The total number of user ratings was 496 (range 0–258), as illustrated in Table 3.

3.2. Cancer content

All 12 apps enabled users to input data related to any symptoms they were experiencing, but only 6 (50 %) **analysed the inputted data and provided medical advice based on user answers**. Symptoms pertained to fever, mood, physical activity, pain, fatigue, and more. General cancer and cancer treatment information was provided by 5 (42 %) of the apps, and 10 (83 %) apps **provided reminders**. These reminders included **prompts to users to record any symptoms they may be experiencing, when medication is due, and links to articles/self-help guides related to their cancer diagnosis and/or SACT**. The average Flesch Reading Ease score across the apps was 42.7 out of 100 (range 19.3–64.5, SD 4.4). The American reading age grade level was grade 12 on average (range 8–19, SD 0.85).

3.3. Functionality

The IMS Institute for Healthcare Informatics Functionality score was used to identify functions available within the apps. For the IMS scale, there was moderate agreement between the two raters of the Apple App store apps, $\kappa = 0.52$, with 95 % CI (0.32 to 0.74), $p < 0.0001$. There was substantial agreement between the two raters of the Google Play apps, $\kappa = 0.62$, with 95 % CI (0.18 – 1.06), $p < 0.05$. Consensus was reached on all items through discussion. The apps had an average of 7.3 functions each (SD: 3.5; range 5–11). The three most common functions were **record** (100 %, n = 12), **collect data** (100 %, n = 12), and **remind/alert** (83 %, n = 10), while the least common were **evaluate** (50 %, n = 6), **intervene** (50 %, n = 6) and **guide** (42 %, n = 5) as illustrated in Fig. 2.

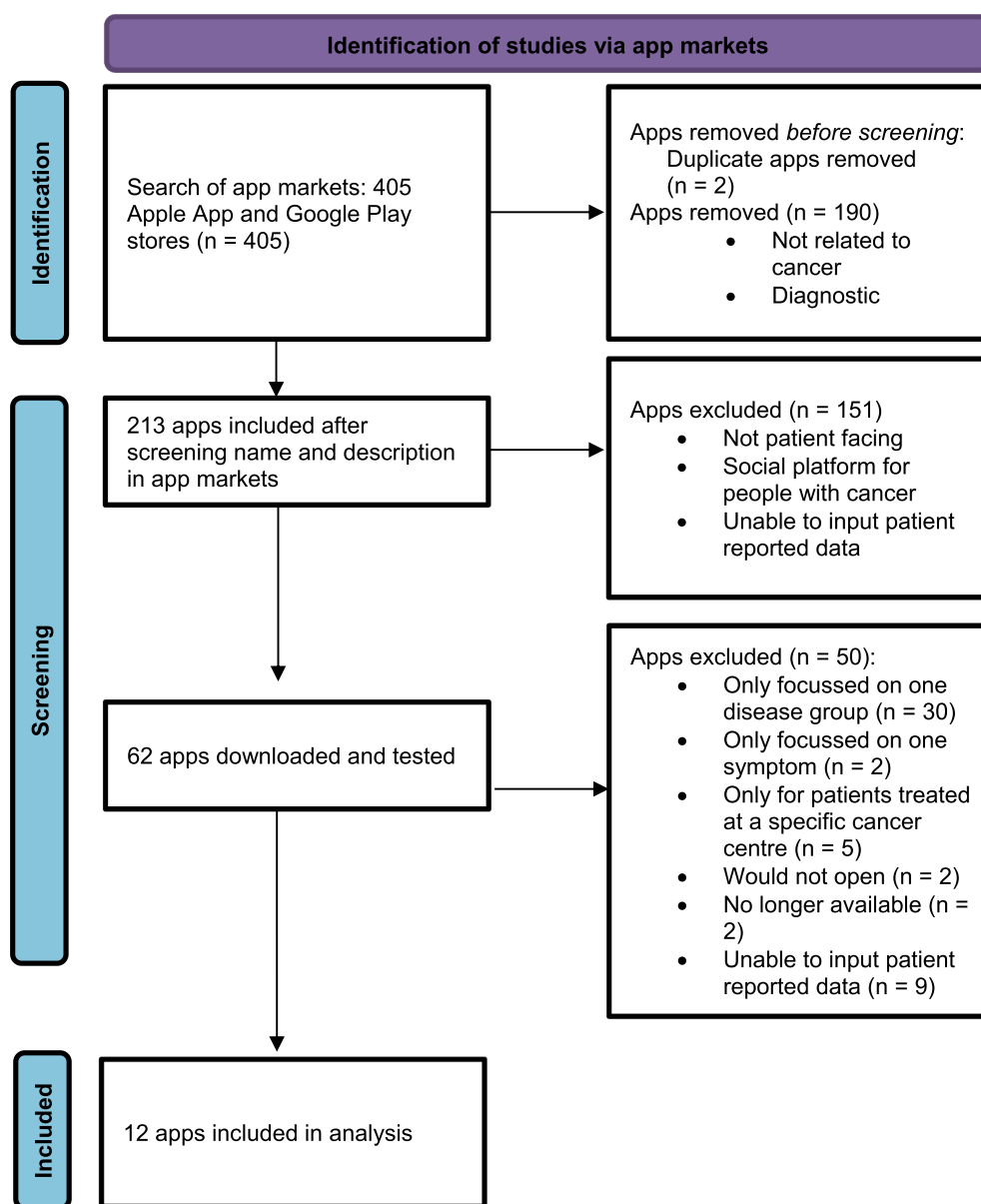


Fig. 1. PRISMA flowchart displaying the search and screening process for patient-facing cancer apps.

3.4. Quality

All apps were reviewed for quality using MARS. There was good agreement between the two raters for the Apple App store apps; ICC, 0.88; 95 % CI (0.81 to 0.92) and moderate agreement between the raters for the Google Play apps; ICC, 0.52; 95 % CI (-0.11 to -0.81). The mean overall quality score was 4.0 out of 5. All apps met the minimum acceptability score of 3 [33]. The highest scoring app was Cancer.net, scoring 4.5. The lowest scoring app was 3.2 for My Cancer Tracker. Mean scores for engagement, functionality, aesthetic, and information quality were 3.8 ± 0.6 , 4.1 ± 0.7 , 4.0 ± 0.7 and 3.7 ± 0.7 respectively. Most apps scored highest for functionality, with scores ranging from 2.8 to 5.0. Information quality was scored the lowest, with scores ranging from 3.0 to 4.8. Five of the apps were mentioned in scientific literature, but only one had been formally trialed/tested.

3.5. Cross-comparing the apps

The IMS and MARS scores were compared to identify the highest performing patient-facing cancer apps. Four apps were identified as

scoring the highest (see Table 4). They include: Careology, ChemoWave, Lifye, and Vinehealth.

4. Discussion

This review evaluates 12 patient-facing mobile apps for people with any cancer type that enable ePROMs to be recorded and explores whether integration with an EHR occurs. All apps were able to record/collect data (i.e., ePROMs), but only half provided clinical advice based on inputted data. None integrated with EHRs, and 7 (58 %) enabled reports to be shared with clinical teams either via email or by printing a copy. Most (75 %) were affiliated with a medical body and/or charity and all had a privacy strategy. The average reading score was 43 out of 100, with the average reading age being equivalent to American grade 12 (UK sixth form). The apps had an average of 7.3 functions each, with a MARS quality score of 4 out of 5, meaning all met the minimum acceptability score. However, only 5 (42 %) had been included in scientific literature, and only 1 (8 %) had been formally evaluated in a feasibility study.

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Table 2

Key characteristics of the 12 reviewed apps.

Characteristics	Number (%)
Purchase costs	
Free to download	12 (100)
In-app purchases	1 (8)
Costs to download	0 (0)
Clearly about cancer	
Yes	9 (75)
No	3 (25)
Affiliated with health body or charity	
Yes	9 (75)
No	3 (25)
Integrate with EHR	
Yes	0 (0)
No	12 (100)
Had a privacy strategy (e.g., login, policy)	
Yes	12 (100)
No	0 (0)
Enabled third-party sharing	
Yes	0 (0)
No	12 (100)
Size of app (MB)	
Median	30.1
Range	20.5 – 43.7

Table 3

User ratings.

App name	Number of user ratings		Average user rating /5	
	Apple	Google Play	Apple	Google Play
Careology	25	0	4.7	NA
Vinehealth	40	31	4.5	4.6
Cancer.Net	2	258	4.5	4.4
CancerAid	5	36	5.0	3.4
chemoWave	17	54	4.3	4.1
ByYourSide	5	NA	5.0	NA
Liyfe	0	0	NA	NA
Unify Health	0	0	NA	NA
MyCancerTracker	0	13	NA	4.2
CANKADO	0	NA	NA	NA
Cancergraph	0	NA	NA	NA
Oncopadi	NA	10	NA	5.0

Note: NA = not applicable.

pandemic has necessitated an increased use of remote care, which has expedited the digital health agenda [35]. This shift to online may result in a willingness to adopt new ways of working and reduce operational pressures on health services. The use of apps could complement existing clinical pathways for people with cancer who are receiving SACT and enable more proactive and robust virtual care. However, it is evident that the functionality and quality of cancer apps varies, and most are not verified by evidence in published scientific literature. Our app review indicated an average MARS score of 4 out of 5, which was much higher than previous app reviews. For example, a review of 45 apps for patients with genitourinary tumours reported a mean score of 2.98 (range 1.95–4.63) [30], while another on 12 cancer apps reported an average score of 2.9 (range 1.7–3.7) [36].

Whilst five of the reviewed apps were mentioned in published scientific literature, none were tested in randomised controlled trials. The CANKADO app was discussed by the managing directors in a paper on how it could benefit workflows and reduce workload, whilst maintaining patient safety, but no data was presented [37]. Two papers focussed on the Vinehealth app, although one is written by the app's co-founder [38]. In one paper, the implementation of the Vinehealth app for people

with brain cancer was assessed through a feasibility study, which illustrated acceptable patient use that led to a subjective improvement in care and demonstrated effective collection of real-world and validated patient reported outcomes [39]. The chemoWave app was included in a review on wearables, whereby authors stated that it appeared to be the first consumer-level integration of wearable data, the benefit of which being increased accuracy compared to self-reported data alone [40]. Two papers assessed the quality of oncology mobile apps for paediatric patients, focussing on medication prompts [41], and nutritional information and behaviour change [36]. Both reviewed the CancerAid app, but neither provided real-world data. Cancergraph was noted to only chart five symptoms, but the ability to create graphs was valued [42].

The exponential growth of mobile technologies has provided opportunities for advancing the delivery of healthcare [43], including self-monitoring. The use of medical devices by patients is not a new concept; patients with diabetes use blood glucose monitors to obtain blood sugar readings, and peak flow meters are used by people with chronic obstructive pulmonary disease. Such devices, when coupled with education and support from clinical teams, have the potential to reduce healthcare use and improve patient QOL [44,45]. Patient-reported symptoms can enable subtle changes to be detected, even when consultations are being conducted remotely. Of the 12 apps reviewed, all have a symptoms log for the user to input details. However, the mean number of symptoms available to choose from in pre-populated lists was 45 (range: 2–91), with 5 (42 %) of the apps enabling the user to input a symptom that is not listed. All symptoms listed were based on CTCAE guidelines that are encountered most frequently within oncology [3], but with varying detail between apps as illustrated by the wide range of user options. It should be noted that some apps are collecting patient generated data less systematically than if they were completing a validated health questionnaire with a clinician. However, their value is still apparent and aligns with the principles of PROMIS [46]. A helpful component in 8 (67 %) of the apps was the ability for data to be displayed graphically, which enables a visual insight into symptom-related trends which could inform clinical management. In addition, none of the apps reviewed in this paper integrated with EHRs; just over half ($n = 7$, 58 %) can share reports with clinicians. Typically, this is done by downloading a report to forward via email or print out, with the intended advertised purpose being to complement an upcoming clinical appointment. As found in similar systematic app reviews, integration of ePROMs into an EHR would further optimise these apps and enhance their role in telemedicine [21].

Exploring practicalities related to remote monitoring is important in ensuring care is safe, effective and that patients feel confident in what they are doing. Research into nurse perspectives regarding tele-monitoring has found that developing a strong nurse-patient relationship improved patient outcomes by complementing and enhancing standard care [47]. Remote monitoring for patients with diabetes was also evaluated and found that lack of clinician resource posed potential safety concerns, as patient data may not be reviewed for several days due to time constraints within their workload [48]. A platform with interactive features including online monitoring and virtual interaction between the nurse and patient was evaluated and findings suggested these features encouraged patients to play a more active role in self-managing their condition [49]. In our review, only half ($n = 6$) of the apps had features that enabled data to be evaluated, with 5 (42 %) apps providing guidance based on user-entered data, with alerts being sent based on data collected with a suggested intervention. The Liyfe app stood out, with its AI triage process providing evidence-based, clinically appropriate responses to user inputted data, providing advice on when to seek help. Apps like this may be safer to use, given they do not rely on a clinician to analyse and interpret the data.

Digital security has been identified as an important area of concern for patients [50]. A previous review explored potential information security and privacy infringement risks for mobile health apps and found 96 % (17,193 out of 17,979) posed potential concern [51]. Additionally,

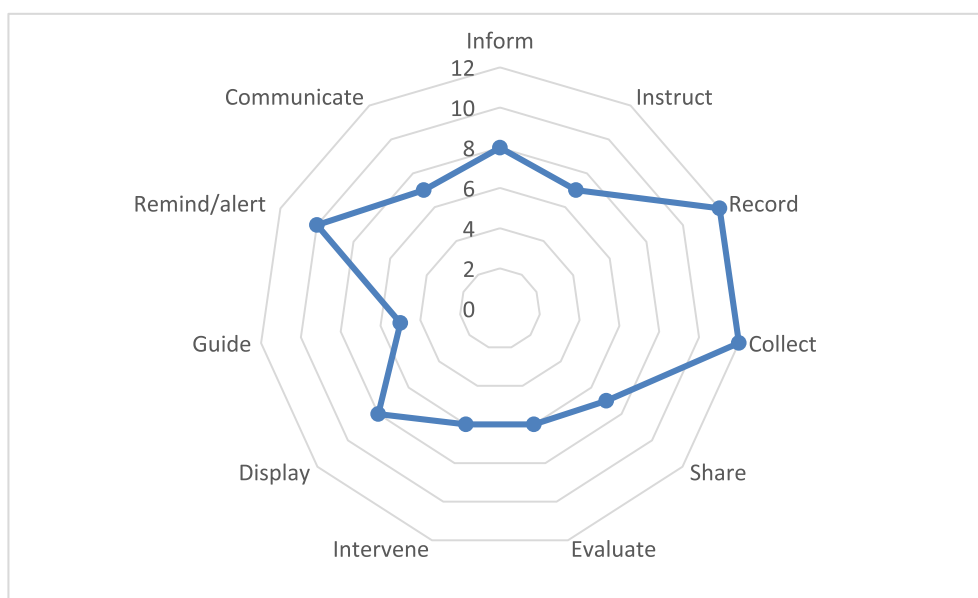


Fig. 2. Functionality of the apps, using items from the IMS Institute for Healthcare Informatics functionality score.

an analysis of more than 20,000 health-related mobile apps reported concerns with privacy and inconsistent privacy practices [52]. However, it was reassuring that all the reviewed apps had a privacy strategy and asked for a password or log in, to protect patient inputted data. Regardless, it must be noted that although authentication is part of an overall solution to provide security and enforce privacy, it is not a guarantee.

It must be acknowledged that digital health technologies can increase inequities between users and non-users. A cross-sectional study of 151 cancer patients explored barriers and enablers of patients' uptake of technology for healthcare services and found over a quarter did not have daily access to the Internet, and nearly a third did not own a smartphone capable of displaying mobile applications [53]. Socioeconomic disparities are evident worldwide, and research illustrates people with lower incomes and less education are less likely to live a healthy lifestyle and access cancer screening programmes [54]. Thus, people from these backgrounds are seen to have increased morbidity and mortality in relation to cancer and other conditions [55]. Other barriers may pertain to usability. Technology-based interventions must be developed with consideration of how it will sit within the user's day-to-day life, by considering ease-of-use and perception of its impact upon disease management and QOL [56]. It was concerning to note that over half ($n = 7$, 58 %) of the apps we reviewed did not provide user instructions, which could have a detrimental impact upon the quality of the data collected, as some users may not find the app intuitive to use. Any reticence from users to engage in remote monitoring can be explained as a perceived feeling of isolation as being away from their clinical team means a loss of physical contact and face-to-face communication. The use of intuitive mobile applications in oncology healthcare services must therefore, complement, and not replace, existing systems.

5. Implications

Further exploration into the feasibility of integration with an EHR could identify if this is possible and how it can be done. Collaborating with key stakeholders (e.g., patients, their caregivers, and oncology teams) and software designers for existing apps that have been trialled/tested would be a priority. Accessibility is also of utmost importance and alternative solutions, such as translation services, ongoing technical support, and loaning of devices, must be offered to ensure that no patient groups are disadvantaged.

6. Strengths and limitations

Limitations of the review must be acknowledged. First, apps only available in the UK at one time-point were included. This may mean that the apps are no longer available or have been updated. Additionally, only English apps were reviewed. Lastly, apps were identified from the Apple App and Google Play stores as they are the dominant operating systems. This means that apps only mentioned in academic literature, released privately, or available on Amazon or Windows were not included.

Strengths include the addition of measures, such as the Flesch-Kincaid metrics and the IMS, which have not been employed in previous app reviews [16,21,22]. These measures help to explore other important aspects of health apps, such as readability of content and functionality. A validated scale, MARS, was also used to explore quality.

7. Conclusion

There has been an exponential growth of mobile health applications in recent years as the world becomes more digitalised. It is apparent that many apps exist for cancer patients, but most do not include all cancer types, and even fewer enable ePROMs to be documented. No apps found in this systematic review appear to integrate with an EHR. This integration function has the potential to refine clinical pathways, improve patient experience and outcomes, and increase efficiency of hospital resources by enabling more proactive care to be delivered to patients. Further research is warranted to explore the feasibility and practicality of integrating existing apps into an EHR. Collaborating with the software designers of existing apps, patients, and oncology teams should be prioritised for developing useful, safe, and intuitive ePROM apps.

Summary table

What was already known on the topic	Enabling people with cancer to self-manage their symptoms and QOL can result in more informed, autonomous patients who are partners in their own care, which can reduce the overall burden on health services by minimising unnecessary hospital attendances. Engaging patients and caregivers in technology-enabled structured symptom collection has several benefits, particularly related to the early detection of
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Table 4

The highest scoring patient-facing cancer apps, when considering functionality and quality.

App name	Market, cost	MARS*	IMS**	Description
Careology	Apple, Google Play Free to download	4.4	10	This app allows patients to set up a personal profile , where cancer details and treatment plans can be stored . They can register which hospital they are treated at and the app inputs the phone number to call if unwell. Patients can input symptoms, helping to understand when to seek help, record how they are responding to treatment, and track vital signs. The app advises appropriate medical advice based on inputted data and provides personalised medication reminders . Tips, articles, recipes, and products to improve wellbeing are included.
ChemoWave	Apple, Google Play Free to download, in-app purchases	4.1	9	This app allows patients to create a profile. They then receive personal insights based on logged activities and experience . Medication details and reminders can be set up. The app provides detailed information related to the logged medication. A subscription is needed to get access to 'My Reports'.
Liyfe	Apple, Google Play Free to download	4.1	9	The Liyfe remote symptom management platform uses artificial intelligence (AI) to automate the oncology nurse triage process by acting as a symptom checker for patients . Cancer patients or their families can access symptom severities and understand the likelihood of a symptom . The AI-based chatbot automates remote patient monitoring by offering a scalable way to access advice regarding symptoms, improve QOL, and generate longitudinal real-world data.
Vinehealth	Apple, Google Play Free to download	4.0	9	This patient-facing app allows a user profile to be created, which stores cancer and treatment details . Symptoms can be inputted, with appropriate advice given in response to user data. Medication and appointments can be scheduled and logged . Personalised information to support self-management is provided. Links to articles of interest are provided .

*Overall mean score for the Mobile App Rating Scale (maximum score 5).

**IMS: Overall score for the IMS Institute for Healthcare Informatics functionality score (range 0–11).

(continued)

What this study added to our knowledge

adverse events, which, if acted on promptly, can prevent unnecessary hospital attendances. There does not appear to be a high-quality patient-facing cancer app available for patients with any cancer type which enables ePROs to be documented and analysed, with findings integrating into the patient's EHR. This integration function has the potential to refine clinical pathways, improve patient experience and outcomes, and increase efficiency of hospital resources by enabling more proactive care to be delivered to patients.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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