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Mobile Applications in Oncology: A Systematic Review of Health Science Databases

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Highlights

- There is an exponential increase in the number of publications that use apps in oncology, but once the research is completed, such apps are removed from the purchasing devices.
- Breast cancer is the most commonly studied tumor in all the objectives to create an app
- The role of apps for early detection of melanoma is noteworthy.
- Access to apps identified in published research studies is especially difficult

It is important to create apps endorsed by health organizations, which are not only limited to research, but also to support continuously patients and health care professionals in caring cancer patient.

ABSTRACT

Introduction: In recent years there has been an exponential growth in the number of mobile applications (apps) relating to the early diagnosis of cancer and prevention of side effects during cancer treatment. For health care professionals and users, it can thus be difficult to determine the most appropriate app for given needs and assess the level of scientific evidence supporting their use. Therefore, this review aims to examine the research studies that deal with this issue and determine the characteristics of the apps involved.

Methodology: This study involved a systematic review of the scientific literature on randomized clinical trials that use apps to improve cancer management among patients, using the Pubmed (Medline), Latin America and the Caribbean in Health Sciences (LILACS), and Cochrane databases. The search was limited to articles written in English and Spanish published in the last 10 years. A search of the App Store for iOS devices and Google Play for Android devices was performed to find the apps identified in the included research articles.

Results: In total, 54 articles were found to analyze the development of an application in the field of oncology. These articles were most frequently related to the use of apps for the early detection of cancer (n=28), particularly melanoma (n=9). In total, 21 studies reflected the application used. The apps featured in nine articles were located using the

App Store and Google Play (n=9), of which five were created to manage cancer-related issues. The rest of the apps were designed for use in the general population (n=4).

Conclusions: There is an increasing number of research articles that study the use of apps in the field of oncology; however, these mobile applications tend to disappear from app stores after the studies are completed.

Keywords: mobile applications; smartphone; medical oncology; neoplasms; medical informatics applications

1. INTRODUCTION

Cancer is a generic term encompassing a broad group of diseases that can affect any part of the body. It is characterized by the rapid multiplication of abnormal cells that can invade adjacent parts of the body and/or spread to other organs. It is a multiphasic and complex process¹. Currently, cancer plays an important role in the health sector as it has high morbidity, prevalence, and mortality, particularly in developed countries. Cancer is the second leading cause of death worldwide, accounting for 8.2 million deaths per year².

Cancer treatment is based on surgery, systemic therapy (chemotherapy, hormonal therapy, and biological therapy), and radiotherapy. These treatments often produce temporary and/or permanent physical and psychosocial problems, and can adversely affect patient function³. The presence of these side effects can result in dose reductions or the suspension of treatment entirely.

Therefore, identifying and treating the physical and psychological symptoms of patients are key to maximizing the therapeutic benefits of drugs and reducing side

effects. Communication is a fundamental tool for identifying and meeting individual needs⁴.

During the treatment of this disease, hospital admissions associated with the secondary effects or complications are frequent. It is possible that early access to information related to prevention and treatment of side effects could aid in reducing the frequency and duration of hospitalizations⁵, improving the quality of life of patients and reducing the costs of treatment⁶⁻⁸.

These are complex patients that require multidisciplinary and personalized treatment which is sometimes not covered by health care systems⁸.

The use of traditional health education strategies, home health care, and day hospitals may be sufficient in some cases, but certain patients demand greater participation in their treatment⁹⁻¹¹. Likewise, current management models¹² allow a for greater emphasis on patient empowerment, self-management of the disease¹³ with the guidance of a health care professional, and the use of information and communication technology (ICT)¹⁴. The use of ICTs offers a new way of understanding the relationship between health care professionals and patients based on communication, interaction, and mutual cooperation.

The incorporation of ICTs in oncology provides new opportunities for service provision, particularly with respect to the early detection of cancer¹⁵, early recognition and monitoring in real time of treatment-related adverse effects⁵, a wider dissemination of information targeted at the healthy population, patients, caregivers, and health care professionals, and improvement of adherence to drug therapy in the home¹⁴.

To provide these opportunities, the most commonly used devices are smartphones, and the use of health-related mobile applications (apps) is increasingly

flourishing^{16,17}. Most adults around the world own a smartphone and download apps, including those who live in communities with limited resources¹⁸. In the general population, 39.6% of individuals have used the Internet as a source of information¹⁹ through their mobile phone.

In this context, mobile health (mHealth) involves the use of apps created to provide health care or health-related services via mobile devices²⁰.

Although there are many benefits of mHealth, for some apps there is insufficient evidence supporting their use, and they may lack up-to-date information and/or have security problems, resulting in issues rather than a useful tool¹⁹. In addition, due to the wide variety of apps available it can be difficult to determine the most appropriate app for each type of patient and the most effective method of use. Thus, it would be useful to provide health care professionals with better knowledge of these apps, enabling them to assess and recommend those that are most appropriate according to the needs of each patient.

Therefore, this review aims to review research studies that deal with this issue and identify the characteristics of the apps used.

2. METHODOLOGY

2.1 Design

This review is structured in two parts. The first involves a systematic review of the literature, with a summary of the results of studies on the subject in order to provide a better understanding of specific aspects²¹ and to allow for the identification of gaps in knowledge. This methodology enables the exploration, reflection, review, and synthesis of the available evidence on the subject, in order to determine the current state of knowledge, suggest a course of action for practice, and identify limitations that could

considered in future searches. As such, this method is useful for the identification of studies that provide scientific evidence on the use of apps²¹.

The second part comprises a search for the apps featured in the research articles found previously using the App Store for iOS devices and Google Play for Android devices.

This study design aims to provide clarification on the use of cancer-related apps, with the possibility of determining which apps are supported by relevant scientific evidence for use in healthcare settings.

In the first phase of this study, the research question and inclusion/exclusion criteria were established. A literature search was then performed and the obtained articles assessed with respect to the inclusion and exclusion criteria. The included articles were subsequently categorized, and a synthesis of the review analysis was developed. The second phase of this study comprised a search for the apps used in the included articles, analysis and categorization of the obtained apps, and a summary of the findings.

2.2 Research Question

The research question was as follows: Which commercially available cancer-related apps for patients, caregivers, and professionals have been used in empirical research studies, and what are their characteristics? Following the PICO structure, here “P” includes patients, caregivers, and oncology professionals, “I” relates to the identification of studies that use the apps, and the “O” focuses on commercial accessibility for all users.

2.3 Criteria for the Selection of Articles

The selection of the articles was performed by two researchers independently, and the inclusion criteria were as follows:

Inclusion Criteria

- Types of studies: randomized clinical trials.
- Types of participants: Patients, caregivers, and health care professionals associated with cancer.

Exclusion Criteria

- Duplicated results in databases.
- Patients with other non-oncological pathologies.
- No access to full text document.
- Use of other virtual devices without using an app, such as web pages or videogames.
- Different types of studies, such as opinion articles and reviews.

2.4 Search Strategy

The search was carried out in November 2017 using the international Medline (Pubmed), Latin America and the Caribbean in Health Sciences (LILACS), and Cochrane Library databases. The search was limited to articles written in English and Spanish that had been published in the last 10 years.

The following Descriptors in Health Sciences (DeCS) and Medical Subject Heading (MeSH) terms were used for the search: “neoplasms” and “mobile applications”, with the Boolean operator “and” between them.

The initial search strategy used with the App Store (iOS) and Google Play (Android) platforms involved finding the brand name of the app used in the research article. Using the search bar of the apps in the App Store (iOS) and Google Play (Android), the name

of the app was displayed; it was then downloaded and analyzed. The iOS apps were downloaded to an iPhone 6s and the smartphone apps were downloaded to a Samsung Galaxy S7 mobile phone.

2.5 Variables for Analysis of the Selected Articles

The following variables were used for the categorization, synthesis, and analysis of the articles included in the review:

Author, title, year of publication, journal, main objective of the app (early detection, prevention of symptoms of the disease, follow-up, diagnosis and treatment), target population (healthy population, active treatment, survivors, caregivers and healthcare professionals), type of cancer, phase of the study (protocol, pilot, or completed), country of study, and name of the app.

To analyze the downloaded apps, an Excel® tool was designed for data extraction; the data was analyzed and categorized using the following variables:

Articles that used an app, the name of the app, availability in operating systems (iOS or Android), download cost, creation dates, date of latest update, language, type of cancer, user rating, type of target population, objective of the app (early detection, prevention of symptoms of the disease, follow-up, diagnosis and treatment), and target population (healthy population, active treatment, survivors, caregivers and health care professionals).

2.6 Data Analysis

A quantitative and qualitative synthesis of the identified studies was carried out according to the search strategy and the identified characteristics; these were later analyzed according to frequencies (n) to facilitate the interpretation of data.

The resulting analysis with respect to these apps consists of a description using frequencies (n) of the characteristics analyzed in the mobile devices.

As this is an integrative review, it was not necessary to request approval from the Ethics Committee to carry out the study. The authors declare that there are no conflicts of interest.

3. RESULTS

3.1 Results of the Process

Through the search strategy, 207 articles were identified in Medline (Pubmed) (n=78), LILACS (n=126), and the Cochrane Library (n=3); of these, 50 were repeated articles. After reading the title and abstract, 70 articles were excluded because they did not provide access to the abstract or full text (n=8) or because they did not feature cancer patients (n=62). After reading the full research texts, n=33 articles were excluded as they were found to be reviews (n=14) or opinion articles (n=9), or did not involve the use of an app (n=10). Finally, 54 articles met the inclusion criteria. Results are reported using the PRISMA flow diagram (Figure 1).

Figure 1: Flowchart of the identification process

3.2 Characteristics of the Included Articles

Of the 54 articles included in the review, all were published in English, except for $n=1^{22}$, which was published in Portuguese. The studied period of publication was between 2010 and 2017, with most articles published during 2015 ($n=20$)^{8,9,11,14,23–38}, and 2016 ($n=16$)^{15,39–53}. The journals with the highest numbers of publications

were *J Med Internet Res* (n=6)^{15,29,30,49,50,54}, *JAMA Dermatol* (n=5)^{32–35,38}, and *Study Health Technol Inform* (n=4)^{9,11,37,55}, as can be seen in the following table.

Table 1. Characteristics of the included articles

Author	Title	Date	Journal
⁵⁶	A Novel Derivation Predicting Survival After Primary Tumor Resection in Stage IV Colorectal Cancer: Validation of a Prognostic Scoring Model and an Online Calculator to Provide Individualized Survival Estimation	2017	<i>Dis Colon Rectum</i>
⁵	Using QR Codes to Enable Quick Access to Information in Acute Cancer Care	2017	<i>Br J Nurs</i>
⁵⁷	Implementation and Preliminary Effectiveness of a Real-Time Pain Management Smartphone App for Adolescents with Cancer: A Multicenter Pilot Clinical Study	2017	<i>Pediatr Blood Cancer</i>
⁵⁸	Can an Educational Application Increase Risk Perception Accuracy Amongst Patients Attending a High-Risk Breast Cancer Clinic?	2017	<i>Breast</i>
⁵⁹	Validation of a Melanoma Risk Assessment Smartphone Application	2017	<i>Dermatol Surg</i>
⁶⁰	The McGill Interactive Pediatric OncoGenetic Guidelines: An Approach to Identifying Pediatric Oncology Patients Most Likely to Benefit from a Genetic Evaluation	2017	<i>Pediatr Blood Cancer</i>
⁶¹	Development of a Mobile Application of Breast Cancer e-Support Program for Women with Breast Cancer Undergoing Chemotherapy	2017	<i>Technol Health Care</i>
⁴²	Effects of the Use of the Provider Resilience Mobile Application in Reducing Compassion Fatigue in Oncology Nursing	2016	<i>Clin J Oncol Nurs</i>
⁶²	Development of a Mobile Application for Oral Cancer Screening	2017	<i>Technol Health Care</i>
⁴¹	PATI: Patient-Accessed Tailored Information: A Pilot Study to Evaluate the Effect on Preoperative Breast Cancer Patients of Information Delivered via a Mobile Application.	2016	<i>Breast</i>
⁵⁰	A Mobile App to Stabilize Daily Functional Activity of Breast Cancer Patients in Collaboration With the Physician: A Randomized Controlled Clinical Trial.	2016	<i>J Med Internet Res.</i>
⁴⁶	Radiologist-Centered Decision Support Applications	2016	<i>J Am Coll Radiol</i>
⁴⁹	Depression Screening Using Daily Mental-Health Ratings from a Smartphone Application for Breast Cancer Patients.	2016	<i>J Med Internet Res.</i>
³⁹	Focalyx Dx, Bx, Tx et Apps: A Novel Contemporary Fusion Paradigm for the Management of Prostate Cancer.	2016	<i>Arch Esp Urol</i>
⁴⁴	Supporting Caregivers of Children With Acute Lymphoblastic Leukemia via a Smartphone App: A Pilot Study of Usability and Effectiveness	2016	<i>Comput Inform Nurs</i>
⁴³	Use of a Point-of-Care Tool to Improve Nurse Practitioner BRCA Knowledge	2016	<i>Clin J Oncol Nurs</i>
⁵¹	Evaluation of the Effect of Diagnostic Molecular Testing on the Surgical Decision-Making Process for Patients with Thyroid Nodules	2016	<i>JAMA Otolaryngol Head Neck Surg</i>
⁴⁵	A Tablet-Interfaced High-Resolution Microendoscope with Automated Image Interpretation for Real-Time Evaluation of Esophageal Squamous Cell Neoplasia	2016	<i>Gastrointest Endosc</i>
⁴⁰	Testing the Effects of Narrative and Play on Physical Activity among Breast Cancer Survivors Using Mobile Apps: Study Protocol for a Randomized Controlled Trial	2016	<i>BMJ Cancer</i>

47	Predicting Individualized Postoperative Survival for Stage II/III Colon Cancer Using a Mobile Application Derived from the National Cancer Data Base.	2016	<i>J Am Coll Surg</i>
15	Estimating Skin Cancer Risk: Evaluating Mobile Computer-Adaptive Testing.	2016	<i>J Med Internet Res.</i>
48	Comparing Image Perception of Bladder Tumors in Four Different Storz Professional Image Enhancement System Modalities Using the iSPIES App	2016	<i>J Endourol</i>
28	Mobile Health Application for Remote Oral Cancer Surveillance	2015	<i>J Am Dent Assoc</i>
36	Construct Validity and Reliability of a Real-Time Multidimensional Smartphone App to Assess Pain in Children and Adolescents with Cancer.	2015	<i>Pain</i>
52	Feasibility of an eHealth Application "OncoKompas" to Improve Personalized Survivorship Cancer Care	2016	<i>Support Care Cancer</i>
53	A Smartphone App to Assist Scalp Localization of Superficial Supratentorial Lesions—Technical Note	2016	<i>World Neurosurg</i>
31	PhosphoPath: Visualization of Phosphosite-Centric Dynamics in Temporal Molecular Networks	2015	<i>J Proteome Res</i>
37	Towards an Ontology-driven Framework to Enable Development of Personalized mHealth Solutions for Cancer Survivors' Engagement in Healthy Living.	2015	<i>Stud Health Technol Inform</i>
8	Information at the Point of Care: An Informational Application for Cancer Resources	2015	<i>Comput Inform Nurs</i>
29	The Cancer Experience Map: An Approach to Including the Patient Voice in Supportive Care Solutions.	2015	<i>J Med Internet Res.</i>
9	A Mobile Application to Manage and Minimise the Risk of Late Effects Caused by Childhood Cancer.	2015	<i>Stud Health Technol Inform</i>
11	A Mobile Application Supporting Outpatient Treatment and Follow-Up.	2015	<i>Stud Health Technol Inform</i>
14	Self-Management Support Intervention to Control Cancer Pain in the Outpatient Setting: A Randomized Controlled Trial Study Protocol	2015	<i>BMJ Cancer</i>
27	Practical Application of New Technologies for Melanoma Diagnosis: Part I. Noninvasive Approaches.	2015	<i>J Am Acad Dermatol.</i>
30	Integrating mHealth in Oncology: Experience in the Province of Trento.	2015	<i>J Med Internet Res.</i>
25	Feasibility of an Interactive ICT-Platform for Early Assessment and Management of Patient-Reported Symptoms during Radiotherapy for Prostate Cancer.	2015	<i>Eur J Oncol Nurs</i>
24	Portable Smartphone Quantitation of Prostate Specific Antigen (PSA) in a Fluoropolymer Microfluidic Device	2015	<i>Biosens Bioelectron</i>
26	Feasibility of a Lifestyle Intervention for Overweight/Obese Endometrial and Breast Cancer Survivors Using an Interactive Mobile Application.	2015	<i>Gynecol Oncol</i>
32	Smartphone Mobile Application Delivering Personalized, Real-Time Sun Protection Advice	2015	<i>JAMA Dermatol</i>
38	Evaluation of Immediate and 12-Week Effects of a Smartphone Sun-Safety Mobile Application	2015	<i>JAMA Dermatol</i>
33	Feasibility and Efficacy of Patient-Initiated Mobile Teledermoscopy for Short-Term Monitoring of Clinically Atypical Nevi	2015	<i>JAMA Dermatol</i>
34	Making Mobile Health Measure Up	2015	<i>JAMA Dermatol</i>
35	Redefining Dermatologists' Role in Skin Cancer Early Detection and Follow-up Care	2015	<i>JAMA Dermatol</i>

23	Mobile Tele dermatology is a Valid Method to Estimate Prevalence of Melanocytic Naevi in Children	2015	<i>Acta Derm Venereol.</i>
63	App for Aftercare.	2014	<i>Dtsch Arztebl Int.</i>
54	Daily Collection of Self-Reporting Sleep Disturbance Data via a Smartphone App in Breast Cancer Patients Receiving Chemotherapy: A Feasibility Study.	2014	<i>J Med Internet Res.</i>
64	Developing Screening Services for Colorectal Cancer on Android Smartphones	2014	<i>Telemed J E Health</i>
65	Mobile Application-Based Seoul National University Prostate Cancer Risk Calculator: Development, Validation, and Comparative Analysis with Two Western Risk Calculators in Korean Men	2014	<i>PLoS One</i>
66	A Preoperative Nomogram for the Prediction of Ipsilateral Central Compartment Lymph Node Metastases in Papillary Thyroid Cancer	2014	<i>Thyroid</i>
55	Cherry: Mobile Application for Children with Cancer.	2013	<i>Stud Health Technol Inform</i>
67	Long-Term Benefits of the Memory-Link Programme in a Case of Amnesia	2013	<i>Clin Rehabil</i>
68	Health Weaver Mobile: Designing a Mobile Tool for Managing Personal Health Information during Cancer Care.	2010	<i>AMIA Annu Symp Proc</i>
22	<i>m-Health no controle do câncer de colo do útero: pré-requisitos para o desenvolvimento de um aplicativo para smartphones</i>	2017	<i>Rev.Electron Comun Inf Inov Saúde</i>
69	Symptoms and Self-Care Following Pancreaticoduodenectomy: Perspectives from Patients and Healthcare Professionals—Foundation for an Interactive ICT Application.	2017	<i>Eur J Oncol Nurs</i>

3.3 Objectives and Profiles of Cancer-Related Apps

The objectives of cancer-related apps were found to be early detection (n=28)^{15,22-24,27,28,31-35,38,45,47-49,53-56,58-60,62-66}, follow-up (n=9)^{9,11,26,37,39,40,50,52,69}, prevention of signs and symptoms (n=8)^{5,14,25,29,30,44,68,70}, treatment (n=5)^{36,41,57,61,67}, and diagnosis (n=4)^{42,43,46,51}. With respect to the target populations, the apps were found to be primarily directed at healthy patients (n=18)^{15,22-24,27,28,31-35,48,53-55,58,59,62}, followed by sick patients under active treatment (n=16)^{5,8,11,14,25,29,30,36,41,49,50,57,61,64,67,68}, survivors (n=9)^{9,26,37,39,40,45,47,52,54,56,60,63,66,69}, health care professionals (n=4)^{42,43,46,51}, and caregivers (n=1)⁴⁴.

With regard to tumor types, apps were mainly related to breast cancer (n=13)^{26,40,41,43,46,49,50,52,54,58,61,68,69}, melanoma (n=10)^{15,23,27,33-35,38,53,59}, and pediatric

cancer (n=7)^{9,36,37,44,55,57,60}. The articles were mostly completed studies (n=35)^{15,22-28,32-36,38,41-43,45-48-54,58,60,62,65-67,69}, followed by methodological studies (n=15)^{5,9,14,29,31,37,39,40,44,55,59,61,63,64,68}, and pilot studies (n=4)^{8,11,30,57}.

The geographical locations of the studies were North America (n=20)^{5,8,26,27,29,32-34,36,37,40,42,43,46,47,51,57,67,68}, Europe (n=14)^{9,11,14,23,25,30,31,39,48,50,52,55,63,69}, Asia (n=9)^{28,36,44,45,49,54,61,64,65}, the United Kingdom (n=5)^{24,41,58-60}, Oceania (n=4)^{15,35,53,66}, and Latin America (n=2)^{22,56} (Table 2).

Table 2. Objectives and profile of the apps associated with cancer

Ref	Objective	Target Population	Type of Tumor or Treatment	Phase	Location
56	Early detection	Survivors	Colon IV	Completed	Singapore (ASIA)
5	Prevention of signs and symptoms	Pat. act. treatment	All types	Protocol	Merseyside (USA)
57	Treatment	Pat. act. treatment	Pediatric cancer	Pilot	Canada (NORTH AMERICA)
58	Early detection	Healthy population	Breast	Completed	Ireland (UK)
59	Early detection	Healthy population	Melanoma	Protocol	Ireland (UK)
60	Early detection	Survivors	Pediatric cancer	Completed	Ireland (UK)
61	Treatment	Pat. act. treatment	Breast	Protocol	China (ASIA)
42	Diagnosis	Healthcare professionals	All types	Completed	California (USA)
62	Early detection	Healthy population	Oral cavity	Completed	Brazil (LATIN AMERICA)
41	Treatment	Pat. act. treatment	Breast	Completed	Ireland (UK)
50	Follow-up	Pat. act. treatment	Breast	Completed	Sweden (EUROPE)
46	Diagnosis	Healthcare professionals	Breast	Completed	Colorado (USA)
49	Early detection	Pat. act. treatment	Breast	Completed	Korea (ASIA)
39	Follow-up	Survivors	Prostate	Protocol	Madrid (EUROPE)
44	Prevention of signs and symptoms	Caregivers	Pediatrics cancer	Protocol	China (ASIA)
43	Diagnosis	Healthcare professionals	Breast	Completed	Michigan (USA)
51	Diagnosis	Healthcare professionals	Thyroid	Completed	Maryland (USA)

45	Early detection	Survivors	Stomach	Completed	China (ASIA)
40	Follow-up	Survivors	Postmenopausal breast	Protocol	Texas (USA)
47	Early detection	Survivors	Colon II / III	Completed	Buffalo (USA)
15	Early detection	Healthy population	Melanoma	Completed	Australia (OCEANIA)
48	Early detection	Healthy population	Bladder	Completed	Amsterdam/Germany/France/Spain/Italy (EUROPE)
28	Early detection	Healthy population	Mouth	Completed	India (ASIA)
36	Treatment	Pat. act. treatment	Pediatric cancer	Completed	Canada (NORTH AMERICA)
52	Follow-up	Survivors	Breast	Completed	Amsterdam (EUROPE)
53	Early detection	Healthy population	Melanoma	Completed	Australia (OCEANIA)
31	Early detection	Healthy population	All types	Protocol	Netherland (EUROPE)
37	Follow-up	Survivors	Pediatric cancer	Protocol	Houston (USA)
8	Prevention of signs and symptoms	Pat. act. treatment	All types + Nursing	Pilot	Alabama (USA)
29	Prevention of signs and symptoms	Pat. act. treatment	All types	Protocol	USA
9	Follow-up	Survivors	Pediatric cancer	Protocol	Germany (EUROPE)
11	Follow-up	Pat. act. treatment	Head/Neck	Pilot	Milan (EUROPE)
14	Prevention of signs and symptoms	Pat. act. treatment	All types	Protocol	Amsterdam (EUROPE)
27	Early detection	Healthy population	Melanoma	Completed	Uthan (USA)
30	Prevention of signs and symptoms	Pat. act. treatment	Capecitabine or sunitinib	Pilot	Italy (EUROPE)
25	Prevention of signs and symptoms	Pat. act. treatment	Prostate	Completed	Sweden (EUROPE)
24	Early detection	Healthy population	Prostate	Completed	England (UK)
26	Follow-up	Survivors	Endometrial breast	Completed	USA
32	Early detection	Healthy population	Melanoma	Completed	Colorado (USA)
38	Early detection	Healthy population	Melanoma	Completed	Colorado (USA)
33	Early detection	Healthy population	Melanoma	Completed	New York (USA)
34	Early detection	Healthy population	Melanoma	Completed	Massachusetts (USA)
35	Early detection	Healthy population	Melanoma	Completed	Australia (OCEANIA)
23	Early detection	Healthy population	Melanoma	Completed	Sweden (EUROPE)
63	Early detection	Survivors	Hodgkin's lymphoma	Protocol	Germany (EUROPE)
54	Early detection	Survivors	Breast	Completed	Korea (ASIA)
64	Early detection	Pat. act. treatment	Colon and rectum	Protocol	China (ASIA)
65	Early detection	Healthy population	Prostate	Completed	Korea (ASIA)
66	Early detection	Survivors	Thyroid	Completed	Australia (OCEANIA)

⁵⁵	Early detection	Healthy population	Pediatric cancer	Protocol	Norway (EUROPE)
⁶⁷	Treatment	Pat. act. treatment	Brain tumor	Completed	Canada (NORTH AMERICA)
⁶⁸	Prevention of signs and symptoms	Pat. act. treatment	Breast	Protocol	Washington (USA)
²²	Early detection	Healthy population	Uterus	Completed	Brazil (LATIN AMERICA)
⁶⁹	Follow-up	Survivors	Breast	Completed	Sweden (EUROPE)

Pat. act. treatment: patients under active treatment; USA, United States of America; UK: United Kingdom

3.4 Apps for Cancer Patients

Of the 54 publications found through the search, $n=33^{5,8,22,23,27,28,33-35,39,43-47,49-51,14,54,56-59,62,63,65-67,15,68,69}$ did not identify the name of the app they had used to carry out their study; the remainder ($n=21$)^{9,11,25,26,29-32,36,37,38,40-42,48,52,53,55,60,24,61} identified the app used, but of these, $n=12^{11,25,29-31,37,41,42,52,53,60}$ did not exist or were not available in the App Store for the iOS system or the Android Market for the Android operating system. The remaining apps ($n=9$)^{9,24,26,36,38,40,48,55,61} are shown in Table 3.

A total of $n=6^{9,26,38,40,48,61}$ apps were available in both the iOS and Android operating systems, whereas $n=2^{24,36}$ were only available in the iOS system and $n=1^{54}$ was only available for Android. All apps were free. These apps were created from 2009 to 2017, with the most apps created in 2014 ($n=3$)^{35,39,54}. All the apps except $n=1^{54}$ were updated in 2017. All the apps were available in English alone, with the exception of $n=3^{24,26,38}$. One app was in English and Italian, while the other two were in 29 and 32 different languages, respectively. The apps were targeted at the healthy population ($n=4$)^{24,26,38,40}, patients under active treatment ($n=2$)^{36,48}, cancer survivors ($n=1$)⁹, and pediatric patients ($n=1$)³⁶, with one aimed at both patients and healthcare professionals. Only $n=2^{26,40}$ apps are currently available for evaluation by users. Of the nine apps, $n=5^{24,36,48,55,61}$ were created exclusively for cancer-related use, whereas the remainder ($n=4$)^{26,38,40} are general apps for both healthy and sick patients. This information is reflected in Table 3.

Table 3. Characteristics of the apps used in the research articles included in the review

Reference number	App name	Operating system	Cost	Year of creation	Update	Languages	Type of population	Objective	Rating	Other details
⁹	Aftercare App	iOs/ Android	Free	2017	2017	English	Survivors	Follow-up	Not avail.	For use in the follow-up of patients with alcohol problems
²⁴	Eat For Life Prostate Cancer	iOs	Free	2009	2017	English/ Italian	Healthy population	Prevention	Not avail.	For healthy patients, with nutritional recommendations
²⁶	Loseit!	iOs/ Android	Free	2017	2017	29 languages	Healthy population	Weight loss	4.3 / 5	For the general public
³⁶	Pain Squad (App)	iOs	Free	2014	2015	English	Pediatric	Treatment	Not avail.	For cancer pain
³⁸	UV Index Widget	iOs/ Android	Free	2016	2017	32 languages	Healthy population	Prevention	Not avail.	For prevention of sun exposure
⁴⁰	Smartgoal	iOs/ Android	Free	2014	2017	English	Healthy population	Motivation	4.8 / 5	For the general public
⁴⁸	Blapper	iOs/ Android	Free	2016	2017	English	Pat. act. treatment	Treatment	Not avail.	For bladder cancer
⁵⁵	Ioncolex	Android	Free	2014	Not avail	English	Pat. act. treatment	Information		Not available as an app, only web content; relates to breast, lung and prostate cancer
⁶¹	Cancer Therapy Advisor	iOs/ Android	Free	2013	2017	English	Prof + patients + survivors	Information	Not avail.	For oncology

App: mobile application; Not avail.: not available; Pat. act. treatment: patients under active treatment;

Prof: healthcare professionals

4. DISCUSSION

In recent years there has been an evident increase in research involving mobile phones for uses relating to cancer, as indicated in this review by the number of articles

identified in the Pubmed, LILACS, and Cochrane databases. This is in accordance with the results of the comparative prospective study performed by Ngoo⁷¹, where a 55.8% increase in number of applications from 2014 to 2017 was reported.

Studies were mostly performed in more developed geographic locations such as the United States and Europe. In contrast, no studies using apps were found in the African context. For these areas, less expensive ICTs such as web sites or videoconferences could be good resources given that they offer greater precision in diagnosis as compared to mobile telephones⁷².

According to the information obtained in the review, apps are most commonly developed for the early detection of cancer^{15,22,24,27,28,31,33–35,38,45,47–49,53–56,58,23,59,60,62–66}, particularly melanoma^{15,23,27,33–35,38,53,59}. These apps are based on melanoma risk calculators. A review by Digital Scholar⁷⁶ indicated that these apps were effective tools in the early detection of skin cancer. Their validity may be limited in many cases due to small samples and brief follow-up periods in related studies; this is an aspect that must be taken into account by the health professionals who use them^{71,73}.

Although many applications have been developed for the early detection of melanoma⁷³, encouraging results have also been shown for apps relating to non-oncological diseases. Examples include the early detection of exacerbations in patients with chronic obstructive pulmonary disease⁷⁴, and the early detection of suicidal behaviors by means of response algorithms⁷⁵.

Early detection apps have also been created for cancer survivors with the aim of detecting tumor recurrence in the colon and rectum^{56,77}, breast^{40,54}, and thyroid⁶⁶, as well as in Hodgkin's lymphoma⁶³ and pediatric patients⁹. In this context, the largest number

of studies on the use of apps for cancer prevention was published in Asia^{28,33,45,49,54,56,65}, an area with one of the highest cancer mortality rates in the world⁷⁸.

Another objective of apps targets health care professionals in order to facilitate breast cancer diagnosis^{42,43,46,51}. These apps are aimed at groups such as nurses^{42,43,46} and physicians⁵¹ and involve the creation of decision algorithms^{42,43,46} or molecular analysis⁵¹. Despite the importance of personalizing the dose of chemotherapy for each patient, no applications have been found that make use of these tools to calculate doses of cytostatic medication, although they have been implemented with the nursing profession and paramedics for the administration of other drugs, with results showing greater levels of confidence and satisfaction⁷⁹. Most of the related studies were carried out in the United States^{42,43,46,51}.

Another objective of these apps relates to providing information for the prevention of side effects in cancer patients undergoing active chemotherapy^{5,14,25,29,30,44,68,70}, with one app aimed at caregivers of pediatric patients⁴⁴. General recommendations^{5,14,29,70} are applicable to all tumors, with the exception of some that are aimed specifically at breast⁶⁸ or prostate²⁵ cancer, or those that refer to certain cytostatic agents such as capecitabine³⁰. In this regard, a greater number of studies was developed in Europe^{14,25,30} and the United States^{5,29,68,70}, possibly due to a higher level of technological development and the greater purchasing power in their healthcare systems.

While there are several apps aimed at medical follow-up and use in patients who have completed cancer treatment, are disease-free, and are considered survivors^{9,26,37,39,40,52,69}, the apps used in patients with breast cancer^{9,11,39,50,52,69}, pediatric cancer^{9,37}, and prostate cancer³⁹ are particularly noteworthy. The creation of mobile applications for patient

follow-up is not unique to the discipline of oncology. In cardiovascular disease, apps relating to follow-up focus on the control of blood pressure⁸⁰. Other examples include the use of apps for monitoring and control of symptoms in chronic digestive conditions such as Crohn's disease, ulcerative colitis, and irritable bowel syndrome⁸¹; the management of anxiety in children and teenagers⁸²; and the monitoring of patients with HIV⁸³ or those in the process of detoxification for drug abuse⁸⁴, among others.

As our results show, most studies relating to apps for cancer survivors were from Europe^{9,11,39,50,52,69}, perhaps since it is the continent with the highest prevalence of cancer and the greatest life expectancy, with continuation of care thus being necessary⁷⁸.

The final identified purpose of apps relating to cancer was for real-time monitoring during the administration of chemotherapeutic treatment, particularly in breast, pediatric^{36,57}, and head and neck⁶⁷ cancers. In one study involving non-cancer patients, Weaver⁷² demonstrated that a telemedicine system which recorded adverse effects through a mobile phone and provided advice on toxicity management was useful for increasing patient safety. Along the same lines, Jongh⁷³ concluded that the use of a reminder message facilitates adherence to treatment.

All of the studies published in order to create real-time monitoring apps for patients were carried out in the United States. The explanation possibly lies in the healthcare system of this region, which aims to reduce costs in healthcare without negative impacts on quality.

Of the 54 articles on the use of apps, only 21 revealed the app used, with nine apps being identified. Of these, only five were created specifically relating to cancer. Despite being found in the publications, it is noteworthy that the apps for early detection of cancer were not subsequently available for iOS and Android devices. However, we were

able to find apps aimed at prevention in healthy patients; Buller³⁸, for example, presented a method for the identification of ultraviolet ray intensity, aiming to prevent exposure during periods of greater solar radiation. In the study by Barbosa²⁴ relating to prostate cancer, while the name of the app in the article matched that of the downloaded app, there were inconsistencies; in the article the app was used for the early detection of prostate cancer using a risk calculator according to the level of PSA, whereas the downloaded app involved nutritional recommendations for the prevention of prostate cancer. In this case, the downloaded app had the same name as that found in the article, but with different content.

Along the same lines, in a study carried out by Kock⁹ using the Aftercare App, the objective was to follow up on pediatric patients who had overcome cancer. However, on downloading the app it was found to be directed at adults with alcoholism problems. The Smartgoal app, used in a study carried out by Lyons⁴⁰ for breast cancer survivors, was originally developed for motivational use for patients without cancer. The Loseit app, used in the study carried out by McCarrol²⁶ for monitoring weight loss in obese female survivors of breast and endometrial cancer, was similarly not created for patients with specific cancer problems, but for the population in general. However, other apps did not show such issues, with one example being the Cancer Therapy Advisor app used in the study by Zhu⁶¹.

Another issue was the lack of apps found in languages other than English. This is in accordance with the revision carried out by Collado¹⁹, where aspects such as the reliability and updates of these tools were also analyzed, but with some differences since all of the apps consulted except one were updated this year. This is very relevant in oncology⁵⁵, as new treatments¹⁹ are constantly emerging. Another aspect identified in

reviews about apps was related to high costs^{19,85}, an aspect that was not found in this study since all apps were free.

Thus, it can be affirmed that the use of mobile applications can provide many benefits and opportunities for the improvement of medical care. Nevertheless, their use is not free from risk^{86,87}. The systematic and continuous evaluation of information technology is important⁸⁸, since this process will contribute to the effectiveness and improvement of current and future health information systems^{86,89,90}.

Through the use of social networks using mobile applications, information can reach a greater number of individuals. This represents an effective means of communication as long as the information is based on evidence; when this is not the case, serious issues can arise⁹¹.

It is also noteworthy that the research was mainly carried out with young people, a group that is less likely to be affected by diseases or limitations as compared to the older population. Therefore, the advantages of using mobile applications in the health sciences should be analyzed with caution⁹².

In conclusion, there has been an exponential increase in the number of publications studying the use of apps in oncology. However, after completion of the studies the apps tend not to be available. With respect to the objectives of the apps, most were related to breast cancer in terms of tumor type, although the role of apps for the early detection of melanoma is noteworthy. It was especially difficult to access the apps found in the published research studies. Thus, it is important to create apps that are endorsed by health organizations, not only for research purposes but also for the continuous support of patients and health care professionals caring for cancer patients. These apps should also be evaluated and analyzed systematically. At present, caution should be taken in

the use of apps, social networks, and websites because of the lack of evidence supporting their use. It is also necessary to create apps for all age groups, since most of the research has been carried out in younger populations.

Journal Pre-proof

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