Review

Digital Health Interventions for Adult Patients With Cancer Evaluated in Randomized Controlled Trials: Scoping Review

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Abstract

Background: Digital care has become an essential component of health care. Interventions for patients with cancer need to be effective and safe, and digital health interventions must adhere to the same requirements.

Objective: The purpose of this study was to identify currently available digital health interventions developed and evaluated in randomized controlled trials (RCTs) targeting adult patients with cancer.

Methods: A scoping review using the JBI methodology was conducted. The participants were adult patients with cancer, and the concept was digital health interventions. The context was open, and sources were limited to RCT effectiveness studies. The *PubMed*, *CINAHL*, *Embase*, *Cochrane Library*, *Research Information Sharing Service*, and *KoreaMed* databases were searched. Data were extracted and analyzed to achieve summarized results about the participants, types, functions, and outcomes of digital health interventions.

Results: A total of 231 studies were reviewed. Digital health interventions were used mostly at home (187/231, 81%), and the *web-based* intervention was the most frequently used intervention modality (116/231, 50.2%). Interventions consisting of *multiple* functional components were most frequently identified (69/231, 29.9%), followed by those with the *self-manage* function (67/231, 29%). *Web-based* interventions targeting symptoms with the *self-manage* and *multiple* functions and *web-based* interventions to *treat* cognitive function and fear of cancer recurrence consistently achieved positive outcomes. More studies supported the positive effects of *web-based* interventions to *inform* decision-making and knowledge. The effectiveness of digital health interventions targeting anxiety, depression, distress, fatigue, health-related quality of life or quality of life, pain, physical activity, and sleep was subject to their type and function. A relatively small number of digital health interventions specifically targeted older adults (6/231, 2.6%) or patients with advanced or metastatic cancer (22/231, 9.5%).

Conclusions: This scoping review summarized digital health interventions developed and evaluated in RCTs involving adult patients with cancer. Systematic reviews of the identified digital interventions are strongly recommended to integrate digital health interventions into clinical practice. The identified gaps in digital health interventions for cancer care need to be reflected in future digital health research.

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KEYWORDS

digital health; adult; neoplasms; randomized controlled trial; mobile phone

Introduction

Background

Digital health care has become a necessity in delivering care. Digital health is defined as health services and information to manage illness and health risks delivered or enhanced through the internet and related technologies, that is, information and communication technology [1,2]. The term digital health is rooted in eHealth [1], which encompasses mobile health, telemedicine, telemonitoring, digital therapeutics, digital health analytics, and digital health systems [3,4]. Wearables, mobile apps, and web pages are examples of digital technologies that are applied to enhance health care.

Digital health receives increased attention because it is expected to improve access to health care, reduce inefficiencies in the health care system, improve quality of care, and lower health care costs [2]. The World Health Organization has recognized the value of digital technologies in advancing universal health coverage and provides recommendations for their use [5]. The COVID-19–related restrictions, which limit person-to-person contact, have accelerated the development and implementation of digital health in practice, potentially making it possible to continue providing the best possible care. Promising outcomes have been suggested from digital health intervention trials; for example, Basch et al [6] incorporated electronic patient-reported outcome monitoring of 12 symptoms during routine cancer treatment and demonstrated less decline in health-related quality of life (HRQoL), less frequent readmission, longer continuation of chemotherapy treatment, and longer quality-adjusted survival.

However, current systematic and scoping reviews on digital health interventions for patients with cancer provide information that is too fragmentary to enable a comprehensive understanding of available digital health interventions for cancer care. Reviews were often focused on specific cancer populations. The most frequently studied were adolescents and young adults, considering their familiarity with digital solutions [7-12]. Mixed outcomes were identified for symptom management [8], physical symptoms and functioning, emotional distress, health behaviors, neurocognitive functioning, health knowledge, and self-efficacy of adolescents and young adults [11]. Digital self-management was not effective in improving HRQoL or moderate-to-vigorous physical activity [9]. Some studies have reviewed the application of digital health for specific types of cancers, that is, breast cancer [13], prostate cancer [14], melanoma [15], and hematologic malignancy [16]. Although digital health is applicable across the cancer continuum, reviews were limited to the postoperative phase [13], survivorship [17,18], and palliative care [7,19,20]. There exists a single digital health review that spans across pediatric patients' cancer continuum (from treatment to survivorship) [11].

A limited number of reviews exist about the effectiveness of particular digital health intervention modalities targeting specific outcomes: mobile health is ineffective for oral anticancer drug adherence [21], telemedicine demonstrates similar or improved care in patients with hematologic malignancies [16], and activity trackers improve activity level and HRQoL [22]. In terms of the outcomes of digital health interventions, improvements in physical activity or exercise [23] and patient-provider communication [24]; benefits in symptom assessment and management, functional capacity, and HRQoL [3,25]; decreases in emergency room visits, unplanned hospitalization, and hospital days; and increased survival [3] have been supported. The use of digital health to support survivorship care planning resulted in positive physical and psychosocial effects, whereas there were mixed effects for fear and anxiety [18]. Inconsistent outcomes have been achieved for diet among cancer survivors [23] and for psychological outcomes of patients with cancer in the treatment or survivorship phase [26] and those receiving palliative care [7].

Digital health care for patients with cancer needs to be effective and safe [27]. A comprehensive overview of available digital health interventions for patients with cancer will help us to understand the current status of digital health in cancer care and identify gaps and areas for further development while readying for the inevitable surge in digital technologies.

Objectives

The purpose of this scoping review was to identify currently available digital health interventions developed and evaluated in randomized controlled trials (RCTs) among adult patients with cancer. The primary research question was as follows: *What digital health interventions were developed and evaluated for adult patients with cancer?*

The subquestions were as follows:

1. What were the characteristics of targets for digital health interventions (age, sex, type and stage of cancer, and trajectory)?
2. What were the types and functions of digital health interventions?
3. How were the digital health interventions applied (frequency, duration, and time spent for intervention)?
4. What nursing problems were sought for intervention with digital health interventions?
5. What were the outcomes of digital health interventions?

Methods

Design

A scoping review was conducted in accordance with the JBI methodology [28]. The population, concept, and context framework for this scoping review was as follows: (1) population: adult patients with cancer or cancer survivors, (2) concept: digital health interventions, and (3) context: open (no limitation).

Search Strategy

The search strategy aimed to identify published RCTs that reported the efficacy of digital health interventions among adult patients with cancer. An initial limited search of *PubMed* was undertaken to identify articles on the topic. The words contained in the titles and abstracts of relevant articles and the index terms used to describe the articles were used to develop a full search strategy for *PubMed, CINAHL, Embase, Cochrane Library, Research Information Sharing Service,* and *KoreaMed.* Key search terms included all identified keywords, and index terms were adapted for each included database and information source (Multimedia Appendix 1). The reference lists of related sources of evidence were screened for additional studies.

Study and Source of Evidence Selection

Studies published from 1999, considering the time when the definition of eHealth was first introduced [29], to July 26, 2021, and published in English and Korean were included. As this scoping review aimed to include outcomes from RCTs, the type of source was set as a published RCT reporting the effect of a digital health intervention; thus, unpublished studies or gray literature were excluded.

After the search, all identified citations were collated into *EndNote* (version 20.0; Clarivate), and duplicates were removed. The team of reviewers paired into 3 groups (SK and KL, JL and JHS, and SHK and S-HY) for screening and data extraction, considering that >5000 articles were retrieved through the database search.

To identify outcomes from digital health interventions applied to patients with cancer, studies that evaluated the effect of digital health interventions in the form of RCTs were included in the review. Trial runs of article selection and relevant discussions facilitated modification of the initial set of eligibility criteria. The final eligibility criteria were as follows: (1) participants needed to be adult patients with cancer (aged ≥18 years), but studies involving adolescents and young adults that included adult patients were also included in this review; and (2) interventions needed to demonstrate their effects in patients with cancer; thus, studies investigating interventions for patients with chronic disease in which patients with cancer also took part or interventions to promote cancer screening among healthy individuals were excluded.

Classic telephone service or replication of clinical service by substituting it using the telephone was not considered a digital intervention according to the criteria outlined by Marthick et al [25], who define the functions of digital health technologies as monitoring, tracking, and providing information on health as well as enabling communication. However, studies of automated systems (interactive voice response) were included if data were obtained from patients and patient-tailored feedback from professionals (tailored automated voice response) was delivered. Interventions in the form of simple videos contained in CD-ROMs or tablet devices were excluded. If the study assessed outcomes by applying digital assessment tools but the intervention itself was not considered digital, it was excluded.

Only RCTs that reported outcomes of the digital intervention were eligible to be included. In the case of pilot RCTs, if the study reported the effect of digital interventions, it was included for review. Cost-effectiveness was considered an effect of the intervention, whereas satisfaction was not.

A pilot selection using 25 randomly selected studies demonstrated 80% agreement among all 6 reviewers in selecting the source of evidence based on titles and abstracts. Among the initially selected 5164 articles, potentially relevant sources were retrieved, and the full text of selected citations was assessed in detail against the eligibility criteria by 2 independent reviewers. Reasons for exclusion of sources of evidence after full-text review were recorded. Any disagreements that arose between the reviewers at each stage of the selection process were resolved through discussion with a third reviewer.

Data Extraction

Data were extracted by 3 groups of 2 independent reviewers (a total of 6 reviewers) using a data extraction tool developed by the reviewers. The data extracted included specific details about the selected article (authors, year, title, and country in which the study was conducted), participants (age, sex, type of cancer, and phase of cancer journey), concept (types and functions of the digital health interventions), context (setting for the intervention), study methods (number of participants; details, frequency, and duration of the intervention; time spent administering the intervention; and types and details of controls) and key findings relevant to the review questions (nursing problems and outcomes), and reported adverse events. Any disagreements that arose between the reviewers were resolved through discussion with a third reviewer.

Data Analysis and Presentation

To quantify the study results, parts of the extracted data were coded. A list of cancers was developed incorporating common and prevalent cancers retrieved from the National Cancer Institute [30] and the World Health Organization [31]. Digital interventions were categorized by type according to the initial categorization of digital interventions by Deloitte [4] and the categorization by Aapro et al [3], which supplemented the list developed by Deloitte [4]. The types of digital health interventions were categorized as *telemonitoring, telemedicine, wearables, web based, mobile apps, health analytics,* and *digitized health systems*. With regard to digital health interventions comprising multiple types—for example, *telemonitoring+telemedicine, wearable+web based,* and *web based+mobile*—each combination was considered a category. The National Institute for Health and Care Excellence (NICE) evidence standards framework for digital health technologies was used [32] to sort digital interventions into 3 tiers and 10 functional categories: tier A (*system services*), tier B (*inform, health diaries,* and *communicate*), and tier C (*preventative behavior change, self-manage, treat, active monitoring, calculate,* and *diagnose*). If a digital health intervention comprised multiple functions, then the function was classified as *multiple*.

Outcomes of digital health interventions were categorized as having positive, no, negative, mixed, or equivalent effects based on the purpose of the study. If significant outcomes were identified that corresponded with the hypothesis, they were

categorized as having positive effects. Insignificant outcomes were categorized as having no effect. Significant opposite outcomes were considered negative outcomes. If the outcome was both positive and negative, it was considered as having a mixed effect. If the study aimed to demonstrate equivalent effectiveness, it was considered as having an equivalent effect. When the outcome was measured with multiple subscales and only partial outcomes were significant, then the study was categorized as having a positive effect. This also applied to longitudinal study outcomes where the same outcome was measured multiple times and a positive outcome identified at some of the time points. When the study had multiple comparisons, the outcomes of each comparison arm were identified.

With regard to summarizing the outcomes of the digital health interventions, if there were multiple digital health intervention studies targeting the same nursing problem, the outcomes were summarized and the effects compared. If the number of studies showing a positive effect outnumbered those with no effect or negative outcomes, the intervention was considered to suggest a positive outcome. If the same number of studies existed with both positive and no effect or negative outcomes, the intervention was considered to have inconsistent outcomes. If there were more studies that demonstrated no effect or negative outcomes, the intervention was considered to suggest no effect or negative outcome. A narrative and quantitative summary was accompanied by the tabulated and charted results.

Results

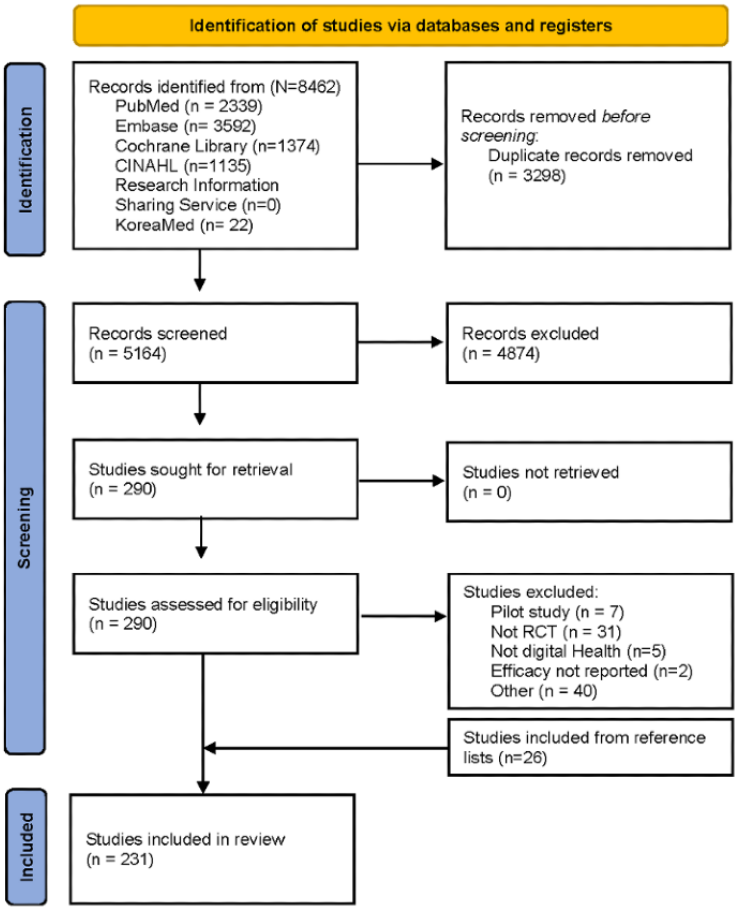
General Characteristics

Of the 5164 articles screened, 231 (4.47%) [6,33-262] were selected and reviewed. The results of the search and the study inclusion process are presented in a PRISMA-ScR (Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews) flow diagram [263] (Figure 1).

Although digital health RCTs for patients with cancer continued to be reported, only a handful of studies were reported until 2012. Of the 231 included RCTs, 19 (8.2%) were published in 2013, whereas 50 (21.6%) were published in 2020. The United States was the country with the largest number of studies (119/231, 51.5%), followed by the Netherlands (26/231, 11.3%) and Australia (18/231, 7.8%).

Two-thirds of the studies were full-size RCTs and evaluated the effectiveness of digital health interventions (163/231, 70.6%), whereas the rest were pilot studies (68/231, 29.4%). Most of the studies were designed as 2-arm RCTs comparing the digital health interventions and control groups (206/231, 89.2%), but there were also 3-arm (22/231, 9.5%) and 4-arm (3/231, 1.3%) studies. Approximately half of the control groups received usual care or standard care (109/231, 47.2%). Waitlist control groups received the intervention after data collection was completed (47/231, 20.3%).

Figure 1. PRISMA-ScR (Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews) flow diagram. RCT: randomized controlled trial.



Participant Characteristics

The number of participants included in the study (both pilot and full-size RCTs) ranged from 8 to 614 for the intervention group and 9 to 621 for the control group. In terms of age, digital interventions were mostly applied to adult patients with cancer (97/231, 42%) or both adult and geriatric patients with cancer (119/231, 51.5%), whereas studies targeting specifically older adults with cancer were scarce (6/231, 2.6%). More than half of the studies included adult patients with cancer of both sexes (124/231, 53.7%), whereas 38.5% (89/231) of the studies included only female patients with cancer. More than half of the studies were conducted with subjects with a single cancer (129/231, 55.8%), and among them, patients with breast cancer were the most frequently studied (79/129, 61.2%), followed by patients with prostate cancer (19/129, 14.7%) and patients with lung cancer (9/129, 7%). Patients with early-stage cancer were targeted in 38.5% (89/231) of the studies, and 32% (74/231) of the studies included patients with cancer of any stage, whereas 9.5% (22/231) of the studies targeted only patients with advanced or metastatic cancer. Studies about cancer survivors accounted for the highest percentage (97/231, 42%), followed by interventions provided along with cancer treatment (70/231, 30.3%).

Types and Functions of Digital Health Interventions

Among the 231 studies, 196 (84.8%) included only digital interventions, whereas the rest (n=35, 15.2%) included digital interventions combined with nondigital interventions such as interventions provided in person (14/35, 40%), by telephone (10/35, 29%), by telephone+in person (10/35, 29%), and by CD-ROM multimedia program (1/35, 3%). The analysis based on digital health interventions showed that *web-based* digital health technology was the most frequently used type of digital intervention (116/231, 50.2%), followed by *mobile app* (31/231, 13.4%), *telemedicine* (17/231, 7.4%), *telemonitoring* (11/231, 4.8%), and *wearable* (9/231, 3.9%). Digital interventions comprising multiple modalities accounted for 20.3% (47/231) of the interventions, in which *web based+mobile app* was the most frequently used modality (23/47, 49%), followed by *wearable+mobile app* (9/47, 19%), *wearable+web based+mobile app* (5/47, 11%), *telemonitoring+telemedicine* (3/47, 6%), *wearable+web based* (2/47, 4%), *telemedicine+web based* (2/47, 4%), *telemedicine+mobile app* (1/47, 2%), *telemedicine+web based+mobile app* (1/47, 2%), and *telemonitoring+wearable+web based+mobile app* (1/47, 2%; Figure 2).

Digital health interventions consisting of *multiple* functional components (69/231, 29.9%) were the most frequently used interventions, followed by interventions for *self-manage* (67/231, 29%). Among the studies that applied digital interventions with *multiple* components, *communicate+self-manage* (18/69, 26%) was the frequently identified combination.

Self-manage was the most prevalent single function of digital health function regardless of patients' cancer stages (185/231, 80.1%; Figure 3). With regard to patients' cancer journeys, *inform* was usually applied at the diagnosis phase. *Self-manage* interventions during the treatment phase accounted for the largest proportion (38/70, 54%) of the provided interventions. Interventions with *multiple* components mostly targeted the survivorship phase (41/97, 42%), which comes after the treatment phase (11/97, 11%; Figure 4).

Figure 2. Types of digital health interventions (N=231).

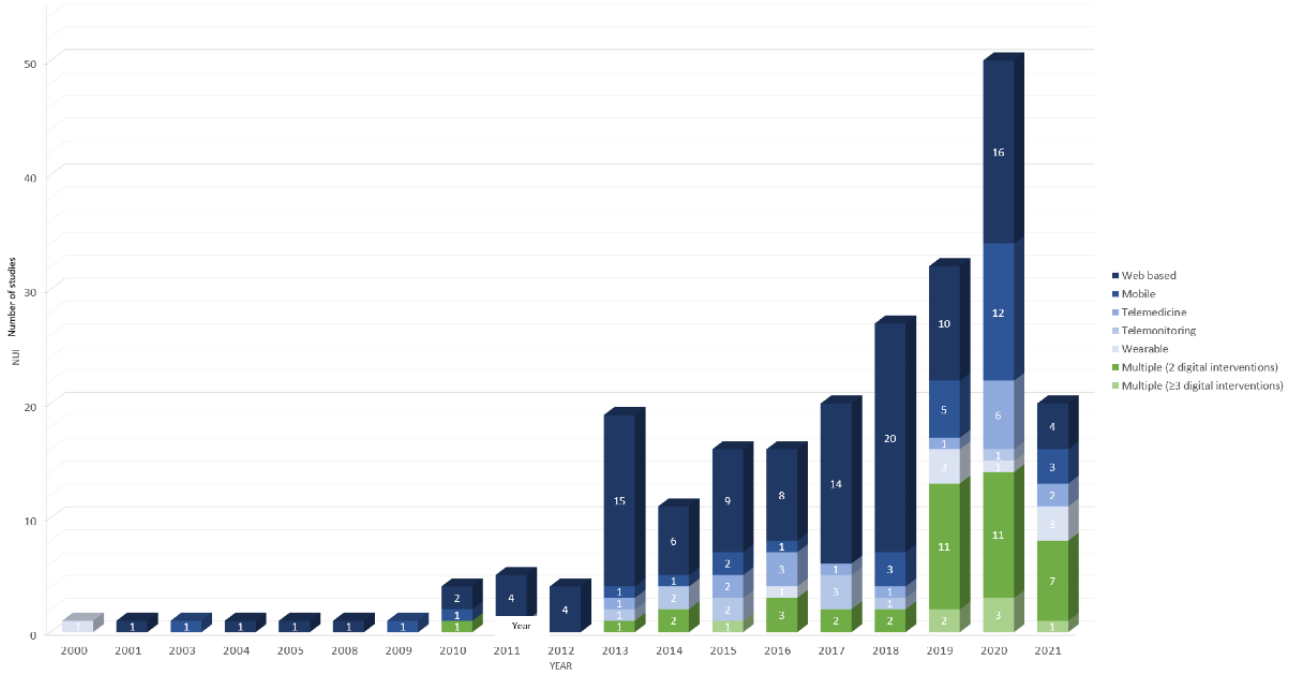


Figure 3. Digital health intervention functions by stage (n=185). NICE: National Institute for Health and Care Excellence.

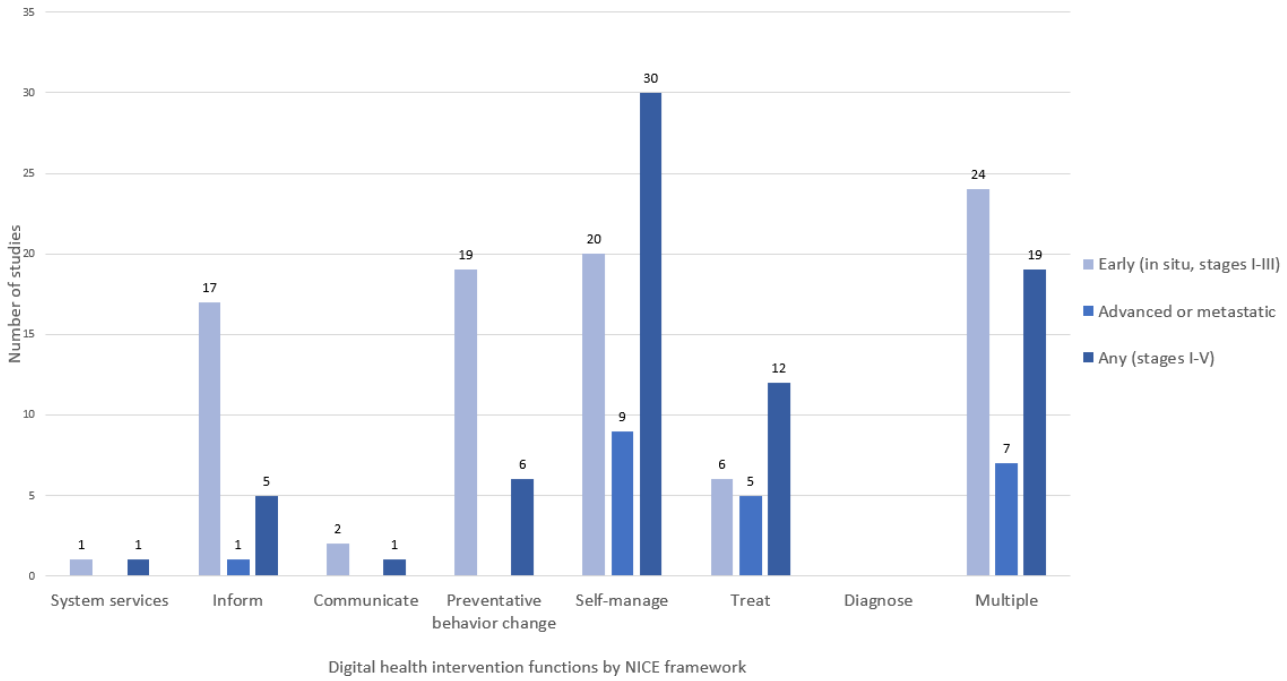
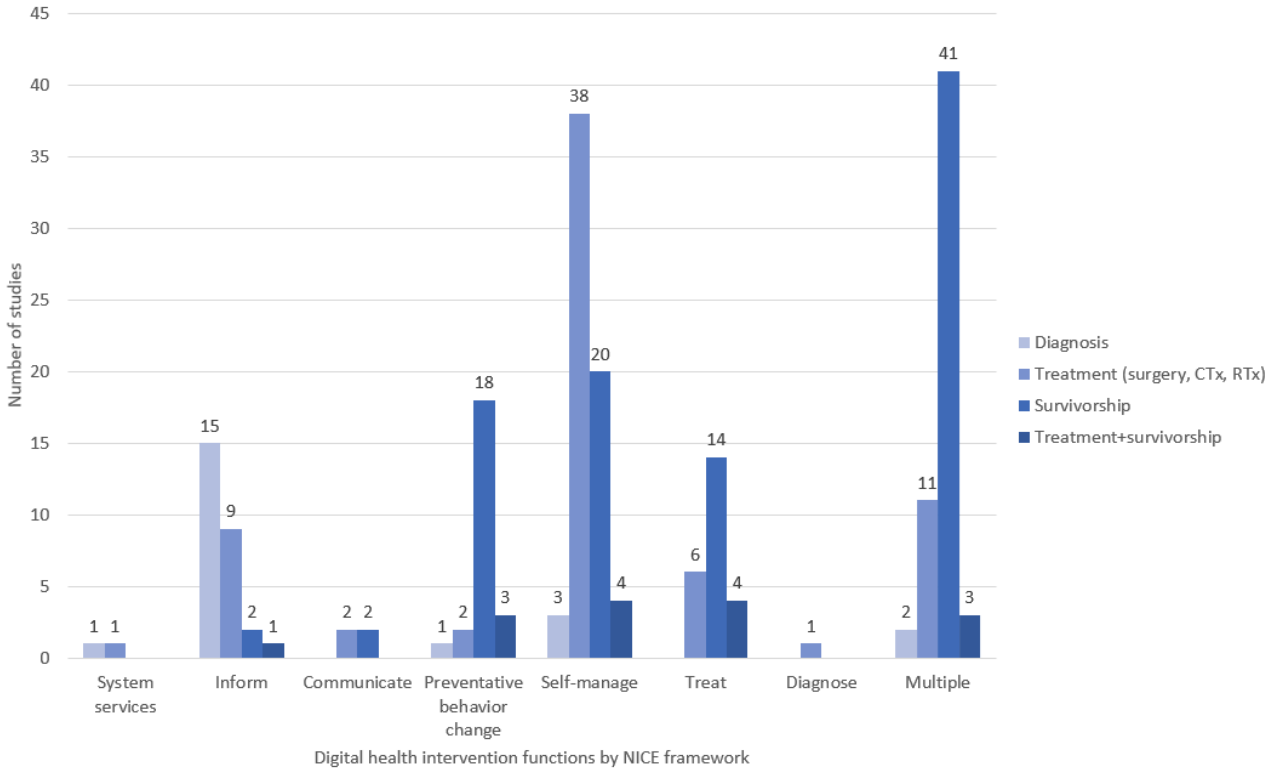


Figure 4. Digital health intervention functions by phase (n=204). CTx: chemotherapy; NICE: National Institute for Health and Care Excellence; RTx: radiation therapy.



Frequency, Duration, and Time Spent Administering Interventions

Most of the digital interventions were applied at home (187/231, 81%). There were several studies that did not report the frequency of application of digital interventions (129/231, 55.8%). Among those that reported the frequency of application (102/231, 44.2%), weekly application accounted for 34.3% (35/102) of the interventions, whereas daily application accounted for 8.8% (9/102). The duration of application ranged from 2 weeks to 144 weeks (152/231, 54.1%); the 12-week application was the most frequent (43/156, 27.6%), whereas 8-week and 24-week periods were applied in 14.7% (23/156) each of the interventions. In most (181/231, 78.4%) of the cases,

the application time per single intervention was not reported. The average application time among the studies that reported information about application time per single intervention was approximately 60 (mean 63.92, SD 49.71; range 5-240) minutes (50/231, 21.6%).

Targeted Nursing Problems and Outcomes

Data from full-size RCTs were used to summarize targeted nursing problems and outcomes of digital health interventions.

To better understand the outcomes of the digital health interventions, outcomes identified from >2 studies with the same target, type, and function were summarized (Table 1). *Wearable* with *multiple-function* interventions for physical activity all demonstrated positive outcomes. *Web-based* interventions to *inform* patients to intervene in anxiety; *preventative behavior change* for physical activity; *self-manage* symptoms; *treat* for cognitive function, depression, fear of cancer recurrence, and sleep; and those with *multiple* functional components for symptoms all demonstrated positive outcomes. *Web-based* interventions combined with *mobile multiple-function* interventions all demonstrated positive outcomes for pain. *Telemonitoring* interventions combined with *telemedicine* and *treat* demonstrated positive outcomes for patients with depression as well as pain.

Table 1. Types, functions, and effects of digital health interventions for nursing problems.

Problems, digital health type, and digital health function	Positive effect	No effect	Negative effect	Mixed effect[a]	Equivalent effect
Adherence: medication					
Mobile					
Self-manage	[133,210]	[108,116]	N/A[b]	N/A	N/A
Anxiety					
Web					
Inform	[138,164,195]	N/A	N/A	N/A	N/A
Treat	[163]	[82]	N/A	N/A	[79]
Multiple[c]	[57][d] [234][d,e]	[170,225,227]	N/A	N/A	N/A
Web+mobile					
Multiple	[117] [205][e] [231][f]	[58][g] [173]	N/A	N/A	N/A
BMI					
Web					
Multiple	[97][e]	[234][d,e]	N/A	N/A	N/A
Breast cancer concerns					
Web					
Multiple	[114][d,e,h]	[44][d] [114][d,e,h]	N/A	N/A	N/A
Cancer-specific distress					
Web					
Self-manage	[218]	[46,47] [208][d,e]	N/A	N/A	N/A
Cognitive function					
Web					
Treat	[82,158]	N/A	N/A	N/A	N/A
Communication with provider					
Web					
Self-manage	[49]	[216]	N/A	N/A	N/A
Competence: health care					
Web					
Multiple	[44][d] [115][d,e]	[44][d] [114][d,e,h] [115][d,e]	N/A	N/A	N/A
Competence: information					
Web					
Multiple	[44][d] [114][d,e,h] [134][d,e]	[44][d] [114][d,e,h] [115][d,e]	N/A	N/A	N/A
Coping					
Web					
Self-manage	[180,209]	[46,47]	N/A	N/A	N/A
Multiple	[44][d] [115][d,e]	[44][d] [114][d,e,h] [115][d,e]	N/A	N/A	N/A
Cost					
Telemedicine					
Treat	[148]	[152]	N/A	N/A	N/A
Web					
Self-manage	N/A	[34]	N/A	N/A	[219]

Problems, digital health type, and digital health function	Positive effect	No effect	Negative effect	Mixed effect[a]	Equivalent effect
Decision-making					
Web					
Inform	[50] [78][i] [243,247,262]	[73,84,157,175]	N/A	N/A	N/A
Depression					
Web					
Self-manage	[86,142,196,203]	[208,234][d,e]	N/A	N/A	N/A
Treat	[82,163] [237][g]	N/A	N/A	N/A	[79]
Multiple	[57][d] [227]	[54,170,183] [204][g] [208][d,e] [225,228] [234][d,e] [240]	N/A	N/A	N/A
Web+mobile					
Multiple	[117]	[58][g] [173] [205][e]	N/A	N/A	N/A
Telemonitoring+telemedicine					
Treat	[140,244]	N/A	N/A	N/A	N/A
Diet					
Web					
Multiple	N/A	[127,240]	N/A	N/A	N/A
Distress					
Web					
Communicate	N/A	N/A	[119,144]	N/A	N/A
Self-manage	[142] [189][f] [212,218,233]	[35,46,47,193]	N/A	N/A	N/A
Treat	[33][g] [72,163] [217][g]	[41][d,e] [158]	N/A	N/A	N/A
Multiple	[76,229]	[59][d] [75] [97][e] [102]	N/A	N/A	N/A
Mobile					
Multiple	[68]	[155]	N/A	N/A	N/A
Emotional processing					
Web					
Multiple	[44][d] [114][d,e,h]	[44][d] [114][d,e,h]	N/A	N/A	N/A
Fatigue					
Web					
Self-manage	[196,218,233]	[208][d,e] [234][d]	N/A	N/A	N/A
Treat	[33,217][g] [235] [237][g]	[82,158]	N/A	N/A	N/A
Multiple	[59][d] [170,227]	[54] [204][g] [208][d,e] [228] [234][d,e] [240]	N/A	N/A	N/A
Web+mobile					
Multiple	[117]	[238]	N/A	N/A	N/A
Fear of cancer recurrence or progression					
Web					
Self-manage	[218]	[221]	N/A	N/A	N/A
Treat	[72,163] [217][g]	N/A	N/A	N/A	[79]
Follow-up					

Problems, digital health type, and digital health function	Positive effect	No effect	Negative effect	Mixed effect[a]	Equivalent effect
Telemedicine					
Treat	[40]	[152]	N/A	N/A	N/A
Function					
Web					
Self-manage	N/A	[86,180] [208][d,e]	N/A	N/A	N/A
Multiple	[39]	[170] [208][d,e]	N/A	N/A	N/A
Functional well-being					
Web					
Self-manage	N/A	[62,209]	N/A	N/A	N/A
Multiple	[114][d,e,h] [115][d,e]	[44][d] [114][d,e,h] [115][d,e]	N/A	N/A	N/A
HRQoL[j]/QoL[k]					
Telemonitoring					
Self-manage	[90,174]	[136,232]	N/A	N/A	N/A
Telemedicine					
Multiple	[207]	[94][e]	N/A	N/A	N/A
Web					
Inform	[138][h] [195]	[175]	N/A	N/A	N/A
Self-manage	[34,46] [189][f] [212,220,233]	[35,47,218] [261][h]	N/A	N/A	N/A
Treat	[33][g] [71,72,163] [217][g]	[41][d,e] [82]	N/A	N/A	[79]
Multiple	[97][e] [102,168] [204][g] [225,227]	[54] [115][d,e] [183] [197][e] [228,249,251]	N/A	N/A	N/A
Mobile					
Self-manage	[118]	[108,260]	N/A	N/A	N/A
Treat	[199]	[107]	N/A	N/A	N/A
Multiple	[68]	[155]	N/A	N/A	N/A
Web+mobile					
Multiple	[58][g] [117,120] [231][f] [238]	[173,214]	N/A	N/A	N/A
Telemonitoring+telemedicine					
Treat	[65][d] [140,244]	[65][d]	N/A	N/A	N/A
Intrusive thoughts					
Web					
Self-manage	N/A	[142,203]	N/A	N/A	N/A
Knowledge					
Web					
Inform	[73,105,157,175,194,211,262]	[84,164]	N/A	[186]	N/A
Multiple	[251]	[102]	N/A	N/A	N/A
Mood					
Web					
Self-manage	[203]	[62]	N/A	N/A	N/A
Pain					

Problems, digital health type, and digital health function	Positive effect	No effect	Negative effect	Mixed effect[a]	Equivalent effect
Web					
Self-manage	N/A	[196,233]	N/A	N/A	N/A
Multiple	N/A	[64] [204][g]	N/A	N/A	N/A
Web+mobile					
Multiple	[173,238]	N/A	N/A	N/A	N/A
Telemonitoring+telemedicine					
Treat	[65][d] [140]	N/A	N/A	N/A	N/A
Physical activity					
Wearable					
Multiple	[113][e] [150][g]	N/A	N/A	N/A	N/A
Web					
Preventative behavior change	[103,250]	N/A	N/A	N/A	N/A
Self-manage	N/A	[233] [234][d,e]	N/A	N/A	N/A
Multiple	[97][e] [128,240]	[89][d] [127] [234][d,e]	N/A	N/A	N/A
Web+mobile					
Multiple	N/A	[117,214]	N/A	N/A	N/A
Personal control					
Web					
Self-manage	N/A	[218,220]	N/A	N/A	N/A
Recall of cancer-related information					
Web					
Inform	[55][d]	[55,56][d]	N/A	N/A	N/A
Self-efficacy					
Web					
Inform	N/A	[101,164]	N/A	N/A	N/A
Self-manage	[34,62,218]	[196,220]	[209]	N/A	N/A
Multiple	[251]	[57][d] [64,183] [197][e]	N/A	N/A	N/A
Web+mobile					
Multiple	[231][f]	[63]	N/A	N/A	N/A
Sleep					
Web					
Treat	[41][d,e] [235] [237][g]	N/A	N/A	N/A	N/A
Web+mobile					
Multiple	[117]	[173,238]	N/A	N/A	N/A
Social support					
Web					
Multiple	[114][d,e,h] [249]	[44][d] [114][d,e,h] [115][d,e] [183] [234][d,e]	N/A	N/A	N/A
Symptom					
Telemonitoring					

Problems, digital health type, and digital health function	Positive effect	No effect	Negative effect	Mixed effect[a]	Equivalent effect
Self-manage	[70,90,136,162,174]	[161,232]	N/A	N/A	N/A
Web					
Self-manage	[34,51,62,180,220,257]	N/A	N/A	N/A	N/A
Multiple	[57][d] [110,183]	N/A	N/A	N/A	N/A
Mobile					
Self-manage	[179,184]	[108,260]	N/A	[129]	N/A

[a]Mixed effect: both positive and negative effects were identified.

[b]N/A: not applicable.

[c]Multiple: multiple digital health functions were combined.

[d]Multiple-arm study and different intervention groups.

[e]Additional intervention was provided by telephone (provided only in some arms in multiple-arm study).

[f]Additional intervention was provided in person.

[g]Additional intervention was provided in person and by telephone.

[h]Multiple-arm study and different control groups.

[i]Additional intervention was provided by CD-ROM.

[j]HRQoL: health-related quality of life.

[k]QoL: quality of life.

More studies with positive outcomes were identified for *web-based* interventions to *inform* decision-making, HRQoL or quality of life (QoL), and knowledge; to *self-manage* depression, distress, fatigue, and HRQoL or QoL; to *treat* distress, fatigue, and for HRQoL or QoL; and *web+mobile multiple-function* interventions for anxiety and HRQoL or QoL. More studies with positive outcomes were also identified for *telemonitoring* to *self-manage* symptoms and *telemonitoring* combined with *telemedicine* and *treat* for HRQoL or QoL.

Studies with no effect or negative outcomes outnumbered *web-based* interventions to *inform* for recall of cancer-related information; *self-manage* interventions for cancer-specific distress and cost; and the following *multiple-function* interventions for anxiety, breast cancer concerns, and competence: health care, coping, depression, distress, fatigue, function, functional well-being, HRQoL or QoL, self-efficacy, and social support. There were also a greater number of studies with no effect or negative outcomes with regard to *mobile self-manage* interventions for HRQoL or QoL and *web-based* interventions combined with *mobile multiple-function* interventions for depression and sleep.

No effects were reported for *web-based* interventions to *inform* targeting self-efficacy or *self-manage* interventions for function, functional well-being, intrusive thoughts, pain, physical activity, and personal control. *Web-based multiple-function* interventions targeting diet and pain demonstrated no effects. *Web-based* interventions combined with *mobile* interventions with *multiple-function* interventions for physical activity also demonstrated no effects.

Notably, the effectiveness of digital health interventions targeting anxiety, depression, distress, fatigue, HRQoL or QoL, pain, physical activity, and sleep depended on the type and function of the interventions.

Two *web-based* interventions with *communicate* functions for distress only demonstrated negative outcomes. Inconsistent outcomes from equivalent numbers of studies with positive effects and no effect or negative effects were identified from the rest of the studies listed (Table 2).

Adverse events were reported in some of the studies [33,72,77,79,117,173,218,251]. There was increased distress because the information content reminded patients of their cancer, because patients felt pressured to engage in healthy behavior, and because patients felt frustrated by options that did not match their situation [117]. In addition, increased symptoms [77,79] and unintended weight loss while trying a healthy diet [117] were reported as adverse events. Some of the adverse events that were unrelated to the digital intervention [72] occurred in 2 participants in the usual-care group who were concerned about cancer recurrence [33] and in the control group participants who played the control game [251] or were similar for both the intervention and control groups [173]. A single serious adverse event occurred, in which 1 participant was admitted to the psychiatric clinic; however, the study did not report whether this event occurred in the intervention group or control group [218].

Table 2. Summary of digital health intervention outcomes.

Types of digital health interventions	Studies with positive outcomes	Studies with positive outcomes outnumbered studies with no effect or negative outcomes	Effectiveness of digital health interventions was subject to their type and function	Studies with no effect or negative outcomes outnumbered studies with positive outcomes	Studies with no effect	Studies with negative outcomes
Telemonitoring	N/A[a]	Self-manage symptom	Anxiety; depression; distress; fatigue; HRQoL[b] or QoL[c]; pain; physical activity; sleep	N/A	N/A	N/A
Telemedicine	N/A	N/A	Anxiety; depression; distress; fatigue; HRQoL or QoL; pain; physical activity; sleep	N/A	N/A	N/A
Wearable	Multiple[d] functions for physical activity	N/A	Anxiety; depression; distress; fatigue; HRQoL or QoL; pain; physical activity; sleep	N/A	N/A	N/A
Web	Inform for anxiety; preventative behavior change for physical activity; self-manage symptoms; treat for cognitive function, depression, fear of cancer recurrence, and sleep; multiple functions for symptom	Inform for decision-making, HRQoL or QoL, and knowledge; self-manage depression, distress, fatigue, and HRQoL or QoL; treat for distress, fatigue, and HRQoL or QoL	Anxiety; depression; distress; fatigue; HRQoL or QoL; pain; physical activity; sleep	Inform for recall of cancer-related information; self-manage intervention for cancer-specific distress and cost; multiple functions for anxiety, breast cancer concerns, and competence (including health care, coping, depression, distress, fatigue, function, functional well-being, HRQoL or QoL, self-efficacy, and social support)	Inform for self-efficacy; self-manage for function, functional well-being, intrusive thoughts, pain, physical activity, and personal control; multiple functions for diet and pain	Communicate for distress
Mobile	N/A	N/A	Anxiety; depression; distress; fatigue; HRQoL or QoL; pain; physical activity; sleep	Self-manage for HRQoL or QoL	N/A	N/A
Web+mobile	Multiple functions for pain	Multiple functions for anxiety and HRQoL or QoL	Anxiety; depression; distress; fatigue; HRQoL or QoL; pain; physical activity; sleep	Multiple functions for depression and sleep	Multiple functions for physical activity	N/A
Telemonitoring+telemedicine	Treat depression and pain	Treat for HRQoL or QoL	Anxiety; depression; distress; fatigue; HRQoL or QoL; pain; physical activity; sleep	N/A	N/A	N/A

[a]N/A: not applicable.

[b]HRQoL: health-related quality of life.

[c]QoL: quality of life.

[d]Multiple: multiple digital health functions were combined.

Discussion

Principal Findings

This scoping review provides a comprehensive summary of digital health interventions for adult patients with cancer or cancer survivors. A total of 231 studies that used digital health interventions were included in the review. By summarizing the broad literature, the major results showed that (1) *web-based* digital health technologies are the most frequently used intervention modality (116/231, 50.2%), (2) digital health interventions with *multiple* functions are the most studied (69/231, 29.9%), and (3) systematic reviews and studies regarding the clinical application of digital health interventions for patients with cancer are worthy of consideration. The effectiveness of digital health interventions targeting anxiety, depression, distress, fatigue, HRQoL or QoL, pain, physical activity, and sleep is subject to the type and function of the interventions, and this needs to be investigated further to select appropriate types and functions of digital health approaches

depending on the targets. Digital health interventions that demonstrate inconsistent outcomes, as well as studies with no effect or negative outcomes that outnumber studies with positive outcomes, are worthy of further investigation, considering the limited number of studies conducted thus far. Digital health interventions that only demonstrated no effect or negative outcomes would have low priority for further investigation.

The number of RCTs using digital health interventions for patients with cancer has increased since 2013, and 50 RCT studies were published in 2020. The number of RCTs using digital health interventions conducted in the United States has been overwhelmingly high in the last 20 years. Since eHealth was first defined [29], it has gradually expanded owing to the change in the medical paradigm, the impact of the Fourth Industrial Revolution, and the popularization of smartphones.

In this review, digital interventions were mostly applied to adult patients (97/231, 42%) or both adult and older adult patients with cancer (119/231, 51.5%). However, digital health intervention studies targeting only geriatric patients with cancer were the rarest (6/231, 2.6%). Cancer is considered a disease of aging. Most of the new cancer diagnoses occur in older adults (aged >65 years) [264], and the incidence of new cancers is expected to double by 2035 among older adults [265]. For these reasons, providing high-quality care for older adults with cancer can be a high-priority item on the clinical agenda. In addition, cancer mortality has decreased, and the 5-year relative survival rate for all cancers has gradually increased to nearly 70% [266]. Considering the number of aging patients with cancer and the increasing number of cancer survivors, it is necessary to suggest directions for how to apply digital health interventions for older adult patients with cancer. As Kemp et al [267] suggested, the variability of digital health literacy in patients with cancer, including age and life circumstances, should be addressed to implement digital health interventions effectively and safely.

More than half (124/231, 53.7%) of the studies in this scoping review included both female and male patients with cancer. However, 38.5% (89/231) of the studies included only female patients with cancer, which is related to the fact that, of the 129 studies for single cancer, 79 (61.2%) were conducted on patients with breast cancer. A previous scoping review of 151 publicly available apps for cancer survivors found that a majority of the apps targeted all cancer types, followed by apps targeting breast cancer [268].

When applying digital health interventions, researchers should prioritize cancer types for which there is sufficient evidence indicating that these interventions are safe and effective. However, more studies are still needed to test their applicability to specific cancer types and broaden the range of cancer types to which they can be applied. Almost three-fourths (163/231, 70.6%) of the studies in this review involved patients with early-stage cancer or patients with cancer of any stage, but only 9.5% (22/231) of the studies targeted only patients with advanced or metastatic cancer. Digital health interventions for cancer survivors accounted for the largest proportion (97/231, 42%), followed by digital health interventions provided along with cancer treatment (70/231, 30.3%). Further studies are particularly required on the direction of digital health interventions for patients with advanced or metastatic cancer because studies of patients with advanced or metastatic cancer in the later stages of life or of caregivers of palliative care reported more unmet needs than studies that included cancer survivors [269].

Most (187/231, 81%) of the digital interventions were applied at home. The clinical context for cancer treatment has shifted to outpatient or home settings in recent years, and digital health technology can be one of the solutions to support patients with cancer in their care continuum [270]. It is expected that the number of digital health interventions applied at home by patients with cancer and their caregivers will increase in the future. As this scoping review focused on digital health interventions for patients with cancer, digital health studies about *system services*, which did not have intervention components, might have been rare.

Digital health interventions using *web-based* methods have been the most frequently evaluated during the past 20 years. Considering their universality and accessibility, it is natural that *web-based* digital health interventions have been the most studied. Before developing digital health interventions for patients with cancer, the key factors affecting their use should be considered from the patients' perspective. Aapro et al [3] outlined 7 factors affecting the uptake of digital tools from the patients' perspective: ease of use, reassurance, high usability and usefulness, improved communication with health care professionals, correct generation of system alerts and fast response to alerts, patient empowerment, and the convenience of real-time reporting of symptoms. Moreover, with the popularization of smartphones, the accessibility of apps has increased, and patients with cancer and their caregivers can easily find some apps related to cancer. Adam et al [268] found that most of the publicly available apps for cancer survivors were developed by commercial or private organizations, and judging quality, effectiveness, clinical utility and data protection issues could be challenging for cancer survivors and health care providers. Researchers need to consider issues specific to digital health in developing and evaluating interventions for patients with cancer.

Among the NICE functional categories, interventions comprising *multiple* functions were the most frequently studied (69/231, 29.9%), followed by interventions comprising *self-manage* functions (67/231, 29%). Digital health interventions with the *self-manage* function provided options for users to record and send data to a health care professional [32]. Digital health interventions for symptom tracking combined with feedback from health care professionals are good candidates for clinical translation. The use of patient-reported outcome measures can improve health professional–patient communication, symptom management, supportive care, and patient satisfaction [271]. *Health diaries* or *active monitoring* were not used as stand-alone features of the interventions in this study, although they were used as part of *multiple* functions. *Calculate* refers to "tools that perform clinical calculations that are likely to affect clinical care decisions," and digital health interventions classified into the *calculate* category are generally used by clinicians or professionals [32]. As this review concerned digital health

interventions for patients with cancer, no studies were identified for the *calculate* function.

Effectiveness could vary in relation to patient population and difference in technology [25], and this review showed heterogeneous outcomes by type and function of the interventions. *Web-based self-manage* interventions for communicating with providers, *web-based self-manage* and *multiple-function* interventions targeting symptoms, and *web-based* interventions to *treat* cognitive function and fear of cancer recurrence showed consistent positive outcomes in this scoping review. Although different types and functions of digital health interventions could result in different outcomes, positive outcomes were also demonstrated by *web-based* interventions to *inform* anxiety, *web-based* as well as *telemonitoring* interventions combined with *telemedicine* interventions to *treat* depression, *web-based* interventions combined with *mobile* interventions with *multiple* functions and *telemonitoring* combined with *telemedicine* interventions to *treat* pain, *wearable* with *multiple* functions and *web-based* interventions for *preventative behavior change* for physical activity, and *web-based* interventions to *treat* sleep. A systematic review evaluating digital health interventions providing supportive care for patients with cancer supported a positive effect on symptoms such as fatigue, pain, and depression [25]. Moreover, more studies with positive outcomes were identified in this scoping review for *web-based* interventions to *inform*, *self-manage*, and *treat* for HRQoL or QoL; *web+mobile multiple-function* interventions for HRQoL or QoL; and *telemonitoring* combined with *telemedicine* to *treat* for HRQoL or QoL. Positive outcomes were identified in some previous reviews that were narrower than this scoping review and focused on specific cancer types such as prostate cancer or, predominantly, breast cancer, indicating the effect of the intervention on HRQoL [14,25]. The results of this review, which has a broader scope in terms of population, showed some positive effects and some null effects. Further systematic study is needed to clarify whether the difference in outcomes arises from patient characteristics or from the intervention. Many previous reviews that evaluated the effectiveness of digital interventions for patients with cancer provided inconsistent and inconclusive results and suggested that well-planned further studies should be conducted; for example, Escriva Boulley et al [26] systematically reviewed the engagement with digital health interventions of patients with cancer and the psychosocial effects of the interventions in 29 articles (24 studies), and the efficacy of digital health interventions in changing psychosocial outcomes was inconsistent. The findings of the study by Roberts et al [23] indicated that digital behavior change interventions for cancer survivors might improve physical activity and BMI, but evidence for diet was mixed. The mixed outcomes for symptom management using the mobile app intervention included the positive effect of lower levels of fatigue and an increase in the number of reports of hand-foot syndrome in the intervention arm. Facilitation of symptom assessment by the mobile app intervention might have contributed to the mixed outcomes [129]. Another set of mixed outcomes concerned knowledge, where the control group reported increased perception of received knowledge, whereas the intervention group reported a decrease in perception of received knowledge [186]. Higher perception of received knowledge among control group participants was interpreted as deriving from patients' satisfaction with the education they received from hospital staff in person. When knowledge was evaluated in terms of the knowledge level rather than the perception of received knowledge, participants in the internet-based patient education program demonstrated a higher level of knowledge. The effect of a personal touch and the effectiveness of digital interventions in increasing knowledge might have resulted in these mixed outcomes. Overall, digital health interventions targeting cognitive function, mindfulness, and strength all demonstrated positive outcomes; however, we did not include mindfulness [72,259] and strength [39,80,96] in Tables 1 and 2 because only a single study existed for each digital health intervention type and function. Future development of digital health interventions and RCTs would provide enriched resources to understand the effectiveness of digital health interventions for patients with cancer.

A negative effect of *web-based communicate* interventions on distress [119,144] and of *web-based self-manage* interventions on self-efficacy [209] as well as a few adverse events that occurred while conducting digital health studies were identified. The influence of digital health modalities such as playing games on dizziness needs to be considered, although the reported adverse events occurred in a control group participant. An increase in distress and symptoms and unintended weight loss could be related to intervention content rather than the digital delivery of the intervention, and this needs to be taken into consideration in developing the contents of future digital health interventions for patients with cancer.

The use of digital health interventions would be inevitable when considering the advances in digital technology and the needs of patients with cancer, caregivers, and health care professionals. Health care providers should help to develop appropriate digital health interventions for patients with cancer because engaging patients with cancer in their care can make for better health outcomes, and this is also expected to decrease health care providers' burden [272]. To develop digital health interventions that qualify as both efficacious and safe for patients with cancer, the collaboration of a multidisciplinary team will be necessary. The strengths of this study include (1) providing a comprehensive overview of digital health interventions for adult patients with cancer or cancer survivors from the time when the definition of eHealth was first introduced to the present day and (2) categorizing digital interventions by type and function and summarizing outcomes, which enables the identification of digital health interventions requiring further investigations and systematic reviews.

Limitations

We applied the highest standard with regard to research design (RCTs) in selecting digital health interventions considering patient characteristics (patients with cancer). According to the NICE evidence standards framework, only tier C digital health interventions for treatment (specifically for *treat*, *active monitoring*, *calculate*, or *diagnose* functions) require a high-quality RCT as the best practice standard [32]. This study was limited because it included only RCTs. The most frequently

identified functions of digital health interventions in this scoping review—*multiple* and *self-manage*—could be evaluated using a study design with a broader scope, including a high-quality quasi-experimental study design with comparison groups; thus, in this scoping review, areas that considered gaps in research could have been overestimated. With regard to outcomes of digital health interventions, outcomes identified from >2 studies of the same target, type, and function were summarized. Of note, there were single well-designed full-size RCTs that demonstrated the effectiveness of digital health interventions of specific types and functions targeting nursing problems, which were not included in Table 1.

Conclusions

This scoping review investigated the types and functions of digital health interventions developed and evaluated for patients with cancer that targeted various nursing problems and summarized their outcomes. Systematic reviews based on this scoping review—for example, a systematic review on the efficacy of interventions in relation to patient characteristics—should be the next step to accumulate evidence regarding the clinical application of digital health interventions for patients with cancer. The relationship between the effectiveness of digital health interventions and their types and functions needs to be investigated further to guide the selection of appropriate types and functions of digital health approaches depending on the targets. Digital health interventions that demonstrate equivalent outcomes, as well as those for which no effect or negative outcomes outnumber positive outcomes in the literature, are worthy of further investigation, considering the limited number of studies conducted. The identified gaps in digital health resources for cancer care need to be reflected in future digital health research.

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Authors' Contributions

KL, SK, SHK, S-HY, JHS, EGO, NK, and JL conceived and designed the study. KL, SK, SHK, S-HY, JHS, and JL selected studies and extracted data. KL and JL analyzed and interpreted the data and wrote the original draft. All authors participated in reviewing and editing the final manuscript. JL received research funding for the study.

Conflicts of Interest

None declared.

Multimedia Appendix 1

Search strategy for PubMed.
[PDF File (Adobe PDF File), 81 KB-Multimedia Appendix 1]

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Abbreviations

HRQoL: health-related quality of life
NICE: National Institute for Health and Care Excellence
PRISMA-ScR: Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews
QoL: quality of life
RCT: randomized controlled trial

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