Supportive eHealth technologies and its effects on physical functioning and quality of life for people with lung cancer:A systematic review

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Abstract

Background: Despite improvements in treatment and early diagnosis people with lung cancer are not living as long as people with other cancers. Therefore, good symptom management and improved quality of life is a priority in this patient group. The more common symptoms of lung cancer; breathlessness, fatigue and depression can be improved by improving patients' physical functioning. However, current health care services have limited capacity to provide this support. One way to address this issue of health care resources is to empower patients to self-manage their condition using electronic health technologies.

Objective: The purpose of this review was to locate and assess available research on technologies that support the person with lung cancer to improve or maintain their physical functioning and/or their quality of life.

Methods: Six databases (PubMed, Web of Science, CINAHL, Medline, SPORTDiscus and PsychInfo) were searched from January 1990 to April 2023. Studies were suitable for inclusion if; study participants included people with lung cancer over the age of 18, participants were exposed to a physical activity, exercise or a training intervention that was delivered via an electronic or web-based application with or without a comparator. Furthermore, the study must have reported on the impact of the intervention on physical function and/or quality of life. Studies that focused on telemedicine without an online intervention were excluded. The GRADE system was used to assess the quality of included papers. Due to the heterogeneity of the studies a narrative synthesis was undertaken.

Results: This review is reported in accordance with the PRISMA guidelines. Seven hundred and ninety-four papers were initially identified through our search; following screening eight papers were confirmed suitable for inclusion in the review. Two papers reported on different stages of the same study therefore only seven studies were included in our analysis. Studies were undertaken between 2010-2018 across multiple countries. Included studies aimed to develop a technology and /or test the technology's feasibility or acceptance. Seven technologies identified included web-based apps, native apps, or gaming consoles. Studies demonstrated impact on walking distance, muscle strength, balance, symptoms of dyspnoea and cancer related fatigue. Quality of life scores also showed improvement.

Conclusions: The findings indicate that electronic health apps are generally acceptable to people with lung cancer and can positively impact their physical functioning and wellbeing. However, there are limited studies that demonstrate the impact of these digital interventions over longer periods. None of the studies report on the implementation or adoption of the mobile or electronic health intervention in routine clinical practice highlighting the need for further research in this area. Clinical Trial: Not a trial but has been registered on the PROSPERO data base. Registration number CRD42023414094

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Review

Supportive eHealth technologies and its effects on physical functioning and quality of life for people with lung cancer- A systematic review

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Abstract

Background: Despite advancements in treatment and early diagnosis people with lung cancer are not living as long as people with other cancers. The more common symptoms of lung cancer; breathlessness, fatigue and depression can be enhanced by increasing patients' physical functioning. Therefore, good symptom management and improved health related quality of life (HRQoL) is a priority in this patient group. However, current health care services have limited capacity to provide this support. One way to address this issue of health care resources is to empower patients to self-manage their condition using electronic health technologies.
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Conclusions: The findings indicate that electronic health apps can positively impact the physical functioning and wellbeing for people with lung cancer but there are limited studies that demonstrate the impact of these digital interventions over longer periods. None of the studies report on the implementation or adoption of the mobile or electronic health intervention in routine clinical practice highlighting the need for further research in this area.

Keywords: lung cancer; physical activity; exercise; physical functioning; mobile technology; smartphone applications; digital health

PROSPERO Registration - CRD42023414094

Introduction

Lung cancer is the most prevalent cancer globally with 2.21 million new cases being diagnosed in 2020; this is anticipated to increase to 3.8 million by 2050(1). Lung cancer also accounts for the highest number of cancer related deaths across all cancer types (2).

In the UK, there are approximately 48,500 new lung cancer cases diagnosed per year(3). It's incidence strongly correlates with age, peaking among older individuals. In the UK from 2016-2018, over 44% of new cases annually were in those aged 75+. Rates rise sharply from around age 45-49, reaching a peak in females aged 75-79 and males aged 85-89, then decline in older age groups. Females typically have lower incidence rates than males, particularly evident at age 90+, where the rate in females is half that of males (3). One-year survival rates have almost doubled since the 1970's due to early diagnosis and improved treatments. Survival at 5 and 10 years has not improved as much as other cancers (3).

For people living with lung cancer, it is imperative that supportive care needs, which are central to patient-centered care (4) are addressed promptly as their condition is associated with a high symptom burden and high levels of unmet need throughout the disease trajectory (5). Additionally, approximately two-thirds of people with lung cancer have at least one other pre-existing health condition, and up to half have two or more (6). Addressing the supportive care need will contribute to efficient use of healthcare resources and minimise hospital admissions. If not managed effectively this could negatively impact patient outcomes including physical functioning, psychological well-being, and HRQoL(4).
Common symptoms of lung cancer include fatigue, breathlessness, depression – all of which can be improved by exercise interventions (9). More generally, other positive implications for people with cancer undertaking physical activity include improvements in HRQoL (10-12,18), lung function (10, 12), sleep (10, 14), immune function and markers (10, 15), mood(10-11), bone strength (10, 16), muscle mass (10,17) and decreased cancer cell proliferation (10,15). However, less than one third of people with lung cancer meet recommended exercise guidelines to reduce time spent sedentary, increase strength, and balance building activities and to undertake 150 minutes aerobic activity per week (19).

Self-management practices, including those with an exercise component, can help patients to regain health and fitness, reduce side-effects from treatment and symptoms of the disease, relax the mind and body, enhance HRQoL and regain a sense of normality post-cancer (20). More recently, the National Institute for Clinical Excellence (NICE) has recognised exercise as a first-line treatment within healthcare and holistic disease management (21). In the absence of a robust national rehabilitation system there is pressure for self-management support to be integrated into routine cancer care (22). But, patient adherence to rehabilitation programs delivered at hospital outpatient centres can be low due to the required travel and associated socioeconomic factors(23), Furthermore studies have demonstrated that home-based rehabilitation improves patient adherence and HRQoL (24).

Web based interventions have grown in popularity over recent years. These interventions enable the user to independently navigate a recommended online program that is operated via a website with the aim to create a positive change to health and wellbeing (25). Government organisations are actively trying to translate 'in-person' activities to online (26). Following the COVID-19 lockdown this was subject to renewed prominence as the advantages of digital technology were highlighted.

Furthermore, earlier reviews have identified several mobile and electronic apps along the cancer continuum from cancer prevention to survivorship (27). The use of mobile health (mHealth) and electronic health (eHealth) technologies such as wearables, activity trackers, apps and web-based programs that can be accessed via smartphones and tablets, provide new methods for educating, monitoring, and supporting patients with chronic conditions/cancer. The World Health Organisation (WHO) recognises the potential of mHealth and eHealth interventions to support health care delivery (28). They can assist patients in self-managing their health behaviours and are considered feasible, acceptable, and effective approaches to providing supportive care (29,30).

There is a growing body of evidence to support technology interventions in health care and this is supported within the UK National Health Service (NHS) Long Term Plan (31). Yet, evidence-based mHealth and eHealth interventions to enhance exercise and physical activity for people with lung cancer remain uncommon. Furthermore, of the cancer related apps that are available, a limited number adopt a personalised approach to physical activity and exercise that accommodates patients' preferences.

Aim

This study aims to establish what mHealth and eHealth technologies have been developed to support people with lung cancer to improve or maintain physical functioning and/or impact their HRQoL.

Objectives

The primary objective of the review was to establish if any mHealth or eHealth technologies identified impacted on the physical functioning and HRQoL of the person with lung cancer.

The secondary objectives were to: assess the demand on clinician's time, the acceptability of the intervention to patients, carers and/or health care professionals, user satisfaction with the technology, identify security features (clinical safety, data protection, technical security), and to identify the cost impact of the mHealth or eHealth app/intervention.

Methods

Design

This review was prospectively registered with the International Prospective Register for Systematic Reviews (PROSPERO; CRD42023414094)
and is reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) to improve the quality of the review and to ensure transparency at all stages.

Inclusion Criteria

Types of Studies

We included all primary research studies, without study design or publication status limitations or language or geographical area restrictions. Case studies were also included. Reference lists of systematic reviews were cross checked to identify any potential studies to include. We limited the search to studies published after 1990, as internet interventions did not exist prior to this date (32).

Population

We included studies that were undertaken with adults (>18 years), diagnosed with a lung cancer-regardless of the stage of their disease, treatment allocation, sex, or where they were cared for.

Intervention:

Study participants in the included studies must have been exposed to a physical activity, exercise or training intervention that was delivered via an electronic or web-based application with or without a comparator.

Outcome Measures

Studies were included if they reported on the impact of the digital intervention on physical function or HRQoL or both HRQoL and physical functioning using any validated measure. We included studies that measured impact at one or multiple timepoints.

Exclusion Criteria

We excluded the following:

- Cancer studies where the total number of participants with lung cancer accounted for less than fifty percent of the study population.
- Studies that focused on tele healthcare only and did not include an electronic or web based online intervention. For example, studies that evaluated remote sessions with a clinician via video link were excluded.
- Apps used to track activity that could be linked to a wearable device but did not provide any other support.

Search Strategy

A search of six databases: PubMed, Web of science, CINAHL, Medline, SPORTDiscus and PsychInfo was carried out on 17th April 2023, via EBSCO, using a list of key terms focusing on three distinct categories; the intervention characteristics (e.g., online, internet, app/application, remote, digital), physical functioning (e.g., activity, exercise, training, movement, athletics) and the population of interest (e.g. lung cancer patient/survivor, cancer). These were amalgamated using Boolean operators to formulate a comprehensive search string. The full list of search terms is listed in Table 1. Other sources such as references of included records were searched.

Table 1. Groups of keywords used in the search strategy.

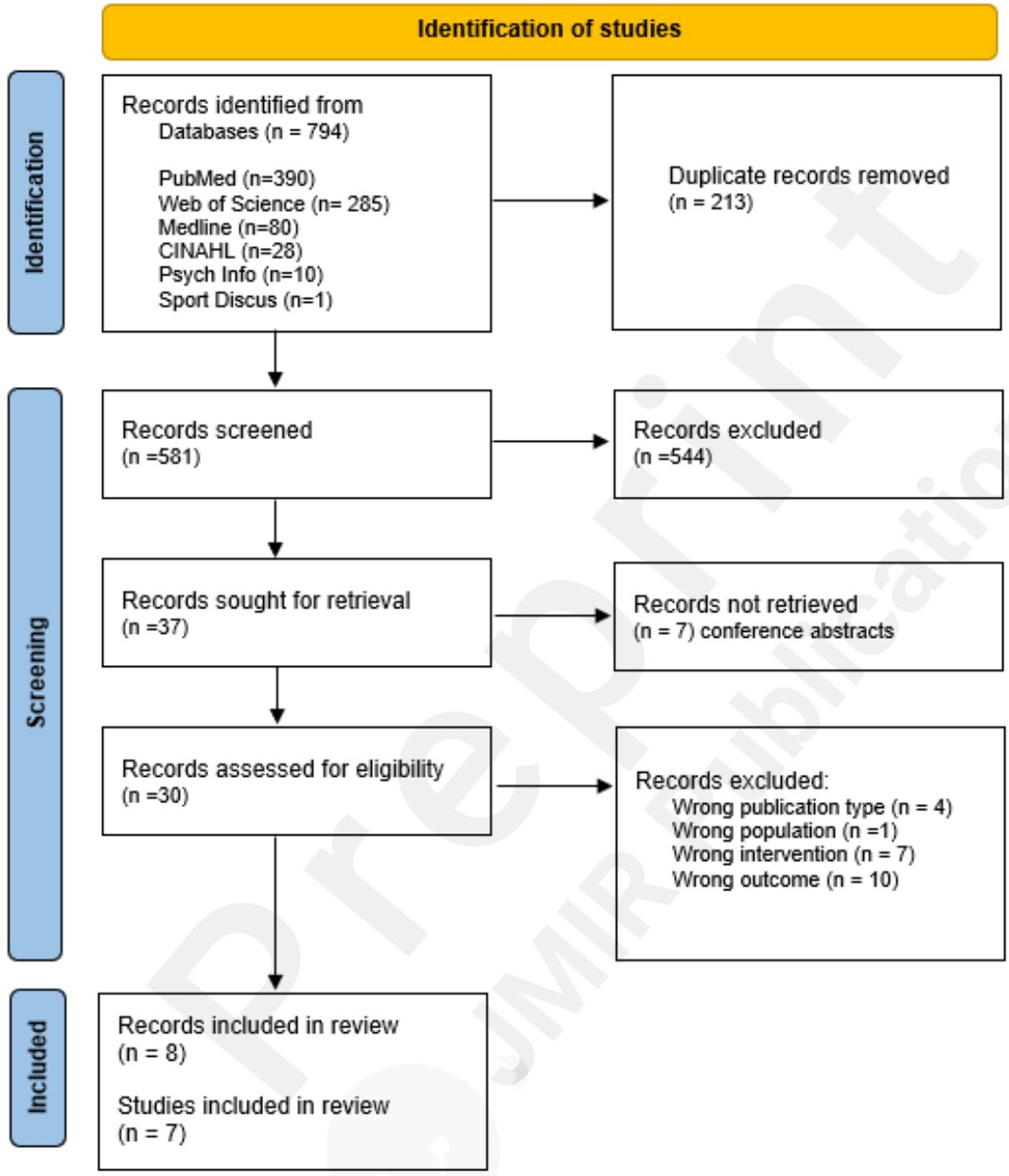
lung cancer patient* or lung cancer surviv* or lung cancer or lung neoplasm* or lung tumor* or lung tumour* or lung adenocarcinoma
AND
physical activity or exercise or training or physical function* or mobility or rehabilitation or prehabilitation or physical fitness training or physical rehabilitation or physical recovery or mobility training
AND
mobile applications or mobile apps or mobile phone apps or phone apps or smartphone apps or smartphone applications or web apps or web applications or mhealth or m-health or ehealth or e-health or online support system or web-based technology or app or apps or software app or cell phone apps or cellular phone apps or mobile technologies or mobile devices or smartphones or technology-enabled care services or interactive apps or telemedicine or virtual medicine or interactive consultative services or Web based tool or activity tracker or fitness tracker or physical fitness tracker or technology enabled care services

Data Collection and Analysis

Selection of Studies

After removing duplicates, 581 papers were retrieved by the search and were screened by two reviewers (SK/PW/CH/ZD). Title and Abstract screening were undertaken, and 544 papers were excluded in this process, leaving 37 papers remaining. A further seven were excluded as they were conference abstracts. A full text screening of the remaining 30 papers was then conducted, and 22 papers were excluded, leaving eight papers remaining for final inclusion. Any discrepancies identified by reviewers during the screening process were resolved by discussion with a third member of the review team. The screening process is outlined in Figure 1.

Figure 1. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) Diagram



Data Extraction

Data was independently extracted from included papers by the lead author (SK) using a data extraction template developed for the purpose of this review. The extracted data was reviewed by the co-authors (CH, ZD, PW) and discrepancies were resolved. In case of missing study data, we attempted to contact the corresponding authors to obtain the required information. Three authors were contacted (33-35), but none replied. These papers were not excluded as they still met the inclusion criteria and reported on some of our objectives.

We extracted the following data:

- Study characteristics; author, year of publication, title, country of study, year of study, study

objective, overall study design, recruitment method, sample size, participant age range, gender, study duration
- Intervention characteristics: technology name, setting, intervention details, exercise details (type, frequency, intensity, and duration)
- Outcome measures of interest (impact on physical function, impact on HRQoL and user acceptability)
- Other outcomes of interest: impact on clinician time, user acceptability/satisfaction, safety features, cost impact

Critical Appraisal

Risk of Bias

Two reviewers (SK and ZD) independently assessed the risk of bias of each included study and confirmed agreement. The Joanna Briggs Institute (JBI) checklists (36) were used to assess randomised controlled trials, quasi experimental studies, qualitative research and cohort studies.

Quality Appraisal

The Grading of Recommendations, Assessment, Development and Evaluation (GRADE) approach was adopted to assess the quality of the evidence used to support the synthesised findings (37,38).

Data Synthesis and Analysis

Due to the methodological heterogeneity of the included studies, we were unable to undertake a meta-analysis. Instead, the Synthesis without meta-analysis reporting items (SWiM) checklist was employed to aid transparency in the reporting process (39).This enabled us to report on the key features of included studies, group the studies and explain our findings. A narrative synthesis (40) was also undertaken according to the study objectives stated earlier.

This allowed us to provide a comprehensive summary of the impact and effectiveness of the interventions identified in our included studies.

Results

Eight papers were identified as suitable for inclusion. But two papers (33,41), reported on different stages of the same study, hence only seven studies were included in the review. The screening process is outlined in the PRISMA diagram shown in Figure 1.

Study Characteristics

Included studies were published between 2013 and 2022, across international settings including the USA (33,41) Netherlands (42), South Korea (35,43,44), the United Kingdom (34) and Canada (45).

Studies were undertaken between 2010 [33] and 2018 [43]. The aim of the included studies was to develop a technology [34] and /or test the technology's usability [42], feasibility [34,42,44,45], acceptance [33,34]and or efficacy [33,35,41,44]. The study designs included primarily quasi experimental, non-randomised experimental studies [33,35,41,42,44,45], as well as one randomised controlled study (43) and one cohort study (34). Research methods of included studies were either quantitative (n= 5) [33,35,43-45) or mixed methods (n= 2) [34,42].

Participants were identified from secondary care settings. The number of participants in studies ranged from 5[45] to 100[44], study participants mean ages ranged from 55.1[44] to 64.6[33,41] years. Overall, there were more female participants(n=195) than male participants (n=145) across four studies [33,42-44); one study did not report the gender breakdown of their participants (34). The intervention duration ranged from 6- 12 weeks; one study (34) did not report the intervention duration but it was clear that the intervention was delivered pre and post operatively with a study duration of no more than 18 months. Characteristics of included studies are detailed in Table 2.

Table 2. Characteristics of included studies

Author (Ref)	Title	Study Country	Year of study	Study Objectives	Study Design	Recruitment method	Sample size (n)	Mean Age (SD)	Gender Female (n) Male (n)	Lung Cancer Stage	Inte n D
Hoffman et al. (2013) (33)	Too Sick Not to Exercise Using a 6-Week, Home-Based Exercise Intervention for Cancer-Related Fatigue Self-management for Postsurgical Non-Small Cell Lung Cancer (NSCLC) Patients	USA	2010	To evaluate the feasibility, acceptability, safety, and changes in study end points of a home-based exercise intervention to enhance perceived self-efficacy for cancer-related fatigue self-management for persons after thoracotomy for NSCLC transitioning from hospital to home.	Quasi Experimental -non randomised experimental study. 1st 6 weeks after discharge (Quantitative)	Potential participants were identified during clinical appointments while undergoing diagnostics to confirm a potential diagnosis of NSCLC	7	64.6 (6.5)	Female - 5 Male- 2	I/II/III	6 w
Hoffman et al. (2014) (41)	Virtual reality bringing a new reality to post thoracotomy lung cancer patients via a home-based exercise intervention targeting fatigue while undergoing adjuvant treatment		2010-2011	To investigate the feasibility, acceptability, and preliminary efficacy of an exercise intervention for post thoracotomy NSCLC patients to include those initiating and completing adjuvant therapy.	Quasi Experimental -non randomised experimental study. Weeks 7 to 16 post discharge (Quantitative)	Participants from phase 1 were asked if they would like to participate in phase 2					10 v
Groen et al. (2017) (42)	Supporting Lung Cancer Patients with an Interactive Patient Portal: Feasibility Study	Netherlands	2014	To evaluate the feasibility and usability of the patient portal and generate preliminary evidence on its impact.	Quasi Experimental -non randomised experimental study. (Mixed Methods)	Patients were approached by letter followed by a phone call from the researchers to discuss participation and check further eligibility criteria	37	59.6 (8.4)	Female - 16 Male- 21	I/II/III	4 m
Ji. et al (2019)	Mobile Health Management Platform–	South Korea	2017-2018	To examine the outcome of home-based pulmonary rehab	Randomised Controlled Trial	Participants identified from the outpatients	64	60.50 (9.8) in fixed	**Fixed Exercise Group**	I-IV	12 v

(43)	Based Pulmonary Rehabilitation for Patients with Non–Small Cell Lung Cancer: Prospective Clinical Trial			regarding exercise capacity, dyspnea symptoms, and QoL in adult patients being treated for non–small cell lung cancer Primary endpoints were pulmonary function parameters. Secondary endpoint was quality of life	(Quantitative)	department from a single tertiary hospital		interactive 57.97 (10.1) in fixed exercise group	Female- 45 Male -21 **Fixed-interactive exercise** Group Female- 51 Male - 24		
Kadiri et al. (2019) (34)	Fit 4 surgery, a bespoke app with biofeedback delivers rehabilitation at home before and after elective lung resection	UK	not reported	To develop a bespoke pulmonary rehabilitation app and test its feasibility and acceptability to patients undergoing lung resection surgery.	Cohort study (Mixed Methods)	Patients deemed eligible for curative lung cancer surgery based on British Thoracic Society guidelines, were referred by the multidisciplinary teams to the regional thoracic surgery unit where potential patients were identified	31	64 (12)	not reported	not reported	unci
Park et al. (2019) (44)	Mobile Phone App–Based Pulmonary Rehabilitation for Chemotherapy-Treated Patients with Advanced Lung Cancer: Pilot Study	South Korea	2016	To determine the feasibility and efficacy of smartphone app–based pulmonary rehabilitation on exercise capacity, symptom management, and QoL in patients with advanced lung cancer undergoing chemotherapy	Quasi Experimental -non randomised experimental study (Quantitative)	Consecutive patients with histologically diagnosed advanced NSCLC were identified	100	55.1 (8.7)	Females- 54 Males- 46	II-IV	12 v

Coats et al. (2020) (45)	Feasibility of an eight-week telerehabilitation intervention for patients with unresectable thoracic neoplasia receiving chemotherapy: A pilot study	Canada	2014	To investigate the feasibility, adherence, and satisfaction of a home-based telerehabilitation program with real-time physiological parameters acquisition in patients with unresectable thoracic neoplasia receiving chemotherapy and to explore its effects on patients' functional capacity.	Quasi Experimental -non randomised experimental study (Quantitative)	Five consecutive eligible patients diagnosed with unresectable thoracic neoplasia and receiving chemotherapy, were recruited	5	62 (7)	Females-2 Males- 3	not reported	8 w
Yang et al. (2022) (35)	Evaluation of a Smart After-Care Program for Patients with Lung Cancer: A Prospective, Single-Arm Pilot Study	South Korea	2015	To evaluate the efficacy of a remote health care program for lung cancer patients - the Smart After-Care Program	Quasi Experimental -non randomised experimental study (Quantitative)	not reported	50	58.3 (11.9)	Females- 22 Males- 28	I-IV	12 v

Quality Appraisal

The risk of bias for all studies was low, and quality appraisal scores were moderate as illustrated in Table 2.

Intervention characteristics

The review identified seven technologies that had been studied in people with lung cancer; four mobile apps (34,35,43,44) and three web-based apps (33,41,42,45). Of the web-based apps two studies used a gaming console to deliver part of the exercise prescription (33,41,45).

The interventions were delivered/accessed from various settings; online (34,35,42,43), home based (33,41,45), or a combination of the outpatient department and home based (44).

The frequency, intensity, time, and type (FITT) formula (46) was used to extract key components about the exercise prescription of each study. Only four of the seven studies reported the full details of the exercise prescription according to the FITT formula (33,34,41,44,25).

The studies that did not provide a detailed exercise prescription provided more general information and recommendations regarding physical activity (35,42); alternatively, the interactive app would support the participant to edit the frequency, intensity, and duration of the exercise (43). Where the technology included an interactive patient portal it was noted that the physical activity support program that was incorporated in the portal was only used by one-third of participants (42).

The intervention details are summarised in Table 3.

Table 3. Intervention characteristics

Author (Ref)	Technology Name	Setting	Intervention Details	Exercise Details			
				Type	**Frequency**	**Intensity**	**Time**
Hoffman et al. (2013) (33) Hoffman et al. (2014) (41)	Nintendo Wii Fit Plus	Home based	Light intensity exercise intervention using a game console	Light intensity walking and balance exercises	Walking- daily for 5 days in week 1 then every day. Balance exercises 5 days /week	Walking - comfortable and self-paced. Balance exercises - less than 3.0 metabolic equivalents	Walking started at 5 minutes each day for 5 days during week 1 and was anticipated to increase by 5 min/d each week with the goal of walking 30 min/d during week 6. Balance exercises duration not reported - based on a gaming format and scoring system
Groen et al. (2017) (42)	MyAVL (Mijn Antoni van Leeuwenhoek) interactive portal	Online	Web based patient portal that included physical activity **advice.**	Used a computerised system that provided advice depending on nutritional status, possible contraindications for physical activity, treatment phase, tumour type (breast or lung cancer), whether the patient is participating in a supervised exercise program, and if yes, whether additional information on physical activity is desired.			
Ji. et al (2019) (43)	efil breath app (A mHealth Management Platform for Patients with Chronic Obstructive) Pulmonary Disease	Online	Personalised pulmonary rehabilitation program using mobile apps - one app included fixed exercises and another app included	Walking, exercises	**Fixed exercise group** - used the fixed exercise program for 12 weeks. 6 levels of walking distance—600 m, 1200m, 1800 m, 2400 m, 3000 m, and 3600 m. When the user achieves a fixed walking distance within a day and 14 times in total, the app increases the walking distance to the next level. **Interactive exercise group –** used the fixed exercise program for 6 weeks then then switched to the app with interactive exercises for the next 6 weeks. The interactive exercise uses 12 levels. Initial walking intensity is set to 80% of the maximum walking speed. Once initiated, a metronome in the app is used to help guide the walking speed of the patient. The level of exercise is then adjusted according to the modified Borg scale.		

			interactive exercises. Also used a patient monitoring website				
Kadiri et al. (2019) (34)	Fit4 Surgery App	Online	Mobile exercise app including 10 exercises based on "Rehabilitation for Operated lung Cancer surgery programme"	10 exercises- upper and lower limb, aerobic and strength based	patients' discretion	Target HR >60 % of maximum HR	3 minutes per exercise = 30 mins
Park et al. (2019) (44)	Smart Aftercare app	Outpatient/ Home based	Pulmonary rehabilitation program using a smartphone app	stretching exercise, aerobic exercise, muscle strengthening	3 x per week	HR target 70% of HR reserve plus resting HR. O2 sats > 88%	30-60 mins
Coats et al. (2020) (45)	TELERP (Telerehabilitation programme)	Home based	Telerehabilitation programme using the Chez-Soi telerehabilitation platform	Exercise ball and elastic bands to exercise upper limbs, wall squats and lunges for lower limbs. Cardio exercise with Xbox dance mat and Wii balance board	3 x 75 mins per week for 8 weeks. 15 supervised and 9 unsupervised	SpO2 >88%. Cardio at moderate intensity. HR 60-80% of the Vo2 peak	Repetitions increased according to patients' tolerance- until 2 sets of 15 reps. 20 mins cardio
Yang et al. (2022) (35)	Smart After-Care app	Online	Mobile app that provided information about rehabilitation exercises and a healthy diet for lung cancer patients	muscle strength using elastic bands, stretching, and breathing	Not Reported	Not Reported	Not Reported

Outcome Measures

Primary outcome measures

Physical Functioning

All included studies demonstrated some improvement in physical functioning, but the methods of assessment varied between studies. The most common assessment was walking time/distance. Both (43) and (45) demonstrated improvement in the 6MWT/D while (35) noted an improvement in the 2min walking distance. An increase in walking duration and step count was also observed by (33)and (34) showed an increase in the shuttle walk test.

No improvement in muscle strength was noted by (45) while (35) demonstrated an improvement in lower extremity strength but not in upper extremity muscle strength. Only one study showed an improvement in balance and cancer related fatigue (33,41) and another showed an improvement in dyspnoea grade (43).
One study identified no significant improvement in physical activity but an improvement in vigorous activity over time (42). Lastly, one study highlighted that although exercise capacity improved in stable patients, this was not the case in patients with progressive disease (44).

Health related quality of life

Almost all studies included in our review report the impact of the digital health intervention on HRQoL (34,35,42-45).

The most common tool used to assess HRQoL was the EORTC QLQ-C30. Improvement in symptom scales were observed by (34,44), improvement in functional scales were observed by (35,44) and one study did not observe any significant changes (45).

Ji et al. used the EQ-VAS score to demonstrate a significant improvement between visit one and visit three but the EQ-5D did not differ between the same time points (43). The SF-36 was employed in one study (42) and no significant changes in the scores were noted.

Secondary outcome measures

Demand on clinician's time

The technologies varied with regard to the level of clinician involvement required to execute and maintain the patient on the technology. The authors attempted to assess the impact on clinicians' time for the various studies. This is outlined in Table 4. Only one study (42) explicitly reported the impact of adopting the intervention on health care professional time - 60 minutes.

Acceptability and user satisfaction

All included studies reported either user satisfaction (43-45) or both acceptability and user satisfaction (33-35,42), as summarised in Table 4. Studies demonstrated high levels of acceptability and user satisfaction.

Safety features

Studies reported primarily on clinical safety features of the technology, for example access to a phone while exercising to contact study nurse [33,41], heart rate monitoring [33,34,41 43), monitoring of oxygen saturation levels [34]as noted in Table 4. Two studies also reported on the technology's security features to ensure limited authorised access to the app [43] or data base [42].

Cost Effectiveness

None of the studies evaluated the cost effectiveness of the digital health intervention in terms of clinical outcomes within a health economic context. Only one single centre, cohort study reported on the cost of implementing the technology (34). They estimated this to be £16-£34 per patient.

Table 4. Study outcome measures

Author	Impact on physical functioning	Impact on HRQoL	Demand on clinician's time	Acceptability of technology	User satisfaction	Safety features	Costs
Hoffman et al. (2013) & (2014) (33,41)	Reduced cancer related fatigue, improve balance and walking duration, increased step count.	Not assessed	Pre op teaching. Post discharge call, home visit to set up equipment, follow up call 24hrs later to assess progress and address queries, home visit at 2 weeks, weekly calls until week 6. Ongoing nurse access via telephone during exercise and nurse would make home visit if there were safety concerns.	All participants strongly agreed that exercising at home was convenient, the nurse interaction from the telephone calls were helpful and they would recommend the program for someone like themselves after surgery	Participants agreed strongly to a high level of satisfaction with the exercise intervention, giving it a mean score of 5.8 of 6, with 6 meaning agreed strongly - exceeding the goal of 4 of 6.	Clinical Safety - participants required phone access while exercising should they need assistance. The nurse was available by phone and could make a home visit if required. Participants were taught how to maintain a light intensity does of exercise, also provided with heart rate monitors.	Not assessed
Groen et al. (2017) (42)	Levels of physical activity did not change significantly, but vigorous physical activity tended to increase over time from a median of 0 (interquartile range, [IQR] 0-840) to 240 (IQR 0-1140) metabolic	SF- 36 - no significant changes	Recruitment procedures, onboarding	93% (25/27) of patients found the app easy to use, 56% (15/27) reported that it contributed to a sense of control over their health, and 69% (18/26) indicated that it was a valuable addition to their health care experience.	Most (22/27, 81%) were satisfied with MyAVL, and 77% (20/26) intended to continue using it.	Authorising procedures (username, password, and text message authentication)	Not assessed

	equivalent of task MET minutes per week						
Ji. et al (2019) (43)	Comparison between pre and post intervention For all participants in both groups, the 6MWD improved significantly from Visit 1 to Visit 3 (from mean 433.43 m [SD 65.60] to 471.25m [SD 75.69]; *P*=.001). Subjective dyspnoea grade measured using the Modified Medical Research Council score improved from Visit 1 to Visit 3 (from 0.94, SD 0.66 to 0.61, SD 0.82; *P*=.02).	Comparison between pre and post intervention results- EQ-VAS score improved significantly from 76.05 (SD 12.37) at Visit 1 to 82.09, (SD 13.67) at Visit 3 (P=.002). The mean value of EQ-5D was not significantly different between time points. No statistical differences were noted between the fixed and fixed-interactive	Use a central monitoring website to store records and access summary of compliance and patient health status; heart rate and SpO2 during exercise, and the 6MWT results	Not assessed	PGA scores measured at V3 showed significant improvement over PGA scores at V2 (from 13.77, SD 3.68 to 15.08, SD 3.99; P=.01).	The apps were linked to a wearable pulse oximeter via Bluetooth, and activity-related data were sent to the monitoring website. This is a secure database, ensures that each participating hospital can only access its patient data.	Not assessed

	No statistical differences were noted between the fixed and fixed-interactive exercise groups	exercise groups					
Kadiri et al. (2019) (34)	Improved shuttle walk test	EORTC QLQ C30- improvement noted in fatigue, pain and dyspnoea. The Global Health score at 5 months for the app significantly increased and returned to baseline level	60 mins HCP time	Considered acceptable by the researchers as patients in the app group managed more sessions during the pre- and post-op period compared with the rehabilitation groups	App was easy to use, ability to see oxygen levels and heart rate was motivational, liked the variety of exercises. The novelty factor of using the app for exercise was appealing to some patients and even patients who had good levels of fitness prior to using the app found it beneficial	Clinical Safety- The app collected baseline measurements of oxygen saturation and heart rate for safety. A safety notification screen to prevent unsuitable patients from continuing on the app	£16-£34 per patient
Park et al. (2019)	Significant difference in	Global health status and	Exercise duration and intensity was prescribed	Not Reported	90% service satisfaction and	Not Reported	Not assessed

(44)	the baseline 6MWD according to baseline ECOG-PS. The mean distance was 416.8 m (SD 55.4) in patients with ECOG-PS 0, 369.8 m (SD 80.3) in those with ECOG-PS 1, and 305.7 m (SD 89.1) in those with ECOG-PS 2 (*P*=.04). After PR, the 6MWD had improved significantly: 380.1 m (SD 74.1) at baseline, 429.1 m (SD 58.6, *P*<.001) at 6 weeks, and 448.1 m (SD 50.0, *P*<.001) at 12 weeks Patients with stable disease showed	QoL tended to improve in patients but it was not statistically significant	by physician and adjusted at every clinic visit		88% would recommend the program to others		

	significantly improved 6MWD: 384.2 m (SD 74.6) at baseline, 426.1 m (SD 6.5, *P*<.001) at 6 weeks, and 447.4 m (SD 50.4, *P*<.001 at 12 weeks The dyspnea scale, evaluated using the EORTC QLQ-C30, did not show any significant improvement in the patients overall, but patients with stable disease tended to improve.						

Coats et al. (2020) [45]	No impact on weight,exercise tolerance or functional capacity. Quadriceps muscle function, the peak torque, total work, and fatigue index did not change significantly. The 6MWT and Timed stair test (TST) were significantly improved (40 ± 20m, p =0.01; and -3.0 ± 0.2s, p = 0.05, respectively).	EORTC QLQ-30 and EORTC QLQ-LC13 - no significant change	15 supervised sessions (supervised by a clinical exercise physiologist/cancer exercise trainer certified by the American College of Sports Medicine), 9 unsupervised sessions. 85 hours kinesiologists time and 36 hrs. spent on installation and uninstallation (technicians and engineers) of the Telerehab Program	Not reported	Quebec User Evaluation of Satisfaction with Assistive Technology questionnaire used - quite to very satisfied	A complete clinical evaluation was made at baseline and following the intervention (within one week after the last exercise session). continuous data acquisition and recording from physiological sensors during rehabilitation sessions	Not assessed
Yang et al. (2022) (35)	No significant difference was observed in upper extremity muscle strength,	EORTC QLQ-C30 survey, for the functional scale-significant improvements were	Exercise instructions and training from rehab specialist at baseline, 6 weeks and 12 weeks. Also, at baseline - training on devices, app and equipment	Acceptable for and supportive of patients with reduced pulmonary function after lung cancer treatment. The SAP was found to be	Assessed at 6 and 12 weeks. In the final satisfaction survey, 88% of patients reported “very good” or “good” overall	not reported	Not assessed

	but significant improvements in lower extremity muscle strength were observed, with repetitions increasing from 18 to 22 for the 30-second chair stand test (p=0.012). A significant improvement was also noted in walking distance in the 2-minute walk test (from 185.7 to 195.0 m; p=0.028)	observed in all subsections (p<0.05). No significant improvement was seen in the symptom scale. No significant differences were observed in the EORTC QLQ-LC13		particularly useful for patients living far from the hospital >80 km.	satisfaction		

Discussion

eHealth

eHealth, which encompasses information and communication technology, facilitates remote care delivery and health information transmission, promoting patient involvement, improving care quality, and enhancing accessibility, particularly in remote areas. Despite benefits like convenience and reduced travel, concerns exist, such as privacy issues, fears of diminished human interaction and access to technology and internet infrastructure (52). eHealth holds promise in supporting patient-centered care and empowers patients by enhancing their involvement in their healthcare (53).

Principal Results

To our knowledge, this is the first review that has looked specifically at digital technologies developed for people with lung cancer and their impact on physical functioning and/or HRQoL. Despite searching across a wide range of data bases we only identified seven studies for inclusion in our review.

The findings of this review suggest that digital health interventions with an exercise component are acceptable to people with lung cancer, as they help them play a more active role in their health care and can positively impact their physical functioning and HRQoL Various tools were employed in the studies to assess HRQoL. The EQ-5D, a questionnaire conventionally employed for economic cost analysis was used in one study to assess HRQoL and despite an observed increase in the EQ-VAS the EQ-5D did not improve [45]. , The evidence to support the use of digital exercise interventions remains sparse as we draw on the findings of only a few studies that aimed primarily to develop and assess the feasibility of the intervention.
Nevertheless, the quality of the studies was high thereby strengthening the credibility of the review findings. Further research to observe the effects of the interventions over a longer period is required, as well as research that explores the potential cost savings associated with using a remote health management mobile application, including reduction in clinician time or number of consultations, improved disease management, the costs of implementing the technologies into routine care, as well as the safety and security risks of the technologies.

Results in context

In recent years there has been a growth in the number of digital health technologies, including mobile and electronic health, and wearable devices that are becoming an integral part of modern healthcare (47). The promotion of patient self-management practices facilitated by digital technology has gained attention as it can improve patient engagement and health care delivery (48) This has become particularly relevant and has exacerbated following the pressures placed on the health service during the COVID-19 pandemic (25). It is anticipated that strategies to encourage patients to self-manage their health behaviors will continue to be integrated into care pathways in the future (49).

In the context of lung cancer, that approximately two-thirds of people with lung cancer

have at least one other pre-existing health condition, and up to half have two or more (27), making this group more complex to treat as they require a more tailored approach to rehab(50). We noted that the technologies identified in our review either produced an exercise prescription relevant to the individual participant's capability or gave the patient guidance on exercises they might be able to undertake. As the participants exercise tolerance improved the prescription was updated, affording a bespoke approach to rehabilitation that might be more relevant to people with lung cancer (51).

This review highlights the benefits of a digital health intervention that includes an exercise component, and demonstrated improvements in cancer related fatigue and balance (33,41), walking duration or distance or step count (33-35,41,45), general activity levels, dyspnoea (43), and muscle strength for people living with lung cancer (35). Nevertheless, there are still areas for development. For example, one of the studies (35) found that while there was an increase in lower extremity muscle strength, no change in upper extremity muscle strength was noted and in another study (44) for participants with progressive disease no improvement was observed in exercise capacity or dyspnoea scale. Furthermore, none of the studies included here provided a bespoke exercise prescription and demonstrated a positive impact on exercise endurance and muscle endurance and symptoms of dyspnoea. This reinforces the need to produce an exercise prescription that is relevant to the participants' disease status and individual exercise goals. More consideration is required to develop technologies with intelligent algorithms or artificial intelligence that can support the person with lung cancer to input data on their current condition and capability before a safe, bespoke, exercise prescription is recommended. This needs to be factored into app development and further research.

Improving HRQoL is a priority goal in supporting people with lung cancer (50). All studies that assessed the impact of HRQoLreported a positive impact. The direction of association between HRQoL and improved physical functioning was consistent across most studies that reported on both outcomes (34,35,43-45). Improvements were primarily noted in the global health state, symptoms and functionals scales, but it is unclear if these improvements are a direct result of the exercise intervention, or improved disease management, and control.

This review highlighted the high levels of acceptability and participant satisfaction with the digital intervention. Having a home-based exercise intervention or online intervention, like the technologies in this review is advantageous as participants were able to continue to exercise during chemotherapy treatment when they're usually advised to limit their contacts with other people to reduce the risk of infections. Furthermore, studies that used a game console as part of their exercise program incentivised their participants to use the technology, work out more often and increase the intensity of the exercise (33,41,45). Other useful features of the technologies that have been highlighted include the use of a virtual environment for exercising (33,41), using dance to work out (45), dietary advice (35) and the value of incentivising participants (33,41,45). Hence, it is important that future app developers consider what incentives can be built into the intervention to improve adherence, reduce the clinician work load, and empower the patient to be more independent with their disease management.

It is anticipated that health apps like the ones identified in this review will enable improved disease management, reduce hospital admissions, and save the NHS money (34). Despite that, there is inadequate cost analysis to date to demonstrate cost impact on health care services, the health care workforce and people living with lung cancer. Our review identified only one cohort study undertaken in a single research active center that reported the cost of the intervention to the health care provider and the estimated time impact on health care professionals.

Limitations

We reported on available evidence within the published reported papers. We faced challenges in gathering details regarding missing study data. Despite our attempts to reach out to the corresponding authors to obtain the necessary information, we did not receive any response from them. Furthermore, it is unclear if any development information not included in the reports of the studies was excluded [33-35).

Studies included in our review were primarily quasi experimental and non randomised [33,35,42,44,45]. Only one randomised controlled trial [43] and one cohort study [34] were included. Included studies focused on technology development and assessing feasibility most frequently for patients undergoing surgery [33-35,42,43). Additionally, the small cell sub type of lung cancer has poorer outcomes than non-small cell sub-types, with a primary focus on treatment being to improve HRQoL; this population was not well represented in our included studies. Furthermore, various tools were used to assess physical functioning and HRQoL making it difficult to draw comparisons across the studies due to their heterogeneity.

Conclusions

There appears to be a consistent relationship between digital technologies employed by people with lung cancer and a positive impact on physical functioning and HRQoL. The technologies reported in the review demonstrated high levels of acceptability or user satisfaction and have the potential to support people with lung cancer to manage their health more independently. However, most of the studies identified here report on the development and feasibility of the technology. Further multi center, large scale research studies using a randomised controlled trial design over an extended period are required to fully assess the true benefit of adopting electronic health technologies in standard care services for health care providers and people with lung cancer and should include a cost effectiveness outcome measure.

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Author contributions

SK drafted the manuscript. CH, ZD, and PW supported the development of the concept for the review. SK and one other (CH/ZD/PW) screened all abstracts and
full texts. SK extracted all data, and this was reviewed by CH, ZD, PW. SK conducted the quality assessment in collaboration with ZD and CH. All authors contributed to the methods for the review, multiple versions of the manuscript, and approved the final

version of the manuscript.

Conflicts of Interest

None to declare.

Abbreviations

COVID- 19: Coronavirus Disease
CRUK: Cancer Research UK
EORTC- QLQ- C30: European Organisation for the Research and Treatment of Cancer Quality of Life Questionnaire
EQ-5D: European Quality of Life Five Dimension
EQVAS: EuroQol-visual analogue scales
FITT: Frequency, Intensity, Time, and Type
GRADE: Grading of Recommendations, Assessment, Development and Evaluation
JBI: Joanna Briggs Institute
NHS: National Health Service
NICE: National Institute for Clinical Excellence
PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses
HRQoL: Health related Quality of Life
SF-36: 36-Item Short Form Health Survey
SWiM: Synthesis without meta-analysis reporting items
6 MWT/D: Six-minute walk test/ distance
UK: United Kingdom
USA: United States of America
WHO: World Health Organisation

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Supplementary Files

Untitled.
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