ORIGINAL PAPER

DOI: https://doi.org/10.61785/ael/200603

Modern technologies in cancer patient rehabilitation: A systematic review of clinical evidence and patient outcomes

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Publishing info

Received: 2024-12-04
Accepted: 2024-10-23
Online first: 2025-02-27

Keywords

patient outcomes
cancer care technology
digital health technology
eHealth interventions
cancer rehabilitation

Abstract

Introduction: Cancer rehabilitation is a vital component of comprehensive cancer care that enhances patients' quality of life throughout their cancer journey. As medical technology advances, innovative solutions are increasingly incorporated into rehabilitation protocols for cancer patients. These technologies support patients across all stages - from diagnosis through treatment and into survivorship - addressing their diverse needs. While technological solutions in cancer rehabilitation are becoming more common, there is a pressing need to evaluate their effectiveness comprehensively. This study examines how technological interventions affect rehabilitation outcomes across four patient groups: those about to begin cancer treatment, patients in active treatment, those who have completed treatment, and cancer survivors. Through analysis of studies 2014–2020, covering 1662 patients, this review provides a thorough assessment of technology-enhanced cancer rehabilitation and its implications for future clinical practice.

Aim: Purpose of the search was to evaluate the effectiveness of the proposed new technologies in rehabilitation outcomes in patients with cancer.

Material and methods: PubMed, PubMed Medline, Google Scholar engines were searched focusing on publications between 2014 and 2020 in the English language.

Results and discussion: The search included and evaluated 16 studies published between 2014 and 2020, which represented 1,662 patients scheduled to initiate cancer treatment, actually undergoing cancer treatment, with terminated cancer treatment, and cancer survivors.

Conclusions: New technologies may improve rehabilitation in cancer patients or cancer survivors but more research is still required with larger trial groups of patients to fully evaluate outcomes and efficacy of such interventions.

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1. Introduction

Cancer is the second leading cause of death worldwide and the cause of 1 in 6 deaths globally, according to WHO.[1] The increasing life expectancy and evolving demographic patterns are significantly impacting cancer incidence and prevalence rates worldwide. Recent epidemiological data from GLOBOCAN indicates that by 2040, the global cancer burden is projected to reach 28.4 million new cases annually, representing a 47% increase from current levels.[2] This substantial rise, coupled with improving survival rates, emphasizes the critical need for comprehensive patient support throughout the cancer journey.

The growing prevalence of cancer-related health challenges necessitates rehabilitation programs that effectively address patients' diverse needs and enhance their recovery experience. While traditional rehabilitation approaches remain fundamental, emerging technologies offer new opportunities to improve patient outcomes and support their healing journey. These technological innovations have demonstrated remarkable success in various medical fields, as shown by virtual reality applications in neurological rehabilitation among stroke patients[3] and individuals with spinal cord injury,[4] where patients have experienced enhanced recovery and improved functional outcomes.

Modern rehabilitation practices are evolving to place patients at the center of their recovery process. The integration of new technologies into physical therapy (PT) enables personalized treatment approaches that adapt to individual patient needs and preferences. Virtual reality and biofeedback therapy offer engaging, interactive experiences that can increase patient motivation and participation in rehabilitation activities. These technologies not only provide treatment but also empower patients by giving them real-time feedback about their progress, helping them actively participate in their recovery journey.

The significance of patient-centered technological solutions has become particularly evident in rehabilitation programs. Digital platforms enable patients to maintain consistent contact with healthcare providers, receive timely support, and access rehabilitation services from the comfort of their homes. This accessibility can significantly reduce the burden of treatment, particularly for patients experiencing fatigue or mobility challenges during cancer treatment. Moreover, these technologies can help alleviate anxiety and isolation by connecting patients with support networks and providing them with tools to track and celebrate their progress.[5]

Furthermore, technology-based rehabilitation systems offer opportunities for more inclusive and comprehensive patient care. These platforms can adapt to various patient capabilities and preferences, ensuring that rehabilitation programs are both challenging and achievable. The ability to collect and analyze patient data helps healthcare providers make informed decisions about treatment adjustments, ensuring that rehabilitation protocols remain aligned with patient needs and recovery goals.

The evolution of cancer rehabilitation through technological integration represents a significant advancement in patient-centered care.[6] These innovations address both the physical and psychosocial aspects of cancer recovery, recognizing that successful rehabilitation extends beyond physical improvement to encompass emotional well-being and quality of life. As cancer treatment continues to advance, the role of supportive rehabilitation technologies becomes increasingly vital in providing patients with the tools and support they need to achieve optimal recovery outcomes.

2. Aim

The aim of this literature review was to evaluate the effectiveness of new technologies in rehabilitation outcomes among cancer patients. This investigation examined the impact of technological interventions across the entire cancer care continuum, encompassing patients undergoing active treatment, those scheduled to initiate treatment, patients who had completed treatment, and cancer survivors. The research focused on both the therapeutic efficacy of these technologies and their role in monitoring and improving patient outcomes. Through systematic analysis of published trials, this review sought to assess the effectiveness of virtual reality, mobile applications, and telerehabilitation systems in cancer rehabilitation, while evaluating patient acceptance and adherence to technology-based interventions. Additionally, the investigation aimed to analyze the impact of these technologies on physical function, quality of life, and psychological well-being, as well as examine the feasibility of implementing these technological solutions in various clinical settings.

3. Material and methods

A comprehensive literature search was conducted utilizing PubMed and Google Scholar databases, focusing on publications between 2014 and 2020 in the English language. The review encompassed various research designs, including randomized controlled trials (RCTs), quasi-randomized controlled trials (CCTs), prospective clinical trials (PCTs), and pilot studies, focusing on patients with cancer undergoing active treatment, scheduled to initiate treatment, those with terminated cancer treatment, and cancer survivors.

The search strategy employed a combination of keywords related to new technologies, virtual reality, mHealth, and telerehabilitation, paired with cancer and oncology terms. Study selection followed a systematic approach as illustrated in the flow diagram (Figure 1).

Studies were included based on specific criteria, including cancer patient participation at various treatment stages, evaluation of new technology applications in rehabilitation, and measurement of physical, functional, or quality of life outcomes. The data extraction process utilized a standardized form to collect comprehensive information about study characteristics, patient demographics, cancer types, intervention details, outcome measures, and study conclusions. This systematic approach ensured thorough and consistent evaluation of all included studies.

4. Results and discussion

The investigation included and evaluated 16 trials published between 2014 and 2020 that concerned two

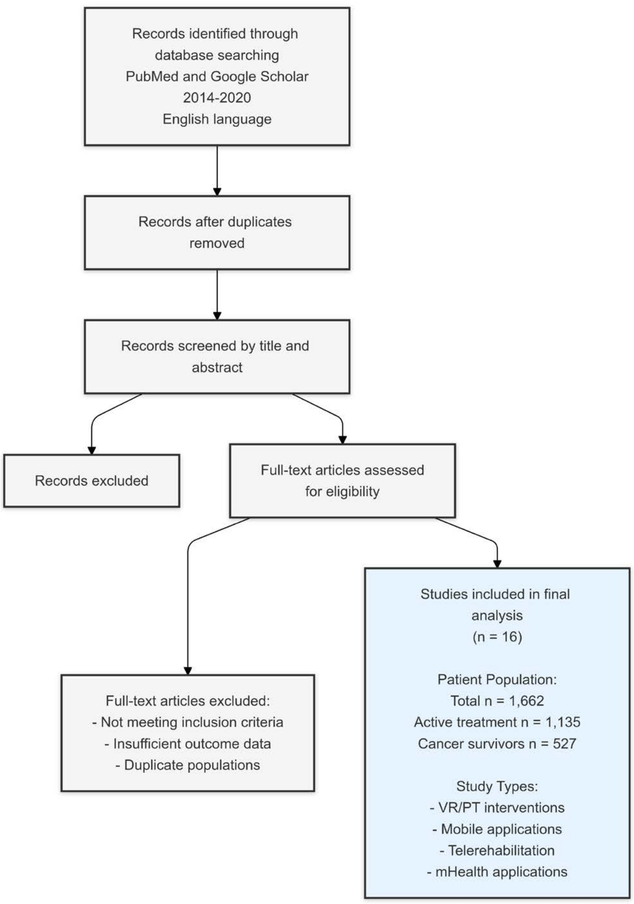

Figure 1. Search strategy flow chart.

ways of new technologies application and benefit. The first way included virtual reality (VR) in physical therapy (Xbox Kinect-based games, Nintendo Wii Fit), and interactive game-based balance training using sensors and computer to analyze sway of body part and center of mass.[7–10]

The second way included special applications assessed participation in physical activity or voluntary physical activity via phone step-recording app (FitBit). A different way of applications activities was daily information (for example in social media), conducting and monitoring breathing exercises and conducting other types of exercises. Among other new technologies employed interventions were video instructions, text messages, telerehabilitation by Internet or smartphone.[11–14]

Three trials assessed receptivity and acceptance of the participants to the implementation of new technologies within the rehabilitation procedures (mHealth). One trial evaluated patients outcomes in the application program with and without personalization option (efil breathe app). One trial assessed the number of exercise performances by patients if application results were available both for patients and nurses, and for patients exclusively (Gobreath app).[15,16]

The included trials measured consequent outcomes: pain, quality of life; with regards to physical efficiency: cardiorespiratory capacity, functionality, muscle strength, grip strength, range of motion, activities of daily living, gait performance and amount of physical activity, self-reported physical activity. Physiological performances include: anxiety, depression, distress, fear of movement, fear of falling. Physiological measures: blood pressure, anthropometry, nutritional status, body composition. Others: fatigue, dyspnea. Outcomes accounted also for satisfaction, acceptance, adherence rate, safety, and technology readiness.

In total, 16 studies representing 1662 patients, actually undergoing cancer treatment such as surgery, radiotherapy and chemotherapy, scheduled to initiate treatment, with terminated cancer treatment and cancer survivors were evaluated. Patients' cancer diagnoses in trials included breast cancer (undergone mastectomy with axillary lymph node dissection, at phase I to III, were overweight or obese),[7,11,14] hematologic malignancies,[8,12] brain tumor (with upper extremity dysfunction),[17] non-small cell lung cancer (post-thoracotomy),[9,13,15] gastric[16,18] and colorectal[19] patients, and patients with chemotherapy-induced peripheral neuropathy.[10]

Thirteen trials were conducted among participants who were currently scheduled for or undergoing active treatment for their cancer (n = 1,135),[7–19] while 3 trials were conducted among cancer survivors (n = 527).[20–22]

Patients trial groups or control groups undergoing rehabilitation interventions with the use of new technologies, received standard physiotherapy/usual care/no intervention/intervention in part dimension.

The results show that new technologies improved rehabilitation outcomes, physical and psychosocial performance. Remote monitoring and communication was acceptable for patients in most of the studies, high acceptance for applications was identified. One study reports that 30% participants were unreceptive to use technology in rehabilitation.[23] Adherence rate was between 66.5% to 88%. Not in all presented studies new technologies proved to be much more effective than usual care with regards to part of the performed interventions within the trial groups or to quality of life.[7,10,11,13] All findings are presented in Table 1 and 2.

5. Conclusions

Based on the systematic review of 16 trials evaluating new technologies in cancer rehabilitation, the implementation of technological interventions demonstrates significant potential in enhancing rehabilitation outcomes. Virtual reality-based interventions, particularly Xbox Kinect and Nintendo Wii Fit systems, showed improvement in physical function and quality of life measures.[7–9] Similarly, mobile health applications and telerehabilitation systems demonstrated efficacy in promoting exercise adherence and facilitating remote patient monitoring.[11–14] Specific applications, such as

Table 1. Definition of margins and indication for adjuvant radiotherapy.

Authors	Participants and methods	Outcome measures	Results
Feyzioğlu et al., 2020[7]	**40 patients** with breast cancer 1) the intervention group (*n* = 20) received virtual reality therapy using **Xbox Kinectbased games** 2) the control group (*n* = 20) received standard rehabilitation **Duration: 6 weeks**	– **pain** (visual analogue scale) – **grip strength** (dynamometer) – **functionality** (disabilities of the arm shoulder and hand questionnaire) – **muscle strength** (handheld dynamometer) – **ROM** (digital goniometer) – **fear of movement** (Tampa kinesiophobia scale - TKS)	– significant changes in pain, ROM, muscle strength, grip strength, functionality, and fear of movement after the treatment in both groups ($P < 0.01$) – significantly improved in the intervention group fear of movement than to control group ($P < 0.05$) – no differences in ROM, muscle strength, grip strength, and pain between the groups after the treatment ($P > 0.05$)
Dong et al., 2019[11]	**60 patients** with breast cancer at phase I to III 1) the intervention group (*n* = 30) procedure included: * **via phone step-recording app**, 4 times per week of completing the target number of steps * **face-to-face remote video** instruction of muscle training 3 times per week * **via social media apps** daily spreads knowledge of rehabilitation in breast cancer 2) the control group (*n* = 30) received **standard rehabilitation** **Duration: 12 weeks**	– **quality of life** (Short Form 36)- primary outcome – **muscle strength** (stand-up and sit-down chair test, arm lifting test) – **cardiorespiratory capacity** (modified Bruce treadmill protocol) – secondary outcome	– significantly improved in vitality ($P = 0.009$), mental health ($P = 0.001$) and reported health transition ($P = 0.048$) in intervention group – significantly improved the standup and sit-down chair test ($P < 0.0001$), arm lifting test ($P = 0.017$) in intervention group no difference in VO2max between the two groups ($P = 0.149$)
Tsuda et al., 2016[8]	**16 patients** with hematologic malignancies 1) the intervention group: 2) from the start of chemotherapy use the **Nintendo Wii Fit** virtual reality **exercise** 5 times per week for 20 minutes once a day 2) no control group **Duration: until hospital discharge**	– **adherence rate** – **safety** – **physical performances** (e.g., Barthel index, handgrip strength, knee extension strength, oneleg standing time, and the scores of timed up and go test and Instrumental Activities of Daily Living) – **psychological performances** (e.g., score of hospital anxiety and depression scale).	– adherence rate for all patients 66.5% – 9 patients completed the virtual reality exercise intervention with 88 sessions, the adherence rate 62.0% – no intervention-related adverse effects maintenance of the physical performance and psychosocial performance
Yoon et al., 2015[17]	**40 patients** with brain tumor and upper-extremity dysfunction 1) the intervention group (*n* = 20) received the **virtual reality program** 30 min per session for 9 sessions and conventional occupational therapy 30 min per session for 6 sessions 2) the control group (*n* = 20) received **conventional occupational therapy** alone 30 min per session for 15 sessions **Duration: 3 weeks**	– **upper-extremity function** (The Box and Block test, the Manual Function test, and the Fugl-Meyer scale) – **activities of daily living** (The Korean version of the Modified Barthel Index)	– significant improvements in upper-extremity function and activities of daily living in both groups after the treatment – greater improvements in shoulder/elbow/forearm function in the intervention group and hand function in the control group

Table 1. Continued on the next page

Table 1. Continued

Authors	Participants and methods	Outcome measures	Results
Hoffman et al., 2014[9]	**7 patients** postthoracotomy for non-small cell lung cancer (NSCLC) 1) the intervention group: received the **Nintendo Wii Fit Plus** – lightintensity exercises using an **virtual-reality** 2) no control group **Duration: 10 weeks**	– **cancer-related fatigue**	– intervention highly acceptable by patients – adherence rate 88% – improvement in participants cancer-related fatigue scores
Cheville et al., 2019[12]	**516 patients** stage IIIC or IV solid or hematologic cancer 1) **control arm** 2) telerehabilitation **arm** 3) telerehabilitation **with pharmacological** pain **management arm** **Duration: 6 moths**	– **blinded assessment of function** (Activity Measure for Postacute Care computer adaptive test) – **pain interference and average intensity** (Brief Pain Inventory) – quality of life (EQ-5D-3L)	– improvement in function (difference, 1.3; 95%CI:0.08-2.35; $P = 0.03$) and quality of life (difference, 0.04; 95%CI:0.004-0.071; $P = 0.01$) in telerehabilitation arm 2 compared with the control arm reduced pain interference (arm 2, -0.4; 95%CI:-0.78 to -0.09; $P = 0.01$ and arm 3, -0.4; 95%CI:-0.79 to -0.10; $P = 0.01$), and average intensity (arm 2, -0.4; 95%CI:-0.78 to -0.07; $P = 0.02$ and arm 3, -0.5; 95%CI:-0.84 to -0.11; $P = 0.006$) in both intervention groups telerehabilitation was associated with higher odds of home discharge in arms 2 (odds ratio – OR, 4.3; 95%CI:1.3-14.3; $P = 0.02$) and 3 (OR, 3.8; 95%CI:1.1-12.4; $P = 0.03$) and fewer days in the hospital in arm 2 (difference, -3.9 days)
Ji et al., 2019[15]	**64 patients** with non-small cell lung cancer rehabilitation program - **efil breath**) 1) **fixed exercise group** 2) **fixed-interactive exercise group** (received the personalized program). **Duration: 12 weeks**	– **physical activity** (6-minute walk distance) – **dyspnea** (modified Medical Research Council score) – **quality of life** (EuroQolvisual analog scale) – **service satisfaction** (Patient Global Assessment)	– significant improvement in 6MWD from a mean of 433.43m (SD 65.60) to 471.25m (SD 75.69; $P = 0.001$) dyspnea from a mean score of 0.94 (0.66) to 0.61 (SD 0.82; $P = 0.02$) and quality of life from a mean 76.05, SD 12.37 vs 82.09, SD 13.67; $P = 0.002$ in all patients
Schwenk et al., 2016[10]	**22 patients** with CIPN 1) the intervention group received **interactive game-based balance training** two 45-min sessions per week 2) the control group: **no intervention**, continued normal activity **Duration: 4 weeks**	– **changes in sway of ankle, hip, and center of mass** (30-second balance tests with increasing task difficulty) – **gait performance**: speed, variability – **fear of falling** (Falls Efficacy Scale-International)	– significant improvement in intervention group compared to control group in balance in feetclosed position with eyes open ($P = 0.010$-0.022, except AP CoM sway) and in semi-tandem position ($P = 0.008$-0.035, except ankle sway) – no significant difference for balance with eyes closed, gait speed, and fear of falling ($P > 0.05$)
Park et al., 2019[13]	**100 patients** with advanced lung cancer 1) intervention group: received a **smartphone app–based pulmonary rehabilitation program** 2) no control group **Duration: 12 weeks**	– **exercise capacity** (6-min walking distance test) – **quality of life** (the European Organization for Research and Treatment of Cancer Quality of Life Questionnaire-C30) – **pain** (numeric rating scale) – **distress, including anxiety** (Generalized Anxiety Disorder-7, GAD-7) – **depression** (Patient Health Questionnaire-9)	– significantly improved the 6MWD ($P < 0.001$) with no significant improvement in the dyspnea scale score – significant improvement in role ($P = 0.02$), emotional ($P < 0.001$), and social functioning ($P = 0.002$) – significant improvement in scale scores for fatigue ($P < 0.001$), anorexia ($P = 0.047$), diarrhea ($P = 0.01$), depression ($P = 0.048$) and anxiety ($P = 0.01$) – no significant difference in quality of life ($P = 0.06$) and severity of pain ($P = 0.24$)
Galiano-Castillo et al., 2016[14]	**81 patients** with I to IIIA breast cancer 1) intervention group ($n = 40$): reveived an **Internet-based, tailored exercise program** 2) control group ($n = 41$): **no intervention**, continued normal activity **Duration: 8 weeks**	– **quality of life** (EORTC QLQ-C30) – **pain** (The Brief Pain Inventory short form) – **fatigue** (Piper Fatigue Scale) – **lower body strength** (the multiple sit-to-stand test) – **isometric handgrip, abdominal and back strength**	– significant improvement in the intervention group in scores for global health status, physical, role, cognitive functioning, and arm symptoms (all $P < 0.01$) as well as pain severity ($P = 0.001$) and pain interference ($P = 0.045$) – significantly improved in the intervention group for handgrip both side (both $P = 0.006$), abdominal, back and lower body strength (all $P < 0.01$), and total fatigue ($P < 0.001$)
Soh et al., 2019[16]	**44 patients** with gastric cancer **Go-breath app** 1) intervention group ($n = 22$): nurse could assess the number of incentive spirometer performances 2) control group ($n = 22$): possible performances acc. to previously fixed and assessed number of incentive spirometer performances **Duration: 2 days**	– **number of performances** (an incentive spirometer index)	– higher performance rates of incentive spirometer count, active coughing, and deep breathing in the intervention group – over 90% of patients wanted more functional options and information.

Table 1. Continued on the next page

Table 1. Continued

Authors	Participants and methods	Outcome measures	Results
Cheong et al., 2018[19]	**102 patients** with colorectal cancer patients received **smartphone aftercare** including mobile application and wearable device to participate in rehabilitation exercise program and get information on their disease and treatment **Duration: 12 weeks**	– **the grip strength test – 30-second chair stand test** – **2-minute walk test** – **amount of physical activity** (IPAQ) – **quality of life** (EORTC QLQ-C30) – **nutritional status** (patient-generated Subjective Global Assessment)	– significantly improved in the lower extremity strength ($P < 0.001$) and cardiorespiratory endurance ($P < 0.001$) – significantly relieved in fatigue ($P < 0.007$) and nausea/vomiting ($P < 0.040$) symptoms

Authors	Participants and methods	Outcome measures	Results
Wu et al. 2019[18]	**43 patients** with gastric cancer patients used **wearable device connected with the platform (mHealth)** to monitor their physical activity	– validate the **feasibility of this system** (defined as the proportion of patients using the device and uploading their results) – **evaluate the clinical value of measuring walking steps** by examining whether they were associated with early discharge (length of hospital stay <9 days)	– the overall daily submission rate 95.5% – every 1000-step increment of walking on postoperative day 5 was associated with early discharge (odds ratio 2.72, 95%CI:1.17-6.32; $P = 0.02$)

Table 2. Trials with cancer survivors and terminated therapy.

Authors	Participants and methods	Outcome measures	Results
Uhm et al. 2017[20]	**356 patients** with terminated cancer treatment 1) the intervention group: the **mHealth** group received a pedometer and a newly developed smartphone application to provide information and monitor the prescribed exercises. 2) control group: received only an **exercise brochure**. **Duration: 12 weeks aerobic and resistance exercise**	– **selfreported physical activity** (international physical activity questionnaire-short form) – **general QOL** (European Organization for Research and Treatment of Cancer Quality of Life Questionnaire Core 30) – **breast cancer-specific QOL** (Quality of Life Questionnaire Breast Cancer Module 23) – user satisfaction survey was assessed in the mHealth group	– significant improvement in physical function, physical activity, and quality of life in both groups
Lozano-Lozano et al. 2019[21]	**80 survivors** of breast cancer 1) the intervention group ($n = 40$): BENECA mobile Health (mHealth) lifestyle application combined with a supervised rehabilitation 2) the control group ($n = 40$) BENECA mHealth and standard care **Duration: 2 months**	– **quality of life** (EORT QLQ-C30) - primary outcome – **upper-limb functionality** – **body composition** - secondary outcome	– significantly better results in quality of life in intervention group (mean difference, 12.76; 95% confidence interval 4.85; 20.67; $P = 0.004$) with a moderate-tolarge effect size ($d = 72$) – improvement in subjective and objective upper-limb functionality higher in intervention group
Gell et al., 2020[22]	**91 cancer survivors** 1) intervention group ($n = 46$): used a pedometer to monitor the number of steps daily taken and recorded their results on the step log on the STRIDE website 2) control group ($n = 45$): used a pedometer but did not have access to the website **Duration: 12 weeks**	– **physical activity** (pedometer) – physiological measures (blood pressure) – anthropometry – physical fitness (6 MWT) – quality of life (SF-36 short form)	– significant improvements in both groups in physical fitness ($P < 0.01$), systolic and diastolic blood pressure ($P < 0.01$), waist girth ($P < 0.01$), mental health ($P < 0.05$), social functioning ($P < 0.01$), and general health ($P < 0.01$) – significant increase in bodily pain ($P < 0.01$) in both groups

efil breathe app and Gobreath app, exhibited effectiveness in monitoring and encouraging breathing exercises among cancer patients.[15,16]

The analysis of patient engagement revealed adherence rates ranging from 66.5% to 88% across studies, indicating substantial patient participation in technological interventions. While the majority of patients demonstrated acceptance of new technologies, it is noteworthy that 30% of participants showed reluctance to incorporate technology into their rehabilitation process.[23] Remote monitoring and communication systems were generally well-received, suggesting feasibility for broader implementation in clinical practice.

Clinical applications of these technologies showed particular effectiveness in several domains, including pain management,[7,12–14] physical activity monitoring,[11,13,19,20] quality of life improvement,[11,13,14,20,21] and functional capacity enhancement.[7,10,17] These findings suggest the versatility of technological interventions in addressing various aspects of cancer rehabilitation.

However, several limitations of the analyzed studies warrant consideration. Methodological constraints included the absence of control groups in multiple studies,[8,9,13,16,18] limited sample sizes with some trials including fewer than 50 participants,[8–10,16] and heterogeneity in intervention types and outcome measures. The varied duration of interventions, ranging from 2 days to 6 months, limited the assessment of long-term effectiveness. Technical considerations included insufficient evaluation of technology accessibility across different age groups and socioeconomic backgrounds, potential bias towards more technologically literate participants, and lack of standardization in technology implementation across studies.

Future research directions should address these limitations through larger-scale randomized controlled trials with adequate sample sizes and longer follow-up periods. Standardization of outcome measures across studies would facilitate better comparability of results. Investigation of cost-effectiveness and development of personalized technological solutions for different cancer types and stages should be prioritized. Additionally, the potential integration of artificial intelligence and machine learning for more adaptive rehabilitation programs warrants exploration.

Furthermore, attention should be directed toward understanding barriers to technology adoption among resistant patient groups and evaluating the impact of socioeconomic factors on technology accessibility and effectiveness. Research into methods to improve technology acceptance among older adults and less tech-savvy populations would enhance the applicability of these interventions.

The integration of new technologies in cancer rehabilitation demonstrates promising potential, particularly in improving physical function, quality of life, and patient monitoring capabilities. However, successful implementation requires careful consideration of individual patient needs, technological literacy, and accessibility. Future research endeavors should focus on addressing the identified limitations while expanding the evidence base for specific applications across diverse patient populations.

CONFLICT OF INTEREST

None declared.

FUNDING

None declared.

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