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Duin, J.J.; Baltussen, J.C.; Albalak, G.; Isselt, E.F.V. van; Portielje, J.E.A.; Mooijaart, S.P.; … ; Bos, F. van den

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Review Article

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The use of wearable technology in studies in older adults with cancer: a systematic review

Jan J. Duin[1,2,*], Joosje C. Baltussen[3], Gali Albalak[1,2], Eléonore F. van Dam van Isselt[2,4], Johanneke E.A. Portielje[3], Simon P. Mooijaart[1,2], Enrique Soto-Perez-de-Celis[5,6], Frederiek van den Bos[1,2]

[1]Department of Internal Medicine, Section of Geriatrics and Gerontology, Leiden University Medical Center, 2300 RC Leiden, The Netherlands,
[2]LUMC Center for Medicine for Older People, Leiden University Medical Center, 2300 RC Leiden, The Netherlands,
[3]Department of Medical Oncology, Leiden University Medical Center, 2300 RC Leiden, The Netherlands,
[4]Department of Public Health and Primary Care, Leiden University Medical Center, 2300 RC Leiden, The Netherlands,
[5]Department of Geriatrics, Instituto Nacional de Ciencias Médicas y Nutrición Salvador Zubirán, 14080 Mexico City, Mexico,
[6]Division of Medical Oncology, Department of Medicine, University of Colorado School of Medicine, Aurora, CO 80045, United States

*Corresponding author: Jan J. Duin, MD, Department of Internal Medicine, Section of Geriatrics and Gerontology, Leiden University Medical Center, Postzone C7-Q, P.O. Box 9600 RC, Leiden, The Netherlands (j.j.duin@lumc.nl)

Abstract

Background: Despite the increasing integration of wearable technology in oncology, its application in the care of older adults, representing most patients with cancer, is poorly defined.

Objective: This systematic review aimed to summarize the current use of wearables in studies in older adults with cancer.

Methods: This systematic review was conducted following the PRISMA guidelines. A systematic search was conducted in PubMed, Embase, Emcare, Web of Science, and Cochrane Library on May 1, 2024. Studies involving wearable devices and patients aged ≥60 years diagnosed with cancer were included. Outcomes reported were study characteristics, wearable outcomes, feasibility and adherence. The mixed method appraisal tool was used to assess the quality of included studies.

Results: A total of 31 publications were included, comprising 1298 older patients. Of these, 12 were pilot/feasibility studies, 12 were observational studies, 6 were randomized controlled trials, and 1 was a cross-sectional study. Most studies used wearable data to measure recovery (19 studies, 61%). Physical activity was the most studied wearable outcome (27 studies, 87%). Adherence to the wearable device was documented in 11 of the 31 studies (35%), with adherence ranging from 74% to 100%.

Conclusions: Our systematic review found wearables were mostly used to measure physical activity, with the most common primary aim of measuring recovery. Most studies reported high adherence, although definitions of adherence were diverse. Our results highlight the need for more and larger studies on wearable technology in older cancer patients, the use of standardized reporting frameworks, and increased participation in research in low- and middle-income countries.

Key words: wearable electronic devices; wearable technology; digital health; systematic review; geriatrics; oncology; geriatric oncology; cancer; older adult.

Implications for practice

Despite large heterogeneity in reported studies, most reported high adherence, implicating that the use of wearable devices in older patients with cancer is feasible. Future research should aim to develop robust protocols that include implementation measures, cost-effectiveness analyses, and real-time data monitoring capabilities. Expanding the types of wearable outcomes studied, such as heart rate variability and stress levels, could provide deeper insights into the health status of older cancer patients.

Introduction

As global populations age, the prevalence of age-related diseases, including cancer, is on the rise. By 2040, it is projected that individuals aged 65 years and older will account for 69% of all new cancer diagnoses in the US and 61% of new cancer cases worldwide.[1,2] Treating older patients with cancer presents unique challenges due to the heterogeneity of this population, which includes variations in physiological reserves, comorbidities, and resilience. This variability significantly impacts the efficacy and tolerability of cancer treatments.[3-5] Older patients, particularly those with frailty and multiple comorbidities, face an increased risk of poor treatment tolerability compared to their younger counterparts.[4,6] Consequently, developing individualized strategies aimed at improving the tolerability of cancer treatment while minimizing its toxicity among older patients with cancer is essential.

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A promising trend in oncological care is the increased use of wearable devices—sensors worn on the body that collect health data remotely. The development of affordable, user-friendly, and consumer-oriented sensors has made wearable technology more accessible. These devices offer multifaceted benefits: they can provide clinicians with insights into a patient's health status before treatment, detect early signs of adverse events, and monitor adherence to prehabilitation and rehabilitation programs.[7] Additionally, the remote capabilities of wearables can enhance access to care, particularly for those with mobility limitations, or who live alone or in rural areas.

Despite the growing literature on wearable technology in oncology, older adults are underrepresented in most studies, and research focused on older adults remains limited.[8] However, older adults represent a demographic that could benefit greatly from wearables through improved health status assessments, early toxicity detection, and continuous monitoring during recovery, all of which can facilitate more personalized treatment plans. Unique challenges such as technological literacy, and age-related impairments of cognitive and motor functions (eg, vision and hearing loss)[9] underscore the importance of studying wearable technology specifically within the population of older patients with cancer.

Our systematic review aims to fill this gap by summarizing the current use of wearable technology in studies in older adults with cancer.

Methods

Search Strategy

This systematic review was conducted following the PRISMA guidelines (http://www.prisma-statement.org/) for reporting and design of systematic reviews (Supplementary Section 1). Registration was not performed. A protocol is not available online. A systematic query was conducted in the databases of PubMed, Embase, Emcare, Web of Science, and Cochrane Library with the assistance of a trained librarian (EvG). Databases were searched up to May 1, 2024, with no limitation in the publication date. Searches were conducted using a combination of keywords related to cancer and neoplasms, terms associated with older adults, and terms related to wearable devices. The complete search strategy can be found in Supplementary Section 2. All results were imported into Rayyan, an online literature screening tool.[10]

Eligibility criteria

The eligibility criteria for the studies included in the review were as follows: (1) All patients in the study population or specific subgroup of patients must be 60 years or older. (2) Patients must have been diagnosed with cancer, including those before, during, and after treatment. (3) The use of a wearable device must be reported. (4) The outcomes related to the wearable device must be reported. (5) The article must have been published in English. The exclusion criteria were (1) studies registered as editorials, letters, reviews, or case reports, and (2) studies utilizing a wearable device solely as a platform to administer questionnaires. The selected search strategy yielded studies, which were screened by two reviewers (J.J.D., J.C.B.) on title and abstract, with each reviewer blinded to the other's decisions. In case of disagreement a third author (E.S.P.d.C. or F.v.d.B.) was involved to make the final decision. Consequently, a full-text assessment of the screened articles was independently performed by 4 reviewers (J.J.D., J.C.B., E.S.P.d.C., F.v.d.B.). Each article was assessed by 3 of the 4 reviewers. In case of disagreement, the fourth author was involved to make the final decision.

Data extraction

Two authors (J.J.D., J.C.B.) independently extracted data from the selected records into a Microsoft Excel spreadsheet. For each record, the following information was recorded: first author, publication date, journal, study design, cancer type, treatment type, sample size, country of conduction, outcome measures, inclusion and exclusion criteria, study objective, associations between wearable data and outcomes, type of wearable, planned wear time, actual wear time, feasibility, adherence and acceptability rates, recruitment rate, retention rate, main findings, and limitations. Wearable types were subdivided according to the type of sensor (single sensor vs combined sensor) and wear mode (eg, wrist- or waist-worn). Additionally, studies were categorized based on the intended wearable use, either for prognostication, treatment monitoring, or recovery. These categories were chosen following a previously published review by Chow et al.[7]

The prognostication category consists of studies that use wearable outcomes to correlate or predict a clinical outcome. The treatment monitoring category consists of studies in which patients received cancer therapy and wearable data was used to characterize changes in clinical parameters or detect adverse events. The recovery category consists of studies in which wearable data was utilized to correlate with physical activity, quality of life, or other measures of well-being, in patients who received cancer therapy. In cases where studies fit the criteria for multiple categories, they were arbitrarily assigned to a category that was felt to best match the above descriptions.

Description of analysis and presentation of data

Tables were used to describe the studies and extract all the results. Table 1 describes the following characteristics of the published studies: author, year of publication, article type (full-text or abstract), study design, wearable usage, sample size, sex distribution, age group, country of conduction, cancer type, study time point (in relation to treatment), treatment type, and wearable name. Table 2 presents a summary of the wearable outcomes and other outcome measures reported in the included studies. Table 3 describes the feasibility and adherence measures of included studies and includes the following information: author, year of publication, planned wearable wear time, cutoff for valid wear time, technical problems regarding the wearables, and adherence and feasibility descriptions (specific to wearables).

Quality assessment

Each study was appraised for study quality independently by 3 authors (J.J.D., E.S.P.d.C., F.v.d.B.) using the Mixed Method Assessment Tool.[11] Briefly, this tool first uses two brief general screening questions to assess if the article is suitable to be assessed using this tool, the tool then applies specific criteria depending on the category of study (qualitative, quantitative randomized controlled trials, quantitative non-randomized, quantitative descriptive, and mixed methods). This tool was chosen since it is suitable to assess the diverse study types included in this review. Each study was assessed by 2 of the 3 authors, and in case of disagreement between authors, the

Table 1. Study characteristics.

Author (year)	Type	Study design	Use of wearable	Sample size	Female, *n* (%)	Age (range or mean [SD])	Country	Cancer diagnosis	Setting	Treatment type	Wearable
Primary use: prognostication											
Broderick (2013)[14]	Full-text article	Observational cohort study	Observational	25 (sub-group)	22 (88)	71.3 (5.0)	Ireland	Any	Pre-treatment	Chemotherapy/radiation therapy	RT3 accelerometer
Chang (2018)[16]	Full-text article	Observational cohort study	Observational	42 (sub-group)	8 (19)	74.3 (6.1)	Taiwan	Lung	Pre-treatment	Not specified	MicroMini Motionlogger Actigraph
Kuo (2020)[23]	Full-text article	Observational cohort study	Observational	33	6 (18)	74.8 (6.2)	Taiwan	Lung	Pre-treatment	Not specified	ActiGraph
Laderman (2024)[24]	Conference abstract	Observational cohort study	Observational	82	Not reported	Not reported	US	Gastro-esophageal	Pre-treatment On-treatment	Not specified	Fitbit
Richards (2020)[36]	Full-text article	Observational cohort study	Observational	85	43 (51)	Median 76 (IQR 72-81)	New Zealand	Colorectal	Pre-treatment	Surgery	Garmin Vivofit 3
Wong (2020)[40]	Conference abstract	Pilot/feasibility study	Observational	26	8 (31)	72	US	Any	On treatment	Not specified	Smartwatch (unspecified)
Yonenaga (2022)[42]	Full-text article	Observational cohort study	Observational	21	8 (38)	70-82	Japan	Lung	Pre-treatment On treatment	Chemotherapy	Kenz Lifecorder-GS
Primary use: treatment monitoring											
Feng (2023)[17]	Full-text article	Observational cohort study	Observational	47	0 (0)	65-88	Canada	Prostate	On treatment	Chemotherapy/ Radiation therapy/ Hormonal therapy	Smartphone or smartwatch
Jonker (2020)[22]	Full-text article	Pilot/feasibility study	Observational	47	16 (34)	65-85	Netherlands	Any	On treatment	Surgery	Fitbit Charge 2
Jonker (2021)[21]	Full-text article	Observational cohort study	Observational	58	20 (34)	72 (5)	Netherlands	Any	On treatment	Surgery	Fitbit Charge 2
Mir (2023)[30]	Full-text article	Pilot/feasibility study	Observational	7	7 (100)	74.9 (6.6)	US	Any	On treatment	Chronic systemic therapy	Accelerometer (unspecified)
Soto-Perez-de-Celis (2017)[38]	Full-text article	Pilot/feasibility study	Observational	40	23 (58)	Median 72.5	Mexico	Any	On treatment	Chemotherapy	Oppo R831 smartphone
Primary use: recovery											
Abad (2022)[12]	Conference abstract	Pilot/feasibility study	Intervention	22	Not reported	70-93	Spain	Hematological	On treatment	Not specified	Not reported
Blair (2021)[13]	Full-text article	Randomized controlled trial	Intervention	54	30 (56)	60-84	US	Any	Post-treatment	Chemotherapy/ Radiation therapy/ Surgery	Jawbone UP2/ Fitbit Alta/ ActivPAL3
Brown (2022)[15]	Full-text article	Pilot/feasibility study	Intervention	20	7 (35)	Median 73.3 (IQR 69.3-77.2)	US	Gastrointestinal	On treatment	Chemotherapy	ActiGraph GT3X+

Table 1. Continued

Author (year)	Type	Study design	Use of wearable	Sample size	Female, *n* (%)	Age (range or mean [SD])	Country	Cancer diagnosis	Setting	Treatment type	Wearable
Gell (2022)[18]	Full-text article	Randomized controlled trial	Intervention	39	31 (79)	70.4 (5.7)	US	Any	Post-treatment	Chemotherapy/ Radiation therapy/ Surgery	ActivPAL4
Harding (2022)[19]	Full-text article	Randomized controlled trial	Intervention	41	23 (56)	70.1 (4.4)	US	Any	Post-treatment	Not specified	ActivPAL3 micro/Jaw-bone UP
Jonker (2020)[20]	Full-text article	Observational cohort study	Observational	50	16 (32)	73 (5.4)	Nether-lands	Any	On treatment	Surgery	Fitbit Charge 2
Lafaro (2019)[25]	Full-text article	Pilot/feasibility study	Intervention	34	14 (41)	66-84	US	Any	On treatment	Surgery	Garmin Vivofit 3
Loh (2023)[26]	Full-text article	Pilot/feasibility study	Intervention	20	7 (35)	71.2 (4.8)	US	Hematolog-ical	On treatment	Chemotherapy	Garmin Fore-runner 35
Loh (2022)[27]	Full-text article	Pilot/feasibility study	Intervention	25	8 (32)	72 (4.9)	US	Hematolog-ical	On treatment	Chemotherapy	Garmin Fore-runner 35
Low (2024)[28]	Full-text article	Pilot/feasibility study	Observational	40	20 (50)	73.4 (4.9)	US		Post-treatment	Chemotherapy/ Radiation therapy/ Surgery	Fitbit Inspire 3/ smartphone
Maeda (2015)[29]	Full-text article	Observational cohort study	Observational	10 (sub-group)	Not reported	Control: 75 (7.9) Reha-bilitation: 72.4 (7.7)	Japan	Lung	On treatment	Surgery	Actimarker EW4800 P-K
Morikawa (2018)[31]	Full-text article	Observational cohort study	Observational	18	9 (50)	70-82	Japan	Lung	On treatment	Chemotherapy	Kenz Lifecord-er-GS
Naito(2018)[32]	Full-text article	Pilot/feasibility study	Intervention	30	10 (33)	70-84	Japan	Pancreatic/ Lung	On treatment	Chemotherapy	Kenz Lifecord-er-GS
O'Neil (2019)[33]	Conference abstract	Randomized controlled trial	Intervention	28 (sub-group)	Not reported	67 (8.7)	Canada	Prostate	On treatment	Not specified	Not reported
Owusu (2022)[34]	Full-text article	Randomized controlled trial	Intervention	213	213 (100)	71.9 (5.9)	US	Breast	Post-treatment	Chemotherapy/ radiation therapy/ surgery	Fitbit Blaze/ Versa
Pinto (2021)[35]	Full-text article	Randomized controlled trial	Intervention	20	19 (95)	71.6 (4.0)	US	Any	Post-treatment	Chemotherapy/ radiation therapy/ surgery	Fitbit Charge 2/ ActiGraph GT3X+
Sajid (2016)[37]	Full-text article	Pilot/feasibility study	Intervention	19	0 (0)	67-93	US	Prostate	On treatment	Hormonal therapy	Pedometer (unspecified)
Su (2015)[39]	Full-text article	Cross-sectional study	Observational	92 (sub-group)	39 (42)	73 (6.1)	Taiwan	Any	Post-treatment	Not specified	ActiGraph
Wu (2021)[41]	Conference abstract	Observational cohort study	Observational	10	3 (30)	71.8 (4.9)	US	Any	On treatment	Not specified	Actigraph watch (unspecified)

Table 2. Wearable outcomes.

Author (year)	Wearable outcomes					Other outcomes									
	Physical activity			Sleep		Quality of life	Functional status	Mood/ cognition	Fatigue	Toxicity/ complications	Hospitalization	Mortality	Body composition	Physical function	Cost
	Stepcount	Sedentary behavior	Activity intensity	Sleep / wake rhythm	Duration										
Primary use: prognostication															
Broderick (2013)[14]			✓											✓	
Chang (2018)[16]				✓								✓			
Kuo (2020)[23]				✓								✓			
Laderman (2024)[24]	✓						✓			✓	✓			✓	
Richards (2020)[36]	✓									✓	✓				
Wong (2020)[40]			✓				✓			✓	✓			✓	
Yonenaga (2022)[42]	✓		✓							✓	✓			✓	✓
Primary use: treatment monitoring															
Feng (2023)[17]	✓									✓					
Jonker (2020)[22]	✓														
Jonker (2021)[21]	✓									✓	✓				
Mir (2023)[30]															
Soto-Perez-de-Celis (2017)[38]	✓														
Primary use: recovery															
Abad (2022)[12]	✓				✓										
Blair (2021)[13]	✓	✓				✓			✓						
Brown (2022)[15]	✓		✓			✓								✓	
Gell (2022)[18]	✓		✓			✓	✓	✓	✓					✓	
Harding (2022)[19]	✓		✓												
Jonker (2020)[20]	✓		✓												
Lafaro (2019)[25]	✓					✓									

Table 2. Continued

Author (year)	Wearable outcomes					Other outcomes									
	Physical activity			Sleep		Quality of life	Functional status	Mood/ cognition	Fatigue	Toxicity/ complications	Hospitalization	Mortality	Body composition	Physical function	Cost
	Stepcount	Sedentary behavior	Activity intensity	Sleep / wake rhythm	Duration										
Loh (2023)[26]	✓					✓		✓	✓						
Loh (2022)[27]	✓					✓		✓	✓						
Low (2024)[28]	✓	✓												✓	
Maeda (2015)[29]			✓												
Morikawa (2018)[31]	✓		✓								✓				
Naito (2018)[32]	✓		✓										✓	✓	
O'Neil (2019)[33]		✓				✓			✓						
Owusu (2022)[34]	✓					✓			✓				✓	✓	
Pinto (2021)[35]	✓	✓	✓												
Sajid (2016)[37]	✓									✓	✓		✓	✓	
Su (2015)[39]			✓	✓											
Wu (2021)[41]	✓														
Total, n (%)	23/31 (74)	4/31 (13)	12/31 (39)	3/31 (10)	1/31 (1)	8/31 (26)	3/31 (10)	3/31 (10)	6/31 (19)	7/31 (23)	7/31 (23)	2/31 (6)	3/31 (10)	10/31 (32)	1/31 (3)
	28/31 (90)			4/31 (13)											

Table 3. Feasibility and adherence.

Author (year)	Planned wear time/cut-off valid wear time	Reported technical problems	Adherence or feasibility description (wearable specific)
Primary use: prognostication			
Broderick (2013)[14]	7 days/≥3 days		Mean (SD) wear time per patient: 5.6 (1.1) days
Chang (2018)[16]	3 days/not reported		Not reported
Kuo (2020)[23]	3 days/not reported		Not reported
Laderman (2024)[24]	3 days/not reported		84% wore device for ≥8 hours
Richards (2020)[36]	14 days/not reported		The wearable activity trackers were well tolerated with no patients re-moving the device during the 14-day period
Wong (2020)[40]	≥7 days/not reported		Not reported
Yonenaga (2022)[42]	12 ± 4 weeks/not reported		Not reported
Primary use: treatment monitoring			
Feng (2023)[17]	3 or 4 weeks/not reported		94% retention rate for physical activity monitoring. 90.5% median overall response rate of reporting physical activity
Jonker (2020)[22]	Preoperative + 3 months postoperative/not reported	✓	Compliance for wearing and synchronization of activity tracker median 90.0% (IQR 77.8-100) Median (IQR) wear time per patient: 81 (70–90) days
Jonker (2021)[21]	Preoperative + 3 months postoperative/not reported	✓	Not reported
Mir (2023)[30]	4 days/not reported		All participants rated the wrist accelerometer with adjustable Velcro band as "Easy." All participants rated the GeRI's touchscreen, user interface, and wearable wrist accelerometer as having "Excellent" or "Very Good" likeability.
Soto-Perez-de-Celis (2017)[38]	7 days + 21-28 days/days with ≥1 step		The patients were followed for a total of 840 days, with at least one step obtained in 91.5% of follow-up days (N = 768) Out of the 40 patients who completed follow-up, 37 (93%; 95% CI, 80%-97%) used the smartphone appropriately and recorded steps for ≥75% of the days of the total planned chemotherapy cycle
Primary use: rehabilitation			
Abad (2022)[12]	Not reported/not reported		55% of patients synchronized the wearable with their own mobile phone.
Blair (2021)[13]	7 days/not reported	✓	100% of patients reported wearing the device on most days Mean (SD) wear time per patient: 6.7 (0.7) days
Brown (2022)[15]	12 weeks/≥4 days with ≥10 hours per day		Not reported
Gell (2022)[18]	7 days/not reported		Not reported
Harding (2022)[19]	7 days/≥4 days with ≥10 hours per day	✓	13% (6/47) incomplete data from physical activity monitor Mean (SD) wear time per patient: Intevention 6.8 (0.8) days. Control 6.7 (0.5) days
Jonker (2020)[20]	Preoperative + 3 months postoperative/not reported		74% (37/50) had valid data at end of follow-up period
Lafaro (2019)[25]	Preoperative + 14 days postoperative/not reported		Not reported
Loh (2023)[26]	4-7 days prior to intervention + 8-12 weeks during intervention/not reported		Not reported
Loh (2022)[27]	4-7 days prior to intervention + 8-12 weeks during intervention/not reported		82% (18/22; 95% CI, 0.60-0.95) of patients entered steps data in app during intervention
Low (2024)[28]	4 weeks/days with ≥8 hours wear time	✓	Mean (range) wear time per patient—Fitbit: 26 (12-29) days; phone: 15 (0-29) days)
Maeda (2015)[29]	5-6 days before surgery and 5-6 days 2 months after surgery/not reported		Not reported

Table 3. Continued

Author (year)	Planned wear time/cut-off valid wear time	Reported technical problems	Adherence or feasibility description (wearable specific)
Morikawa (2018)[31]	7 days + hospitalization duration + 21 days/days with ≥5 hours wear time		Not reported
Naito (2018)[32]	7 days + 6-10 weeks/days with ≥5 hours wear time		Patients wore pedometers/accelerometers ≥5 hours a day for a median of 98% of the total intervention days.
O'Neil (2019)[33]	3 months/not reported		Not reported
Owusu (2022)[34]	20 weeks/not reported		Not reported
Pinto (2021)[35]	7 days + 12 weeks/not reported		100% found the Fitbit to be helpful for physical activity 89% of the sample (17/19) wore the Fitbit on>90% of study days
Sajid (2016)[37]	12 weeks/not reported		Not reported
Su (2015)[39]	≥3 days/not reported		Not reported
Wu (2021)[41]	Not reported/not reported		Total of 3624 days actigraphy data (210 ± 88 days pre-cancer; 153 ± 81 days post-cancer)

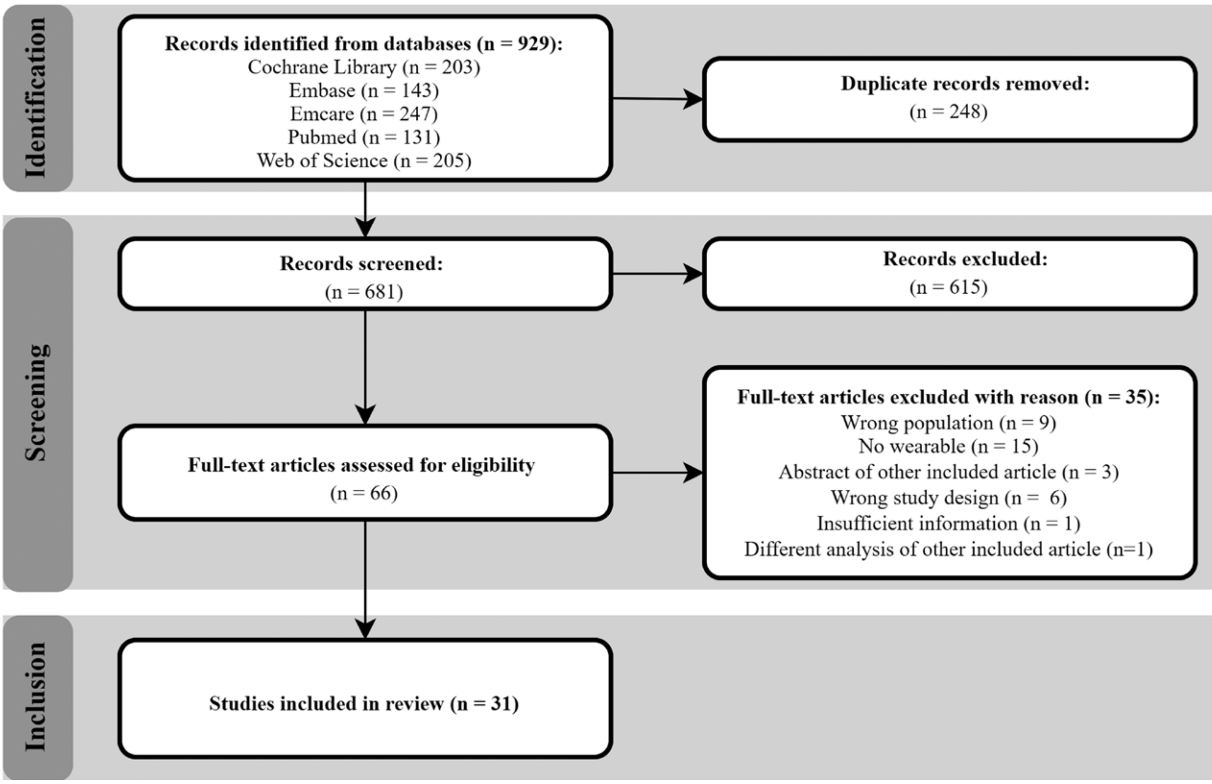

Figure 1. Study selection based on PRISMA methods.

third author was involved to make the final decision. Quality assessments are presented per study since reporting summary statistics based on this tool is discouraged.

Results

The flowchart of the study selection process is presented in Figure 1. Initially, our search yielded 929 records, which were subsequently refined to 681 after the removal of duplicates. These records underwent screening based on title and abstract, leading to the assessment of 66 articles for eligibility through full-text review. Following this comprehensive evaluation, 35 records were excluded, resulting in a final inclusion of 31 articles in our review.[12-42]

Study characteristics

Table 1 provides an overview of the general characteristics of the included studies. A total of 1298 older patients were included in the 31 studies, with a median sample size of 33 (interquartile range [IQR] 20 – 47). Among these, 12 were pilot or feasibility studies, 12 were observational studies, 6 were randomized controlled trials, and 1 was a cross-sectional study. The studies were distributed geographically as follows: 18 in North America, 7 in Asia, 5 in Europe, and 1 in Oceania. Of the 31 studies reviewed, 16 (52%) included patients with any type of cancer, 5 (16%) focused specifically on lung cancer, 3 (10%) on hematological cancers, 3 (10%) on prostate cancer, and 1 study each (3%) on breast cancer, colorectal cancer, gastroesophageal cancer, gastrointestinal cancer, and pancreatic cancer combined with lung cancer. Seven studies (23%) were conducted in patients undergoing multiple treatment types, 7 studies (23%) in patients undergoing chemotherapy, 6 (19%) in patients undergoing surgery, 1 (3%) in patients with hormonal therapy, and 1 (3%) in patients with chronic systemic therapy. In 9 studies (29%) treatment type was not specified. The quality of the studies, assessed with a mixed-method appraisal tool is reported in Supplementary Section 3. Briefly, 2 of the 31 studies did not pass the 2 screening questions and might therefore not be suitable to be assessed using this screening tool.[24,40] Of the 29 studies which passed the screening questions, 27 studies had one more quality criteria answered as "no" or "can't" tell.

Wearable characteristics

When considering the primary use of the wearable, 7 studies (23%) used wearable data for prognostication, 5 studies (16%) used wearable data for treatment monitoring, and 19 studies (61%) used wearable data for measuring or improving recovery. Wearables were employed as part of a health intervention in 13 studies (42%), while in 18 studies (58%) they were used solely for observational purposes. Six out of 7 prognostic studies conducted wearable measurements before treatment, while the treatment monitoring and recovery studies all had wearable measurements performed either during or after treatment. Wrist-worn devices were the most used type of wearable (20 studies, 65%), either with multiple sensors (15 studies, 38%) or accelerometer only (5 studies, 16%). Other types of wearable devices used were waist-worn accelerometers in 6 studies (19%), thigh-worn accelerometers in 3 studies (10%), and mobile phones in 3 studies (10%). Four studies (13%) did not report on the type of wearable used. The most reported wearable device brands were Fitbit in 8 studies (26%) and Garmin in 4 studies (13%). Seven studies (23%) did not report on the brand of wearable used. The duration of planned wearable device use ranged from 3 days to 20 weeks. All studies collected wearable data for retrospective review and none of the studies utilized live monitoring of wearable data.

Outcome measurements

Table 2 provides an overview of the outcome measures in the included studies. Physical activity measured by wearable devices was reported in 28 out of the 31 studies (90%). Measures of physical activity included step count (23 studies), sedentary behavior (4 studies), and activity intensity (12 studies) (Table 2). Sleep as measured by wearables, was reported in 4 out of 31 studies (13%). Measures of sleep included sleep/wake rhythm (3 studies) and sleep duration (1 study). Wearable-related outcomes were assessed in combination with quality of life (8 studies), fatigue (6 studies), mood/cognition (3 studies), functional status (3 studies), toxicity and complications (7 studies), hospitalization (7 studies), mortality (2 studies), body composition (3 studies), physical function (10 studies), and costs (1 study). Physical activity was most frequently measured using a wrist-worn device with multiple sensors (13 studies), while wrist-worn accelerometers were most used to measure sleep (3 studies).

Feasibility and adherence

Table 3 presents data on the results on feasibility and adherence of the studies. Seven of the 31 studies (23%) set a criterion for defining a valid wear day. Of these, 6 studies used a time-based cutoff while one study used a data-based cutoff (at least 1 step). Adherence specific to the wearable device was reported in 11 of the 31 studies (35%). Adherence ranged from 74-100%, although it was differently measured and reported. Total days of wearable data or wear days per patient were reported in 5 studies. Other feasibility descriptions related to wearables were reported in 5 of the 31 studies (16%). These measures included: synchronizing the wearable device (2 studies), retention (1 study), and user experience (2 studies). Technical issues were reported in 5 of the 29 studies (16%). Reported technical issues included malfunction of wearable (1 study), inability to retrieve data due to wearable manufacturer discontinuation (1 study), smartphone not suitable to run the required wearable-synchronization app (1 study), and not further specified (1 study).

Discussion

Principal findings

Our systematic review found, considering the number of older people with cancer, relatively few studies assessing the use of wearable technology in older patients with cancer. Furthermore, these studies showed significant heterogeneity. This heterogeneity is found across study design and reporting, including the type of wearable used, the moment in the cancer care continuum where wearable technology is intended to be implemented, and the types of measured outcomes. Studies utilizing wearables among older adults with cancer mostly measured physical activity or sleep and were intended for observation or monitoring rather than for interventions. Although we found many pilot studies, there was a paucity of implementation studies. Approximately a third of included studies reported on adherence to the wearable device, which represents a common question when testing technology among older individuals. Although these adherence measures were highly heterogeneous, most studies reported high levels of adherence, highlighting that wearables can be utilized among older populations.

Comparison with prior work

As far as we are aware, this is the first systematic review focusing specifically on studies that assess the use of wearables in the older cancer population. When comparing our results to those of a recent systematic review on wearables in the general oncologic population,[7] several differences and similarities emerge. Notably, the scope of the review by Chow et al[7] was 199 studies, while our review only found 31 relevant studies. The median sample size of the studies included in our review was 33, which is somewhat smaller compared to the median sample size of 46 reported by Chow et al.[7] Furthermore, a large proportion of the studies in both reviews were conducted in the US, with 43% in our review and 51% in the general oncology review. Both reviews identified physical activity as the most frequently reported wearable outcome, although it should be noted that studies that reported solely on wearables for sleep were excluded in the other review. Furthermore, none of the studies in our review examined heart rate as a wearable outcome, while it was reported in 12 studies (6%) in the general oncology review. Recovery/rehabilitation was found to be the most common intended use of wearable data in both reviews.

Considering feasibility and adherence, we found that 35% of included studies reported adherence specific to the wearable device, which is comparable to the 43% reported in the general oncologic population.[7] Adherence rates in our review ranged from 74% to 100%, aligning with the high adherence rates reported by Chow et al, where 73% of studies reported adherence exceeding 80%. Another review by Beauchamp et al,[43] which focused on the use of wearables during cancer treatment and included only studies that reported on adherence, showed adherence rates ranging from 45% to 100%, with only 20% of studies reporting adherence below 75%. In our review, valid wear time was defined in only 23% of studies, a large difference from the 64% of studies defining valid wear time in Beauchamp et al's review, perhaps indicating that studies reporting on adherence are also more likely to define valid wear time. Additionally, only 16% of studies in our review reported technical difficulties, leaving ambiguity as to whether the actual rate of technical issues is low or merely underreported.

The combination of the low number of studies, the heterogeneity, and the small sample sizes, limit the ability to draw strong conclusions. However, the above-mentioned findings suggest that, despite some differences, the trends observed in wearable use in geriatric oncology research align with those with research trends in the broader oncologic population, albeit on a smaller scale. Despite the variability in measures used, most studies included in our review indicated high adherence and feasibility, underscoring the potential of wearable devices in the older population as well. So, considering this evidence, there is no reason to exclude older adults with cancer from these innovative techniques.

Low- and middle-income countries

Another significant barrier to interpretation, also present in other areas of cancer care, is the disproportionate availability of studies conducted in high-income countries (HICs). The lack of data from low- and middle-income countries (LMICs) is particularly concerning since these settings could potentially benefit the most from mobile technologies, including wearable devices, to improve access to care.[44] Currently, the predominance of research on wearables in older adults with cancer being conducted in HICs risks widening the digital divide between regions and excluding a significant proportion of the aging population.[45] Mobile health interventions are increasingly complex due to the rapidly evolving characteristics of digital technology and the reliance of their outcomes on human behavior.[46] Consequently, interventions effective in one setting may not be suitable for another, underscoring the importance of local community involvement and engagement for successful implementation.

Designing and implementing wearable studies in LMICs has several challenges. These include inadequate infrastructure, limited availability of equipment, lack of interoperability, and difficulties integrating with existing healthcare information systems. Addressing and overcoming these barriers is essential for conducting successful studies.[47,48] Despite these challenges, there are numerous opportunities for improving access to wearables for older adults with cancer in LMICs, and researchers across the globe should build collaborations to achieve this objective. Recent advances in communications and computing, including the advent of artificial intelligence, the massive connectivity of the growing 5G networks, and the reduced cost of wearables and sensors, could lead to improved access to high-quality digital health.[49,50]

Future research

Before the widespread implementation of wearables in clinical practice can occur, more robust and homogeneous studies are needed to confirm their effectiveness. We propose several avenues for future research in this field. Researchers should strongly consider including implementation measures to demonstrate cost-effectiveness or cost-benefit, considering local and/or regional economic, social, and cultural contexts. Additionally, mobile phones are relatively underused and could represent widely available and cheap wearable sensors. Furthermore, modern wearables could provide insight into other parameters than activity and sleep, such as heart rate variability, temperature, and stress levels. Studying these different biometrics could potentially provide novel insights. Moreover, while using wearables for real-time monitoring could potentially detect side effects or toxicity earlier, this also comes with additional logistical overhead and should be explored further.

Our results revealed a significant degree of heterogeneity in both outcomes and feasibility measures employed across the included studies. This variability makes it challenging to compare and draw meaningful conclusions about the effectiveness of wearable technology in geriatric oncology. To address this issue and enhance the reliability of future research, it is essential to develop standardized outcome, adherence, and feasibility measures that can be consistently employed across studies. The establishment of uniform measures could reduce variability and improve comparability, thereby facilitating more robust assessments of wearable interventions. In addition to the need for standardized outcomes, we propose several recommendations that can be readily incorporated into the reporting of wearable studies (Box 1). By consistently reporting these elements, researchers can improve the robustness and comparability of studies involving wearable technology: specify the brand and model of the wearable device used in the study, as different devices may have varying accuracy and features (brand and type of wearable); clearly outline the expected duration for which participants are intended to wear the device (planned wear time); provide a precise definition of what constitutes valid wear time, including any thresholds or criteria used (definition valid wear time); report the average wear time achieved by each participant, highlighting

Box 1: Reporting recommendations for wearable studies.

Wearable study reporting recommendations

- Brand and wearable type
- Planned wear time
- Definition valid wear time
- Actual wear time
- Adherence
- Technical issues

any deviations from the planned wear time (actual wear time per participant); report the level of adherence to the wear protocol by the participants, noting any factors that may have influenced compliance (adherence); document any technical problems experienced during the study, including device malfunctions or data recording errors (technical issues).

Strengths and limitations

This review has several strengths. As far as we are aware, this study is the first to comprehensively assess both the feasibility and outcomes of studies on wearables in older adults with cancer. We conducted an extensive and systematic literature search, and each full-text article was evaluated by at least three independent reviewers. However, limitations also apply. One limitation of this review is the exclusion of non-English language studies, which may have resulted in the omission of relevant research published in other languages. Furthermore, the heterogeneity of the studies limited our ability to draw strong conclusions, such as associations between wearable measures and clinical outcomes. This heterogeneity also limited our ability to perform a uniform quality assessment. To surpass this limitation, we used a valid mixed-methods tool to assess each study's quality. Additionally, the categorization of outcome measures may be subject to bias, potentially influencing the interpretation of results. Despite these limitations, our study provides a comprehensive overview of the current state of research on wearables in older adults with cancer and identifies gaps in current study design and reporting.

Conclusions

This systematic review of 31 studies on the use of wearable technology among older adults with cancer demonstrates that wearables have mostly been utilized to measure physical activity and sleep and are most frequently used for assessing recovery after treatment. The review reveals a geographic disparity, with most research conducted in HICs, underscoring the necessity for inclusive research efforts in LMICs. Overall, studies reported high adherence, although definitions of adherence were heterogeneous. Based on this finding we have provided recommendations for future studies, in addition to the need for standardized reporting guidelines. Despite these challenges, wearables hold promise in both providing continuous at-home measurements and enhancing accessibility to care for older patients with cancer across the care continuum.

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Author contributions

Jan J. Duin: Conception/design, collection and/or assembly of data, data analysis and interpretation, manuscript writing, final approval of manuscript. Joosje C. Baltussen: Conception/design, collection and/or assembly of data, data analysis and interpretation, manuscript writing, critical revision of the manuscript, final approval of manuscript. Gali Albalak: Conception/design, data analysis and interpretation, manuscript writing, final approval of manuscript. Eléonore F. van Dam van Isselt: Conception/design, critical revision of the manuscript, final approval of manuscript. Johanneke E.A. Portielje: Conception/design, critical revision of the manuscript, final approval of manuscript. Simon P. Mooijaart: Conception/design, critical revision of the manuscript, final approval of manuscript. Enrique Soto-Perez-de-Celis: Conception/design, collection and/or assembly of data, data analysis and interpretation, manuscript writing, critical revision of the manuscript, final approval of manuscript. Frederiek van den Bos: Conception/design, collection and/or assembly of data, data analysis and interpretation, manuscript writing, critical revision of the manuscript, final approval of manuscript.

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Conflicts of Interest

None declared.

Data availability

The search strategy is available in the appendix, and any additional data are available on reasonable request to the corresponding author.

Supplementary material

Supplementary material is available at *The Oncologist* online.

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