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Current Landscape of Ecological Momentary Assessment (Real-Time Data) Methodology in Cancer Research: A Systematic Review

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ABSTRACT

Objective: To critically synthesize and describe the use and methods of ecological momentary assessment (EMA) in cancer research.
Data Sources: A systematic review was conducted and has been reported according to the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) Guideline. Electronic databases (APA PsycINFO, CINAHL, Cochrane Central Register of Controlled Trials, MEDLINE, Scopus, and Web of Science Core Collection) were searched using a variety of keywords and subject headings by an expert systematic review librarian. All publications were double screened by two reviewers using predetermined exclusion and inclusion criteria throughout the full review process. The review used Covidence Systematic Review Software. Methodological quality assessment and data extraction were performed. A narrative synthesis was conducted to examine the aim for EMA, the characteristics of the study samples, the EMA sampling procedures, EMA completion rates, outcome measures, and any implications of findings for survivorship care.
Conclusion: A total of 42 EMA studies in cancer were included. Most studies used an electronic mobile device to capture EMA data apart from several that used paper diaries. Existing studies were found to have significant heterogeneity in methods and widely varying approaches to design and self-report measurements. While EMA in cancer research holds significant promise to advance cancer care research into the future by increasing ecological validity and reducing retrospective bias and can capture the unique idiographic within-person change over time, in real-time, further research is needed to develop standardized EMA self-report questionnaires.
Implications for Nursing Practice: This is the first comprehensive systematic review to describe the use and methods of EMA in cancer research. There is significant heterogeneity in methods and widely varying approaches to design and self-report measurements in EMA cancer research. People affected by cancer found taking part in EMA studies reported benefit from the experience. However, researchers must engage with cancer survivors in the development and co-design of future EMA questionnaires to ensure relevant and acceptability of EMA data collection protocols.

Introduction

Historically, assessment of patient experiences has been conducted by standardized patient reported outcome instruments and qualitative study designs, both of which are prone to retrospective questioning and retrospective memory recall bias. When people are asked how they felt or how often some event occurred commonly they will rely on heuristic strategies or will rely on experiences that are recent or important for them to estimate an answer.[1] Therefore, the real-life validity of data presented from existing studies using these designs is unknown.[2] Within the suite of self-report measures the ecological momentary assessment (EMA) methodology captures real-time, real-world, self-reports in participants naturalistic environments.[3-5] The EMA method is uniquely designed to capture momentary data collection in participants natural home environments at multiple time points, and there are several cardinal advantages within cancer research. First, EMA eliminates retrospective memory recall bias completely, because it captures data in real-time in that moment for the participant rather than a summary of responses based upon memory. Second, the EMA data collection

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occurs in the participants' home, which in turn increases the ecological validity of the assessments. Third, because EMA captures repeated detailed in-depth assessments (which may include several times in the course of a day, weeks, or even months) about quality of life, symptoms (frequency, bother, and severity), and behaviors, it can identify individuals unique experiences, and expose subtleties in behaviors, symptoms, and cognitions over time.[6] Finally, EMA can provide valuable insights in time-varying relationships and dynamics between cognition, behavior, and symptoms and its correlations.[1,2,4]

EMA is now being increasingly used to assess behaviors and health-related symptoms in a variety of conditions, including pain,[7] asthma,[8] heart disease,[9] arthritis,[10] stress-related diseases,[11] and now cancer.[12,13] Many individuals affected by cancer can experience significant suffering and distress as a consequence of cancer and its associated treatments.[14] In the main, evaluations of patient sensitive outcomes within cancer are based on retrospective patient-reported outcome measures (PROMs) and qualitative evaluations which have provided insight into the past experiences, but noteworthy, not their current present reality in the context of cancer. There are many advantages of EMA for cancer care research, and there has been an observed increase in the use of technologies to implement EMA which has translated to a large uptake of EMA studies in cancer. However, it is important to point out that EMA is a highly specialized research method and knowledge of its implementation in the cancer context is important. For example, the EMA method can be interval, signal, and event contingent protocols.[1,3,5] An interval contingent design requires the participant to record their self-report at predetermined intervals. A signal contingent data collection protocol will prompt the participant by a signaling alert (that is, an audio sound or vibrations) at fixed or random time intervals. Whereas an event contingent protocol is based on incidents of interest in phenomenon whereby participants will complete a self-report each time a particular experience of interest occurs. Furthermore, little is known about the effects of EMA among people affected by cancer and whether it causes distress triggered by the constant reminders of living with cancer and thereby noting the associated negative impacts on quality of life.[15] Existing research has identified that such approaches can expose methodological complexities in cancer research.[15] These complexities can include: 1) reactance, 2) habituation, 3) increased complexity, and 4) gradual entrainment.[1,15] Reactance can occur if the participants change their behavior as a result of completing the EMA. A reactive measure is one that changes the phenomenon it is designed to assess. This effect is desirable if the measurement occurs as part of an intervention aimed at changing behavior but is problematic when the measurement designed over time is used only to assess the phenomenon of interest. Habituation has been described as the development of habitual responses when completing the self-report, that is, a tendency to skim over questions that rarely apply to the participants' experience.[1] Increased complexity refers to the development of a more advanced understanding of a particular construct as a result of repeated exposure to the surveyed domain, whereas gradual entrainment has been described as participants changing their conceptualization of their illness to fit with those measured in the self-report. It is well recognized that the sampling of the EMA places significant burden on participants to complete, and therefore important consideration must be taken for people affected by cancer.

This systematic review aimed to summarize and comprehensively describe the use and methods of EMA in cancer research. The main purpose of this systematic review was to examine the aim for EMA, the characteristics of the study samples, the EMA sampling procedures, EMA completion rates, outcome measures, and any implications of findings for supportive care. The rationale for this review is that by reporting these aspects improvements can be made in reproducibility and assist in future research to clarify the significance of EMA design decisions in the context of cancer.

Method

A systematic review has been reported according to the referred reporting items for systematic reviews.[16] This systematic review was conducted according to a protocol registered with PROSPERO (CRD42022379986).

Search Strategy

A systematic literature search was conducted by an expert systematic review librarian. The following electronic databases were searched: APA PsycINFO, CINAHL, Cochrane Central Register of Controlled Trials, MEDLINE, Scopus, and Web of Science Core Collection. Searches used a variety of keywords and subject headings, for example (ecological momentary assessment, EMA, electronic device, electronic diaries, self-report, e-PREMS, e-PROMs, daily diary, mobile, device, technology, etc.) See Supplementary Table 1 for the full record of database searches. The goal was to identify all previous EMA studies in cancer research and the search terms were inclusive to capture all EMA studies whereby the authors themselves may not have mentioned EMA to limit any unintentional exclusion of studies in the current systematic review. Electronic databases were searched from inception until June 2023.

Eligibility Criteria

Study design

All studies in cancer that had reference to EMA were included and related EMA methods. All commentaries, editorials, and studies that did not present empirical data or studies that captured real-time assessments of self-reports as part of an intervention were excluded from the review. The included studies had one or more assessments per day.

Types of participants

All participants affected by cancer, irrespective of age, cancer type, stage, treatment, time since diagnosis, or treatment were included. All other clinical population groups were excluded.

Types of outcomes

All assessments of variables captured in EMA studies were included irrespective of the context of cancer. Outcomes included the characteristics of the study samples, the EMA sampling procedures, EMA completion rates, outcome measures, and implications of findings for supportive care.

Selection of studies

Following the search, all identified citations were exported to Endnote and then imported into Covidence systematic review software. All duplicates were removed in Covidence. All titles and abstracts were screened independently by two reviewers (CP and LA). Then all full-text articles were assessed according to the inclusion and exclusion criteria by both reviewers. Throughout the review process, all conflicts were resolved by discussion. Full-text studies that did not meet the inclusion criteria were excluded with reasons, and the study selection process was described using the PRISMA flow diagram.[16]

Data extraction

Data were tabulated in a study characteristics table, which included: sample characteristics (sample size, age, gender, cancer

tumor, stage of the disease, time since diagnosis or treatment, comparison groups, and country of investigation), EMA data collection methods, the type of device, application name and operating system, the EMA study schedule, monitoring periods which reported on monitoring duration (number of days) and period (number of times per day), participation rate, attrition rate, missing data, incentives, outcome measures, and any implications of findings for supportive care. Data were extracted by one reviewer and quality-checked by a second reviewer. The data extraction table was designed using the adapted STROBE Checklist for Reporting EMA Studies (CREMAS).[17] Data extraction was conducted by two review authors and cross-checked to ensure quality assurance processes were maintained during this activity.

Data synthesis

A narrative synthesis approach was used to summarize the evidence.[18] This process involved a tabulation of primary research studies, identifying similarities and differences within and between studies, and seeking explanations for these differences. The analysis implicated the following steps: data reduction and subgroup classification based on EMA characteristics and the review aims, narrative data comparison (iterative process of making comparisons and identifying relationships), and, finally, drawing conclusions. Data synthesis was conducted by two review authors (CP and LA).

Methodological Quality Assessment

A methodological quality assessment was undertaken using the mixed-methods assessment tool (MMAT).[19] Noteworthy, previous EMA reviews[6,7,12,13] have not included a quality assessment of their included studies; therefore, little is known about the quality of existing EMA studies. A further methodological quality assessment consideration is that EMA studies do not have questionnaires readily available to researchers with demonstrated reliability or validity. In the main they have been developed from existing retrospective standardized PROMs. Given these considerations this review also used the COSMIN method for evaluation of self-report PROMs[20] to assess reliability and validity of the EMA PROMs used in the included studies.

Findings

The results of the electronic database search identified 506 publications, a further 6 publications were identified by citation searching, and 42 studies were included, see Fig 1. Existing EMA studies were conducted in United States of America (n = 28), United Kingdom (n = 3), Spain (n = 1), The Netherlands (n = 2), Switzerland (n = 1), South Korea (n = 1), New Zealand (n =1), Canada (n = 1), Australia (n = 1), Mexico (n =1), Germany (n = 1), and multicountry (n = 1) (see Table 1). Overall, the methodological quality of the included studies was good (see Table 2). However, the assessment of EMA PROMs according to COSMIN[20] criteria underscored that none of the included studies reported validity or reliability in any of their measures (see Supplementary Table 2), and this should be an important focus for future research to move the EMA field forward.

Aim of EMA in Cancer

It was apparent that existing EMA studies in cancer had a broad and heterogeneous focus in research aims. Studies used EMA to measure and assess cognitive predictors of physical activity[21-27] and sleep,[28] whereas other studies measured thoughts, affect and

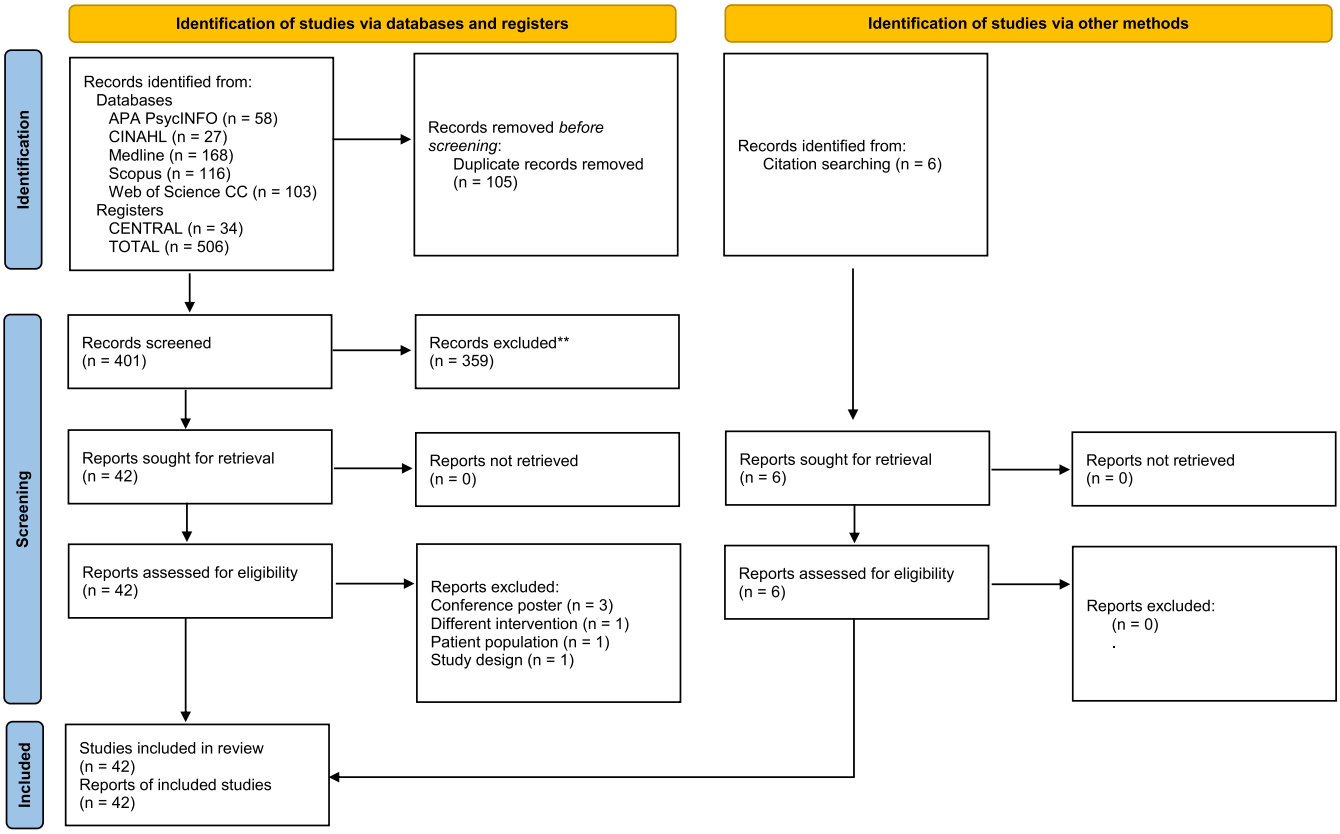

Figure 1. PRISMA Flow Diagram.

Table 1
Study Characteristics.

Study Characteristics Authors and Country	Aim	Participant Characteristics	EMA Data Collection Methods Outcomes	System Characteristics	EMA Schedule	Response-Related Results
Abraham et al, 2015	To explore cross-cultural experiences of women taking estrogen plus progestin therapies (EPT) and develop a symptom-based electronic diary (eDairy) and impact questionnaire for EPT-related breast symptoms	Sample size: N=20 Cancer Type: Breast cancer Treatments: EPT Cancer Stage: Not specified Age: Postmenopausal Gender: women Treatment trajectory: Country of origin: USA	Primary outcome: Descriptions of breast sensations associated with EPT and impact on HRQL Secondary outcomes: Experience of completing eDiary	Device: hand-held electronic device (eDiary) Application name: BPT-DD Operation system: Not specified	Monitoring periods: 1 time per day Duration: 12−14 days Data sampling: Interval contingent Prompts frequency: Not specified Prompt interval: Not specified Snooze option: Not specified	Participation rate: 18/20 Attrition: Not specified Missing data: Not specified Incentive: Not specified
Aigner et al 2016	To examine the association between pain and smoking among cancer patients with pain enrolled in a smoking cessation treatment program	Sample size: N= 34 Cancer Type: Breast, lung, and head and neck Treatments: Chemotherapy, hormone therapy, radiation therapy, and multiple therapies Cancer Stage: Age: 52 years (SD 10−30) Gender: 55% women Treatment trajectory: Country of origin: USA	Primary outcome: Immediate precipitants of smoking behavior among cancer patients enrolled in cessation treatment Secondary outcomes:	Device: palmtop personal computer (PPC) Application name: 20 HP iPAQ H1945 PPCs Operation system: Window Mobile 5	Monitoring periods: 1 time per day Duration: 2-weeks Data sampling: Interval contingent Prompts frequency: Not specified Prompt interval: Not specified Snooze option: Not specified	Participation rate: 73% Attrition: Not specified Missing data: Not specified Incentive: Not specified
Ainsworth et al, 2018	To evaluate the acceptability of the Life in a Day app for time use among breast cancer survivors	Sample size: N=40 Cancer Type: Breast cancer Treatments: Surgery, radiation and/or Chemotherapy Cancer Stage: I, II, IIIa Age: 55 years (SD 8) Gender: 100% female Treatment trajectory: Not specified Country of origin: USA	Primary outcome: Life in a Day app user experience Secondary outcomes: Shifts in time use	Device: Smartphone Application name: Life in a Day Operation system: iOS or Android	Monitoring periods: Log all activities 24-hours a day Duration: 5 days Data sampling: Event contingent Prompts frequency: Not specified Prompt interval: Not specified Snooze option: Not specified	Participation rate: 100% Attrition: Not specified Missing data: Not specified Incentive: Not specified
Aldaz et al, 2019	The aim of the study was to explore the covariation of daily fluctuations in treatment-related distress and well-being with illness uncertainty and experiential avoidance of uncertainty-related thoughts and/or emotions in patients with cancer across a week of oncology treatment with curative intent	Sample size: N=31 Cancer Type: Mixed cancers Treatments: Chemotherapy, radiotherapy, Herceptin, hormonal therapy and surgery Cancer Stage: I−IV Age: 60 years (SD 14) Gender: 61.3% female Treatment trajectory: Country of origin: New Zealand	Primary outcome: Daily treatment-related distress and well-being Secondary outcomes: daily illness uncertainty and experiential avoidance	Device: Paper-based daily diary Application name: N/A Operation system: N/A	Monitoring periods: once a day in the evening Duration: 7 days Data sampling: Interval contingent Prompts frequency: Not specified Prompt interval: Not specified Snooze option: Not specified	Participation rate: 87.1% Attrition: Not specified Missing data: 1.8% Incentive: $20 grocery voucher
Auster- Gussman et al, 2022	To use EMA assessments of concurrent and previous day exercise self−efficacy, physical outcome expectations, psychological outcomes expectations, and goal setting combined with objectively measured moderate−vigorous and light intensity physical activity to prospectively examine the relationship between these SCT constructs and daily physical activity	Sample size: N= 67 Cancer Type: Breast cancer Treatments: Chemotherapy Cancer stage: I, II, III Age: 48.5 years (SD 10.3) Gender: 100% female Treatment trajectory: During treatment Country of origin: USA	Primary outcome: Social cognitive theory Secondary outcomes: Not specified	Device: AntiGraph Application name: wGT3X−BT, AntiGraph Corporation Operation system: Device: SMS link- online questionnaire Application name: Not specified Operation system:	AntiGraph Monitoring periods: Continuous monitoring Duration: 10 days Data sampling: Interval contingent Prompts frequency: No Prompt interval: Not specified Snooze option: Not specified SMS: EMA Monitoring periods: am and pm Duration: 3 × 10 days Data sampling: signal contingent Prompts frequency: 3 Prompt interval: 15 minutely Snooze option: Not specified	Participation rate: 84% Attrition: Not specified Missing data: Not specified Incentive: Not specified

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Table 1 (*Continued*)

Study Characteristics Authors and Country	Aim	Participant Characteristics	EMA Data Collection Methods Outcomes	System Characteristics	EMA Schedule	Response-Related Results
Badr et al, 2006	To determine the feasibility of using electronic diaries to assess physical activities and cancer symptom burden in breast cancer (after completing chemotherapy) and ovarian cancer (still undergoing chemotherapy).	STUDY 1 Sample size: N=23 Cancer Type: Breast cancer Treatments: Chemotherapy Cancer Stage: I, II, III Age: 56.7 years (SD 10.2) Gender: Not specified Treatment trajectory: Post treatment STUDY 2 Sample size: N=42 Cancer Type: Ovarian cancer Treatments: Carboplatin, Paclitaxel or both Cancer Stage: Stage III or IV Age: 58.3 years (SD 11.1) Gender: 100% Female Treatment trajectory: Active treatment Country of origin: USA	Primary outcome: Physical activity and cancer symptoms Secondary outcomes: Mood states	STUDY 1 Device: Electronic Diary Application name: Palm M100 or M105 and Palm Zires Operation system: Not specified STUDY 2 Device: Electronic Diary Application name: Palm M100 or M105 and Palm Zires Operation system: Not specified + weekly retrospective questionnaires for physical function and emotional wellbeing	STUDY 1 Monitoring periods: 4 times per day Duration: 7 days Data sampling: Signal contingent Prompts frequency: Not specified Prompt interval: Not specified Snooze option: Not specified STUDY 2 Monitoring periods: 4 times per day Duration: 1 Chemotherapy cycle-approx. 3 weeks Data sampling: Signal contingent Prompts frequency: Not specified Prompt interval: Not specified Snooze option: Not specified	STUDY 1 Participation rate: 69% Attrition: Not specified Missing data: Not specified Incentive: Not specified STUDY 2 Participation rate: 79% (study); 86% (assessments) Attrition: 26% Missing data: Not specified Incentive: Not specified
Badr et al, 2010	To assess the unique effects of patient and partner pain appraisals on mood and relationship function	Sample size: N= 59 couples Cancer Type: Metastatic breast cancer Treatments: Cancer Stage: stage 4 Age: 49 years (SD 10.76) and partner 51 years (SD 11.51) Gender: women; partners male Treatment trajectory: Not reported Country of origin: USA	Primary outcome: Patient's pain, and partners mood, the provision/receipt of social support Secondary outcomes: The degree to which cancer interfered with their relationship	Device: ePalm Tungsten E or E2 computers Application name: Not specified Operation system: Not specified	Monitoring periods: 6 times per day Duration: 14 days Data sampling: signal contingent Prompts frequency: A stratified-random sampling scheme Prompt interval: alarm signal Snooze option: Not specified	Participation rate: 69.78% Attrition: Missing data: 34% Incentive: $80 gift card
Badr et al, 2013	To evaluate whether social-cognitive theory variables, as measured by questionnaire and ecological momentary assessment, predicted exercise in endometrial cancer survivors	Sample size: N=97 Cancer Type: Endometrial cancer Treatments: Surgery, radiation and/or Chemotherapy Cancer Stage: I, II, IIIa Age: 57 years (SD not specified) Gender: 100% female Treatment trajectory: Not specified Country of origin: USA	Primary outcome: Self-efficacy Secondary outcomes: Physical activity	Device: Hand-held computer Application name: Not specified Operation system: Hewlett-Packard iPAQ RX1950 Device: Accelerometer Application name: GT1M Operation system: ActiGraph	Monitoring periods: Wake, sleep times and physical activity participation Duration: 4 × 10/12 days (baseline, 2 months, 4 months, and 6 months) Data sampling: Interval contingent Prompts frequency: Not specified Prompt interval: Not specified Snooze option: Not specified	Participation rate: 97% Attrition: Not specified Missing data: Not specified Incentive: $40 for laboratory assessments; EMA incentive prorated on compliance $5−$30 per period.
Basen-Engquist et al, 2013	To evaluate whether social-cognitive theory variables, as measured by questionnaire and ecological momentary assessment, predicted exercise in endometrial cancer survivors	Sample size: N=97 Cancer Type: Endometrial cancer Treatments: Surgery, radiation and/or Chemotherapy Cancer Stage: I, II, IIIa Age: 57 years (SD not specified) Gender: 100% female Treatment trajectory: Not specified Country of origin: USA	Primary outcome: Self-efficacy Secondary outcomes: Physical activity	Device: Hand-held computer Application name: Not specified Operation system: Hewlett-Packard iPAQ RX1950 Device: Accelerometer Application name: GT1M Operation system: ActiGraph	Monitoring periods: Wake, sleep times and physical activity participation Duration: 4 × 10/12 days (baseline, 2 months, 4 months, and 6 months) Data sampling: Interval contingent Prompts frequency: Not specified Prompt interval: Not specified Snooze option: Not specified	Participation rate: 97% Attrition: Not specified Missing data: Not specified Incentive: $40 for laboratory assessments; EMA incentive prorated on compliance $5-$30 per period.

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Table 1 (*Continued*)

Study Characteristics Authors and Country	Aim	Participant Characteristics	EMA Data Collection Methods Outcomes	System Characteristics	EMA Schedule	Response-Related Results
Belcher et al, 2011	Examined within-couple daily support processes and their association with daily relationship well-being in couples coping with early-stage breast cancer.	Sample size: N= 45 Cancer Type: Breast cancer Treatments: Lumpectomy or mastectomy followed by radiation or chemotherapy or hormonal therapy Cancer Stage: I, II, IIIa, or ductal carcinoma Age: 53 (SD 9.7) Gender: female patients and male partners Treatment trajectory: Post treatment Country of origin: USA	Primary outcome: daily relationship intimacy reported by each partner Secondary outcomes: Not specified	Device: Internet based Application name: Not specified Operation system: Not specified	Monitoring periods: once per day, in the evening Duration: 7-days Data sampling: Interval contingent Prompts frequency: Not specified Prompt interval: Not specified Snooze option: Not specified	Participation rate: 70% Attrition: Missing data: Incentive: $25 on the return of the questionnaire and $5 for each diary completed, $5 bonus for completion of all seven diaries ($130)
Buck & Morley 2006	To investigate the use of attentional strategies in a naturalistic setting within the complex and variable context of cancer pain, where the threat value of pain was expected to be high	Sample size: N= 26 Cancer Type: Not specified Treatments: Not reported Cancer Stage: Not reported Age: 55.5 years (SD 11.5) Gender: 12 male and 14 female Treatment trajectory: Palliative Country of origin: UK	Primary outcome: measures of pain, intensity, affect, coping, coping efficacy, and the novelty and predictability of pain, Secondary outcomes: measure of catastrophizing	Device: Paper based diary Application name: N/A Operation system: N/A	Monitoring periods: 3 time per day Duration: 10-days Data sampling: Event contingent Prompts frequency: Not specified Prompt interval: Not specified Snooze option: Not specified	Participation rate: 96.5% Attrition: 4 participants Missing data: Not specified Incentive: Not specified
Campbell et al, 2022	To evaluate the feasibility of an intensive symptom and function monitoring protocol before and during a full regimen of 6 cycles of chemotherapy treatment for gynecological cancers	Sample size: N= 25 Cancer Type: Gynecological - ovarian, uterine/ endometrial, or cervical cancer Treatments: Platinum and Taxane Chemotherapy Cancer Stage: III and IV Age: 60.6% Gender: 100% female Treatment trajectory: During treatment Country of origin: USA	Primary outcome: Daily symptom and function monitoring Secondary outcomes: sense of symptom controllability	Device: Paper and pencil diary Application name: N/A Operation system: N/A Device: ActiWatch - Legacy ActiGraph Application name: Not specified Operation system: Not specified	Monitoring periods: daily Duration: 6 × 21 day cycles Data sampling: Interval contingent Prompts frequency: Not specified Prompt interval: Not specified Snooze option: Not specified Monitoring periods: Continuous for 7 days Duration: 6 × 7 days (3 days before chemotherapy and 4 days after chemotherapy) Data sampling: Continuous Prompts frequency: Not specified Prompt interval: Not specified Snooze option: Not specified	Participation rate: 83% Attrition: 4 participants Missing data: increased with subsequent cycles- percentage not specified Incentive: $20 for each study assessment completed and $1 for each daily diary completed. Potential total $240
Curran et al, 2004	To examine the diurnal patterns of fatigue in a sample of breast cancer survivors.	Sample size: N= 74 (25 BC, 24 BBP and 25 HC) Cancer Type: Breast cancer Treatments: Chemotherapy and/or Radiation Cancer Stage: Stage 0, I, II and Benign Breast Problems Age: 48.2 (SD8.6) BC; 49.1 (SD8.2) BBP; 48.1 (SD 8.6) HC Gender: 100% Female Treatment trajectory: Post treatment Country of origin: USA	Primary outcome: Fatigue Secondary outcomes: Pain, Mood and Activity	Device: Daily Diary and Pedometer Application name: Not specified Operation system: Not specified	Monitoring periods: 4 times per day Duration: 6 days Data sampling: Interval contingent Prompts frequency: Not specified Prompt interval: Not specified Snooze option: Not specified	Participation rate: Not specified Attrition: Not specified Missing data: less than 1% Incentive: $50

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Table 1 (*Continued*)

Study Characteristics Authors and Country	Aim	Participant Characteristics	EMA Data Collection Methods Outcomes	System Characteristics	EMA Schedule	Response-Related Results
Escudero-Vilaplana et al, 2022	To assess the usability of the app eB2-ECOG concerning patient's characteristics, acceptability and satisfaction.	Sample size: N=106 Cancer Type: Unresectable or metastatic lung cancer, gastrointestinal stromal tumor, sarcoma or head and neck cancer Treatments: Systemic anticancer therapies Cancer Stage: Not specified Age: 64.7 (SD 15.7) Gender: 63.8% Male Treatment trajectory: Not specified Country of origin: Spain	Primary outcome: ECOG-PS and HRQoL Secondary outcomes: Patient's acceptability and satisfaction	Device: Smartphone Application name: eB2-ECOG Operation system: Android (version 4.4 or higher) or iOS (version 10 or higher)	Monitoring periods: 24-hour cycle Duration: continuous monitoring over 6 months Data sampling: Continuous contingent/ Event contingent Prompts frequency: Not specified Prompt interval: Not specified Snooze option: Not specified	Participation rate: 89% Attrition: Not specified Missing data: Not specified Incentive: Not specified
Glaus et al, 1993	The aim of the study (a) to develop a simple, self-assessment tool for measurement of fatigue over daily periods, (b) to explore symptoms and levels of fatigue in cancer patients.	Sample size: N=20 Cancer Type: Malignant lymphoma, myeloma, breast cancer, lung cancer and other solid tumors Treatments: Chemo- or chemo-hormone therapy, or radiotherapy Cancer Stage: Age: 54 years (SD 14.73) Gender: 13/20 female Treatment trajectory: Not specified Country of origin: Switzerland	Primary outcome: measurement of fatigue over daily periods Secondary outcomes: manifestation of symptoms and levels of fatigue in cancer patients	Device: Fatigue assessment Scale – paper based Application name: N/A Operation system: N/A	Monitoring periods: 4 times per day Duration: 7 days Data sampling: Interval contingent Prompts frequency: N/A Prompt interval: N/A Snooze option: N/A	Participation rate: Not specified Attrition: Not specified Missing data: Not specified Incentive: Not specified
Grassi et al, 2015	To prospectively explore the association of psychosocial variables, including emotional distress, maladaptive coping styles and the doctor-patient relationship, with CINV and QoL among cancer outpatients	Sample size: N = 302 Cancer Type: Gastrointestinal, breast, genitourinary, respiratory and blood cancers Treatments: Chemotherapy alone or in combination with hormone therapy or radiotherapy or both Cancer Stage: local or locoregional 55.6% and metastatic 44.4% Age: Adult population 18-65 years Gender: 59.6% female Treatment trajectory: Country of origin: Austria, Italy and Spain	Primary outcome: CINV Secondary outcomes: QoL	Device: Daily diary – paper based Application name: N/A specified Operation system: N/A	Monitoring periods: Daily Duration: 5 days after chemotherapy Data sampling: Interval contingent Prompts frequency: Not specified Prompt interval: Not specified Snooze option: Not specified	Participation rate: 80.9% Attrition: Not specified Missing data: Not specified Incentive: Not specified
Hacker et al, 2006	To examine the patterns of fatigue, physical activity, health status, and quality of life before and after high-dose chemotherapy and hematopoietic stem cell transplantation (HSCT) and to examine the feasibility of obtaining real-time fatigue and physical activity data	Sample size: N = 17 Cancer Type: Lymphoma Chronic myelogenous, leukemia Acute myelogenous, leukemia Acute lymphocytic, leukemia Multiple myeloma, Myelofibrosis, and Plasma cell leukemia Treatments: High-dose chemotherapy followed by hematopoietic stem cell transplantation Cancer Stage: Age: 48.65 years (SD not specified) Gender: Female 55% Treatment trajectory: Not specified Country of origin: USA	Primary outcome: fatigue, physical activity, health status, and QOL before and after high-dose chemotherapy and HSCT Secondary outcomes: determine the feasibility of using the	Device: Actiwatch-Score Application name: Mini Mitter Company Operation system: Not specified	AntiGraph Monitoring periods: continuous Duration: 10 days Data sampling: continuous Prompts frequency: Not specified Prompt interval: Not specified Snooze option: Not specified EMA- data entered into Actiwatch-score Monitoring periods: 3 times per day Duration: 10 days Data sampling: interval; contingent Prompts frequency: Not specified Prompt interval: Not specified Snooze option: Not specified	Participation rate: 87% Attrition: Not specified Missing data: Not specified Incentive: Not specified

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Table 1 (*Continued*)

Study Characteristics Authors and Country	Aim	Participant Characteristics	EMA Data Collection Methods Outcomes	System Characteristics	EMA Schedule	Response-Related Results
Hacker et al, 2007	To EMA its applicability to capture real-time, real-world assessments of fatigue in cancer patients receiving intensive therapy.	Sample size: N=20 Cancer Type: Hematological malignancies Treatments: High dose chemotherapy and Hematological stem cell therapy Cancer Stage: Not specified Age: 48.7 years (range 23-64 years) Gender: 55% female Treatment trajectory: Not specified Country of origin: USA	Primary outcome: Response rate Secondary outcomes: Fatigue assessment	Device: Actiwatch-score Application name: Not specified Operation system: Mini Mitter	Monitoring periods: 3 times per day Duration: 3 days before receiving HSCT and 3 days (total 6 days) after receiving HSCT Data sampling: Interval contingent Prompts frequency: Not specified Prompt interval: Not specified Snooze option: Not specified	Participation rate: 87% Attrition: Not specified Missing data: Not specified Incentive: Not specified
Hacker et al, 2017	To explore the relationship between real-time fatigue and free-living physical activity.	Sample size: N=50 (25 HTC cancer survivors with persistent fatigue; 25 HC) Cancer Type: Hematological malignancies Treatments: Hematopoietic stem cell transplantation, including chemotherapy and or radiation Cancer Stage: III and IV Age: 52.8 (SD11.8) Gender: 56% men (N=28); 44% female (N=22) Treatment trajectory: Post treatment/ transplantation Country of origin: USA	Primary outcome: Fatigue Secondary outcomes: Physical Activity	Device: Wrist-worn Accelerometer Application name: Actiwatch-Score (Philips Respironics) Operation system: Actiware software (V.60)	Monitoring periods: 5 times per day Duration: 7 days Data sampling: Diurnal signal contingent; wake and sleep times event contingent Prompts frequency: Not specified Prompt interval: Not specified Snooze option: Not specified	Participation rate: Not specified Attrition: Not specified Missing data: approx. 50% (calculated by number of real-time fatigue scores) Incentive: Not specified
Hanisch et al, 2009	To identify the pathophysiology and evaluate treatments of hot flushes.	Sample size: N= 47 Cancer Type: Prostate cancer Treatments: Androgen deprivation therapy Cancer Stage: Not reported Age: 71 years (54-88 years) Gender: 100% Males Treatment trajectory: active treatment Country of origin: USA	Primary outcome: Record of hot flushes Secondary outcomes: Not specified	Device: Meditrace sliver/silver chloride electrodes connected to a Biolog monitor Application name: Not reported Operation system: Not reported Device: Paper diary Application name: N/A Operation system: N/A	Monitoring periods: Continuous Duration: 2 × 48 hours Data sampling: Patient prompted Prompts frequency: Not specified Prompt interval: Not specified Snooze option: Not specified Monitoring periods: 2 times per day Duration: 2 × 48 hours Data sampling: Interval contingent Prompts frequency: Not specified Prompt interval: Not specified Snooze option: Not specified	Participation rate: 87% Attrition: Not specified Missing data: 13% Incentive: Not specified Participation rate: 39/47 Attrition: Not specified Missing data: 17% Incentive: Not specified
Harnas et al, 2021	To illustrate how automated individual time series analyses can be applied to personalize CBT for cancer related fatigue in cancer survivors.	Sample size: N=3 Cancer Type: Breast cancer Treatments: Chemotherapy, Mastectomy, Radiotherapy and/ or Hormonal therapy Cancer Stage: Not specified (Curative) Age: 60 years, 56, year and 50 years Gender: 100% Female Treatment trajectory: Post treatment-still receiving hormone therapy Country of origin: The Netherlands	Primary outcome: Fatigue Secondary outcomes: Personalized Cognitive Behaviour Therapy	Device: Web-based questionnaire Application name: Not specified Operation system: Not specified	Monitoring periods: 5 times per day Duration: 2 × 14 days Data sampling: Signal contingent Prompts frequency: 30-mins reminder text message Prompt interval: Not specified Snooze option: 60 minutes to complete questionnaire	Participation rate: 100% Attrition: 0 Missing data: 6% (calculated) Incentive: Not specified

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Table 1 (*Continued*)

Study Characteristics Authors and Country	Aim	Participant Characteristics	EMA Data Collection Methods Outcomes	System Characteristics	EMA Schedule	Response-Related Results
Harper et al, 2012	To understand whether physicians, if provided with patient reported QOL data prior to clinic visits, will find this information clinically meaningful in evaluating patients' response to Phase I clinical cancer treatments.	Sample size: N= 30 patients, 3 physicians Cancer Type: Colorectal, breast or lung Treatments: Not reported Cancer Stage: 4 Age: 56.65 (SD 12.41) Gender: 47% female and 53% male Treatment trajectory: Active treatment Country of origin: USA	Primary outcome: Biomedical and patient-reported decision factors for physicians Secondary outcomes: Influences in treatment decisions	Device: electronic daily diary (EDD) device – web based Application name: Not specified Operation system: Not specified	Monitoring periods: Daily Duration: 52 days (SD = 31.5 Data sampling: Interval contingent Prompts frequency: Not specified Prompt interval: Not specified Snooze option: Not specified	Participation rate: 88% Attrition: Not specified Missing data: Not specified Incentive: Not specified
Heathcote et al, 2022	To assess the feasibility, acceptability and validity of EMA as a research tool to study scanxiety among AYA survivors of childhood cancer.	Sample size: N=30 Cancer Type: Not specified Treatments: Not specified Cancer Stage: Not specified Age: 11-25 years Gender: Not specified Treatment trajectory: Completed active cancer treatment of curative intent Country of origin: USA	Primary outcome: Feasibility of EMA procedures Secondary outcomes: Validity of EMA surveys to capture scanxiety	Device: Smartphone Application name: Life data Operation system: Not specified	Monitoring periods: 3 times per day Duration: 5 days before, on the day of and 5 days after oncologist appointment (11 days) Data sampling: Signal contingent Prompts frequency: 3 reminders Prompt interval: 20 minute intervals Snooze option: Not specified	Participation rate: 83% Attrition: 1/30 Missing data: Not specified Incentive: $20 for baseline questionnaire, $2.50 for each completed EMA survey and a $25 bonus for all completed surveys
Kim et al, 2016	1. To evaluate the potential of a mobile mental- health tracker that uses three daily mental-health ratings as indications for depression 2. To discuss three approaches to data processing (ration, average and frequency) 3. To examine the impact of adherence on reporting using a mobile mental-health tracker and accuracy in depression screening	Sample size: N=85 Cancer Type: Breast cancer Treatments: Not specified Cancer Stage: Not specified Age: Not specified Gender: Not specified Treatment trajectory: Not specified Country of Origin: South Korea	Primary outcome: Mental health rating Secondary outcomes: Data processing approaches and adherence to screening	Device: Smart-phone Application name: Pit-a-Pat Operation system: Not specified	Monitoring periods: 3 times per day Duration: 14 days Data sampling: Interval contingent Prompts frequency: Not specified Prompt interval: Not specified Snooze option: Not specified	Participation rate: 92% Attrition: 8% Missing data: 34.41% Incentive: Not specified
Langer et al, 2018	To examine intra- and interpersonal associations between communication (both enacted and perceived) and relationship satisfaction (RS) among patients with stage II to IV breast or colorectal cancer and their spouses.	Sample size: N=107 Cancer Type: Breast, colon or rectal cancer Treatments: Chemotherapy and/or hormone therapy Cancer Stage: II to IV Age: 51 Gender: 64.5% female patients and 37.4% female spouses Treatment trajectory: Active treatment Country of origin: USA	Primary outcome: Communication Secondary outcomes: Relationship satisfaction	Device: Smartphone Application name: lifedata-corp.com Operation system: iOS and Android	Monitoring periods: 2 times per day Duration: 14 days Data sampling: Signal contingent Prompts frequency: 2 hour window to complete Prompt interval: Not specified Snooze option: Not specified	Participation rate: 88.8% Attrition: Not specified Missing data: Not specified Incentive: $75 for >85% more completed responses OR $3 per notification completed if less than 85%
Müller et al, 2019	To investigate whether co-rumination is related to increases in daily relationship satisfaction in both members of the couple.	Sample size: N= 101 dyads Cancer Type: colorectal cancer Treatments: Cancer Stage: I, II, III and IV Age: 64.3 years (10.2) patient, 63.2 (SD 11.2) spouse Gender: 66.3% male partner, 33.7% male spouse Treatment trajectory: Not specified Country of origin: Netherlands	Primary outcome: co rumination Secondary outcomes: catastrophizing	Device: Electronic diary Application name: intuitive diary app Operation system: Not specified	Monitoring periods: 3 times a day Duration: 14 days Data sampling: Signal contingent Prompts frequency: Not specified Prompt interval: Not specified Snooze option: Not specified	Participation rate: Not specified Attrition: Not specified Missing data: Not specified Incentive: €50 gift card

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Table 1 (*Continued*)

Study Characteristics Authors and Country	Aim	Participant Characteristics	EMA Data Collection Methods Outcomes	System Characteristics	EMA Schedule	Response-Related Results
Otto et al, 2015	To examine daily intimacy and well-being in women with breast cancer and their intimate partners.	Sample size: N= 99 total (sample 1- 45 couples; sample 2-54 couples) Cancer Type: Breast cancer Treatments: Cancer surgery – lumpectomy or mastectomy Cancer Stage: I, II, IIIa stage Age: 52 years (SD 10.43) and spouses 54 years (SD = 11.94) Gender: patient women Treatment trajectory: post treatment Country of origin: USA	Primary outcome: Mechanism of capitalization Secondary outcomes: Social support	Device: Electronic dyadic daily diary Application name: Not specified Operation system: Not specified	Sample 1 Monitoring periods: Duration: 7-day daily diary Data sampling: Interval contingent Prompts frequency: Not specified Prompt interval: Not specified Snooze option: Not specified Sample 2 Monitoring periods: daily diary Duration: 10-day daily diary Data sampling: Event contingent Prompts frequency: Not specified Prompt interval: Not specified Snooze option: Not specified	Sample 1 Participation rate: 82% Attrition: Not specified Missing data: Not specified Incentive: Not specified Sample 2 Participation rate: 81% Attrition: Not specified Missing data: Not specified Incentive: Not specified
Paterson et al, 2019	To identify self-management strategies among men affected by prostate cancer	Sample size: N=12 Cancer Type: Prostate cancer Treatments: All therapies Cancer Stage: All stages Age: Over 18 Gender: 100% male Treatment trajectory: Not specified Country of origin: UK	Primary outcome: Self-management Secondary outcomes: Health-related quality of life	Device: Digital personal assistant Application name: Dell Axim X51 Operation system: Not specified	Monitoring periods: 3 times per day Duration: 31 days Data sampling: Signal contingent Prompts frequency: Not specified Prompt interval: Not specified Snooze option: snooze for 5-60 minutes	Participation rate: 83.8% Attrition: Not specified Missing data: 1 participant Incentive: Not specified
Paterson et al, 2020	To identify the lived experiences of men affected by prostate cancer participating in an EMA study	Sample size: N=12 Cancer Type: Prostate cancer Treatments: All treatments Cancer Stage: All stages Age: 51-75 years Gender: 100% Male Treatment trajectory: Curative to palliative Country of origin: UK	Primary outcome: Lived experience	Device: Personal Digital Assistant Application name: Not specified Operation system: Not specified	Monitoring periods: 3 times per day Duration: One-month Data sampling: Signal contingent and event contingent Prompts frequency: Not specified Prompt interval: Not specified Snooze option: Not specified	Participation rate: 100% Attrition: Not specified Missing data: Not specified Incentive: Not specified
Paxton et al, 2022	The aim of this study was to examine the associations of daily physical activity and sedentary behavior with symptom burden, pain interference, and fatigue among patients who were undergoing active cancer treatment.	Sample size: N= 22 Cancer Type: Not specified Treatments: surgery, chemotherapy or radiotherapy Cancer Stage: Localized- stage not specified Age: 57 years Gender: 73% women Treatment trajectory: active treatment Country of origin: USA	Primary outcome: treatment-related symptoms Secondary outcomes: lifestyle behaviors	Device: Daily diary Application name: printed survey Operation system: Not specified	Monitoring periods: Daily Duration: 10 days Data sampling: Interval contingent Prompts frequency: Not specified Prompt interval: Not specified Snooze option: Not specified	Participation rate: 88% Attrition: Missing data: 12% Incentive: Not specified

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Table 1 (*Continued*)

Study Characteristics Authors and Country	Aim	Participant Characteristics	EMA Data Collection Methods Outcomes	System Characteristics	EMA Schedule	Response-Related Results
Phillips et al, 2020	To use EMA methodology to prospectively examine relationships between daily symptom burden and physical activity in breast cancer	Sample size: N= 67 Cancer Type: breast cancer Treatments: Chemotherapy Cancer Stage: I-III Age: 48.6 years (SD 10.3) Gender: 100% females Treatment trajectory: Active treatment Country of origin: USA	Primary outcome: Daily symptom burden Secondary outcomes: Physical activity	Device: AntiGraph accelerometer Application name: wGT3X-BT, AntiGraph Corporation, Pensacola, FL Operation system: ActiLife 6.13.3 Device: Smartphone Application name: EMA text prompts Operation system: Not specified	AntiGraph Monitoring periods: continuous 24hr per day Duration: 10 days Data sampling: Continuous Prompts frequency: 15 mins (open for 60 mins) Prompt interval: 2 hours Snooze option: Not specified EMA texts prompts Monitoring periods: 4 times per day Duration: 10 days Data sampling: Signal contingent Prompt interval: 15 mins (open for 60 mins) Prompt interval: 2 hours Snooze option: Not specified	Participation rate: 84% Attrition: Missing data: Not specified Incentive: Not specified
Pinto et al, 2021	To explore longitudinal trends in sedentary behavior (SB) using accelerometers and associated variables via EMA among breast cancer survivors.	Sample size: N=22 Cancer Type: Breast cancer Treatments: Not specified Cancer Stage: 0-3 Age: 51.5 Gender: 100% female Treatment trajectory: <5 years since diagnosis Country of origin: USA	Primary outcome: Sedentary behavior Secondary outcomes: Not specified	Device: Smartphone and AntiGraph accelerometer (GT3X) Application name: ilumivu Operation system: Android or Apple AND Device: AntiGraph accelerometer Application name: GT3X Operation system:	Monitoring periods: 5 times per day Duration: 5 × 7-day assessment periods at 0, 3, 6, 9, and 12 months Data sampling: 1x event contingent (wake up) and 4x signal contingent Prompts frequency: Prompt interval: Snooze option:	Participation rate: 78.62% Attrition: 9% Missing data: Not specified Incentive: 1. $10 data usage allowance 2. $20 for wearing AntiGraph 3. $1 per response
Ratcliff et al, 2014	To examine the interplay between sleep and cancer related symptoms during a cycle of CT.	Sample size: N=21 Cancer Type: Breast cancer Treatments: Neoadjuvant or Adjuvent CT Cancer Stage: I, II or III Age: Not specified Gender: 100% female Treatment trajectory: Active cancer treatment Country of origin: USA	Primary outcome: Sleep quality Secondary outcomes: Symptoms and mood	Device: Palm PC Application name: Casio E-100 Operation system: Windows CE PPC	Monitoring periods: 4 times per day Duration: 21 days Data sampling: Signal contingent Prompts frequency: 2 prompts Prompt interval: 5 mins Snooze option: Not specified	Participation rate: 57% Attrition: 1/21 Missing data: Not specified Incentive: Not specified
Rivera-Rivera et al, 2022	To evaluate the trajectory of distress, wellbeing, social support and social constraint over time in people with cancer.	Sample size: N= 48 Cancer Type: cervical or head/neck cancer Treatments: Surgery, radiation or both Cancer Stage: all stages Age: 56 years (SD 7.90) Gender: male 63% Treatment trajectory: Not specified Country of origin: USA	Primary outcome: Social support Secondary outcomes: Social constraint	Device: Proactive, phone-based interactive voice response (IVR) system, or paper questionnaire Application name: Not specified Operation system: Not specified	Monitoring periods: daily Duration: 30-days Data sampling: Interval contingent Prompts frequency: Not specified Prompt interval: Not specified Snooze option: Not specified	Participation rate: 72% Attrition: Missing data: Not specified Incentive: $20 for completion of the baseline assessment and up to $80 for the daily assessments

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Table 1 (*Continued*)

Study Characteristics Authors and Country	Aim	Participant Characteristics	EMA Data Collection Methods Outcomes	System Characteristics	EMA Schedule	Response-Related Results
Schuler et al, 2023	To test wearable sensor (WS) to trigger ecological momentary assessments (EMAs) and electronic patient-reported outcomes in community palliative care with patient−caregiver dyads.	Sample size: N= 15 dyads (30 participants) Cancer Type: Not specified Treatments: Not specified Cancer Stage: Not specified Age: 59 years Gender: 80% female patients and 27% female caregivers Treatment trajectory: Palliative Country of origin: Australia	Primary outcome: Feasibility and acceptability of wearable sensor Secondary outcomes: Not specified	Device: Wearable Sensor (WS) Application name: vivosmart4 Operation system: Garmin, Olath Device: Smart phone – apps installed and configured Application name: "Garmin-Connect"and"mEMA" Operation system: Garmin, Olath	WS Monitoring periods: Continuous Duration: 5 weeks Data sampling: Continuous Prompts frequency: Not specified Prompt interval: Not specified Snooze option: Not specified Smartphone app Monitoring periods: Daily, weekly and triggered by a signal contingent Duration: 5 weeks Data sampling: Event contingent and signal contingent from data received from WS Prompts frequency: Not specified Prompt interval: Not specified Snooze option: Not specified	Participation rate: Wearable sensor daytime data – 73% (patients (69%); caregivers (77%)) Daily EMA - 44% Weekly IPOS - 79%. Attrition: Missing data: Not specified Incentive: Not specified
Shiyko et al, 2019	To randomly sample mindfulness states in a sample of mindfulness-untrained individuals following hospital discharge.	Sample size: N=66 Cancer Type: Non-small cell lung cancer Treatments: Minimally invasive surgery via video-assisted thoracotomy (VATS lobectomy) OR Stand thoracotomy and lobectomy (THOR) Cancer Stage: I Age: 66.1 (SD 7.9) Gender: 61% female Treatment trajectory: Post-surgery Country of origin: USA	Primary outcome: Mindfulness Secondary outcomes: Not specified	Device: Portable Palm Pilot (PDA) Application name: Not specified Operation system: Not specified	Monitoring periods: 2 times per day Duration: 14 days Data sampling: Signal contingent Prompts frequency: Not specified Prompt interval: Not specified Snooze option: Not specified	Participation rate: 61% Attrition: 25% Missing data: 39% Incentive: Not specified
Solk et al, 2019	The purpose of this study is to determine the feasibility and acceptability of EMA data collection via smartphone and accelerometers in breast cancer patients using chemotherapy	Sample size: N=68 Cancer Type: Breast cancer Treatments: Chemotherapy Cancer Stage: I, II or III Age: Not specified Gender: 100% Female Treatment trajectory: Active cancer treatment Country of origin: USA	Primary outcome: EMA data collection Secondary outcomes: Accelerometer	Device: Smartphone Application name: Web-based browser Operation system: Not specified Device: Accelerometer Application name: GT3X-BT Operation system: ActiGraph	Monitoring periods: 4 times per day Duration: 10 days Data sampling: Signal contingent Prompts frequency: 3 prompts Prompt interval: 15 mins Snooze option: Not specified	Participation rate: 86% (EMA); 82.3% (Accelerometer) Attrition: 5/68 Missing data: Not specified Incentive: Not specified
Steffen et al, 2018	To examine how daily hope, defined as goal-directed effort and planning to meet goals, and daily stigma were related to same- and next-day functioning in lung cancer patients receiving cancer treatment	Sample size: N= 50 Cancer Type: Lung cancer Treatments: Chemotherapy or Radiation Cancer Stage: IIIa- IV Age: Not specified Gender: 58% female Treatment trajectory: Active treatment Country of origin: Mexico	Primary outcome: Hope Secondary outcomes: Stigma	Device: online, paper, or via telephone – patient preference Application name: Not specified Operation system: Not specified	Monitoring periods: Daily Duration: 21 days Data sampling: interval contingent Prompts frequency: Not specified Prompt interval: Not specified Snooze option: Not specified	Participation rate: 99.2% Attrition: Missing data: under 5% Incentive: $30 for initial questionnaire, $3 for each daily entry, $4 for each week they completed, and $6 for completing all 21 days. Paid in gift card

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Table 1 (*Continued*)

Study Characteristics Authors and Country	Aim	Participant Characteristics	EMA Data Collection Methods Outcomes	System Characteristics	EMA Schedule	Response-Related Results
Stephenson et al, 2018	To examine between-person and within-person associations between pain intensity and analgesia use in breast cancer patients	Sample size: N=53 Cancer Type: Breast cancer Treatments: Chemotherapy, radiation and hormone therapy Cancer Stage: I, II, III and IV Age: 49.38 years (SD 10.76) Gender: 100% Female Treatment trajectory: Active cancer treatment Country of origin: Canada	Primary outcome: Pain intensity Secondary outcomes: Analgesia use	Device: Electronic diary Application name: Palm Tungsten E Operation system: Not specified	Monitoring periods: 6 times per day Duration: 14 days Data sampling: Signal contingent Prompts frequency: 3 prompts Prompt interval: 5 mins Snooze option: Not specified	Participation rate: 70% Attrition: 5/68 Missing data: Not specified Incentive: up to $80 based on percentage of completed assessments
Vandenberg et al, 2022	To evaluate the feasibility and descriptive quality of capturing PROMs through daily micro surveys using a smartphone.	Sample size: N=95 Cancer Type: Breast, Skin/ Soft tissue/ Endocrine, and Abdominal Cancers Treatments: Not specified Cancer Stage: Not specified Age: 52.1 (SD 12.9) Gender: 66% Female Treatment trajectory: Perioperative Country of origin: USA	Primary outcome: Feasibility of daily micro surveys Secondary outcomes: HRQoL	Device: Smartphone Application name: Beiwe Operation system: Android or iOS	Monitoring periods: Daily micro surveys and 4 RAND short form-36 completed pre-op then 4 weeks, 12 weeks and 14 weeks post op Duration: Daily micro surveys completed preoperative to 24-weeks post op Data sampling: Interval contingent Prompts frequency: Not specified Prompt interval: Not specified Snooze option: Not specified	Participation rate: 34% daily micro surveys; 74% SF-36 Attrition: 4% Missing data: Not specified Incentive: No compensation
Vehling et al, 2018	To assess intraindividual changes in loss orientation and life engagement for people with advanced cancer	Sample size: N= 17 Cancer Type: Gastrointestinal, Genitourinary, breast, lung or other (not specified) Treatments: Surgery chemotherapy, radiation. Cancer Stage: IV Age: 61 years (SD not specified) Gender: 10/17 female Treatment trajectory: Palliative Country of origin: Germany	Primary outcome: Acceptability of daily assessments of death-related concerns Secondary outcomes: Loss orientation and life engagement	Device: Paper booklet Application name: N/A Operation system: N/A	Monitoring periods: Daily Duration: 7 days Data sampling: Interval contingent Prompts frequency: Not specified Prompt interval: Not specified Snooze option: Not specified	Participation rate: 46% participation rate, 97% diary completion rate Attrition: Not specified Missing data: Not specified Incentive: Not specified
Whitaker et al, 2022	To understand real-time relationships between physical activity and symptoms during chemotherapy using ecological momentary assessment.	Sample size: N=67 Cancer Type: Breast cancer Treatments: Chemotherapy Cancer Stage: I to III Age: 48.6 (SD 10.3) Gender: 100% Female Treatment trajectory: In treatment Country of origin: USA	Primary outcome: Physical activity Secondary outcomes: Symptoms	Device: ActiGraph Accelerometer Application name: wGT3X-BT Operation system: Actilife 6.13.3 AND Device: Smartphone Application name: Not specified Operation system: Not specified	Monitoring periods: 4 times per day Duration: 3 × 10 days Data sampling: Signal contingent Prompts frequency: Not specified Prompt interval: 15 mins prompts for 60 mins Snooze option: Not specified	Participation rate: Not specified Attrition: Not specified Missing data: Not specified Incentive: Not specified

Table 2
Results of Quality Assessment

Qualitative Study	Item number of check list						
	S1.	S2.	1.1.	1.2.	1.3.	1.4.	1.5.
Paterson et al, (2020)	Y	Y	Y	Y	Y	Y	Y

Item number check list key*: S1. Are there clear research questions, S2. Do the collected data allow to address the research questions, 1.1. Is the qualitative approach appropriate to answer the research question, 1.2. Are the qualitative data collection methods adequate to address the research question, 1.3. Are the findings adequately derived from the data, 1.4. Is the interpretation of results sufficiently substantiated by data, 1.5. Is there coherence between qualitative data sources, collection, analysis and interpretation.

Quantitative Descriptive Studies	Item number of check list						
	S1.	S2.	4.1.	4.2.	4.3.	4.4.	4.5.
Abraham et al, (2015)	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**
Aigner et al, (2016)	Y	Y	Y	U	Y	U	U
Aldaz et al, (2019)	Y	Y	Y	U	U	U	Y
Badr et al, (2006)	Y	Y	Y	Y	Y	Y	U
Badr et al, (2010)	Y	Y	Y	Y	Y	Y	Y
Basen-Enquist et al, (2013)	Y	Y	Y	Y	Y	Y	Y
Belcher et al, (2011)	Y	Y	Y	Y	Y	U	Y
Buck & Morley (2006)	Y	Y	Y	Y	Y	Y	Y
Curran et al, (2004)	Y	Y	Y	Y	Y	Y	Y
Escudero-Vilaplana et al, (2022)	U	U	Y	Y	U	Y	U
Glaus et al, (1993)	Y	Y	Y	Y	Y	U	Y
Grassi et al, (2015)	Y	Y	Y	Y	Y	Y	Y
Hacker et al, (2006)	Y	Y	Y	Y	Y	Y	Y
Hacker et al, (2007)	Y	Y	Y	Y	Y	Y	Y
Hacker et al, (2017)	Y	Y	Y	Y	Y	U	Y
Hanisch et al, (2009)	Y	Y	Y	Y	Y	Y	Y
Harnes et al, (2021)	U	Y	N	U	Y	N	U
Harper et al, (2012)	Y	U	Y	Y	U	U	U
Heathcote et al, (2022)	Y	Y	Y	Y	Y	U	Y
Kim et al, (2016)	Y	U	U	Y	Y	Y	Y
Langer et al, (2018)	Y	Y	Y	Y	Y	Y	U
Müller et al, (2019)	Y	Y	Y	Y	Y	Y	Y
Otto et al, (2015)	Y	Y	Y	Y	U	U	Y
Paterson et al, (2019)	Y	Y	Y	Y	Y	Y	Y
Paxton et al, (2022)	Y	U	Y	U	Y	U	Y
Phillips et al, 2020	Y	Y	Y	U	Y	Y	Y
Pinto et al, (2021)	Y	Y	Y	Y	Y	Y	U
Ratcliff et al, (2014)	Y	Y	Y	Y	Y	Y	Y
Rivera-Rivera et al, (2022)	Y	Y	Y	Y	Y	Y	Y
Shiyko et al, (2019)	U	Y	Y	Y	U	U	U
Solk et al, (2019)	Y	Y	Y	Y	Y	Y	U
Steffen et al, (2018)	Y	Y	Y	Y	Y	Y	Y
Stevenson et al, (2018)	Y	U	U	Y	U	Y	Y
Van den Berg et al, (2022)	Y	U	U	Y	Y	U	Y
Whitaker et al, (2022)	Y	Y	Y	Y	Y	Y	Y

Item number check list key*: S1. Are there clear research questions, S2. Do the collected data allow to address the research questions, 4.1. Is the sampling strategy relevant to address the research question, 4.2. Is the sample representative of the target population, 4.3. Are the measurements appropriate, 4.4. Is the risk of non-response bias low, 4.5. Is the statistical analysis appropriate to answer the research question

Mixed Methods	Item number of check list						
	S1.	S2.	5.1.	5.2.	5.3.	5.4.	5.5.
Ainsworth et al, (2018)	Y	Y	Y	Y	Y	Y	Y
Auster–Gussman et al, (2022)	Y	Y	Y	Y	Y	Y	Y
Campbell et al, (2022)	Y	Y	Y	Y	Y	Y	Y
Schuler et al, (2023)	Y	Y	Y	Y	Y	Y	Y
Vehling et al, (2018)	Y	Y	Y	Y	Y	Y	Y

Item number check list key*: S1. Are there clear research questions, S2. Do the collected data allow to address the research questions, 5.1. Is there an adequate rationale for using a mixed methods design to address the research question, 5.2. Are the different components of the study effectively integrated to answer the research question, 5.3. Are the outputs of the integration of qualitative and quantitative components adequately interpreted, 5.4. Are divergences and inconsistencies between quantitative and qualitative results adequately addressed, 5.5. Do the different components of the study adhere to the quality criteria of each tradition of the methods involved

*Three levels of assessment quality scores
Yes (Y)
Unclear (U)
No (N)

symptoms,[29-39] pattern of fatigue following and during cancer treatment,[23,40-45] quality of life,[46-48] mindfulness,[49] pain management,[50] hot flushes,[51] "scanxiety" in young people affected by cancer,[52] depression screening,[53] spousal communication and satisfaction,[54-58] hope and stigma,[38] assessment of self-management behaviors,[57,59] and explored participants experiences of taking part in an EMA study.[15]

Sample Characteristics

As the aims of the studies were diverse, so were the included cancer populations. Most of the studies included participants affected by breast cancer,[21,24-28,30,35,40,43,50,53,56,58] breast and ovarian,[29] endometrial,[22] colorectal,[57] mixed cancer groups,[31-34,36,39,44,46-48,54]

haematological,[41,42,45] prostate,[15,51,57] and lung,[38,49] and four studies did not report cancer types.[23,37,52,59] Participants completed the EMA study before cancer treatment,[47] during active cancer treatment,[23,25,26,28-30,33-35,38,44,48,50-52,54] post treatment,[31,32,40,41,43,49,56] and palliative care,[37,39,59] and a considerable number of studies did not report on the treatment trajectory.[15,21,22,24,36,39,42,46,53,55,57] The majority of the studies were biased in favor of females with the exception of several studies with mixed gender samples,[15,23,26,31,32,34,41,44-46,49,54,57,59] and two studies did not report on gender.[52,53] All of the studies included adults with cancer with the exception of one study that included children and young people affected by cancer.[52] The samples across the studies also included couple dyads.[37,54-56,58,60]

EMA Sampling Approach

The EMA sampling protocols included interval contingent,[22,23,27,30-34,36,38-40,42,44,45,47,48,51,53,56,58,59] event contingent,[21,46] and signal contingent.[15,24-26,28,29,35,37,41,43,49,52,55,57] The EMA sampling protocol durations lasted from 3[42] to 4,[51] 5,[21,34] 6,[40] 7,[24,29,32,39,41,44,56,58] 10,[23,25-27,45,59] 11,[52] 14,[30,31,43,49,50,53-55,57] 21,[28,38] and 31 days,[15,36,37,48,57] including much longer protocols capturing real-time data up to 4–6 months.[22,33,46,47] Most of the studies used either smartphones, handheld computers, or web-based browsers, and some studies used paper-based diaries.[23,32-34,39,40,44,51,59] The paper-based studies.[23,32-34,39,40,44,51,59] lacked a date and time stamp and, consequently, participants could have forwarded or back-filled their diary answers. However, most EMA studies in cancer are now time-stamping assessment of entries, which is the gold standard. Unfortunately, most of the studies did not report on the software application used to collect real-time data.

EMA Response Rates

Information on the participant response rates were reported in most included studies. Overall, the response rate to daily EMA questionnaires were moderate to high: 50–69%,[28,49,55] 70–79%,[24,31,35-37,47,50,56] <80–89%,[15,23,25,27,29,33,34,42,45,46,48,51,52,54,57,58] and <90–100%,[21,22,30,32,38,39,43,53,59] and four studies did not report this information.[26,40,41,44,57] It is also important to point out that some of the studies[22,24,32,33,36,40,50,52,54,55] used monetary compensation for participants to complete their agreed EMA data collection intervals, which may have introduced bias in response rates.

EMA Outcome Measures in Cancer

A detailed overview of the constructs measured, individual question items, and rating scales are detailed in Supplementary Table 3. It was important to capture the EMA outcome items for future EMA studies in cancer and making these accessible to cancer care researchers. What is clearly apparent, however, within existing EMA studies in cancer is that there is significant heterogeneity and lack of consistency, and this shortcoming does warrant attention to develop core outcome sets to be used in EMA cancer research. Similar constructs were captured across the studies to illustrate this point: distress,[32] mood,[24-29,31,32,35,40,43,52,53,55] fatigue,[23,25,26,29,40-45,57] pain[23-26,29,30,35,40,50,55,57] (with the exception of two studies[25,26] that assessed pain using the same item and scale), illness uncertainty,[32] coping,[32] self-efficacy,[22,25,27,43] exercise,[22,23,25-27,35,40-42,46] self-management behaviors,[52,57,59] anxiety,[26,53] and relationship intimacy,[56] but most studies did not measured these constructs in the same way and in the main also did not report on content validity or reliability.

Implications of Findings for Supportive Care

Evidence across the studies have demonstrated that people affected by cancer have shown acceptability towards mobile real-time measurements[25,30,46] including children and young people,[52] patients and partners[54,56,58] which has the potential for informing future interventions.[21] Across the exercise studies there were some nuanced findings. Firstly, within the context of exercise in cancer a causal relationship was observed between morning self-efficacy and exercise minutes, which suggests that real-time interventions to target daily variation in self-efficacy may benefit exercise adherence.[22,27] There was an inverse relationship between real-time reports of fatigue and physical activity levels.[41-43] It would be important to consider fatigue and self-efficacy on exercise adherence in development of future interventions.[61]

In people affected by cancer fatigue and pain have been shown to be significantly associated with greater negative mood in real time[29,55] and remained problematic 18 months after treatment was completed.[40] From a clinical perspective, this observation underscores the importance of timely identification and routine screening for mood disorders[32,53] in patients. This finding was particularly important for children and young people affected by "scanxiety" who were found to report significantly more daily fear of cancer recurrence and negative mood several days before a scan compared to the days after surveillance scans, and support should be provided in this context.[52]

Many patients affected by various cancers experienced distressing and daily fluctuations in symptoms,[23,30-35,37,38,44,48,50,51,55,57] on average four symptoms daily,[23] a range of unmet supportive care needs,[15] sadness, anxiety and stress reported on a daily basis,[24,36] and poor sleep.[28] Patients valued completing daily real-time reporting and some participants expressed that they developed an increased awareness and understanding of their condition by participating in the EMA.[15] Only one study explored[15] experiences of men affected by prostate cancer participating in an EMA study, therefore, knowledge about the methodological complexities which may, or may not exist, for EMA cancer research remains unknown.

Discussion

This systematic review set out to critically synthesize the current state of the evidence using EMA in cancer. What is apparent is the significant heterogeneity in methods and widely varying approaches to design and self-report measurements. With 42 studies being included it is apparent that this approach is increasingly being used and is appealing to researchers given its documented advantages. EMA in cancer care research can be superior in comparison to existing retrospective PROMs such as capturing in real-time symptom burden and distress, impacts on survivorship and unmet supportive care needs, yet to be identified using EMA. This review has also shown in the context of cancer research that little if any consideration has been given to the validity and reliability of the EMA PROMs used to date. To advance the scientific field of EMA in cancer addressing this gap would be the first central step. This review specifically captured all self-reported items across all the studies in this review to advance this first important step. Strikingly while similar constructs have been measured across many different EMA cancer studies, researchers have used widely different items and response anchors. It was also observed that previous researchers have developed their EMA self-report items from existing standardized questionnaires. One approach to measuring an EMA item construct based from an existing standardized PROMs, is for the EMA questionnaire item to adopt the questionnaire item which had the highest factor loading[2] for that particular construct. However, items from existing questionnaires are not automatically valid in EMA and therefore, researchers must focus their efforts on standardizing valid and reliable questionnaires for use in EMA cancer studies. One approach might be to adopt the COSMIN guideline,[20] which was used as part of this review to assess existing EMA PROMs. However, this guideline might offer a practical step in the right direction for future EMA

studies in cancer care research. In the development of EMA questionnaires, it is acknowledged that there is a fine balance between burden on participants so generally the questionnaires are short in length which can create further challenges in the development of EMA questionnaires. A further important methodological consideration to advance the field is for cancer researchers to adopt the CREMAS guideline[17] to standardize the reporting of future studies[17] to enhance the comparability, reproducibility, and interpretation of findings.

The adoption and growing focus of EMA in cancer has the powerful potential to provide rich and valuable new insights for implications for survivorship care and identify solutions to address unmet supportive care needs in real time.[14] This review identified some real-time insights with implications for survivorship. However, given that the focus of the studies was so broad in this review not all studies had the focus on implications for optimizing survivorship for people affected by cancer, therefore the full potential of EMA in cancer care is not yet fully realized. For example, EMA methods could be embedded as part of a supportive care clinical randomised trial to optimize survivorship providing real-time assessments of the intervention and linking people's cognitions, behaviors, and feelings simultaneously.

Strengths and Limitations

To the best of our knowledge, this is the first comprehensive systematic review to describe the evidence-base for EMA in cancer research. Clearly, researchers will need to take careful considerations to design decisions in EMA studies in the future, however this review has provided a valuable first step to advance the field. There were no language limiters or date limited set in this review to ensure it captured all EMA studies in cancer. The database searches were conducted by and expert systematic review librarian to increase the inclusiveness, sensitivity, and specificity of the searches. This review also followed a rigorous process throughout all stages and was conducted independently by two reviewers. This review was conducted in Covidence Systematic review software and due to the limitation of this software the authors were unable to provide the full reference list of the six articles excluded articles at the full text review as a supplementary file.

Implications for Cancer Survivors

People affected by cancer found taking part in EMA studies to be acceptable and some reported benefit from the experience in taking part. However, researchers must engage with cancer survivors in the development and co-design of future EMA PROM items and questionnaires.

Conclusion

There is significant heterogeneity in methods and widely varying approaches to design and self-report measurements in EMA cancer research. While EMA in cancer research holds significant promise to advance cancer care research into the future by increasing ecological validity, reducing retrospective bias, and captures the unique idiographic within-person change over time, in real-time, further research is needed to develop standardized EMA self-report questionnaires. Capturing real-time assessments over-time can leverage the potential to understand patients' quality of life, unmet supportive care needs while simultaneously linking affect, thoughts, and behaviors in naturalistic settings.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.soncn.2023.151514.

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