Title: The application of the 24-hour movement paradigm in people diagnosed with cancer: A scoping review

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ABSTRACT

Background: The 24-hour movement (physical activity – sedentary behavior – sleep) paradigm can promote an ability-focused approach to changing movement behaviours in people diagnosed with cancer. This scoping review aimed to explore how the 24-hour movement paradigm has been applied in people diagnosed with cancer, examining behaviour measurement methods and associations between 24-hour movement behaviours and health variables.

Methods: A systematic search was conducted on the 8th August 2024. Medline, Embase, and CINAHL were searched. There were five steps: identifying the research question; identifying studies; study selection; charting the data; collating, summarising and reporting results. Study design, sample demographics, movement behaviour measurement, analytical approach, and study outcomes were extracted. The review was conducted according to the PRISMA-Scr framework.

Results: Of 88 records identified, seven studies met inclusion criteria. All studies were cross-sectional with movement behaviours as the exposures. One study was conducted in children. Four studies used device-based measures for all behaviours, two used device-based measures of daytime behaviours with self-reported sleep, and one study used self-report for all behaviours. All studies used isotemporal substitution modelling. One study applied a compositional data approach. Outcomes included anthropometrics, quality of life, cognitive function, and bone health. Reallocating time into moderate-to-vigorous physical activity was associated with the most consistent health benefits.

Conclusions: Limited studies have applied the 24-hour movement paradigm in this population. Most used devices for measurement. While current evidence is constrained by cross-sectional

designs and limited generalisability, results support the positive impact of reallocating time from other behaviours into physical activity.

INTRODUCTION

Cancer is a major contributor to the global disease burden[1]. Earlier detection and improved treatments and survival rates mean a large population of people are living with and beyond cancer[2]. A substantial body of trial evidence demonstrates multiple benefits for physical activity (PA) after a cancer diagnosis[3-6]. This includes evidence for improved patient-oriented endpoints such as improved fatigue and quality of life[6-8] as well as health-related endpoints including cancer survival[9,10]. Accordingly, the American College of Sports Medicine recommends that people diagnosed with cancer engage in 150-300 minutes per week of moderate intensity PA or 75 to 150 minutes per week of vigorous intensity PA to improve outcomes after diagnosis[3].

Despite these recommendations, many people diagnosed with cancer do not meet the recommended amounts of moderate-to-vigorous intensity PA (MVPA) per week and this group demonstrates consistently lower levels of physical activity compared to adults without cancer[11]. A systematic review of physical activity levels in people with cancer undergoing chemotherapy demonstrated that most people diagnosed with cancer do not achieve the recommended amounts of MVPA, with or without intervention[12] and adherence is as low as 7.5% in people diagnosed with colorectal cancer[13]. Accelerometer-derived MVPA across the included studies was low, ranging from 7 minutes to 22 minutes of MVPA per day[12]. A 2023 study using a nationally representative sample of people diagnosed with cancer in the United States reported that the prevalence of meeting the aerobic PA recommendations is 40%, although this varied across cancer types such as skin cancer (51%) and stomach cancer (27%)[14]. Similar prevalence estimates have also been documented in the United Kingdom[15].

There is substantial evidence indicating that engaging in PA of moderate-to-vigorous intensity has the greatest benefit to health[16-18]. However, Sabiston et al. and Lynch et al. reported that MVPA accounts for<2% of waking hours in their respective studies of people diagnosed with breast cancer[19,20]. Regular participation in structured leisure-time PA can be unappealing due to many reasons. This includes some barriers that are commonly identified in the general population such as logistical demands, low mood, low self-efficacy, and preference for other activities[21,22]. Specifically in people diagnosed with cancer, barriers such as disease related side effects (e.g., fatigue), the presence of comorbidities, and the logistical demands of attending appointments and cancer care are consistently reported [22,23]. Therefore, it is useful to look beyond structured exercise to instead consider the distribution of PA across the day, including behaviours such as vigorous intermittent lifestyle physical activity (VILPA[24]) and behaviours that constitute much larger proportions of the 24-hour day such as LPA and SB[17].

The 24-hour movement paradigm acknowledges that each day is made up of time spent across sleep, SB, and PA of different intensities[25,26], recognising that these behaviours are interdependent and any increase in time spent in one must result in a reduction in time spent in another[27]. Rather than focusing on a single behaviour in isolation, increasing evidence suggests that the overall composition of the day is critical for health outcomes[28,29]. Accordingly, recent studies have examined the effects of making small incremental changes across all movement behaviours on health outcomes such as cardiovascular disease and blood pressure[30,31]. This reflects the increasing recognition that improving all behaviours simultaneously and achieving an overall healthier movement composition can have a synergistic effect on health[29,32]. This has contributed to the publication of new 24-hour activity guidelines for the general population in countries such as Canada[25].

Despite uptake in general population research, the 24-hour movement approach has rarely been applied to people diagnosed with cancer. Therefore, its potential to take an ability-focused perspective on physical activity- one that accounts for individuals' physical capabilities and limitations within the cancer care context- remains underexplored[33]. In an international review of 98 studies exploring PA intervention preferences of people diagnosed with cancer at different sites and at all stages of treatment, the importance of having achievable forms of PA was highlighted, recognising that high intensity PA can be daunting and challenging to perform after diagnosis[23]. Emphasising the benefits of small changes across other movement behaviours such as LPA and standing time, and breaking up SB may seem more achievable to people with reduced physical capacity and/or are experiencing fatigue resulting from their diagnosis and treatment[34].

The aim of this scoping review is to synthesise and describe the available evidence on how the 24-hour movement paradigm has been applied in people diagnosed with cancer. The objectives are: 1) to examine how 24-hour movement behaviours are simultaneously measured and analysed within an integrated framework in people diagnosed with cancer, and 2) to explore associations between these integrated 24-hour movement behaviours and other health variables in people diagnosed with cancer.

METHOD

The protocol for this scoping review was developed using Lely et al.'s template for scoping reviews[35]. The protocol was registered prospectively with the Open Science Framework on 22 February 2024 (https://osf.io/j25ge/). The methodology was guided by the Joanna Briggs Institute's (JBI) guidance for conducting scoping reviews and Arksey and O'Malley's framework[36-38]. See Supplementary Materials for a completed PRISMA-Scr Checklist[39]. Conducting the review included five steps; 1) identifying the research question; 2) identifying

relevant studies; 3) study selection; 4) charting the data; and 5) collating, summarising, and reporting the results.

Identifying the research question

Prior to beginning the scoping review, preliminary searches of electronic databases were conducted in November 2023 to explore existing literature and guide the development of the research question. Due to the limited evidence available and heterogeneity of outcomes, a scoping review was deemed appropriate to map existing research, assess methodological approaches, identify knowledge gaps, and inform future research[40,41].

Identifying relevant studies

The lead researcher (S.L.S.) formulated the search strategy with input from an information specialist librarian at University College London (D.M.). Subject headings and keywords were piloted to ensure a comprehensive search and that relevant known studies were identified. Search strategies of previous literature reviews about the measurement of movement behaviours were collated and refined to align with the research question[42,43].

The databases Medline, Embase and Cumulative Index of Nursing and Allied Health Literature (CINAHL) were searched on 8th August 2024. The search strategy was modified from the registered protocol - the requirement of terms for device-based measures was removed to ensure that studies that only used self-report but applied the 24-hour movement paradigm would be included. Terms for PA, SB, and sleep were combined with the 'AND' Boolean operator to ensure that studies included a measure of each type of behaviour necessary for 24-hour movement examination. The full search strategies for the Medline, Embase, and CINAHL databases are available in the Supplementary Materials. The identified records from each database were

downloaded into Endnote (version 20[44]). Endnote was used for deduplication before exporting into Microsoft Excel[45].

Reference lists from review papers and included studies were also searched[33]. Conference abstracts were excluded from this review due to insufficient information on the required methodology. No search for conference abstracts in the grey literature was conducted on conference websites. A grey literature search was conducted in Google Search using the terms from the search strategy as well as searching open access theses repository websites. (e.g., EBSCO Open Dissertations[46]).

Study selection

The study selection process was implemented over two stages. Two reviewers (S.L.S. and L.B.) screened titles and abstracts of the records identified from the searches according to the inclusion criteria outlined below (stage 1). Any disagreements were resolved by discussion and consensus. Where there was uncertainty, records were brought to the full text screening stage where the same inclusion criteria were applied (stage 2).

Inclusion criteria

Person

Included studies must have involved humans who had received a clinical diagnosis of cancer. No distinction was made between those who had completed treatment or those who were still receiving treatment. No restrictions on age, cancer type or any other demographic or clinical characteristics were imposed.

Concept

Included studies must have measured PA, SB, and sleep using self-report or device-based measures. The registered protocol originally stated that a compositional approach to data analysis must have been used. Compositional data analysis is widely used in studies in the general population and accounts for the fact that movement behaviours are codependent (i.e. time spent in one behavioural necessarily displaces time spent in another)[16]. Converting data into compositional data (usually achieved using isometric log ratios[16,47]) enables researchers to perform modelling such as isotemporal substitution within the constraints of a 24-hour day. For example, researchers can examine the proportion of time spent in SB *relative* to the total 24-hour day. This overcomes the limitations of traditional models, which cannot adjust for all remaining movement behaviours due to multicollinearity[47]. However, using compositional data analysis with this population was very limited, so the search strategy was modified to also include studies that analysed 24-hour movement using isotemporal substitution without compositional constraints. Isotemporal substitution involves the hypothetical replacement of one type of activity or behaviour with another of equal duration while keeping the overall time constant[48]. For example, researchers can model the impact of reallocating 30 minutes from MVPA into SB on a marker of health.

Context

Studies conducted in any setting were eligible for inclusion.

Exclusion criteria

Studies in non-human subjects were excluded. Studies in languages other than English were also excluded if there was no English translation available. Conference abstracts were excluded. Where multiple sources reported on the same data (e.g., a thesis and published articles), only the peer-reviewed publications were included.

Charting the data

Data extraction was performed by two independent reviewers (SS and LB). After initial pilot extraction of 2 articles by both reviewers, additional headings were added to the original data extraction form. The headings indicated: basic study information; the study design; description of study sample; the type of measure for each behaviour (self-report or device-based); device type, data processing methods, and wear protocol (if relevant); the self-report measure (if relevant); whether 24-hour movement was the exposure or outcome; the other health variable(s) and associated measure(s) examined in relation to 24-hour movement behaviours; whether independent associations were examined; description of results based on the different model approaches (i.e., single, partition, and isotemporal substitution models); covariates included in the final models; summary of the key study findings. The full list of data extraction form headings is provided in Supplementary Materials. Where information was missing or unclear, corresponding authors were contacted for clarification via email. Any disagreements were resolved through discussion between the two reviewers.

Collating, summarising and reporting the results

One researcher (SS) collated, summarised, and reported the results. A descriptive study summary table was created to outline key study details and provide a comprehensive map of the existing evidence.

Data analysis

Measurement of behaviours

Information on how behaviours were measured was extracted and presented in a table to allow for comparison of movement behaviour definitions across the included studies. For studies using

device-based measures, this included identifying device type, device placement (wrist, hip, or thigh), and any software or algorithms used for data processing and reduction. Wear protocols for devices were also reviewed including monitoring period, criteria for a valid day (i.e., minimum wear time requirements) and the number of valid days needed for inclusion in the analysis. Additionally, information on wear-time compliance was explored and presented. For self-report measures, the specific questionnaires used in studies were presented.

Association with 24-hour movement

Study outcomes were extracted to identify key variables examined in relation to 24-hour movement behaviours in this population and the position of 24-hour movement as an exposure or outcome in the analysis. Specific outcome measures and their assessment methods (e.g., self-report) were presented in the descriptive study summary table.

Quality appraisal

The methodological quality of included studies was critically appraised using the Critical Appraisal Skills Programme (CASP) checklist for cross-sectional studies[49]. One reviewer (SS) independently conducted the appraisal for each study. A narrative summary of quality was recorded alongside each study along with a final rating (e.g., low, moderate, high) based on the overall strengths and limitations identified. The CASP checklist for cross-sectional studies is presented in the Supplementary Materials.

RESULTS

Figure 1 presents the flow of study selection. From 88 identified publications and two theses, seven studies met the eligibility criteria and were included in this review. Disagreement occurred over two protocol papers during screening[50,51]. After agreement that these studies may include an

analysis plan, both were brought forward to full text review, but were not included in the final review. One thesis was identified as a source of two included studies and was excluded to avoid duplication, with the peer-reviewed publications retained[52,53]. These studies used the same sample to examine different outcomes[52,53], meaning seven studies using six distinct samples were included in the review.

Study characteristics

Study characteristics are presented in Table 1. All were cross-sectional. Three studies were conducted in the United States[52-54], two in Australia[55,56], one in Canada[57], and one in Spain[58]. Three studies investigated multiple cancer types[52,53,58], two investigated breast cancer[54,55], one Non-Hodgkin's Lymphoma[56], and one kidney cancer[57]. Sample sizes ranged from 73[52,53] to 463[57]. Six studies were conducted in adults[52-57] and one was conducted in children and adolescents (<18 years old)[58]. Movement behaviours were the exposures in all studies. Four studies used device-based measures for all behaviours[52-54,58], two used device-based measures of daytime behaviours with self-reported sleep[55,56], and one study used self-report for all behaviours[57]. All studies used isotemporal substitution modelling to investigate the impact of reallocating movement behaviours on the outcomes. One study applied a compositional data approach to isotemporal substitution in children diagnosed with cancer[58]. Most also reported single models (only examining one movement behaviour without taking others into account)[52-57] and partition models (examining one movement behaviour while holding the other behaviours constant)[53-57].

Quality appraisal

Table 2 presents the summarised quality appraisal results. Six of the included studies were rated as low quality[52-57] and one was moderate quality[58]. Briefly, studies demonstrated strengths such

as the use of device-based measures[52-56,58], validated outcome tools[53,56-58], and appropriate analytical approaches[52-58]. However, reporting on cancer-specific validity of measures was limited. In the analyses, the issue of residual confounding is likely as studies did not account for key factors such as comorbidities[52-54,58] and socioeconomic position[52,53,58]. The generalisability of studies was limited due to small sample sizes, evidence of selection biases, and samples comprising better functioning, health-conscious participants[52-58]. Despite methodological limitations, studies were rated as valuable due to their exploratory nature and highlighting of areas for future research.

Measurement of behaviours

Table 3 presents how movement behaviours were measured and defined across studies.

Device-based measures

SB and PA of different intensities were measured using devices in six studies[52-56,58]. Sleep was measured using devices in four studies[52-54,58].

Wear protocols

Table 4 presents the wear protocols for the devices used across studies. Only one study included cancer-specific wear instructions advising women diagnosed with lymphedema or experiencing discomfort on their non-dominant side to wear the device on their dominant wrist while sleeping[54].

Self-report measures

One study used self-reported measures of SB and PA of different intensities[57]. Three studies used self-report measures for sleep[55-57].

Outcomes examined

Outcomes across studies and their measures are presented in Table 1. Three studies examined movement behaviours in relation to quality of life[53,56,57]. Specifically, Vallance et al. examined health-related quality of life and fatigue in people diagnosed with Non-Hodgkins Lymphoma[56]. Body mass index (BMI) was explored as an outcome in two studies[52,55] . Cognitive function was explored as an outcome in one study[54]. Waist circumference was explored in another study[55]. Bone health was explored as an outcome in children diagnosed with cancer[58].

Analyses conducted

Statistical significance

Results of the isotemporal substitution models from seven studies are presented in Table 5. Five studies converted time spent in behaviours into 30-minute units for reallocation models[52-56]. One study used 10-minute units and only examined the replacement of sedentary behaviour with other behaviours[57]. Only the study with children diagnosed with cancer explicitly accounted for the compositional nature of the 24-hour day and used isometric log ratios to investigate the impact of reallocating time across behaviours with bone health[58]. The hypothetical reallocation of time into MVPA demonstrated the most positive impact on health outcomes. Shading in Table 5 indicates where the modelled reallocation of time between behaviours is associated with a statistically significant improvement in the outcome of interest (i.e., beneficial to participants), for instance, improved fatigue. Unshaded rows indicate where there is a statistically significant association that is not in a beneficial direction to participants (e.g., worsened fatigue).

Clinical significance

Three studies reported on clinical significance[53,56,57]. Vallance et al. reported clinically important differences for fatigue when 30 minutes of MVPA replaced 30 minutes of sleep, SB and LPA[56]. Replacing 30 minutes of sleep, prolonged sedentary time, non-bouted sedentary time, or LPA with bouted MVPA achieved the threshold for determining a clinically important difference in health-related quality of life, although this was not statistically signficant[56,59]. Hidde et al. reported a clinically meaningful decrease in quality of life when reallocating time from MVPA to sleep, sedentary time, or LPA[53]. In people diagnosed with kidney cancer, Tabaczynski et al. estimated the threshold at which substituting behaviours can produce clinically meaningful changes in quality of life[57]. They reported that 83, 200, and 65 minutes of MVPA, sleep and LPA respectively were needed to replace SB to achieve a clinically meaningful improvement[57].

DISCUSSION

This is the first review of studies that have examined integrated physical activity, sedentary behaviour and sleep (24-hour movement) in people diagnosed with cancer. All studies in this review were cross-sectional with 24-hour movement behaviours as the exposures. Six out of seven employed device-based measures to assess PA and SB[52-56,58]. While four studies used a device-based measure of sleep[52-54,58], two studies supplemented their device-based PA and SB with a self-reported measure of sleep (single sleep duration item from the PSQI[60]) and used this to estimate the total time variable[55,56]. One study used self-report for assessing all behaviours[57].

Despite differences in measures across studies, isotemporal substitutional modelling consistently indicated the positive impact of hypothetically reallocating time from other behaviours into PA, particularly PA of moderate-to-vigorous intensity. Improvements were reported across a range of outcomes including lower waist circumference, lower BMI, faster cognitive processing, improved fatigue and improved bone health[52,54-58]. Results mostly supported the deleterious impact of reallocating time from other behaviours into SB[52,54,56-58].

Few studies were identified, and the overall methodological quality of studies was low. This limits the strength of the current evidence but highlights key priorities for future research. Addressing residual confounding, achieving more representative sampling, and reducing measurement bias will be critical to further understand the observed associations in people diagnosed with cancer. Despite these limitations, the studies offer exploratory insights and are useful in mapping the 24-hour movement paradigm in people diagnosed with cancer.

Study design

All studies were cross-sectional in nature, consistent with research in the general population where studies applying the 24-hour movement paradigm to longitudinal data are lacking[29,61,62].

Similar to the findings of a review of 103 time reallocation studies, interpreting the results in the current review is limited by the reliance on theoretically modelling reallocations of time using cross-sectional data[62]. Employing longitudinal or repeated measures designs can facilitate examination of how actual changes in 24-hour movement behaviours over time impact on health outcomes[63] and contribute to the understanding of temporal ordering. Longitudinal data can also enable advanced methods such as target trial emulation approaches[64] to identify which behavioural shifts can offer the greatest benefit.

Further, few studies in the general population[65] and no studies in this review have investigated the 24-hour movement behaviour composition as the outcome. In this context, it is possible to explore how composition of behaviours changes in response to a stimulus such as an intervention[66] or change in environment[67]. People diagnosed with cancer typically demonstrate inactive activity profiles[12] and there is a need to develop effective interventions to promote PA in this population[68]. In physical activity randomised controlled trials, evaluating the intervention effect on the singular outcome behaviour is important for the efficacy result. However, examining the impact of the intervention on the 24-hour movement composition can provide a meaningful picture of its real-world effect, allowing for better understanding of how time is redistributed, and helping to avoid oversimplification of intervention effects[69,70]. For instance, an observed increase in MVPA may be a positive intervention outcome, but if this change primarily reflects a reduction in LPA, rather than a reduction in SB, the net health benefit may be limited. Given how disease and treatment side-effects may influence behaviour patterns in complex ways when promoting physical activity in cancer populations, exploring 24-hour movement as an outcome may offer valuable insights as the 24-hour movement paradigm continues to evolve.

All studies included in this review used isotemporal substitution to examine the impact of hypothetically reallocating time across different movement behaviours, with most also including single and partition model effects[52-58]. The single and partition effect models are valuable in isolating and explaining relationships, while isotemporal substitution is a more holistic approach operationalising the 24-hour movement paradigm by modelling real-world shifts in activity patterns. For instance, Boyle et al.'s partition model reported that sleep, non-prolonged SB and MVPA were significantly associated with lower waist circumference and lower BMI in people diagnosed with breast cancer[55]. However, the isotemporal substitution model provides a more nuanced understanding of where the most beneficial changes can be made for each outcome[55]. Further advancement on this approach recognises the relative nature of the time-use components and the recent GRANADA statement endorses the use of compositional data analysis to examine reallocations between different behaviours on health outcomes[71] and to explore how changes in behaviours can have differential effects depending on a person's starting level of activity[62]. Reviews of studies applying a compositional data approach to analysis reported an increase from three studies in 2018[18] to 103 in 2023[62]. However, its application in clinical populations is lacking[62] and the current review only identified one study[58], highlighting a significant gap for future research investigating 24-hour movement within this disease context.

Measurement of behaviours

Self-report and device-based measures offer different but complementary information on movement behaviours. Self-report measures capture an individual's perceived and contextual recall of activities over a specified time period and can be disseminated at low cost and lower participant burden than devices[72]. This differs from device-based measures which use predefined thresholds and algorithms applied to the data collected to define movement

behaviour types[73]. Device-based measures can capture unstructured or incidental activity, and particularly light-intensity physical activity which is often under-reported or omitted in self-report measures focused on structured activities[74,75]. These differences are evident in the current review, where Tabaczynski et al.'s study using self-report reported lower LPA (14 minutes per day) compared to the other studies (e.g., 318 minutes per day[56]) and higher MVPA. The results of the current review converge with the consistent finding in the general population that shifting time from other behaviours into MVPA leads to health benefits, regardless of how the movement behaviour is measured[62].

Device-based measures formed the main source of evidence for this review and capture detailed and continuous information on 24-hour movement behaviors[76,77]. The type and positioning of the device varied across the included studies. While wrist-worn devices can demonstrate higher compliance rates, thigh-worn devices can offer more specificity when discriminating between postural behaviours such as sitting and standing[42,78]. Monitoring over a 7-day period – the most widely used protocol in studies of both the general population and people diagnosed with cancer – is advantageous to understand different weekday or weekend patterns of 24-hour movement[76]. Compliance is a key consideration when deciding on device type and positioning[42,76] and reporting compliance to wear protocols enables researchers to understand the issues they might encounter, particularly in specific populations such as people diagnosed with cancer. Where reported, compliance was high in the included studies[52-56], though only one study acknowledged potential wear-related difficulties specific to cancer populations[54]. However, no studies reported the average number of valid wear days per participant, limiting the ability to assess the overall volume of data contributing to the behaviour durations across the monitoring periods. This is a

recognised issue in methodology reporting and should be addressed in future studies employing device-based measures[79].

Accelerometer reporting recommendations have highlighted the importance of comprehensively describing how time spent in each behaviour is interpreted from the available data[76,80]. A recent review reported that Freedson cut-points are the most frequently used cut-points in adult and older adult populations[76]. Similarly, three studies in this review applied these cut-points to the raw data to classify movement behaviours[54-56], reflecting their widespread use in cancer populations too[81]. While this commonality can facilitate better comparisons to be made across studies, the use of the same thresholds for PA and SB that are established in a much younger cohort (university students[73]) may not be suitable when applied to older people diagnosed with cancer[81,82]. This may limit the accuracy of activity classification and confidence in the findings and should be acknowledged as a limitation in studies with people diagnosed with cancer[81]. Relating to SB, only two studies partitioned time spent being sedentary into prolonged and non-prolonged sedentary time[55,56] despite growing recognition that the way in which SB is accumulated can impact outcomes differentially[83]. This represents a gap when measuring SB in future research, particularly in people diagnosed with cancer who often spend large amounts of time sedentary[11] and experience side-effects such as cancer-related fatigue[84].

Lastly, accurate sleep measurement in free living conditions is consistently highlighted as an issue[85]. Despite differences in sleep measurement by self-report versus various device algorithms, results of this review suggest that reallocating time from PA into sleep is associated with poorer outcomes[54-56,58] while reallocating from SB into sleep was associated with lower BMI and improved health-related quality of life[52,57]. These trends are in the same direction as the general population where Miatke et al. reported that there is some evidence for health

improvements when reallocating time from SB to sleep[62]. Future research should aim to improve our understanding of sleep and recognise that factors such as sleep quality may have differential associations with outcomes than sleep duration alone[86-88]. Further considerations for device-based measures of 24-hour movement in people diagnosed with cancer are provided in the Supplementary Materials.

Optimising the reallocation of 24-hour movement behaviours

Despite the limitations of the studies in this review, results are consistent with studies in the general population demonstrating the potency of reallocating time to MVPA in improving a range of outcomes and the adverse impact of reallocating time out of this intensity activity[62]. In Vallance et al.'s study, the magnitude and direction of modelled effects on fatigue were broadly similar across reallocations into bouted MVPA from sleep, SB, or LPA in people diagnosed with non-Hodgkins Lymphoma[56]. This suggests that MVPA is beneficial irrespective of the behaviour is replaces and therefore, aligns with previous research demonstrating the positive impact of MVPA when considered as an absolute exposure outside of the 24-hour movement paradigm[89]. However, this review offers more nuanced insights by using the 24-hour approach to highlight that replacing SB with MVPA yields the most beneficial effects. Results demonstrated that converting SB into MVPA demonstrated the most consistent improvements when modelling changes in behaviors across cancer types, age groups, and health domains including physical, cognitive, and skeletal patient-reported outcomes[54-58].

The studies in this review, along with previous research, demonstrate that sedentary time is high in people diagnosed with cancer[90]. Changing accumulation patterns may also provide an avenue to experience health benefits. Boyle et al. highlighted the detrimental impact of increased prolonged SB in particular on waist circumference and BMI[55], while Vallance et al. reported that replacing

both non-prolonged and prolonged SB with MVPA was associated with improved fatigue[56]. In people with prediabetes and type 2 diabetes, reallocating time from either prolonged (>60 minutes) or non-prolonged sedentary time into MVPA demonstrated consistent improvements in BMI and waist circumference, whereas breaking up SB (i.e., reallocating prolonged into non-prolonged) showed no significant benefit[91]. These inconsistencies within and across clinical populations highlight the need for further investigation into how the interruption of sitting patterns may benefit health, particularly as health guidelines move toward broader behavioural targets[92]. Future research should aim to explore these associations further for a more granular understanding of how to optimise movement patterns, particularly in cancer populations experiencing persistently high SB.

Common side-effects of cancer and its treatment include cancer-related fatigue[84], pain[93] and deconditioning[94] which can limit a patient's ability to engage in higher intensity PA. Patients also report barriers such as lack of access to physical activity services, lack of information from healthcare professionals and lack of motivation to start exercising[22,95]. The results of the current review provide some support for benefits resulting from converting time spent sedentary into other activities including LPA[52,54,58] and sleep [52,57]. This may be important for people diagnosed with cancer to have the opportunity make changes that are more feasible to their current treatment stage and physical capacity, rather than higher intensity activities like MVPA[33]. Device-based studies of individuals in the US diagnosed with cancer have reported that most of their physical activity occurs at the light-intensity level[90,96]. While this review demonstrates the additional positive impact of then reallocating LPA into MVPA, the proposed benefits of reallocating SB into LPA highlight how this shift may serve as a practical and achievable starting point with evidenced improvements in outcomes for people diagnosed with cancer[33]. Cognition

was the only outcome where this reallocation did not indicate the same positive impact[54], although this relationship direction aligns with previous research and may be due to contextual activities of SB that may improve cognitive health[62,97], e.g., reading, computer use, and work-related sedentary time[98,99].

Three studies discussed the clinically meaningful results of changes in 24-hour movement behaviour patterns as well as statistically significant results, offering a more practical interpretation of findings[53,56,57]. For example, Tabaczynski estimated the minutes of reallocation needed to achieve clinically meaningful differences, enhancing the utility of their findings in a real-world context[57]. These meaningful thresholds are particularly important for clinical populations, where patient-reported outcomes are critical to understand the lived experience beyond traditional clinical measures. Future research should aim to explore a wider range of outcomes that are prevalent in people diagnosed with cancer such as depression[100] and anxiety[101], as well as replicating observed results in other samples. Consideration of these clinical thresholds will better inform practice and policy in cancer survivorship.

No studies identified in this review examined clinical endpoints such as survival or recurrence. Evidence for the positive impact of post-diagnosis PA on cancer-specific outcomes is accumulating, particularly in larger cancer populations such as breast [102] and prostate cancer[103]. As the 24-hour paradigm continues to evolve in people diagnosed with cancer, further examining where optimal changes can be made represents a key area for future investigations.

Strengths and limitations

This review is distinct from previous similar reviews in its requirement that all three movement behaviours (PA, SB and sleep) are included in the analyses, incorporating device-based and

self-report measures. To our knowledge, this is the first review to collate the available evidence on studies using the 24-hour movement paradigm in people diagnosed with cancer, despite increasing recognition of its value within this population[34]. This will enable future researchers to have a resource to reference when examining all movement behaviours in this population and to identify research gaps such as examining the associations between 24-hour movement behaviours and cancer-related endpoints. This review was informed by best practice guidelines, including guidance for scoping reviews and the PRISMA-ScR Checklist, but was not without its limitations[35,39]. Unlike prior reviews in this area (e.g., Montoye et al.[80]), no clear recommendations could be given based on the limited available evidence. Only studies published in the English language were included in this review so there is the possibility of other studies published in other languages that were not identified.

Conclusion

The current review is the first to collate existing literature that has investigated all three movement behaviours that comprise the 24-hour day in people diagnosed with cancer. The limited availability of studies highlights a need for more studies to apply this paradigm in people diagnosed with cancer. The heterogeneity of outcomes across studies limits the ability to draw strong conclusions but demonstrates the need for future research replicating and expanding this work. Improved methodological rigour and appropriate movement behaviour measurement considerations will improve our understanding of 24-hour patterns and provide more generalisable insights across diverse cancer populations. Future research can benefit from applying longitudinal designs to investigate how actual changes in the 24-hour composition relate to health outcomes. As the 24-hour movement approach continues to progress with the development of new movement guidelines, future studies should address these gaps to ensure

comprehensive inclusion and consideration of people diagnosed with cancer. Improving the understanding of 24-hour movement methodologies and their appropriate application in this population will be critical in enabling researchers to develop evidence-based strategies to support long-term health and well-being for people diagnosed with cancer.

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COMPETING INTERESTS

The authors declare no competing interests.

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TABLES

Table 1. Characteristics of studies included in the review (N=7)

Study	Country	Cancer type	Sample size[a]	Self-report or device-based	Device used	Covariates	Outcomes examined
Boyle et al., 2017[55]	Australia	Breast	256 WC 238 BMI	Self-reported sleep Device-based PA and SB	Actigraph	Age, socioeconomic status, comorbidity, smoking status	BMI (self-report) Waist circumference (self-report)
Vallance et al., 2017[56]	Australia	Non-Hodgkins Lymphoma	149	Self-reported sleep Device-based PA and SB	Actigraph	Age, sex, socioeconomic status, working status	Fatigue (FS)[104] Health-related quality of life (FACT-G)[105]
Ehlers et al., 2018[54]	United States	Breast	269 Task-Switch stay 268 Task-Switch switch 269 Trail Making Task	Device-based	Actigraph	Age, months of adjuvant hormonal therapy, receipt of chemotherapy, total time the accelerometer was worn	Cognitive function (Task-Switch task[106], Trail Making task[107])
Tabaczynski et al., 2020[57]	Canada	Kidney	463	Self-report	N/A	Age, sex, education level, marital status, alcohol consumption, smoking status, BMI, comorbidities, time since diagnosis drug therapy, current treatment status, current	Quality of life (FACT-G[105], FACT-F[104], Trial Outcome Index-Fatigue[105])

						cancer status, recurrence status	
Hidde et al., 2022[53]	United States	Mixed cancers[b]	73	Device-based	ActivPAL Actiwatch	Age, cancer type, time since diagnosis	Quality of life (FACT-G[105])
Hidde et al., 2024[52]	United States	Mixed cancers[b]	73	Device-based	ActivPAL Actiwatch	Age, cancer type, time since diagnosis	BMI (self-report or laboratory visit)
Marmol-Perez et al., 2024[58]	Spain	Mixed paediatric cancers[c]	116[d]	Device-based	Actigraph	Rest of movement behaviours, time since treatment completion, radiotherapy exposure, region-specific lean mass.	Bone health (DXA scan)

[a]Final N included in analysis. [b]Breast, colorectal, leukemia/lymphoma and other. [c]Acute lymphoblastic leukemia, lymphoma, central nervous system, renal tumor, neuroblastoma, malignant bone tumor, histiocytosis, soft tissue and other extraosseous sarcomas retinoblastoma hepatic tumor, other malignant epithelial neoplasms, and unknown. [d]Sample size may be slightly varied for some variables due to missing data across the models. Abbreviations: WC=Waist circumference; BMI: Body Mass Index; PA=Physical Activity; SB=Sedentary behaviour; FS=Fatigue Scale[104]; FACT-G =Functional Assessment of Cancer-General[105];FACT-F=Functional Assessment of Cancer-Fatigue[104]; DXA=Dual-energy X-ray Absorptiometry.

Table 2. Summary of included study quality using the Critical Appraisal Skills Programme checklist[49]

Study	Clearly focused issue?	Appropriate method?	Acceptable recruitment?	Measured accurately to reduce biases?	Data collected to address research issue?	Enough participants?	Presentation of results?	Sufficiently rigorous data analysis?	Clear statement of fundings	Results applicable to local population	Valuable?	Overall rating
Boyle et al., 2017[55]	Yes	Yes	Some concerns	Some concerns	Yes	Can't tell	Yes	Some concerns	Yes	No	Yes	Low
Vallance et al., 2017[56]	Yes	Yes	No	Some concerns	Yes	Can't tell	Yes	Some concerns	Yes	No	Yes	Low
Ehlers et al., 2018[54]	Yes	Yes	No	Yes	Yes	Can't tell	Yes	Some concerns	Yes	No	Yes	Low
Tabaczynski et al., 2020[57]	Yes	Yes	No	No	Yes	Can't tell	Yes	Some concerns	Yes	No	Yes	Low
Hidde et al., 2022[53]	Yes	Yes	No	Yes	Yes	Can't tell	Yes	Some concerns	Yes	No	Yes	Low
Hidde et al., 2024[52]	Yes	Yes	No	Some concerns	Yes	Can't tell	Yes	Some concerns	Yes	No	Yes	Low
Marmol-Perez et al., 2024[58]	Yes	Yes	Some concerns	Yes	Yes	Can't tell	Yes	Some concerns	Yes	No	Yes	Moderate

Table 3. Measurement and definition of light physical activity (LPA), moderate-to-vigorous physical activity (MVPA), sedentary behaviour (SB), and sleep across studies (N=7)

Study	Placement	Defining physical activity	Defining sedentary behaviour	Defining sleep	Data processing
Boyle et al., 2017[55]	Hip	Time in LPA: 100–1,951 counts per minute (CPM) and in MVPA: ≥1952 CPM.	Time spent sedentary:<100 CPM. Sedentary time partitioned into prolonged bouts of sedentary time (≥20 minutes) and non-prolonged sedentary time.	Pittsburgh Sleep Questionnaire Index (PSQI)[60]. Sleep duration derived from the question "During the past month, how many hours of actual sleep did you get at night (this may be different than the number of hours you spent in bed)?".	Raw acceleration data
Vallance et al., 2017[56]	Hip	Time in LPA: 100–1,951 counts per minute (CPM) and in MVPA: ≥1952 CPM. MVPA partitioned into bouted MVPA (≥10 minutes).	Time spent sedentary:<100 CPM Sedentary time partitioned into prolonged bouts of sedentary time (≥20 minutes) and non-prolonged sedentary time.	Pittsburgh Sleep Questionnaire Index (PSQI)[60]. Sleep duration derived from the question "During the past month, how many hours of actual sleep did you get at night (this may be different than the number of hours you spent in bed)?".	Raw acceleration data
Ehlers et al., 2018[54]	Hip and wrist	Data reduced into time spent in LPA (100–1,951 CPM) and in MVPA (≥1952 CPM).	Time spent sedentary:<100 CPM.	Data scored using the Sadeh algorithm: average daily minutes of sleep[108]. Data scored using the Sadeh algorithm: average daily minutes of sleep[108].	Actilife software

Tabaczynski et al., 2020[57]	N/A	A modified Godin Leisure Time-Questionnaire[57,109]. Daily MVPA calculated by summing minutes spent in PA of moderate intensity and two times the time spent in PA of vigorous intensity.	A modified version of the Domain-Specific sitting Time Questionnaire[110]. Five workdays and two non-workdays were averaged to represent total daily sitting time in minutes, regardless of working. A modified version of the Domain-Specific sitting Time Questionnaire[110]. Five workdays and two non-workdays were averaged to represent total daily sitting time in minutes, regardless of working.	Sleep duration was measured by a single-item measure from the modified Domain-Specific Sitting Time Questionnaire[57].	N/A
Hidde et al., 2022[53] Hidde et al., 2024[52]	Thigh and wrist	A "daytime" variable was created by subtracting non-wear time and time spent in bed from 24 hours MVPA defined as "stepping time, in minutes, with a cadence ≥ 75 and duration > 1 min" and "cycling time" LPA calculated by subtracting MVPA and sedentary time from this daytime variable.	Time spent sedentary was derived from time spent sitting or lying down (excluding sleep).	The start of the sleep interval was identified where there were 10 consecutive minutes with no activity counts (sleep onset) and the sleep interval concluded after 10 consecutive minutes with no activity counts was disrupted by another activity (sleep offset).	ActivPAL software

Marmol-Perez et al., 2024[58]	Wrist	Time spent in LPA, MVPA and SB were calculated based on milligravity units (mg): MVPA: 200 mg, LPA: 35–200 mg[111]. Time spent in LPA, MVPA and SB were calculated based on milligravity units (mg): MVPA: 200 mg, LPA: 35–200 mg[111].	Time spent sedentary was based on milligravity units (mg): SB: 35 mg)[111]. Time spent sedentary was based on milligravity units (mg): SB: 35 mg)[111].	Using the z angle of the device to differentiate between sleeping and waking.	Raw acceleration data with GGIR in R

Table 4. Wear protocols for devices used across studies (N=6)

Study	Length of monitoring period	Wear protocol	Number of valid days required for inclusion	Definition of a valid day	% valid	Average daily wear time in minutes, *M* (SD)	Average number of valid days worn
Boyle et al., 2017[55]	7 days	Actigraph on right hip to measure physical activity and sedentary behaviour during waking hours.	1 day	>10 hours of waking wear time.	95%	Waking= 870.0 (66)	Not reported.
Vallance et al., 2017[56]	7 days	Actigraph on right hip to measure physical activity and sedentary behaviour during waking hours.	1 day	>10 hours of waking wear time.	94%	Waking=870.0 (78)	Not reported.
Ehlers et al., 2018[54]	7 days	Actigraph on non-dominant hip during waking hours, switch to non-dominant wrist at night, return to hip upon waking.	4 days	>10 hours of waking wear time.	97%	Total=1322.8 (44) Waking=912.4 (61)	Not reported
Hidde et al., 2022[53] Hidde et al., 2024[52]	7 days	activPAL on thigh continuously for 24 hours/day for physical activity and sedentary behaviour measurement Actiwatch on wrist continuously for sleep measurement.	4 days including 1 weekend day	>20 hours of wear.	100%	Not reported.	Not reported.

Marmol-Perez et al., 2024[58]	7 days	Actigraph on non-dominant wrist, except for water-based activities.	1 day	23 hours registered by device with 16 hours waking.	Not reported	Not reported.	Reported only 1 participant only had just 1 valid day. No further information reported.

Table 5. Statistically significant results of isotemporal substitution models reallocating time between moderate-to-vigorous physical activity (MVPA), light physical activity (LPA), sedentary behaviour (SB), and sleep (N=7)[a]

Time reallocation	Change in outcome of interest	Cancer type	Study
Reallocating to MVPA			
Sleep into MVPA	Lower waist circumference	Breast	Boyle et al., 2017[55]
	Lower body mass index	Breast	Boyle et al., 2017[55]
	Faster times on task-switch switch trials[b]	Breast	Ehlers et al., 2018[54]
	Faster times on trails A completion[b]	Breast	Ehlers et al., 2018[54]
	Faster times on trails B completion[b]	Breast	Ehlers et al., 2018[54]
	Improved fatigue[c]	Non-Hodgkins Lymphoma	Vallance et al., 2017[56]
	Improved bone health at total body, total hip and lumbar spine	Mixed (prepubertal)	Marmol-Perez et al., 2024[58]
SB into MVPA	Lower waist circumference[d]	Breast	Boyle et al., 2017[55]
	Lower body mass index[d]	Breast	Boyle et al., 2017[55]
	Improved fatigue	Kidney	Tabaczynski et al., 2020[57]
	Improved fatigue[ce]	Non-Hodgkins Lymphoma	Vallance et al., 2017[56]
	Faster times on task-switch stay trials[b]	Breast	Ehlers et al., 2018[54]
	Faster times on task-switch switch trials[b]	Breast	Ehlers et al., 2018[54]
	Improved bone health at total body, total hip and lumbar spine	Mixed (prepubertal)	Marmol-Perez et al., 2024[58]
LPA into MVPA	Improved fatigue[c]	Non-Hodgkins Lymphoma	Vallance et al., 2017[56]
	Lower waist circumference	Breast	Boyle et al., 2017[55]
	Faster times on task-switch stay trials[b]	Breast	Ehlers et al., 2018[54]

	Faster times on task-switch switch trials[b]	Breast	Ehlers et al., 2018[54]
	Faster time on Trails A completion[b]	Breast	Ehlers et al., 2018[54]
	Faster time on Trails B completion[b]	Breast	Ehlers et al., 2018[54]
	Improved bone health at total body, total hip and lumbar spine	Mixed (prepubertal)	Marmol-Perez et al., 2024[58]
Reallocating to LPA			
Sleep into LPA	Improved bone health at total body, total hip, and femoral neck	Mixed (peri/postpubertal)	Marmol-Perez et al., 2024[58]
	Improved bone health at total body and femoral neck	Mixed (prepubertal)	Marmol-Perez et al., 2024[58]
SB into LPA	Slower time on Trails A completion[b]	Breast	Ehlers et al., 2018[54]
	Slower time on Trails B completion[b]	Breast	Ehlers et al., 2018[54]
	Lower body mass index	Mixed	Hidde et al., 2024[52]
	Improved bone health at total body, total hip, lumbar spine and femoral neck	Mixed (peri/postpubertal)	Marmol-Perez et al., 2024[58]
	Improved bone health at total body and femoral neck	Mixed (prepubertal)	Marmol-Perez et al., 2024[58]
MVPA into LPA	Worsened fatigue[c]	Non-Hodgkins Lymphoma	Vallance et al., 2017[56]
	Higher waist circumference	Breast	Boyle et al., 2017[55]
	Slower times on task-switch stay trials[b]	Breast	Ehlers et al., 2018[54]
	Slower times on task-switch switch trials[b]	Breast	Ehlers et al., 2018[54]
	Slower time on Trails A completion[b]	Breast	Ehlers et al., 2018[54]
	Slower time on Trails B completion[b]	Breast	Ehlers et al., 2018[54]
	Worsened bone health at total body, total hip and lumbar spine	Mixed (prepubertal)	Marmol-Perez et al., 2024[58]
Reallocating to SB			

Sleep into SB	Higher body mass index	Mixed	Hidde et al., 2024[52]
	Improved bone health at total hip	Mixed (peri/postpubertal)	Marmol-Perez et al., 2024[58]
	Worsened health-related quality of life	Kidney	Tabaczynski et al., 2020[57]
Prolonged SB into non-prolonged SB	Lower waist circumference	Breast	Boyle et al., 2017[55]
	Lower body mass index	Breast	Boyle et al., 2017[55]
LPA into SB	Faster time on Trails A completion[b]	Breast	Ehlers et al., 2018[54]
	Faster time on Trails B completion[b]	Breast	Ehlers et al., 2018[54]
	Higher body mass index	Mixed	Hidde et al., 2024[52]
	Worsened bone health at total body, total hip, lumbar spine and femoral neck	Mixed (peri/postpubertal)	Marmol-Perez et al., 2024[58]
	Worsened bone health at total body and femoral neck	Mixed (prepubertal)	Marmol-Perez et al., 2024[58]
MVPA into SB	Higher waist circumference[d]	Breast	Boyle et al., 2017[55]
	Higher body mass index[d]	Breast	Boyle et al., 2017[55]
	Worsened fatigue[ce]	Non-Hodgkins Lymphoma	Vallance et al., 2017[56]
	Worsened fatigue	Kidney	Tabaczynski et al., 2020[57]
	Slower times on task-switch stay trials[b]	Breast	Ehlers et al., 2018[54]
	Slower times on task-switch switch trials[b]	Breast	Ehlers et al., 2018[54]
	Worsened bone health at total body, total hip and lumbar spine	Mixed (prepubertal)	Marmol-Perez et al., 2024[58]
Reallocating to sleep			
SB into sleep	Lower body mass index	Mixed	Hidde et al., 2024[52]
	Improved health-related quality of life	Kidney	Tabaczynski et al., 2020[57]

	Worsened bone health at total hip	Mixed (peri/postpubertal)	Marmol-Perez et al., 2024[58]
LPA into sleep	Worsened bone health at total body, total hip, lumbar spine and femoral neck	Mixed (peri/postpubertal)	Marmol-Perez et al., 2024[58]
	Worsened bone health at total body and femoral neck	Mixed (prepubertal)	Marmol-Perez et al., 2024[58]
MVPA into sleep	Higher waist circumference	Breast	Boyle et al., 2017[55]
	Higher body mass index	Breast	Boyle et al., 2017[55]
	Slower times on task-switch switch trials[b]	Breast	Ehlers et al., 2018[54]
	Slower time on Trails A completion[b]	Breast	Ehlers et al., 2018[54]
	Slower time on Trails B completion[b]	Breast	Ehlers et al., 2018[54]
	Worsened fatigue[c]	Non-Hodgkins Lymphoma	Vallance et al., 2017[56]
	Worsened bone health at total body, total hip and lumbar spine	Mixed (prepubertal)	Marmol-Perez et al., 2024[58]

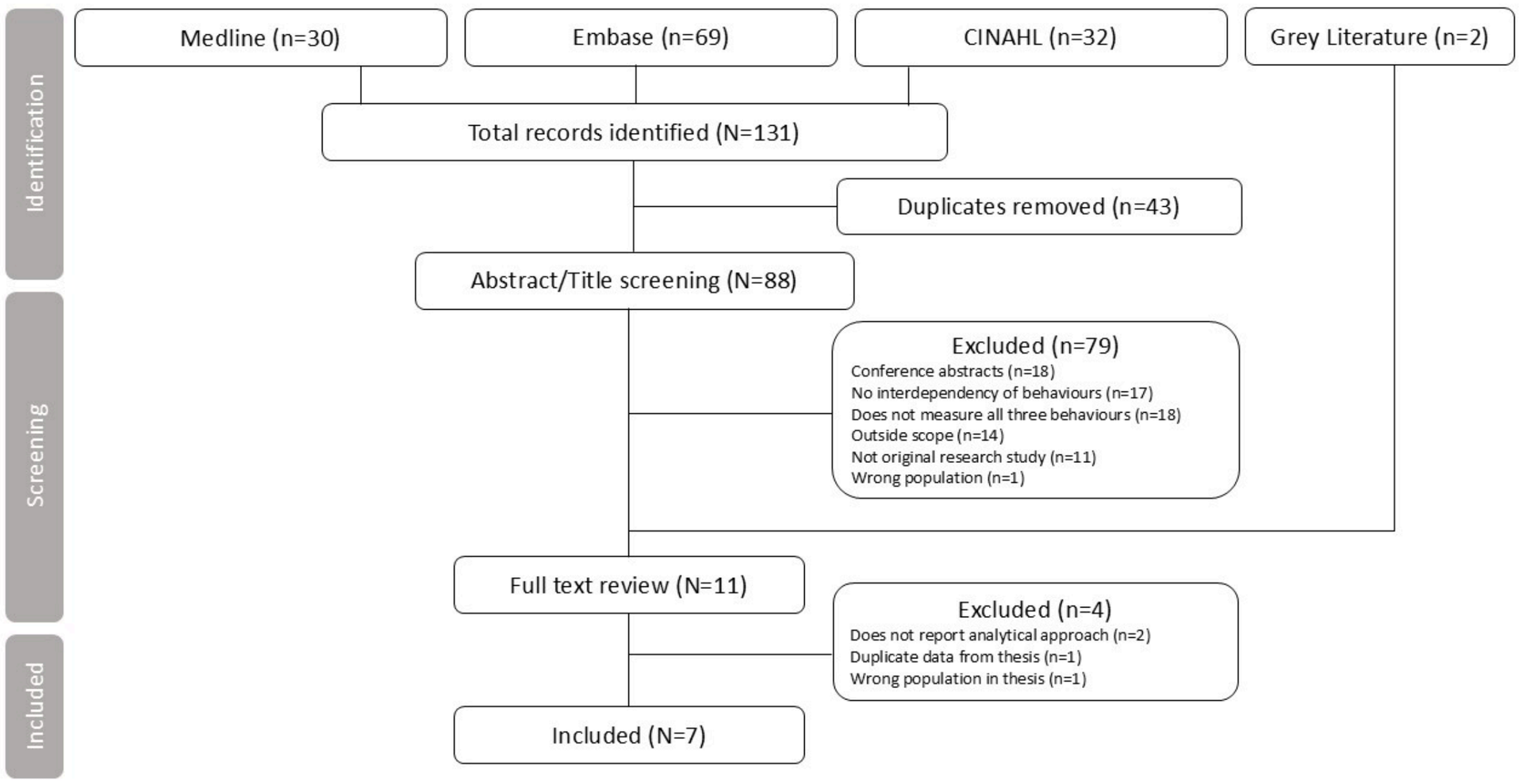
[a]Associations that were not statistically significant are not presented. Tabacynski et al.'s study only evaluated the effects of reallocating time from sedentary behaviour to other activities, and did not examine substitutions between other behaviours (e.g., MVPA → LPA, LPA → sleep)[57]. [b] While reallocating behaviours impacted on the speed of completing cognitive tasks, no effect was found on the accuracy of such tasks. [c]Effects observed only for bouted MVPA (10+ minutes). [d]Effects observed only for prolonged SB (>20mins uninterrupted). [e]Effects observed for both prolonged (>20mins uninterrupted) and non-prolonged SB.

Table 6. Statement of funding sources reported in the included studies (N=7)

Boyle et al., 2017[55]	This work was supported by Breast Cancer Research Centre - Western Australia (Grant to T. Boyle, J.K. Vallance and B.M. Lynch), Cancer Council Western Australia (Award to T. Boyle); the Australian National Health and Medical Research Council (Fellowship #1072266 to T. Boyle); the Canadian Institutes of Health Research (Fellowship #300068 to T. Boyle); the Michael Smith Foundation for Health Research (Trainee Award #5553 to T. Boyle); Killam Trusts (Postdoctoral Research Fellowship to T. Boyle); the Canada Research Chairs (J.K. Vallance); Alberta Innovates – Health Solutions (Population Health Investigator Award to J.K. Vallance); US National Cancer Institute (Grant #1R01CA198971 to M.P. Buman); and the Australian National Breast Cancer Foundation (Fellowship to B.M. Lynch).
Vallance et al., 2017[56]	This work was supported by a grant from Cancer Council Western Australia awarded to Terry Boyle.
Ehlers et al., 2018[54]	Dr. Ehlers and this project were supported by an American Cancer Society (ACS) Postdoctoral Fellowship (PF-16-021-01-CPPB) at the University of Illinois at Urbana-Champaign. ACS was not involved in the design of the study; collection, analysis, and interpretation of data; or writing of the manuscript.
Tabaczynski et al., 2020[57]	Kerry S Kourneya is supported by the Canada Research Chairs Program.
Hidde et al., 2022[53]	This work was supported by the Department of Health and Exercise Science at Colorado State University.
Hidde et al., 2024[52]	No funding statement.
Marmol-Perez et al., 2024[58]	This study has been partially supported by the Spanish Ministry of Science and Innovation (ref. no. PID2020-117302RA-I00 financiado por MCIN/AEI/10.13039/501100011033), La Caixa Foundation (ref. no. LCF/BQ/PR19/11700007), the University of Granada Plan Propio de Investigación 2021-Excellence actions: Unit of Excellence on Exercise, Nutrition and Health (UCEENS), and the CIBEROBN, Centro de Investigación Biomédica en Red (CB22/03/00058), Instituto de Salud Carlos III, Ministerio de Ciencia e Innovación and Unión Europea–European Regional Development Fund. AM-P is recipient of a predoctoral fellowship (FPU20/05530) by the Spanish Ministry of Education, Culture and Sport. EU-G is supported by the Maria Zambrano fellowship by the Ministerio de Universidades y la Unión Europea–NextGenerationEU.

FIGURES

Figure 1. PRISMA flow diagram illustrating identification of seven included studies



Supplementary Materials 1

Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) Checklist [1]

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
TITLE			
Title	1	Identify the report as a scoping review.	1
ABSTRACT			
Structured summary	2	Provide a structured summary that includes (as applicable): background, objectives, eligibility criteria, sources of evidence, charting methods, results, and conclusions that relate to the review questions and objectives.	1
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known. Explain why the review questions/objectives lend themselves to a scoping review approach.	3-4
Objectives	4	Provide an explicit statement of the questions and objectives being addressed with reference to their key elements (e.g., population or participants, concepts, and context) or other relevant key elements used to conceptualize the review questions and/or objectives.	4
METHODS			
Protocol and registration	5	Indicate whether a review protocol exists; state if and where it can be accessed (e.g., a Web address); and if available, provide registration information, including the registration number.	5
Eligibility criteria	6	Specify characteristics of the sources of evidence used as	6-7

		eligibility criteria (e.g., years considered, language, and publication status), and provide a rationale.	
Information sources*	7	Describe all information sources in the search (e.g., databases with dates of coverage and contact with authors to identify additional sources), as well as the date the most recent search was executed.	5
Search	8	Present the full electronic search strategy for at least 1 database, including any limits used, such that it could be repeated.	Supplementary materials
Selection of sources of evidence†	9	State the process for selecting sources of evidence (i.e., screening and eligibility) included in the scoping review.	6-7
Data charting process‡	10	Describe the methods of charting data from the included sources of evidence (e.g., calibrated forms or forms that have been tested by the team before their use, and whether data charting was done independently or in duplicate) and any processes for obtaining and confirming data from investigators.	7
Data items	11	List and define all variables for which data were sought and any assumptions and simplifications made.	7&Supplementary materials
Critical appraisal of individual sources of evidence§	12	If done, provide a rationale for conducting a critical appraisal of included sources of evidence; describe the methods used and how this information was used in any data synthesis (if appropriate).	8
Synthesis of results	13	Describe the methods of handling and summarizing the data that were charted.	7-8
RESULTS			
Selection of sources of evidence	14	Give numbers of sources of evidence screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally using a flow diagram.	8, Figure 1
Characteristics of sources of	15	For each source of evidence, present characteristics for which	9, Table 1

evidence		data were charted and provide the citations.	
Critical appraisal within sources of evidence	16	If done, present data on critical appraisal of included sources of evidence (see item 12).	9
Results of individual sources of evidence	17	For each included source of evidence, present the relevant data that were charted that relate to the review questions and objectives.	8-9, Table 1, Table 3, Table 4, Table 5
Synthesis of results	18	Summarize and/or present the charting results as they relate to the review questions and objectives.	8-9, Table 1, Table 3, Table 4, Table 5
DISCUSSION			
Summary of evidence	19	Summarize the main results (including an overview of concepts, themes, and types of evidence available), link to the review questions and objectives, and consider the relevance to key groups.	11-12
Limitations	20	Discuss the limitations of the scoping review process.	20
Conclusions	21	Provide a general interpretation of the results with respect to the review questions and objectives, as well as potential implications and/or next steps.	20
FUNDING			
Funding	22	Describe sources of funding for the included sources of evidence, as well as sources of funding for the scoping review. Describe the role of the funders of the scoping review.	Table 6

JBI = Joanna Briggs Institute; PRISMA-ScR = Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews.

* Where *sources of evidence* (see second footnote) are compiled from, such as bibliographic databases, social media platforms, and Web sites.

† A more inclusive/heterogeneous term used to account for the different types of evidence or data sources (e.g., quantitative and/or qualitative research, expert opinion, and policy documents) that may be eligible in a scoping review as opposed to only studies. This is not to be confused with *information sources* (see first footnote).

‡ The frameworks by Arksey and O'Malley (6) and Levac and colleagues (7) and the JBI guidance (4,5) refer to the process of data extraction in a scoping review as data charting.

§ The process of systematically examining research evidence to assess its validity, results, and relevance before using it to inform a decision. This term is used for items 12 and 19 instead of "risk of bias" (which is more applicable to systematic reviews of interventions) to include and acknowledge the various sources of evidence that may be used in a scoping review (e.g., quantitative and/or qualitative research, expert opinion, and policy document).

References

OBJ

1. Tricco AC, Lillie E, Zarin W, et al. PRISMA Extension for Scoping Reviews (PRISMA-ScR): Checklist and Explanation. *Annals of Internal Medicine*. 2018/10/02 2018;169(7):467-473. doi:10.7326/M18-0850

Supplementary Materials 2

Search strategies for Medline, Embase, and CINAHL

Medline search strategy

Ovid MEDLINE(R) ALL<1946 to August 6, 2024>

1 sedentary behavior/ 14408

2 ((sedentary adj2 (time or behavio*)) or ((sit or sitting) adj2 (time or behavio*)) or (screen adj1 time) or screen-time).ti,ab. 19093

3 exercise/ 150317

4 ((physical adj2 (activit* or inactivit* or behavio* or exercise)) or sport).ti,ab. 230729

5 exp sleep/ 103452

6 (sleep* or alertness or wakefulness).ti,ab. 256483

7 (24-hour movement behav* or integrated behav*).ti,ab. 1012

8 1 or 2 25743

9 3 or 4 312767

10 5 or 6 274706

11 8 and 9 and 10 2698

12 7 or 11 3591

13 cancer survivor/ 10284

14 ((cancer adj2 surviv*) or (cancer adj2 patient*)).ti,ab. 363012

15 LWBC.ti,ab. 29

16 "People living with and beyond cancer".ti,ab. 105

17 13 or 14 or 15 or 16 364379

18 12 and 17 30

Embase search strategy

Embase<1974 to 2024 August 06>

1 sedentary time/ or sedentary lifestyle/ or screen time/ or sitting/ 55761

2 ((sedentary adj2 (time or behavio*)) or ((sit or sitting) adj2 (time or behavio*)) or (screen adj1 time) or screen-time).ti,ab. 23184

3 exp exercise/ or exp physical activity/ or exercise intensity/ 933416

4 ((physical adj2 (activit* or inactivit* or behavio* or exercise)) or sport).ti,ab. 305804

5 exp sleep/ 287828

6 (sleep* or alertness or wakefulness).ti,ab. 385307

7 (24-hour movement behav* or integrated behav*).ti,ab. 1222

8 1 or 2 64734

9 3 or 4 1024605

10 5 or 6 462760

11	8 and 9 and 10	4689
12	7 or 11	5783
13	cancer survivor/	37080
14	((cancer adj2 surviv*) or (cancer adj2 patient*)).ti,ab.	584288
15	LWBC.ti,ab.	46
16	"People living with and beyond cancer".ti,ab.	155
17	13 or 14 or 15 or 16	591863
18	12 and 17	69

CINHAL search strategy

S1: MH life style, sedentary

S2: TI ((sedentary N2 (time or behavio*)) or (sit* N2 (time or behavio*)) or (screen N1 time) or screen-time)) OR AB ((sedentary N2 (time or behavio*)) or (sit* N2 (time or behavio*)) or (screen N1 time) or screen-time)

S3: MH physical activity OR MH exercise

S4: TI (((physical N2 (activit* or inactivit* or behavio* or exercise)) or sport)) OR AB (((physical N2 (activit* or inactivit* or behavio* or exercise)) or sport)

S5: MH sleep OR MH sleep duration

S6: TI (((sleep* or alertness or wakefulness))) OR AB (((sleep* or alertness or wakefulness))

S7: S1 OR S2

S8: S3 OR S4

24-hour movement in people diagnosed with cancer

S9: S5 OR S6

S10: S7 AND S8 AND S9

S11: TI ((24-hour movement behav* or integrated behav*)) OR AB ((24-hour movement behav* or integrated behav*)

S12: S10 OR S11

S13: MH cancer survivors

S14: TI ("people living with and beyond cancer") OR AB ("people living with and beyond cancer"

S15: TI LWBC OR AB LWBC

S16: TI (((cancer n2 surviv*)) or (cancer N2 patient*))) OR AB (((cancer n2 surviv*)) or (cancer N2 patient*))

S17: S13 OR S14 OR S15 OR S16

S18: S12 AND S17

Supplementary Materials 3

Column headings in the data extraction form

Supplementary table 1. Column headings used in the review data extraction form

Study information	Title
	Authors
	Journal, issue
	Date (Year)
	Study country of origin
	Study design
	Brief description of study sample. Note: Geographical location, age, gender, sample size
	Cancer type
Measures	How was each movement behaviour measured (self-report, device-based)
	Self-report instrument (e.g., GLTEQ)
	Accelerometer make and model
	Accelerometer body placement *Enter 1 = thigh, 2 = waist/hip, 3 = wrist, 4 = back, 5 = multiple sensors, 6 = other (if 5 add 1-4 as appropriate to indicate placement)*
	Minimum accelerometer weartime criteria (for inclusion)
	Adherence to wear protocol (% valid data)
	Accelerometers processing approach
	Type of movement behaviours measured (e.g., Physical activity, Sedentary behaviour, sitting, sleep)
	Movement behaviours included in the analysis

	Variables examined in relation to 24h movement (outcome and measure/instrument used)
Analytical approach	24h movement: Outcome or exposure?
	Covariates
	Analyses conducted (e.g., isotemporal substitution)
	Independent associations examined?
Results	Results of independent effects model (if applicable) Results of partition models (if applicable)
	Results of substitution models (if applicable)
	Summary of results
Additional information	REVIEWER NOTES: PLEASE ADD ANY RELEVANT INFORMATION REGARDING THIS STUDY. PARTICULARLY REGARDING ITS SUITABILITY FOR INCLUSION

Supplementary Materials 4

Critical Appraisal Skills Programme Checklist

CASP Checklist:

For Descriptive/Cross-Sectional Studies

Reviewer Name:	
Paper Title:	
Author:	
Web Link:	
Appraisal Date:	

During critical appraisal, never make assumptions about what the researchers have done. If it is not possible to tell, use the "Can't tell" response box. If you can't tell, at best it means the researchers have not been explicit or transparent, but at worst it could mean the researchers have not undertaken a particular task or process. Once you've finished the critical appraisal, if there are a large number of "Can't tell" responses, consider whether the findings of the study are trustworthy and interpret the results with caution.

Section A: Are the results valid?	
1. Did the study address a clearly focused issue?	Yes No Can't Tell
CONSIDER: *A question can be 'focused' in terms of* • *the population studied* • *the risk factors studied*	

• *is it clear whether the study tried to detect a beneficial or harmful effect* • *the outcomes considered*	
2. Did the authors use an appropriate method to answer their question?	Yes No Can't Tell
CONSIDER: • *Is a descriptive/cross-sectional study an appropriate way of answering the question* • *did it address the study question*	
3. Were the subjects recruited in an acceptable way?	Yes No Can't Tell
CONSIDER: *We are looking for selection bias which might compromise the generalisability of the findings:* • *Was the sample representative of a defined population* • *Was everybody included who should have been included*	

4. Were the measures accurately measured to reduce bias?	Yes No Can't Tell

CONSIDER:

Look for measurement or classification bias:

- *did they use subjective or objective measurements*
- *do the measurements truly reflect what you want them to (have they been validated)*

5. Were the data collected in a way that addressed the research issue?	Yes No Can't Tell

CONSIDER:

- *if the setting for data collection was justified*
- *if it is clear how data were collected (e.g., interview, questionnaire, chart review)*
- *if the researcher has justified the methods chosen*
- *if the researcher has made the methods explicit (e.g. for interview method, is there an indication of how interviews were conducted?)*

6. Did the study have enough participants to minimise the play of chance?	Yes No Can't Tell
CONSIDER: • *if the result is precise enough to make a decision* • *if there is a power calculation. This will estimate how many subjects are needed to produce a reliable estimate of the measure(s) of interest.*	
7. How are the results presented and what is the main result?	Yes No Can't Tell
CONSIDER: • *if, for example, the results are presented as a proportion of people experiencing an outcome, such as risks, or as a measurement, such as mean or median differences, or as survival curves and hazards* • *how large this size of result is and how meaningful it is* • *how you would sum up the bottom-line result of the trial in one sentence*	
8. Was the data analysis sufficiently rigorous?	Yes No Can't Tell

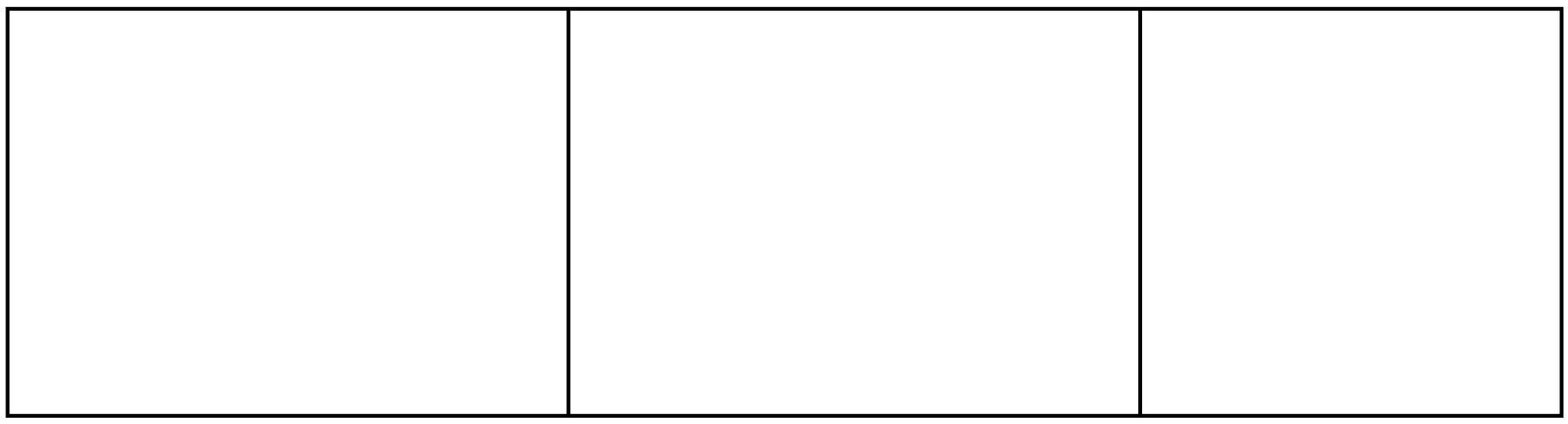
CONSIDER: • *if there is an in-depth description of the analysis process* • *if sufficient data are presented to support the findings*	
9. Is there a clear statement of findings?	Yes No Can't Tell
CONSIDER: • *if the findings are explicit* • *if there is adequate discussion of the evidence both for and against the researchers' arguments* • *if the researchers have discussed the credibility of their findings* • *if the findings are discussed in relation to the original research questions*	
10. Can the results be applied to the local population?	Yes No Can't Tell
CONSIDER: • *the subjects covered in the study could be sufficiently different from your population to cause concern.* • *your local setting is likely to differ much from that of the study*	
11. How valuable is the research?	Yes No Can't Tell

CONSIDER:

- *one descriptive/cross-sectional study rarely provides sufficiently robust evidence to recommend changes to clinical practice or within health policy decision making*
- *if the researcher discusses the contribution the study makes to existing knowledge (e.g., do they consider the findings in relation to current practice or policy, or relevant research-based literature?)*
- *if the researchers have discussed whether or how the findings can be transferred to other populations*

APPRAISAL SUMMARY: *List key points from your critical appraisal that need to be considered when assessing the validity of the results and their usefulness in decision-making.*

Positive/Methodologically sound	**Negative/Relatively poor methodology**	**Unknowns**



Referencing recommendation:

CASP recommends using the Harvard style referencing, which is an author/date method. Sources are cited within the body of your assignment by giving the name of the author(s) followed by the date of publication. All other details about the publication are given in the list of references or bibliography at the end.

Example:

Critical Appraisal Skills Programme (2024). CASP (insert name of checklist i.e. cross sectional Checklist.) [online] Available at: insert URL. Accessed: insert date accessed.

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Supplementary Materials 5

Considerations when using devices to measure 24-hour movement behaviours in people diagnosed with cancer

Supplementary Table 2. Summary of measurement considerations in studies using device-based measures of behaviours[a]

Consideration	Findings from this review
Device placement	Hip-worn devices were most commonly used[1-3]. These are constrained by limitations in detecting lower body posture and distinguishing time spent in SB versus standing[4]. Hip-worn devices are not typically worn at night so need to be supplemented by self-reported sleep[2,3] or a wrist-worn device[1]. Wrist-worn devices enable continuous wear but were used only for measuring sleep in three studies[1,5,6]. but share limitations in detecting lower body posture and distinguishing time spent in SB versus standing[4]. Thigh-worn devices can offer more specificity when discriminating between postural behaviours such as sitting and standing[7] and were used one study only for waking behaviours[5,6] and one study for all behaviours[8]. Researchers must consider the best suited measure for their research question and the significance of various movement behaviours to their outcome[4]. The implementation of commercial-grade wearables in future research could also overcome limitations such as seasonal variation in 7-day monitoring periods[9] and enable longer monitoring periods with higher compliance[10].
Wear protocols	All studies in people diagnosed with cancer used a 7-day wear protocol[1-3,5,6,8].
Compliance	Despite differences in positioning, compliance was high - over 90% in the five studies that gave compliance information[1-3,5,6]. This was despite the requirement for four valid days (≥95% compliance[1,5,6]) and studies requiring one valid day (≥94% compliance[2,3]). In people diagnosed with cancer, treatment side-effects such as skin sensitivity and lymphedema (swelling) may impact device wear[11,12]. Minor skin irritation attributable to device wear is a commonly reported in device-based studies which may impact their uptake in this population[7]. Only one study in this review acknowledged specific difficulties faced by cancer side-effects and advised women

	diagnosed with lymphedema or experiencing discomfort on their non-dominant side to wear the device on their dominant wrist while sleeping[1]. In this study,14/300 (5%) did not wear the accelerometer at nighttime due to lymphedema, swelling, or discomfort[1].
Average wear time	Although studies reported compliance with the minimum validity day criteria, there was limited information on the average wear time of devices. Three studies provided information on average daily-wear time1-3, but no studies gave information of the average wear time across the monitoring period to give an estimate of adherence to the 7-day protocols. This limits the ability to assess the overall volume of data contributing to the behaviour durations across the monitoring periods and represents a key gap to be addressed in reporting on device-based measurement.
Data reduction methods	**Summarising behaviours** Four studies in this review used cutpoints to summarise the data into behaviours[1-3,8]. Three applied Freedson cut-points[13] to the raw data to classify movement behaviours[1-3] and one used GGIR methods[8]. The use of the same thresholds for waking behaviours that are established in a much younger cohort (university students[13]) may not be suitable when applied to older people diagnosed with cancer[14,15]. Reduced functional capacity may alter the perceived relative effort of activities, affecting classification accuracy. This should be acknowledged as a limitation in studies with people diagnosed with cancer[15]. **Epoch length** Only two studies stated the epoch length[2,3]. Shorter epochs may be more suitable for detecting brief periods of activity and transitions between different intensities of activity while longer epochs may average out activities of different intensities and give a broader perspective on PA and SB trends[16]. The most suitable epoch length remains to be established for 24-hour movement in people diagnosed with cancer.
Reporting on methodology	There is a need for more transparency in reporting of data processing methods. This echoes previous reviews in the general population and cancer populations that call for reporting of all processing-related paradata to enable replicability and comparability in future research[4,14,15].