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Theory-based physical activity and/or nutrition behaviour change interventions for cancer survivors: A systematic review

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Abstract

Purpose: Theory-based interventions aimed at promoting long-term health behaviour change in cancer survivors seem to be effective but remain scarce and target mostly short-term adherence and outcomes. This review aimed to synthesize the evidence from randomized controlled trials (RCT) evaluating the efficacy of theory-based behaviour change interventions on physical activity and/or diet behaviours targeting cancer survivors.

Methods: A systematic search in three electronic databases (PubMed, PsycInfo and Web of Science) identified studies that (i) targeted adult cancer survivors; and (ii) reported on any theory-based RCT designed to influence physical activity, diet, or weight management. Study quality was assessed with an adapted version of the EPHPP Quality Assessment Tool for Quantitative Studies.

Results: Twenty-six studies met eligibility criteria. Diet-only trials reported significant improvements on at least one aspect of dietary intake, while in multiple behaviour trials, only five out of nine showed significant improvements in at least one aspect of diet. However, six of these nine trials, reported significant improvements in physical activity. In physical activity-only trials, eleven out of fifteen RCTs showed significant improvements in physical activity. Socio-Cognitive Theory seems to be the most used theory of reference, showing promising results in changing the two target behaviours. Several other theories were used in isolation or combined, but less frequently, and others showing increased relevance in recent decades, like Self-Determination Theory, could not be identified in interventions with cancer survivors.

Conclusions: Theory-based interventions seem to be important when it comes to improving physical activity and diet behaviours in cancer survivors. Still, more studies testing theory-based interventions in good-quality studies and including thorough descriptions of intervention contents and behaviour change techniques, are required to confirm or refute these findings.

Keywords: Systematic-review, Cancer, Behaviour change interventions, Physical activity, Diet

Resumo

Objetivo: Intervenções baseadas em teoria, destinadas a promover mudanças nos comportamentos de saúde a longo prazo em sobreviventes de cancro, são eficazes, mas escassas, focando-se sobretudo no curto prazo. Esta revisão procurou sintetizar a evidência de ensaios clínicos randomizados controlados (RCT) que avaliaram a eficácia de intervenções comportamentais, baseadas na teoria, na dieta e/ou exercício físico, em pacientes com cancro.

Métodos: A pesquisa foi realizada em três bases de dados (PubMed, PsycInfo e Web of Science), procurando estudos (i) com sobreviventes de cancro adultos; (ii) reportados em RCT baseados em teoria, com o objetivo de influenciar a atividade física, dieta ou controlar o peso. A qualidade dos estudos foi avaliada com uma versão adaptada da EPHPP Quality Assessment Tool for Quantitative Studies.

Resultados: Vinte e seis estudos preencheram os critérios de elegibilidade. Os estudos focados apenas na alteração da dieta relataram melhorias significativas em pelo menos um aspeto da ingestão alimentar. Naqueles que avaliaram ambos os comportamentos, apenas cinco de nove mostraram melhorias significativas em pelo menos um aspeto da dieta. Contudo, seis desses nove estudos reportaram melhorias significativas na atividade física. Em ensaios focados apenas na alteração da atividade física, onze dos quinze mostraram melhorias significativas. A Teoria Sociocognitiva parece ser a teoria mais utilizada, com resultados promissores na mudança destes dois comportamentos. Outras teorias foram usadas isoladamente ou de forma combinada, mas menos frequentemente, e outras que têm mostrado grande relevância nas últimas décadas, como a Teoria da Autodeterminação, não foram sequer identificadas em intervenções nesta população.

Conclusões: Intervenções baseadas em teoria parecem melhorar comportamentos de atividade física e dieta em sobreviventes de cancro. Porém, são necessários mais estudos com elevada qualidade metodológica testando intervenções baseadas na teoria, com boas descrições dos seus conteúdos e técnicas de alteração comportamental, para se poderem confirmar ou refutar estes resultados.

Palavras-chave: Revisão sistemática, Cancro, intervenções de mudança de comportamento, Atividade física, Dieta

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Glossary

7-PAR – Seven-Day Physical Activity Recall

ACT – Acceptance and Commitment Therapy

GLTEQ – Godin Leisure-Time Exercise Questionnaire

GPAQ - Global Physical Activity Questionnaire

HAPA – Health Action Process Approach

LPA – Light intensity Physical Activity

LSI – Leisure Score Index

MPA – Moderate intensity Physical Activity

MVPA – Moderate to Vigorous intensity Physical Activity

PA – Physical Activity

PASE – Physical Activity Scale for the Elderly

RCT – Randomised Controlled Trial

SCT – Social Cognitive Theory

SDT – Self-Determination Theory

SQUASH – Self-reported Short QUestionnaire to ASsess Health-enhancing PA

SRT – Self-regulation Theory

TPAQ – Total Physical Activity Questionnaire

TPB – Theory of Planned Behaviour

TTM – Transtheoretical Model

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Background

The global Cancer burden

Cancer is expected to become the leading cause of premature death (i.e., death that occurs before the average age of death in a certain population) in the near future. In fact, some reports say cancer has already overtaken cardiovascular disease in 57 of 127 countries (Bray et al., 2021). In 2020, there were approximately 19.3 million new cancer cases and almost 10.0 million cancer deaths and the global cancer burden is expected to be 28.4 million cases in 2040, a 47% rise from 2020. Breast cancer is now the most diagnosed cancer, followed by lung, colorectal, prostate, and stomach cancers. On the other hand, lung cancer remained the leading cause of cancer death, followed by colorectal, liver, stomach, and female breast cancers (Sung et al., 2021). The increasing number of new cancer diagnoses, which reflects the growing and aging of the world's population, combined with improvements in early detection and diagnostics and advances in treatment, are also leading to an increase in the number of cancer survivors (i.e., from diagnosis to the end of life), which brings new challenges to cancer care (Bray et al., 2021).

Despite the advances in treatment, cancer survivors still have several treatment side-effects, experienced during or after its cessation, increased risk of cancer recurrence, and higher vulnerability to other chronic diseases (Kenneth. Miller & Triano, 2008). Cancer survivors commonly report pain, fatigue, depression or mood disturbance, sleep disruption and cognitive limitation (Wu & Harden, 2015). Combined, long-term and late effects of cancer may worsen survivors' risk of poor mental and physical health-related quality of life and are associated with disability and healthcare utilization, which can be improved through modifying behavioural and psychosocial risk factors.

The importance of healthy lifestyle behaviours

Although the causes of most cancers are not fully understood, there are some well-established factors that put people at a higher risk of developing cancer. Risk factors for cancer include non-modifiable factors such as age, sex, race and ethnicity, family history,

and genetics, and modifiable factors related to health behaviours and lifestyle factors such as tobacco use, alcohol consumption, obesity, exposure to ultraviolet radiation and occupational carcinogens, inadequate nutrition, and physical inactivity (Lewandowska et al., 2019). Lifestyle behaviours such as physical activity (PA), which consists of any bodily movement that results in energy expenditure (Caspersen CJ et al., 1985), and healthy eating patterns have an important role in survivorship management. PA has been consistently identified as an important adjunct therapy to be incorporated in cancer care (Cormie et al., 2017), given that it optimizes health outcomes in cancer survivors (Patel et al., 2019), such as physical functioning, role function, social functioning, overall quality of life (Mishra et al., 2014), cancer-related fatigue (Cramp & Byron-Daniel, 2012), and seems to reduce the risk of recurrence (Cormie et al., 2017), mortality from cancer and from any cause (Patel et al., 2019), as well as improve the effectiveness and tolerance of anticancer treatment (Hojman et al., 2018). Simultaneously, diet also plays a major role in improving total health. Many studies have shown that cancer survivors are amongst the most malnourished of all patients (Bozzetti, 2009; Tangvik et al., 2015). Cancer cachexia, affecting 50-80% of cancer patients, is responsible for the death of at least 20%, and sarcopenia, besides being associated with asthenia, fatigue, and impaired physical function, is also associated with reduced tolerance to treatments, impaired quality of life and reduced survival (Ryan et al., 2016). On the other hand, cancer survivors with healthier diets seem to have an improved treatment response, recovery, side-effect management, and disease outcomes (Bodai & Tuso, 2015; Ornish, Lin, et al., 2008; Ornish, Magbanua, et al., 2008; Schwedhelm et al., 2016). A recent umbrella review found evidence supporting a positive association between alcohol consumption and the risk of colon, rectum, breast, oesophageal, head and neck, and liver cancer, an inverse association of calcium, dairy, and whole grain consumption and the risk of colorectal cancer, as well as an inverse association of coffee consumption and the risk of liver and skin basal cell carcinoma (Papadimitriou et al., 2021).

For these reasons, several health organizations, such as the American Cancer Society and the World Cancer Research Fund, provide specific health behaviour recommendations to cancer survivors related to achieving and maintaining a healthy

body weight throughout life, being physically active, consuming a healthful diet, and avoiding or limiting alcohol intake to reduce cancer risk (Rock et al., 2022). Specifically, to achieve health benefits from PA, cancer survivors should practice at least 150 minutes/week of moderate-intensity PA, or 75 minutes/week of vigorous-intensity PA, or an equivalent combination of both intensities. Strength training should be performed at least two days a week, involving the main muscle groups (K. L. Campbell et al., 2019). There are even some studies suggesting that the amount and intensity of PA in cancer patients should be higher than the current recommendations. For example, a recent meta-analysis proposes that at least 300 mins/week of moderate-intensity PA should be recommended to reduce mortality in breast cancer patients (Lee, 2019). In what concerns to diet, the recommendations are to follow a healthy eating pattern at all ages, which includes eating nutrient-dense foods in quantities that lead to achieving and maintaining a healthy body weight, a variety of vegetables, fruits, and whole grains, and to limit the amount of red and processed meats, sugar-sweetened beverages, highly processed foods, refined grain products, and alcohol consumption (Rock et al., 2022).

Nonetheless, and despite the beneficial effects, only a minority of cancer survivors meets PA or fruit and vegetable consumption recommendations (Blanchard et al., 2008; Zhang et al., 2015), and even when there is a good compliance at the beginning of a behaviour change program, relapse is not uncommon (Glanz & Bishop, 2010). This may happen due to several factor such as lack of motivation and interest, time, or due to symptoms related to the disease and/or treatment, like fatigue and pain (Blaney et al., 2013; M. S. Lee et al., 2017).

The importance of theory-based behaviour change interventions

Given the difficulty people have in initiating and maintaining healthy behaviours over time, interventions seeking to promote health-conducive behaviours, such as increased PA and healthy eating, are of utmost importance. Consequently, in recent years, there has been a growing body of evidence trying to understand which factors explain adherence to lifestyle recommendations and which factors can increase it (e.g., Kampshoff et al., 2016; Lunde Husebø et al., 2013).

Interventions based on behavioural theories seem to be more effective than atheoretical approaches and strategies that combine multiple theories and concepts appear to have larger effects on improving healthy behaviours (Glanz & Bishop, 2010; Noar et al., 2007). Moreover, they provide a better understanding of the factors that mediate behaviour change and thus why interventions might have succeeded or failed, besides offering guidance on what needs to be changed and over which determinants there is a need to intervene, how it can be changed, using which behaviour change techniques from which theory. In fact, theory-based interventions, using evidence-based behaviour change techniques, and aimed at promoting long-term health behaviour change in cancer survivors appear effective (Grimmett et al., 2019), but remain scarce (Rothman A et al., 2011), and target mostly short-term adherence and outcomes (Courneya, 2010). Besides, little information is available on what interventions work best.

A recent meta-analysis examining Social Cognitive Theory (SCT)-based PA and nutrition interventions found that these interventions are safe and result in meaningful changes in diet and PA behaviour that can result in health improvements in cancer survivors (Stacey et al., 2015). Other interventions, based on different theoretical rationales, also showed promising results in other specific populations. For instance, prior research has shown that a person-centred, need-supportive intervention climate, and internal (better quality) motivations play an important role in long-term, sustained, behaviour adoption in individuals with overweight/obesity (Silva et al., 2010; Teixeira et al., 2012; Wyke et al., 2019), suggesting the use of self-determination theory (SDT) as a valid framework also for cancer survivors. There are also other theories, such as the transtheoretical model of behaviour change (TTM), proposing the existence of different stages of change (precontemplation, contemplation, preparation, action, and maintenance) that seem to have a positive effect on diet (M. Miller et al., 2020), PA or both (Rogers et al., 2009).

Aim of this review

To our knowledge, there are currently no systematic reviews synthesizing the effects of theory-based behaviour change interventions on both PA and dietary patterns targeting cancer survivors with multiple types of cancer. Although there is significant evidence supporting the benefits of diet and PA on health-related outcomes, there is still insufficient information about which interventions work best for cancer survivors in what concerns to change and sustain behaviour changes in the long run, which assumes particular importance to inform future research and practice.

Therefore, this systematic review aimed to synthesize the evidence on randomized controlled trials evaluating the efficacy of theory-based behaviour change interventions on PA and/or diet behaviours in cancer survivors. To the extent of our knowledge, this is the first study providing such a comprehensive perspective.

Methods

This systematic review is reported in accordance with the PRISMA statement for reporting systematic reviews (Page et al., 2021). The methodological aspects of this review were specified in advance and documented in a protocol (PROSPERO registration number: CRD42021283338; see **Appendix 1**).

Eligibility Criteria

To be included, studies had to meet the following criteria: i) include adults aged 18 years or older, diagnosed with any type of cancer (at any point from diagnosis and at any stage of disease/treatment); ii) report on any theory-based RCT designed to influence PA and/or diet quality, including behavioural weight management interventions which typically target both these lifestyle behaviours. The intervention group could be compared with any parallel control group with no intervention/waiting list, usual care, or other interventions. The outcomes could be PA levels/volumes and/or diet quality and adherence.

Observational studies and non-intervention studies (e.g., cross-sectional and cohort studies, case reports), studies with no original data (e.g., reviews, editorials, commentaries), dissertations/thesis, qualitative studies, pilot studies, protocols and studies not published in peer-reviewed journals were excluded. All studies with children and adolescents or pharmacological or surgical interventions targeting diet and PA were also excluded.

Search Strategy

A comprehensive search of peer-reviewed articles published from inception until January 2022 (including online ahead of print publication) was conducted in three electronic databases - PubMed, PsycInfo and Web of Science -, using the following search strings:

1. Terms concerning the health condition or population of interest (e.g., Cancer, cancer survivor, cancer patient);

2. Terms concerning the intervention (e.g., Lifestyle/behavioural interventions);
3. Terms concerning the behaviour change outcomes of interest (e.g., Diet, PA, weight loss/maintenance/change);
4. Terms concerning the types of study to be included (i.e., RCT);

A sample of the search strategy is listed in the **Appendix 2.** Searches were limited to English language articles and humans. Other searches included manual cross-referencing of literature cited in prior reviews, and hand-searches of the content of key scientific journals.

Study Selection

All titles and abstracts identified from the literature searches were screened for potential eligibility by three researchers (BBF, BR and IN) and the full text of the remaining titles was retrieved and screened for potential eligibility by the same authors. Decisions to include or exclude studies in the review were made by consensus. When consensus was not achieved, disagreements were solved by discussion with a fourth author (IS or EVC). The study selection procedure was conducted using the CADIMA software (Kohl et al., 2018).

Data extraction

A data extraction form was developed by the authors, based on the information relevant to the present review and informed by the PRISMA statement for reporting systematic reviews (Page et al., 2021). Data extraction was conducted by three authors (BBF, BR and IN) and comprised information about the article (e.g., authors, year), participants (e.g., demographics, type of cancer, phase of treatment), brief intervention description (including the theoretical framework), outcomes of interest (instruments and time of assessment) and main findings.

Study quality assessment

Study quality was assessed with an adapted version of the Quality Assessment Tool for Quantitative Studies, developed by the Effective Public Health Practice Project (Thomas et al., 2004). The current adaptation was based on recommendations from several authors (Deeks et al., 2003; Mackenbach et al., 2014; Moher et al., 2000) and has been previously used (Mackenbach et al., 2014; Teixeira et al., 2015). This tool includes 19 items, organized in eight key methodological domains: study design, blinding, representativeness (selection bias), representativeness (withdrawals/dropouts), confounders, data collection, data analysis, and reporting. Each domain is classified as Strong, Moderate or Weak based on specific criteria. A global rating is determined based on the scores of each component. Two researchers independently rated each of the eight domains and overall quality (BBF, IN). Discrepancies were resolved by consensus. When consensus was not achieved, disagreements were solved by discussion with a third author (BR or IS or EVC).

Outcome measures

Total PA levels and/or discriminated by intensity or domains constituted one of the primary outcomes of this review, together with dietary intake and/or diet quality. Regarding PA, exercise energy expenditure (Kcal per day or week), volume (minutes per week or day), activity counts, step counts, or other measure of PA levels were considered. Concerning dietary intake, we considered caloric intake (Kcal per day or week), overall diet quality, and consumption (cup/ounces/grams/times/servings per day or week) of whole or refined grains, whole grain bread, fish, red and/or processed meat, fibre, alcohol, cruciferous, fruit, vegetables or fruit and vegetables.

Data Synthesis

This review analysed the impact of behavioural change interventions on PA and dietary outcomes in cancer survivors. Characteristics of the included studies were qualitatively synthesized and presented in tabular form, organized by i) outcome, and ii) number of theories used in each intervention.

Certainty assessment

Certainty of evidence refers to how confident we can be that a review provides a complete and accurate summary of the best available evidence, and thus, that an estimate of effect is correct (Granholm et al., 2019). Following the most recent PRISMA recommendations (Page et al., 2021), the certainty of the evidence gathered in the present review was assessed with the SURE *checklist* (The SURE Collaboration, 2011) by two researchers *(BBF, IN)*. This checklist includes 5 criteria to assess the identification, selection, and appraisal of studies; 5 criteria to evaluate how findings were analysed in the review; and one criterion for other considerations). Based on the number and type of limitations identified on these criteria, a conclusion regarding the degree of confidence in the evidence of a systematic review is obtained.

Results

Search results

Database searches resulted in 2725 potentially relevant articles after duplicates removal (656 articles). Of these, 2593 were excluded based on title/abstract screening, leaving 132 articles for full-text screening. 26 articles met eligible criteria and were included in this review. **Figure 1** shows the flow diagram of studies through the review process and the reasons for exclusion.

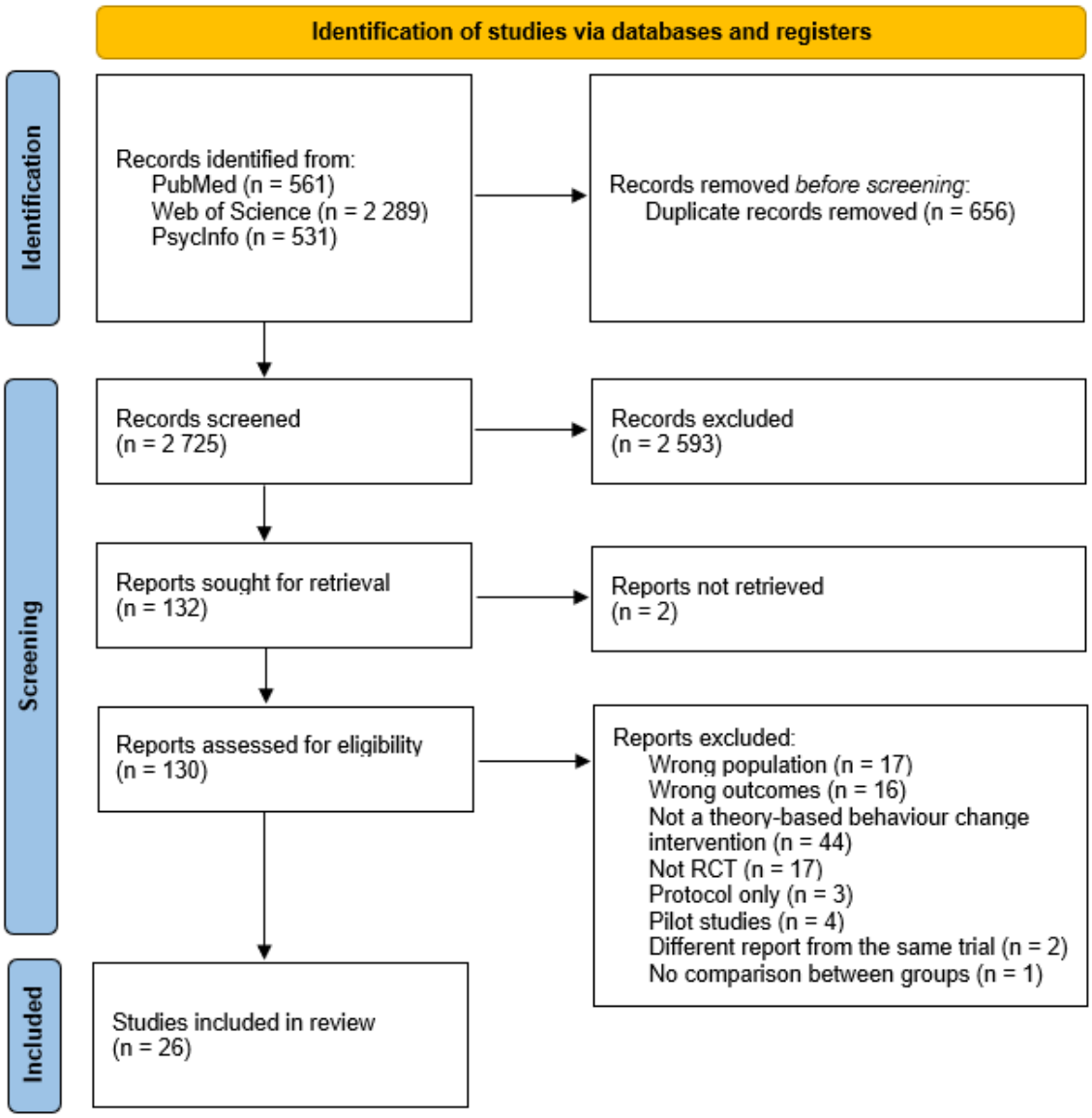

Figure 1 PRISMA flow diagram

Studies' characteristics

Table 1 summarizes (and Appendices 3, 4 and 5 details) the characteristics of all included studies (k=26). Studies are synthetised by intervention topic: PA-only (k=15), diet-only (k=2), or multiple health behaviours (PA and diet) (k=9).

Population

Most studies (k = 13) included both men and women. Only one study (Parsons et al., 2020) focused on men only, whereas almost half of the studies (k = 12) included women only (Gruenigen et al., 2012, 2008; Hirschey et al., 2018; Kong et al., 2021; Pinto et al., 2013, 2015; Rogers et al., 2009, 2014; Short et al., 2015; Sturgeon et al., 2016; Vallance et al., 2016; Weiner et al., 2019). The mean age ranged from 46,1 to 66,5 years.

Seventeen studies focused on one type of cancer only and, in this subgroup, breast cancer (k = 10) was the most studied cancer (Gruenigen et al., 2012, 2008; Hirschey et al., 2018; Kong et al., 2021; Pinto et al., 2013, 2015; Rogers et al., 2009, 2014; Short et al., 2015; Sturgeon et al., 2016; Vallance et al., 2016; Weiner et al., 2019), followed by colorectal (k = 4) (M. Campbell et al., 2009; Courneya et al., 2016; Hawkes et al., 2013; C. F. Lee et al., 2018), endometrial (k = 2) (Gruenigen et al., 2012, 2008) and prostate cancer (k = 1) (Parsons et al., 2020). Two studies included two types of cancer (breast + prostate) (Mosher et al., 2012), (colorectal + prostate) (Golsteijn et al., 2018) and seven studies included ≥3 cancers (Bélanger et al., 2014; Kanera et al., 2016; May et al., 2009; McGinnis et al., 2021; M. Miller et al., 2020; Ungar et al., 2016; Webb et al., 2019).

The two diet-only trials reported a total of 496 participants (range 53 – 443). One of them targeted prostate cancer survivors (Parsons et al., 2020) and the other included cancers of mixed diagnoses (M. Miller et al., 2020). The fifteen PA-only trials reported a total of 2567 participants (range 33 – 478). Eight trials targeted breast cancer survivors (Hirschey et al., 2018; Kong et al., 2021; Pinto et al., 2013, 2015; Rogers et al., 2014; Short et al., 2015; Vallance et al., 2016; Weiner et al., 2019), one colon cancer (Courneya et al., 2016), one targeted both colorectal and prostate cancer survivors (Golsteijn et al., 2018), and five included cancers of mixed diagnoses (Bélanger et al., 2014; May et al., 2009; McGinnis et al., 2021; Ungar et al., 2016; Webb et al., 2019). There were nine PA and diet trials, comprising a total of 2012 participants (range 35 – 489). Two trials

targeted breast cancer survivors (Rogers et al., 2009; Sturgeon et al., 2016), one targeted both breast and prostate cancer survivors (Mosher et al., 2012), two targeted endometrial cancer (Gruenigen et al., 2012, 2008), three colorectal (M. Campbell et al., 2009; Hawkes et al., 2013; C. F. Lee et al., 2018) and one included cancers of mixed diagnoses (Kanera et al., 2016).

Theoretical Framework

Most studies (k = 15) were based on one theory only, ten studies were based on two theories and one study was based on more than three theories.

The most used theory was the Social Cognitive Theory (k = 17) (M. Campbell et al., 2009; Golsteijn et al., 2018; Gruenigen et al., 2012, 2008; McGinnis et al., 2021; M. Miller et al., 2020; Mosher et al., 2012; Parsons et al., 2020; Pinto et al., 2013, 2015; Rogers et al., 2009, 2014; Short et al., 2015; Sturgeon et al., 2016; Webb et al., 2019; Weiner et al., 2019), which includes the Self-Efficacy Theory (a subset of Bandura's SCT) that was mentioned in one RCT (Hirschey et al., 2018), followed by the Transtheoretical Model (k = 7) (M. Campbell et al., 2009; Golsteijn et al., 2018; Kong et al., 2021; M. Miller et al., 2020; Pinto et al., 2013, 2015; Rogers et al., 2009) and the Theory of Planned Behaviour (k = 6) (Bélanger et al., 2014; Courneya et al., 2016; C. F. Lee et al., 2018; Short et al., 2015; Vallance et al., 2016; Webb et al., 2019). Other theories mentioned include: the Health Action Process Approach (HAPA), mentioned in 3 studies, the Integrated Model for Change (I-Change Model), mentioned in 2 studies, and the Self-Regulation Theory mentioned in 2 studies. All other theories, such as the Self-Management Theory, the Control Theory, Goal setting Theory, the Acceptance and Commitment Therapy, the Health Belief Model and Precaution Adoption Process Model were mentioned only once.

Intervention's mode of delivery

In what concerns to the **diet-only trials**, one intervention was delivered by telephone (Parsons et al., 2020) and divided in 4 phases: The first phase included 6 counselling telephone calls over 1 month; the second included 4 calls over 2 months; the third 4 calls over 4 months; and the fourth included 8 calls over 16 months plus one month of follow-up. The other intervention (M. Miller et al., 2020) was delivered weekly in face-to-face

Table 1 - Characteristics of included studies.

Characteristics	Number of Studies
Sample Size	
<100	11
100-199	3
200-299	6
300-399	1
>=400	5
Participants	
Gender	
Both genders	13
Men only	1
Women only	12
Mean age, years	
>= 18*	2
45-54,9	8
55-64	12
>=65	4
Types of cancers	
Breast	10
Colon	1
Colorectal	3
Endometrial	2
Prostate	1
2 types of cancer	2
Multiple Cancers	7
Theories used	
1 Theory	15
2 Theories	10
>= 3 Theories	1
Outcome Assessment	
< 6 months	9
= > 6 months	8
Both	9
Quality assessment score	
Weak	18
Moderate	8
Strong	0

* Participants' age was grouped into ranges

90-min group meetings, during the 8-week intervention period plus 15 weeks of follow-up.

Regarding **PA-only trials**, interventions were delivered face to face (k = 3) (May et al., 2009; McGinnis et al., 2021; Rogers et al., 2014), by email or with online tools (k = 3) (Bélanger et al., 2014; Golsteijn et al., 2018; Webb et al., 2019), by telephone (k = 1) (Pinto et al., 2015) or by mail (k = 1) (Short et al., 2015), and using a booklet/resource kit (k=2) (Hirschey et al., 2018; Vallance et al., 2016). The other interventions (k = 5) used a combination of delivery formats, including telephone (Courneya et al., 2016; Kong et al., 2021; Pinto et al., 2013; Ungar et al., 2016; Weiner et al., 2019), face-to-face counselling (Courneya et al., 2016; Kong et al., 2021; Pinto et al., 2013; Ungar et al., 2016; Weiner et al., 2019), mail (Courneya et al., 2016) and email (Weiner et al., 2019). Interventions lasted 12 weeks on average (May et al., 2009; McGinnis et al., 2021; Pinto et al., 2015; Rogers et al., 2014; Short et al., 2015; Webb et al., 2019; Weiner et al., 2019) ranging from 1 week (Hirschey et al., 2018) up to 3 years (Courneya et al., 2016). One study does not specify the duration of the intervention (Bélanger et al., 2014). The majority were home-based, with only 4 interventions reporting supervised PA sessions (Courneya et al., 2016; May et al., 2009; McGinnis et al., 2021; Rogers et al., 2014).

In **combined trials**, interventions were delivered via an online program platform (k = 2) (Kanera et al., 2016; Sturgeon et al., 2016) by telephone (k = 1) (Hawkes et al., 2013), with face to face counselling (k = 1) (Rogers et al., 2009), mail (k = 1) (Mosher et al., 2012) and all others (k = 4) used a combination of delivery formats, including telephone (M. Campbell et al., 2009; Gruenigen et al., 2012, 2008; C. F. Lee et al., 2018), face-to-face counseling (Gruenigen et al., 2012, 2008; C. F. Lee et al., 2018), mail (C. F. Lee et al., 2018) and online tools (M. Campbell et al., 2009). Intervention duration was variable: 3 months (Rogers et al., 2009), 6 months (Gruenigen et al., 2012, 2008; Hawkes et al., 2013; Kanera et al., 2016), 10 months (Mosher et al., 2012) or 12 months (M. Campbell et al., 2009; C. F. Lee et al., 2018; Sturgeon et al., 2016). Only one study had supervised exercise training (Rogers et al., 2009).

Outcomes' assessment

The two **diet-only** studies evaluated dietary intake in terms of nutritional composition with interviews and a Nutrition Data System for Research software and

nutrient database(Parsons et al., 2020) or the Dietary Screener Questionnaire (DSQ) (M. Miller et al., 2020). During the 2-year intervention (Parsons et al., 2020), outcomes were assessed at baseline, 12-month and 24-month follow-up. In the other RCT (M. Miller et al., 2020), outcomes were assessed at baseline, post-intervention (9 week), and at follow-up (15 week).

Regarding **PA-only trials**, one trial used an objective measure (accelerometer) to assess PA behaviour change (Weiner et al., 2019), while eight studies relied on self-reported measures such as the original or adapted versions of the Seven-Day Physical Activity Recall (7-PAR), the Global Physical Activity Questionnaire (GPAQ), the Godin Leisure-Time Exercise Questionnaire (GLTEQ), the Leisure Score Index from Godin Leisure-Time Exercise Questionnaire (LSI), the Physical Activity Scale for the Elderly (PASE), the Self-reported Short Questionnaire to Assess Health-enhancing PA (SQUASH), the Total Physical Activity Questionnaire (TPAQ) (Bélanger et al., 2014; Courneya et al., 2016; Kong et al., 2021; May et al., 2009; McGinnis et al., 2021; Pinto et al., 2013; Ungar et al., 2016; Webb et al., 2019). All others (k = 6) used both a subjective and an objective measure (such as an accelerometer, a pedometer and a Fitbit®) to assess PA. Outcomes were assessed at baseline, immediately post-intervention (Courneya et al., 2016; Kong et al., 2021; May et al., 2009; McGinnis et al., 2021; Pinto et al., 2013, 2015; Rogers et al., 2014; Ungar et al., 2016; Webb et al., 2019; Weiner et al., 2019), during the intervention (Courneya et al., 2016; Golsteijn et al., 2018; Pinto et al., 2013), and at follow-up (Golsteijn et al., 2018; Hirschey et al., 2018; Kong et al., 2021; Pinto et al., 2013, 2015; Rogers et al., 2014; Short et al., 2015; Ungar et al., 2016; Vallance et al., 2016; Webb et al., 2019).

In the nine **PA and diet trials**, two types of dietary outcomes were evaluated, using a range of self-reported measures and questionnaires: caloric intake (Gruenigen et al., 2012, 2008; Mosher et al., 2012; Rogers et al., 2009; Sturgeon et al., 2016) and dietary intake (M. Campbell et al., 2009; Gruenigen et al., 2012; Hawkes et al., 2013; Kanera et al., 2016; C. F. Lee et al., 2018; Mosher et al., 2012), with one study assessing overall diet quality using the 100-point Diet Quality Index-Revised score (Mosher et al., 2012). In terms of PA assessment two trials used an objective measure (accelerometer) to assess PA behaviour change (Lee et al., 2018; Rogers et al., 2009) while six studies relied

on self-reported measures such as the original or adapted versions of the Seven-Day Physical Activity Recall (7-PAR), the Leisure Score Index from Godin Leisure-Time Exercise Questionnaire (LSI), the Self-reported Short QUestionnaire to ASsessHealth-enhancing PA (SQUASH), and an interviewer administered Modifiable Activity Questionnaire (M. Campbell et al., 2009; Gruenigen et al., 2008; Hawkes et al., 2013; Kanera et al., 2016; Mosher et al., 2012; Sturgeon et al., 2016). The last study used both an objective (pedometer) and a subjective measure to assess PA (V. von Gruenigen et al., 2012). Outcomes were assessed at baseline, immediately after the end of intervention (M. Campbell et al., 2009; Gruenigen et al., 2012, 2008; Hawkes et al., 2013; Kanera et al., 2016; C. F. Lee et al., 2018; Rogers et al., 2009; Sturgeon et al., 2016), and before, during the intervention (Gruenigen et al., 2012, 2008; C. F. Lee et al., 2018) and after the end of the intervention (Gruenigen et al., 2012, 2008; Hawkes et al., 2013; C. F. Lee et al., 2018; Mosher et al., 2012; Rogers et al., 2009).

Synthesis of results

The characteristics extracted from the included RCTs are detailed in **Appendixes 3, 4 and 5** and summarized in **Table 2.**

Diet-only Trials

In diet-only trials, one RCT was based on **Social Cognitive Theory** (Parsons et al., 2020) and reported significant improvements in every aspect of dietary intake. The other RCT was based on **Social Cognitive Theory and the Transtheoretical Model**, reporting significantly lower daily servings of processed meat at 9 weeks and 15 weeks in the intervention group, but no statistically significant differences in fruits and vegetables and whole grain consumption between groups (M. Miller et al., 2020).

PA-only Trials

Regarding PA-only trials, the RCT which was based on the **HAPA** (Ungar et al., 2016) reported significant behaviour changes on self-reported PA 4 weeks after intervention, but no significant differences 14 weeks after intervention, when compared to the control group. Interventions based on the **Self-Management Theory** (May et al., 2009), or the **Transtheoretical Model** (Kong et al., 2021), reported no effect on subjectively measured PA between groups. Three studies used the **Theory of Planned Behaviour**; of

these, one reported that the intervention was not statistically superior when compared to a standard recommendation for both objective (daily average pedometer steps) and subjective PA (light intensity PA (LPA) minutes, moderate intensity PA (MPA) minutes, vigorous intensity PA minutes and total moderate to vigorous PA (MVPA) minutes per day) (Vallance et al., 2016); significant differences were reported in PA from baseline to 1 year (Courneya et al., 2016) and in total PA at 3 months in the subgroup of participants who initially reported ≤300 minutes/week of PA and participated in the intervention group compared to the control group (Bélanger et al., 2014). Of the two studies based on **Social Cognitive Theory (SCT),** one study reported a greater increase in minutes per week of MVPA in the intervention group compared to the control group, although hypothesis testing was not performed (McGinnis et al., 2021) and the other reported significant improvements for PA measured by accelerometery at 3 months and in self-reported PA at 3 and 6 months, when compared with the control group (Rogers et al., 2014). There was still an RCT based on **Self-Efficacy Theory** (a subset of Bandura's SCT) that reported positive significant differences in objectively measured steps but not in self-reported PA between intervention and control groups (Hirschey et al., 2018). Five RCTs used a combination of SCT and another theory. Considering the two interventions using **SCT plus Theory of Planned Behaviour**, there was an improvement in self-reported PA at 3 months (Webb et al., 2019) compared to the control arm. At 4 months, the tailored intervention group significantly reduced the odds of not doing any resistance-based PA, while increasing the odds of meeting resistance training guidelines (Short et al., 2015); no change was observed in the odds of meeting aerobic guidelines or on mean daily steps. Regarding the two RCTs using **SCT plus the Transtheoretical Model**, increases in intervention participants' subjectively measured MPA (Pinto et al., 2013) and in both self-reported and accelerometer measured MVPA (Pinto et al., 2015) were reported at both 3 and 6 months, when compared to the control group, although this beneficial effect dissipated at 12 months (Pinto et al., 2013). The intervention which used **SCT plus Control Theory** reported no differences between groups in objectively measured LPA but positive significant differences in accelerometer measured MVPA (Weiner et al., 2019) .

Table 2 – Summary of results by outcome.

Outcome	Number of Reports	Positive Results	Theories used	Negative Results	Theories used
Diet-only Trials					
Dietary Intake	2	2	1 SCT 1 SCT + TTM	-	-
PA-only Trials					
Objective PA	8	5	1 SCT 1 SCT + TTM 1 SCT + Control Theory 1 SCT + TTM + HAPA + I-Change + … 1 Self-Efficacy	3	1 SCT + Control Theory 1 SCT + TPB 1 TBP
Subjective PA	14	9	1 SCT 2 SCT + TTM 2 SCT + TPB 2 TBP 1HAPA 1 SCT + TTM + HAPA + I-Change + …	5	1 SCT* (p-value NA) 1 TTM 1 TBP 1 Self-Efficacy 1 Self-Management
Diet and PA Trials					
Caloric intake	5	2	2 SCT	3	2 SCT 1 SCT + TTM
Diet quality	1	1	1 SCT	-	-
Dietary intake	8	3	1 SCT 1 SCT + TTM 1 TPB + HAPA	5	1 SCT 2 SCT + TTM 1 ACT 1 I-Change + SRT
Objective PA	4	4	1 SCT 2 SCT + TTM 1 TBP + HAPA	-	-
Subjective PA	7	5	4 SCT 1 ACT	2	1 SCT + TTM 1 I-Change + SRT

One study (Golsteijn et al., 2018)) used **multiple theories**: SCT, Transtheoretical Model, HAPA, Integrated Model for Change (I-Change Model), Health Belief model, goal setting theories, self-regulation theories and the Precaution Adoption Process Model. At 3 months, participants in the intervention group significantly improved MVPA and days with at least 30 min of PA, and at 6 months, results indicated significant improvements in self-reported PA. Objectively measured MVPA also increased significantly in the intervention group, whereas the increase in objectively assessed days ≥30 min of PA was borderline significant.

Diet and PA Trials

In combined trials, the RCT based on **Acceptance and Commitment Therap**y (Hawkes et al., 2013) had no significant group differences found at 6 or 12 months for fruit, fibre, or alcohol intake but the intervention group was more likely to meet Australian PA recommendations, when compared to the control group.

Four RCTs used **Social Cognitive Theory** (Gruenigen et al., 2012, 2008; Mosher et al., 2012; Sturgeon et al., 2016). One (Gruenigen et al., 2012) reported significant improvements between intervention and control groups, in every aspect of diet intake including caloric intake and another RCT showed significant differences in total percent of calories from fat, and in diet quality, measured with the Diet Quality Index-Revised score, although fruit and vegetable intake did not significantly differ between groups at the 2-year follow-up (Mosher et al., 2012). The remaining two studies reported non-significant differences for caloric intake (Gruenigen et al., 2008; Sturgeon et al., 2016) in the intervention groups.

As for PA, one study reported positive results on both objectively and subjectively measured PA: at 3 months, only the PA subjectively measured with the LSI reported significant improvements, while at 6 months positive significant differences were reported for steps per day, LSI and in PA minutes; at 12 months there were still positive significant differences in LSI and in PA minutes (Gruenigen et al., 2012). The remaining three studies focused only on subjectively measured PA and reported significant differences in PA measured with the LSI at 3, 6 and 12 months (Gruenigen et al., 2008), and for daily caloric expenditure by the end of the 12-month intervention (Sturgeon et

al., 2016). One study reported non-significant differences between groups (Mosher et al., 2012).

Risk of Bias assessment

Risk of bias results are reported in **Table 3**, which shows the detailed classification of each quality domain and the overall methodological quality of each study.

The two diet-only studies were classified as having weak methodological quality (M. Miller et al., 2020; Parsons et al., 2020). Of the fifteen PA-only studies, five were rated as moderate (May et al., 2009; Pinto et al., 2013; Rogers et al., 2014; Short et al., 2015; Webb et al., 2019), and ten as weak (Bélanger et al., 2014; Courneya et al., 2016; Golsteijn et al., 2018; Hirschey et al., 2018; Kong et al., 2021; McGinnis et al., 2021; Pinto et al., 2015; Ungar et al., 2016; Vallance et al., 2016; Weiner et al., 2019). In the nine multiple behaviour studies, three were rated as moderate (M. Campbell et al., 2009; Hawkes et al., 2013; C. F. Lee et al., 2018) and six as weak (Gruenigen et al., 2012, 2008; Kanera et al., 2016; Mosher et al., 2012; Rogers et al., 2009; Sturgeon et al., 2016).

Every study scored strong on the study design, as they were experimental. The most common areas with a high risk of bias were selection bias, given that all studies involved samples of volunteers, being classified as weak. Blinding was not performed in several studies, constituting an additional source of bias. This happened because all participants were aware of the research question, and if the outcome assessor was also aware of the intervention status of participants, studies were rated as weak methodological quality. Seven studies were rated as weak as the control of confounders was not described. In terms of data collection tools, all studies were rated as strong, discussing validity and reliability of data collection tools, except for one study (Gruenigen et al., 2012), which was classified as moderate. Most studies (n=18) scored strong in the use of appropriate statistical analyses, while the rest scored moderate.

Assessment of the certainty of evidence

Assessment of the certainty of evidence results are reported in **Appendix 6.** The SURE checklist (The SURE Collaboration, 2011) indicated that this systematic review has

Table 3 – Risk of bias assessment.

Study	*Design*	*Blinding*	*Selection bias*	*Drop-outs*	*Confounders*	*Data collection*	*Data analysis*	*Report*	*Global rating*
Diet only									
(M. Miller et al., 2020)	Strong	Weak	Weak	Moderate	Weak	Strong	Moderate	Strong	Weak
(Parsons et al., 2020)	Strong	Weak	Weak	Strong	Weak	Strong	Strong	Strong	Weak
PA only									
(Webb et al., 2019)	Strong	Moderate	Weak	Strong	Strong	Strong	Strong	Strong	Moderate
(Hirschey et al., 2018)	Strong	Weak	Weak	Strong	Strong	Strong	Moderate	Strong	Weak
(Pinto et al., 2013)	Strong	Moderate	Weak	Strong	Strong	Strong	Strong	Strong	Moderate
(Ungar et al., 2016)	Strong	Weak	Weak	Strong	Weak	Strong	Moderate	Strong	Weak
(Weiner et al., 2019)	Strong	Weak	Weak	Moderate	Strong	Strong	Strong	Strong	Weak
(Kong et al., 2021)	Strong	Weak	Weak	Strong	Strong	Strong	Strong	Strong	Weak
(Courneya, 2010)	Strong	Weak	Weak	Strong	Weak	Strong	Moderate	Strong	Weak
(Bélanger et al., 2014)	Strong	Weak	Weak	Strong	Strong	Strong	Strong	Strong	Weak
(Rogers et al., 2014)	Strong	Moderate	Weak	Strong	Strong	Strong	Strong	Strong	Moderate
(Vallance et al., 2016)	Strong	Weak	Weak	Strong	Strong	Strong	Strong	Strong	Weak
(McGinnis et al., 2021)	Strong	Moderate	Weak	Strong	Weak	Strong	Moderate	Moderate	Weak
(May et al., 2009)	Strong	Moderate	Weak	Strong	Strong	Strong	Strong	Moderate	Moderate

(Short et al., 2015)	Strong	Moderate	Weak	Strong	Moderate	Strong	Strong	Strong	Moderate
(Pinto et al., 2015)	Strong	Weak	Weak	Strong	Moderate	Strong	Moderate	Moderate	Weak
(Golsteijn et al., 2018)	Strong	Weak	Weak	Moderate	Strong	Strong	Strong	Strong	Weak
Diet + PA									
(M. Campbell et al., 2009)	Strong	Moderate	Weak	Strong	Strong	Strong	Moderate	Moderate	Moderate
(Sturgeon et al., 2016)	Strong	Moderate	Weak	Strong	Weak	Strong	Moderate	Strong	Weak
(Lee et al., 2018)	Strong	Moderate	Weak	Strong	Strong	Strong	Strong	Strong	Moderate
(Hawkes et al., 2013)	Strong	Moderate	Weak	Strong	Strong	Strong	Strong	Strong	Moderate
(Gruenigen et al., 2008)	Strong	Weak	Weak	Strong	Moderate	Strong	Strong	Strong	Weak
(Kanera et al., 2016)	Strong	Weak	Weak	Strong	Strong	Strong	Strong	Strong	Weak
(Mosher et al., 2012)	Strong	Weak	Weak	Strong	Strong	Strong	Strong	Strong	Weak
(Rogers et al., 2009)	Strong	Weak	Weak	Strong	Weak	Strong	Strong	Strong	Weak
(Gruenigen et al., 2012)	Strong	Weak	Weak	Moderate	Strong	Moderate	Strong	Strong	Weak

important limitations. First, language bias was not avoided, considering that the search was restricted to papers written in English. Therefore, a more comprehensive search could have resulted in a higher number of retrieved papers. Second, the list of excluded studies was not provided. Third, results could not be combined, and heterogeneity could not be explored due to methodological differences in studies and to scarcity of studies per theory. Nevertheless, the findings of the current systematic review can be considered as reliable.

Discussion

Overview of findings

The aim of this systematic review was to synthesize the existing literature on the effectiveness of theory-based behaviour change interventions on PA and/or diet targeting cancer survivors, to better inform future interventions designed to assist cancer survivors in making positive PA and diet behaviour changes. Twenty-six trials were included, generally supporting the efficacy of theory-based interventions in changing PA and diet behaviour in cancer survivors.

Our results indicated that diet-only interventions have beneficial effects on at least one aspect of dietary intake (e.g., reducing the consumption of processed meat), while only five out of nine interventions focusing on multiple behaviours showed statistically significant improvements in at least one aspect of diet. Three of the four trials that did not find improvements in dietary intake had the primary aim of decreasing weight (Gruenigen et al., 2008), improving PA and health-related quality of life (Hawkes et al., 2013), and improving cardiovascular and bone health outcomes (Sturgeon et al., 2016), which may explain the absence of results in diet-related aspects. On the other hand, six of these nine multiple behaviour trials reported significant improvements in PA. In PA-only trials, eleven out of fifteen RCTs showed beneficial effects on PA. SCT seems to be the most studied theory when it comes to interventions designed to change and maintain PA and dietary behaviours, followed by the Transtheoretical Model (n = 7) and the Theory of Planned Behaviour (n = 6). All other theories were addressed in 3 or less interventions.

In diet-only RCTs, interventions based on SCT only or in combination with TTM, showed significant improvements in at least one aspect of diet. The same happened with PA-only trials, where interventions based on SCT only or in combination with other theories, such as TTM, TPB and Control Theory, and Self-Efficacy Theory (a subset of Bandura's SCT), showed beneficial effects on PA. As for combined trials, of the four RCTs that used SCT, two had significant improvements in at least one aspect of diet while 3 had significant improvements in PA. Of the other two RCTs which were based in SCT plus

TTM, one reported significant improvement in one aspect of diet and the other one in accelerometer measured PA. Our positive results mirror the results reported in a recent meta-analysis (Stacey et al., 2015) which found that SCT-based interventions targeting diet or physical activity, in cancer survivors, are safe and result in meaningful changes in diet and physical activity behaviours that can result in health improvements. In fact, self-efficacy is the central construct in SCT, among other key constructs, influencing behaviour directly (i.e., by believing in their abilities to apply skills effectively in difficult situations, individuals change their behaviour) and indirectly (i.e., by influencing their motivation to change the behaviours (Bandura, 2004, 2007).

Three of the PA-only RCTs were based on TPB and reported positive results in at least one aspect of PA in each of these studies. Three of the interventions that used TPB in combination with other theories (HAPA or SCT) also reported positive results in PA, and in both diet and PA. This theory proposes that attitudes, subjective norms, and perceived behavioural control are antecedents of intentions, which is one of the best predictors of behaviour (Ajzen, 1991), and has been previously used in many interventions in different contexts/populations. For example, one RCT targeting the general population, found an increase in perceived behavioural control, and that attitudes and intentions became stronger; objectively measured walking increased from 20 minutes on the day after the intervention to 32 minutes per day at 6-week follow-up (Darker et al., 2010). Previous meta-analyses (Godin & Kok, 1996; McEachan et al., 2011) have also demonstrated the capacity of the TPB-based interventions to predict dietary behaviours.

One RCT that used TTM showed no significant improvements in PA; three out of four RCTs that were based in TTM together with other theories, reported beneficial effects in PA, and two out of three RCTs showed significant improvements in at least one aspect of diet. Taken together, these results seem to be in line with those reported by a recent review examining mediators of PA behaviour change in healthy adults (Rhodes & Pfaeffli, 2010), which stated that TTM-based interventions show mixed results in terms of efficacy. When it comes to diet, an RCT using TTM and targeting people with diabetes (Jones et al., 2003) reported a significant decrease in energy intake from fat, higher daily vegetable and fruit intake, and a decrease in HbA1C, when compared to usual care,

acknowledging, however, the importance of more studies to validate the efficacy of the TTM in nutrition counselling.

Interventions based on HAPA showed improvements in every outcome tested, related to PA or diet, at least at some moments in time, even when based also in other theories. These results are consisted with those found in a pilot RCT that tested a HAPA-based intervention and showed significant increases in the frequency of breaks from sitting in full-time university students (Sui & Prapavessis, 2018).

Other theories such as ACT, Control Theory (used in combination with SCT), I-Change, the SRT or the Self-Management Theory, were used in very few RCTs, thus making it difficult to draw conclusions about their effectiveness. Interestingly, no self-determination theory (SDT)-based behavioural interventions targeting dietary and/or PA changes in cancer survivors were found, although prior research has shown that internal (better quality) of motivations play an important role in long-term, sustained, behaviours adoption (Silva et al., 2010; Teixeira et al., 2012; Wyke et al., 2019), supporting the use of SDT as a valid framework.

Most studies (k = 13) included both men and women, although almost half of the studies (k = 12) included women only. Seventeen studies focused on one type of cancer only, two studies included two types of cancer and seven studies included ≥3 cancers. Breast cancer was the most studied type of cancer, which is consistent with the fact that it is the most diagnosed cancer in women, and also the leading cause of cancer death in this population. In men, lung cancer is the most diagnosed cancer and the number one cause of cancer death (Sung et al., 2021). Nevertheless, none of the studies focusing in one or two types of cancer addressed it and only one of the studies with multiple cancer mentioned it, even in a small percentage of its population. Colorectal and prostate cancer, which are highly diagnosed (Sung et al., 2021), were also some of the cancers most studied in this systematic review. Intervention duration was highly variable, ranging from 1 week up to 3 years, as well as outcome assessment, with most studies assessing its outcomes 6 or more months after intervention.

Most interventions (k=13) used face-to-face counselling, others (k=12) were delivered by phone, and many (k=7) were delivered by email or other online

tools/platforms. In some RCTs, interventions were also delivered through mail and using a booklet/resource kit. This is an important aspect to be taken into consideration since the way interventions are delivered may influence their outcomes and because health-promotion interventions should be as entertaining and engaging as possible specially when compared with other competing activities. Communication technologies play an essential role in everyday life and should therefore be used to engage people's interest in a better healthy life (Glanz & Bishop, 2010).

This is the first study summarising the evidence of RCTs evaluating the effects of multiple behaviour change theories on both PA and dietary patterns targeting cancer survivors with multiple types of cancer, providing a broad overview over a large number of theory-based interventions by gathering the most relevant evidence published so far.

Limitations and suggestions for future research

The present systematic review has a number of limitations that should be taken into consideration when interpreting the results. This review comprehensively searched several databases; however, it made no attempt to search for non-English publications or unpublished literature and the list of excluded studies was not provided.

Pilot studies were excluded as well as study protocols. Studies needed to explicitly state that the intervention was based on a behaviour change theory, which was very dependent on the author's trial description. Consequently, in trials where it was unclear if the study was based on a theoretical framework or that did not specify which theory the intervention was based on, were excluded. The review included a broad definition of cancer survivors, including those both during and after completion of active treatment. While this increases the breadth of evidence, it likely contributed to the heterogeneity of the included studies.

Outcomes regarding body weight and sedentary behaviour were not included; therefore, some studies indirectly targeting PA may have been excluded. The limited number of trials addressing diet only limits the conclusions that can be drawn regarding this type of interventions although the literature suggests that behaviour change

interventions should aim to promote changes in both diet and physical activity concomitantly (Greaves et al., 2011).

In this review, more than two thirds of the studies were scored as “weak quality” and the remaining interventions were scored as “moderate quality”. This finding suggests the need for improvements in research methodologies, especially regarding the process of selection of participants, the blinding of participants and staff assigned to assess the outcomes, and the need for adjustment of the analysis for confounders. However, these are characteristics under researchers’ control and therefore are simple to solve in future research if careful planning and implementation procedures are taken.

Additionally, PA outcomes were predominantly based on self-reported data, with only 7 PA-only and 3 combined PA and diet trials reporting objectively measured PA. Only 2 of the trials included in this review focused on promoting resistance training (May et al., 2009; Short et al., 2015), despite current recommendations saying that strength training should be performed at least two days a week, involving the main muscle groups (K. L. Campbell et al., 2019) and despite the clinically important positive effects on muscular function and body composition resistance training has shown to produce in cancer patients during and after cancer treatment in a recent review and meta-analysis (Strasser et al., 2013). Moreover, trials that focused on PA behaviours had predominantly unsupervised interventions, that can limit the involvement and motivation of participants and thus, the beneficial effects of these types of interventions.

Furthermore, results could not be combined and quantitatively summarised due to methodological differences in studies and to the scarcity of studies per theory. Comparing the effectiveness between interventions using different health theories through meta-analysis would be a useful gap to address in the future, as would be research assessing whether single or multiple health behaviour interventions have the greatest benefit to improve PA and diet behaviours. Additionally, the testing of moderators, such as the mode of delivery, may help to enlighten future interventions targeting this specific population.

Further work should also include trials which focus on resistance training that meet current recommendations, as well as supervised exercise training. The development of criteria to assess to what extent interventions are based on theoretical frameworks, so that scientist can understand which components and behaviour change techniques are essential to initiate and maintain healthy behaviours and therefore develop programs and guidelines to support this population to increase and maintain PA levels and a healthy diet, is critical.

Despite the limitations of this review, it seems that theory-based interventions are useful for improving PA and diet behaviours of cancer survivors.

Conclusions

This systematic review suggest that theory-based interventions seem to be important when it comes to improving PA and diet behaviours in cancer survivors. SCT seems to be the most used theory of reference when it comes to interventions designed to change and maintain PA and dietary behaviours, showing promising results. Other theories, such as TPB, TTM and HAPA also show favourable results.

Further work is required to understand how and why these interventions offer promise for improving behaviour. This information can contribute to the development of more effective interventions designed to promote adherence to lifestyle behaviours. Notwithstanding the beneficial effects of the 21 interventions included in this systematic review and the valuable indications about the theories behind, more research is needed to identify optimal features of interventions for cancer survivors.

Final remark

This systematic review is being prepared to be submitted to Cancer, one of the American Cancer Society journals (IF 6.860).

Part of the results of this systematic review was presented in the Annual Meeting of the International Journal of Behavioural Nutrition and Physical Activity (ISBNPA), which took place in Phoenix, Arizona, USA, during May 2022 (**Appendix 7**).

Conflict of interest

The authors have no potential financial or personal conflicts of interest to disclose in relation to this work.

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Appendix 1 - Prospero Protocol

Theory-based physical activity and/or nutrition behaviour change interventions for cancer survivors – A systematic review

Beatriz Benquerença Francisco, Bruno Rodrigues, Eliana V. Carraça, Inês Nobre, Helena Cortez-Pinto, Inês Santos

Citation

Review question

What is the current state of the evidence on the effect of theory-based physical activity (PA) or nutrition intervention that target cancer survivors?

Searches

A comprehensive search of peer-reviewed articles published until January 2022 (including online ahead of print publication) was conducted in 3 electronic databases (PubMed, PsycInfo and Web of Science).

Searches included various combinations of three sets of terms:

1. Terms concerning the health condition or population of interest (e.g., Cancer, cancer survivor, cancer patient).
2. Terms concerning the intervention (e.g., Lifestyle/behavioural interventions)
3. Terms concerning the behaviour change outcomes of interest (e.g., Diet, Physical activity, weight loss/maintenance/change)
4. Terms concerning the types of study to be included (i.e., RCT);

Types of study to be included

INCLUDED: experimental designs (i.e., randomized controlled trials).

EXCLUDED: Observational studies and non-intervention studies (e.g., cross-sectional and cohort studies, case reports), studies with no original data (e.g., reviews, editorials, commentaries), dissertations/thesis, qualitative studies, protocols, pilot studies. Studies not published in peer-reviewed journals were excluded.

Condition or domain being studied

Theory-based interventions, using evidence-based behaviour change techniques, aimed at promoting long-term health behaviour change in cancer survivors are effective [eg, Grimmett et al., 2019], but remain scarce (Rothman et al., 2011) and target mostly short-term adherence and outcomes [Courneya et al., 2010].

Prior research has shown that internal (better quality) motivations play an important role in long-term, sustained, behaviour adoption (eg, Silva et al., 2010; Teixeira et al., 2012; Wyke et al., 2019). Previous studies have also shown that a person-centred, need-supportive intervention climate enhances people's wellbeing, body image, and their ability to self-regulate and sustain behaviour changes (Martinez et al., 2016; Carraça et al., 2011; Carraça et al., 2012).

Participants/population

INCLUSION CRITERIA: Samples of adults aged 18 years or older, diagnosed with any cancer (at any stage of disease/treatment)

EXCLUSION CRITERIA: Children and adolescents.

Intervention(s), exposure(s)

INCLUSION: Clinical or community "lifestyle/behavioural interventions" defined as interventions that promote change in energy balance-related behaviours (such as diet

and physical activity). Interventions targeting weight loss and/or maintenance through the promotion of changes in physical activity and/or diet will also be included.

EXCLUSION: pharmacological or surgical interventions targeting diet and physical activity.

Comparator(s)/control

Studies might compare the intervention to no intervention (control), usual care or other interventions.

Note: A comparison/control group might not be present, as single-arm intervention studies might also be retrieved from search (e.g., a pre-post intervention design).

Context

Primary care setting, community setting, residential/home setting, academic setting.

One-to-one interventions, group interventions.

Face-to-face, internet-based, telephone-based, mail-based interventions.

Main outcome(s)

Physical activity or diet.

Additional outcome(s)

None

Data extraction (selection and coding)

All abstracts identified from the literature searches were screened for potential inclusion eligibility by three authors (BQF, BR IN). A data extraction was developed by

the authors, based on the information relevant to the present review. Data extraction was conducted by the first author and included information about the article (e.g., authors, year), participants (e.g., demographics, type of cancer), study design, intervention characteristics (e.g., aim, length, follow-up) and outcomes of interest and how the theory constructs were operationalized and assessed.

Risk of bias (quality) assessment

Study quality was assessed with an adapted version of the Quality Assessment Tool for Quantitative Studies, developed by the Effective Public Health Practice Project.

This tool includes 19 items, organized in eight key methodological domains: study design, blinding, representativeness (selection bias), representativeness (withdrawals/dropouts), confounders, data collection, data analysis, and reporting. Each domain is classified in Strong, Moderate and Weak methodological quality based on specific criteria. A global rating is determined based on the scores of each component. Two researchers independently rated each of the eight domains and overall quality. Discrepancies were resolved by consensus.

Strategy for data synthesis

Initially, the characteristics of the included studies was described. Next, data was qualitatively synthetized by behaviour change outcome and presented in tabular form. Further quantitative analyses (meta-analyses) will be conducted if feasible, separately by behaviour change outcome. Sensitivity analyses will be carried out to explore if results are affected by studies with weak quality or outlier values.

Analysis of subgroups or subsets

None planned.

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Type and method of review

Systematic review

Anticipated or actual start date

1st of October of 2021

Anticipated completion date

30th June 2022

Funding sources/sponsors

Conflicts of interest

None known

Language

English

Country

Portugal

Stage of review

Has started

Subject index terms status

Subject indexing assigned by CRD

Subject index terms

Date of registration in PROSPERO

Date of first submission

Details of any existing review of the same topic by the same authors

Stage of review at time of this submission

The review has not started

Stage	**Started**
Preliminary searches	Yes
Piloting of the study selection process	Yes
Formal screening of search results against eligibility criteria	Yes
Data extraction	Yes
Risk of bias (quality) assessment	Yes
Data analysis	Yes

The record owner confirms that the information they have supplied for this submission is accurate and complete and they understand that deliberate provision of inaccurate information or omission of data may be construed as scientific misconduct.

The record owner confirms that they will update the status of the review when it is completed and will add publication details in due course.

Versions

Appendix 2 - Search Strategy

1) Diet* OR eating OR nutrition OR “nutrition therapy” OR “lifestyle intervention” OR “dietary intake" OR food

2) “Weight management” OR “Weight control” OR “Weight loss” OR “Weight maintenance”

3) training OR “Physical activity” OR exercise OR walking OR aerobic

4) ("behaviour intervention" OR "behavior intervention" OR "behavioral intervention" OR “behavioural intervention” OR “behaviour therapy” OR “behavior therapy” OR “behavioral therapy” OR “behavioural therapy” OR “behaviour program” OR “behavior program” OR “behavioral program” OR “behavioural program” OR “behaviour change” OR “behavior change” OR “behavioral change” OR “behavioural change”

5) Cancer OR “cancer survivor*” OR “cancer patient”

6) RCT OR “randomised controlled trials” OR “randomised controlled trial”)

7) 1) OR 2) OR 3)

8) 5) AND 4) AND 6) AND 7)

Appendix 3 - Diet-only Trials

Authors	Cancer Type/Phase	Sample	Intervention	Theory	Outcomes	Results
Parsons et al., 2020	Prostate (stage < cT2) with no prior prostate cancer treatment with surgery, radiation, local ablation, or androgen deprivation therapy or metastatic disease;	Overall: 443; IG: 226, 0% women, 63,7 ± 6,5 years; CG: 217, 0% women, 63,5 ± 6,6 years;	IG: 4 phases telephone counselling intervention: The first phase (6 counselling telephone calls over 1month) focused on building self-efficacy; the second (4 calls over 2 months) on consolidating the new dietary pattern; the third (4 calls over 4 months) on relapse prevention; and the fourth (8 calls over 16 months) on providing positive feedback and monitoring for declining interest. CG: Printed materials from the Prostate Cancer Foundation encouraging consumption of a vegetable-rich diet. 24 months	- Social Cognitive Theory	Diet composition (Interviews using the Nutrition Data System for Research software and nutrient database) Baseline, 12-month follow-up, and 24-month follow-up.	At 12-month follow-up, intervention participants reported significant increases compared with controls in daily total vegetable servings (mean change 2,43 vs. 0,45; $p < 0.001$) and cruciferous servings (mean change, 43.10 g/d vs 6.44 g/d; $p < 0.001$). At 24-month follow-up, significant between-group differences persisted for total vegetable servings (mean change, 2.01 vs 0.37; $p < 0.001$) and cruciferous servings (mean change, 0.50 vs 0.01; $p < 0.001$).

Miller et al., 2020	Multiple cancers at any stage, who completed active cancer treatment (Breast 47%, Metastatic breast 11%, Blood 9%, Female reproductive 8%, Multiple cancers specified 11%, Other 13%)	Overall: 53, 92% women, 61,2 ± 10,5 years; IG: 26, 92% women, 59,5 ± 9,7 years; CG: 27, 93% women, 62,8 ± 11,1 years	IG: Eight, in-person, 90-min group meetings convened weekly at community-based organizational facilities with: (1) Nutrition Education (2) Structured Group Learning and Support (3) Cooking Demonstration + Sharing and Caring Potluck + recipe cards + workbook + S.M.A.R.T Goal-Setting Worksheets CG: CCK printed educational materials (7 written summaries of weekly nutrition content and 14 recipes that emphasized the weekly nutrition themes) 8 weeks intervention + 15 weeks follow up	- Social Cognitive Theory; - Trans theoretical Model	Dietary Intake (Dietary Screener Questionnaire (DSQ) in the NHANES 2009-10): - Total Fruit and Vegetable, cup equivalents per day - Whole Grains Total, ounce equivalents per day - Processed Meat, times per day (1/2 cup equivalent fruit and vegetable: 1 daily serving. A total of 0.56 oz equivalent whole grains: 1 daily serving.) Baseline, post-intervention (9 week), and at follow-up (15 week)	There were no statistically significant differences in fruits and vegetables and whole grain consumption between groups. The intervention group had significantly lower daily servings of processed meat in comparison to the control group at 9 weeks (mean 0,04±0,05 vs 0,10±0,18) and 15 weeks (mean 0,04±0,05 vs 0,11±0,17; $p < 0.05$).

Appendix 4 - Diet and PA Trials

Authors	Cancer Type/Phase	Sample	Intervention	Theory	Outcomes	Results
Hawkes et al., 2013	Colorectal at any stage/phase of treatment	Overall: 410; IG: 205, 48,3% women, 64,9 ± 10,8 years; CG: 205, 43,9% women, 67,8 ± 9,2 years;	IG: Telephone-delivered health coaching intervention (11 sessions) + participant handbook + regular motivational postcard prompts + a pedometer + newsletter CG: usual care - educational brochures produced by Cancer Council Australia on understanding CRC and cutting cancer risk, diet, and PA. 6 months	Acceptance and commitment therapy	- Dietary intake (Cancer Council Victoria Food Frequency Questionnaire) - PA (modified Leisure Score Index (LSI) from Godin Leisure-Time Exercise Questionnaire (GLTEQ)) Baseline, 6 and 12 months	- No significant group differences were found at 6 or 12 months for fruit, fibre, or alcohol intake ($p>0.05$). - Compared with the control group, the intervention group was also more likely to meet Australian PA recommendations ($p = 0.047$).
Sturgeon et al., 2016	Breast cancer survivors (BRCA1/2+)	Overall: 35, 100% women,	IG: web-based program with 3 daily activities: workout—completing relative and	- Social Cognitive Theory	- Caloric intake (self-reported logging on 3-day dietary records);	- There was no significant difference for caloric intake between groups.

	who underwent prophylactic oophorectomy and are now cancer free	46,1 ± 4 years; IG: 16, 100% women, 47,2 ± 3,8 years; CG: 19, 100% women, 45,1 ± 4 years:	progressive strength-training and aerobic exercises; habit—completing a nutritional/lifestyle habit (new habits followed every 2 weeks; and lesson — reading lessons on health, nutrition, fitness, or behaviour change. CG: Waitlist 12 months		- Caloric expenditure (interviewer administered Modifiable Activity Questionnaire) Baseline and after the 12-month intervention (follow-up).	- There was a significant difference between group difference for daily caloric expenditure with the intervention group increasing PA more by the end of the intervention period (740,6±330,2 vs 425,2±325,6; p = 0.04).
Gruenigen et al., 2008	Endometrial (stage I-II), who had a total abdominal hysterectomy, and bilateral salpingo-oophorectomy	Overall: 45; IG: 23, 100% women, 54 ± 2,0 years; CG: 205, 100% women, 55,5 ± 1,6 years;	IG: 6-month individual counselling + newsletter + pedometer CG: usual care - informational brochure 6 months	- Social Cognitive Theory	- Quantitative dietary intake: three-day food records - PA (LSI from the GLTEQ) Baseline, 3, 6 and 12 months	- There were no significant differences for kilocalories intake (p>0.05). - There was a significant difference in PA between the intervention group and usual care at 3 months (mean group difference = 19.6, 95% CI = 2.5 to 36.7; p=0.025), 6 months (mean difference = 13.6; 95% CI = 1.8 to 25.3; p=0.038) and 12 months (mean

						difference = 15.8; 95% CI = 4.5 to 27.0; p= 0.007).
Mosher et al., 2012	Early stage (in situ, localized, or regional) Breast or Prostate cancer	Overall: 489, 62,58% women, 57,2 ± 10,7 years;	IG: tailored materials designed to increase fruit and vegetable (F&V) intake, decrease fat intake, and/or increase PA. CG: mailed print materials on diet and PA available in the public domain 10 months	- Social Cognitive Theory	- Diet: Number of servings of F&V per day, percentage of kcal from fat (The Diet History Questionnaire (DHQ)), and diet quality, (100-point Diet Quality Index-Revised score) - PA: Total minutes per week of MVPA (7-day Physical Activity Recall (7-day PAR)); Baseline, 2-year follow-up	- F&V intake and PA did not significantly differ between groups at 2-year follow-up. - Diet Quality Index-Revised score (IG: 71,5±10,5 vs CG: 68,9± 10,6; p<0.001), - and total percent of calories from fat (IG: 36,5±6,6 vs CG: 37,8±5,6; p=0.001) were significantly different between groups. - PA did not significantly differ as a function of group assignment
Gruenigen et al., 2012	Endometrial (stage I-II), after a total abdominal	IG: 41, 100% women, 57,0 ± 8,6	IG (SUCCEED intervention): Physician face-to-face counselling + feedback and support via newsletters,	- Social Cognitive Theory	- Dietary intake: fruit/vegetable servings/day, kilocalories (Nutrition Data System	- Fruit intake only had positive significant differences at 12 months (IG: 2,1 ± 2,5 vs CG: 1,8±1,8; p=0.032).

	hysterectomy, bilateral salpingo-oophorectomy	years; CG: 34, 100% women, 58,9 ± 10,9 years;	telephone and email + pedometer CG: usual care - informational brochure: “Healthy Eating & Physical Activity Across Your Lifespan, Better Health and You” 6 months		for Research Software (NDSR) versions 2008 and 2009) - PA minutes (LSI from the GLTEQ); calculated as the number of moderate minutes plus two times vigorous minutes. Diet and PA minutes: Baseline, 3, 6, 12 months - Pedometer step count was assessed at baseline and 6 months for a one-week period and an average daily count was calculated.	- Vegetables intake had positive significant differences at 3 (IG: 4,2±2,9 vs CG: 3,0±2,1; p<0.001), 6 (IG: 4,0±2,5 vs CG: 3,2±2,4; p=0.001) and 12 months (IG: 3,7±2,5 vs CG: 3,4±2,0; p=0.004). - F&V had positive significant differences at 3 (IG: 6.2±3.5 vs CG: 5.0±2,5; p<0.001), 6 (IG: 5,9±3,2 vs CG: 4.9±3.0; p<0.001) and 12 months (IG: 5,6±3,6 vs CG: 5,0±2,4; p<0.001). - Kilocalories intake had positive significant differences at 3 (IG: 1553,2±448.4 vs CG: 1723,8±533,3; p<0.001), 6 (IG: 1635,2±579,2 vs CG 1844,6±624,5; p<0.001) and 12 months (IG: 1606,6±495,5 vs CG: 1806,9±631,6; p<0.001) - There were positive significant differences in steps per day (p=0.015) between groups at 6 months. Mean change from baseline to 6 months was 2353 in the IG group versus

						−9.4 steps/day in CC [difference (95% CI) of 2362 (494, 4230); p=0.015]. - No significant differences in PA minutes at 3 months, but positive significant differences between groups at 6 (IG: 249±227 vs CG: 144±180; p=0.038) and 12 months (IG: 216±190 vs CG: 142±128; p=0.020). - Positive significant differences in leisure score index at 3 (IG: 39,5±31,5 vs CG: 28,4±20,4; p<0.001), 6 (IG: 33,0±23,5 vs CG: 20,9±18,6; p<0.001), and 12 months (IG: 30,7±21,1 vs CG: 23,4±18,9; p<0.001).
Rogers et al., 2009	Breast (stage I-IIIA), receiving hormonal therapy	Overall: 41, 100% women, 53 ± 9 years; IG: 21, 100% women, 52 ± 15 years;	IG: 6 discussion group sessions with a clinical psychologist + 12 individual exercise sessions with an exercise specialist + 3 individual counselling sessions with an exercise specialist	- Social Cognitive Theory; - Trans-theoretical Model	- Daily caloric Intake (3-d diet record (i.e., 1 weekend and 2 weekdays) + Diet Analysis Plus software, version 7.0.1) - PA: total daily activity counts, weekly minutes	- Daily caloric intake showed a significant time effect (i.e., mean for baseline, 1,880.4; postintervention, 1,624.7; and 3 months postintervention, 1,624.6; F = 8.34; P < 0.001) with no significant effects of group (F = 0.03; P = 0.87) or group by time interaction (F = 0.35; P = 0.70).

		CG: 20, 100% women, 54 ± 8 years; 3 months	CG: Usual care: received written materials about PA available through the American Cancer Society.		of moderate plus vigorous PA (GT1M accelerometer (Actigraph)); baseline, 3, 6 months	- Daily PA counts: a significant group by time interaction (F = 4.28; P = 0.013) was noted. -Similarly, weekly minutes of moderate plus vigorous activity and stage of motivational readiness showed significant group by time interactions (F = 3.51; P = 0.035; and F = 7.85; P < 0.001, respectively).
Campbell et al., 2009	Colorectal	Overall: 266; 49,4%* women, 66,5±10,0* years; TPC: 70 13,3%* women, 66,2±10,5* years; TMI: 72 10,9%* women,	IG: - Tailored Print Communication (TPC): personalized computer-tailored newsletters focused on F&V consumption, PA, and follow-up surveillance as recommended by the participant's physician; - Telephone Motivational Interviewing Intervention (TMI): four brief (20-min) MI calls; - TPC+TMI	- Social Cognitive Theory; - Trans-theoretical Model;	- Fruit&Vegetable Consumption: servings/day (36-item modified version of the Block food F&V: estimate one's intake with a 2-item screener + 35-item questionnaire (based on Block food frequency questionnaire (FFQ)) + average of both); - Weekly PA: frequency (minutes/week) and MET	- 35-item measure: No significant intervention effects were found for colorectal cancer survivors. - 2 item measure: Statistically significant increases for all three intervention groups were found, compared to the control group, with both the TMI-only and combined groups showing an increase of more than one daily serving. The three intervention groups did not differ statistically from each other, however. (CG: 4,3±2,0 vs TPC: 4,9±1,6 (p≤0,05) or TMI: 5,0±2,0 (p<0,01) or TPC+TMI: 5,2±2,4 (p<0,01))

		67,1±9,5* years; TPC+TMI: 58 12,5%* women, 66,9±9,8* years; CG: 66, 12,7%* women, 66,6±10,1* years; *sample consisted of cancer and non-cancer participants	CG: Generic Printed Health Information: two mailings of generic (nontailored) health information that was not related to the primary study outcomes. 12 months		hours/week of MVPA (modified version of 7-day PAR data) Baseline and 12 months	- Averaging the 35-item and 2-item measures, no significant treatment differences among CRC survivors. - None of the interventions produced significant effects on increasing PA among cancer survivors.

Kanera et al., 2016	Multiple cancers at any stage, who have completed primary treatment at least 4 weeks and up to 56 weeks prior to initial participation (Breast 16,0%, colorectal 3,8%, lymphoma 17,0%, thyroid 13,7%, testes	Overall: 462; IG: 231, 79,2% women, 55,6 ± 11,5 years; CG: 231, 80,5% women, 56,2 ± 11,3 years;	IG: KNW, a web-based computer tailored intervention: Based on the screening questionnaire measuring several concepts such as Diet and PA + Dutch nutritional and PA guidelines, participants receive feedback on their dietary habits and their own level of PA and to which extent they reach the recommended level and then, they are encouraged to set a goal. Subsequently, dietary advice is given, personalized to the participant's individual situation CG: usual care/waiting list	- Integrated Model for Change (I-Change Model) - Self-Regulation Theory	- Dietary behaviour: vegetable, fruit, whole grain bread, and fish consumption (8 items of the Dutch Standard Questionnaire on Food Consumption) - PA (Short Questionnaire to Assess Health Enhancing Physical Activity (SQUASH)); baseline and at the 6-month follow-up	- No significant intervention effects were found for dietary variables after controlling for multiple testing (p>005). - There were no significant differences in change over time concerning MPA between IG and CG after controlling for multiple testing (p>0.05). No significant results were found for Weekly days >30 min, Light PA min and Vigorous PA min (p>0.05).

	12,3%, leukemia 6,6%, cervix 6,1%, brain 6,1%, others 18,4%)		6 months			
Lee et al., 2018	Colorectal, any stage, within one year of completion of main cancer treatment from the surgical/oncological departments	Overall: 223; Group A: 55, 32,7% women, 63,2 ± 11,4 years; Group B: 56, 39,3% women, 65,9 ± 9,8 years; Group C: 56, 28,6% women, 66,6 ± 9,5	IG: Group A (dietary and PA interventions), Group B (dietary only), Group C (PA only): individual face-to-face motivational interviews (two sessions for Groups A and B and one session for Group C), fortnightly motivational phone calls, mailed monthly stage-of-change matched educational pamphlets, mailed quarterly newsletters, and quarterly group meetings	- Theory of Planned Behaviour; - Health Action Process Approach (HAPA)	Diet: Changes of dietary consumption, servings/day + Achieving behavioural targets (FFQ): - Red and Processed Meat target: weekly intake of <5 servings, including <2 servings of processed meat, - Refined Grains target: daily intake <2 servings, PA: Changes of PA level, accumulated minutes of MVPA per week +	Dietary interventions significantly: - increased the odds of achieving the targets of consuming less processed meat at all time-points and refined grain at months 6 and 24 - reduced processed meat (all p<0.01) and refined grains (all p<0.01) consumptions. - In the subgroup of 49 patients who had <300 minutes of MVPA per week at baseline, PA interventions did not significantly improve the two PA targets. - However, patients who received the PA interventions had significantly larger increases in PA at months 6 (difference = 174.2, [34.7–313.7], p = 0.015)

		years; Group D: 56, 46,4% women, 64,9 ± 9,4 years;	CG: Group D (usual care): 5 pamphlets with general health advice that encouraged healthy lifestyles by eating a wide variety of food, more fruit and vegetables, increasing PA levels, quitting smoking and avoiding alcohol abuse. 12 months		Achieving behavioural targets (accelerometer): - PA general health target: 30 minutes of MVPA 5 days a week - PA cancer outcome target: 60minutes of MVPA 5 days a week; Baseline, 6, 12, 18 and 24 months	and 18 (179.0 [36.6–321.3], p = 0.014) than those who did not receive the PA interventions.

Appendix 5 - PA-only Trials

Authors	Cancer Type/Phase	Sample	Intervention	Theory	Outcomes	Results
Ungar et al., 2015	Multiple cancers at any stage, receiving out-patient therapy (acute or maintenance therapy) or finished this therapy not longer than six months ago (Breast 32,8%, Colorectal 11,9%, Prostate	**Overall:** 67; **IG:** 35, 54,3% women, 56,69 ± 13,43 years; **CG:** 32, 50% women, 54,09 ± 11,72 years	**IG - exercise intervention:** 1-h individual counselling session + booklet with behaviour change techniques; 3 weekly telephone calls (M = 14 min/call); 4-week practicing at home; and meeting with an exercise role model (physically active cancer patient) for walking/cycling together was encouraged **CG - stress management intervention:** 1-h individual counselling session + booklet with stress-management techniques; 3 weekly	- HAPA-based counselling (enhancing self-regulation) + role model support.	PA: exercise min/week (self-reported Short QUestionnaire to ASsessHealth-enhancing PA (SQUASH) at T1, T2 and T3 and an accelerometer at T1 and T2.) baseline (T1), 4 weeks (T2) and 14 weeks (T3).	- At 4 weeks after intervention, the intervention group had more PA than the control group: 45.7% of patients in the IG vs 18.8% in the CG increased their activity levels to meet PA guidelines (>150 min/week; χ 2 (1) = 5.51, p = 0.019). - At 14 weeks after intervention, there were no significant differences (p = 0.225).

	7,46%, others 47,8%)		telephone calls (M = 14 min/call); 4-week practicing at home; without PA information 4 weeks			
Hirschey et al., 2018	Breast (stage Ia to IIb) being 2 months to 10-year status post-surgery, radiation, and chemotherapy	**Overall:** 58; **IG:** 29, 100% women, 59 ± 10 years; **CG:** 29, 100% women, 57 ± 12 years	**IG:** Exercise theory-guided booklet containing narrative messages, writing, and thinking activities intended to increase outcome expectations dimensions of importance, certainty and accessibility. **CG:** Similar booklet focused on diet instead of exercise. 1 week intervention + 12 weeks follow up	- Self-Efficacy Theory	PA: - objective: Fitbit ® - subjective: GLTEQ baseline, 4-, 8-, and 12-weeks post intervention	There were positive significant differences in objectively measured steps between groups (IG: more 970 steps, p=0.0283), but not in subjective PA (p=0.268).

May et al., 2009	Multiple cancers at any stage, medical treatment ≥3 months ago (Breast 55,8; Haematological 16,6%; Gynaecological 11,6&; Urogenital 5,5%; lung 2,7; other 6,2%	**Overall**: 147, 83,7% women, 48,8 ± 10,9 years; **IG: 76**, 86,8% women, 47,8 ± 10,5 years; **CG:** 71, 80,3% women, 49,9 ± 11,3 years	**IG:** Physical training + cognitive-behavioural training **CG:** Physical Training: supervised exercise programme: aerobic and resistance exercise, and group sports 12 weeks	Self-Management	PA: Physical Activity Scale for the Elderly (PASE) baseline, 12 weeks	Changes in PA from baseline to post-intervention were not significantly different between groups (p>0.05)
Rogers et al., 2014	Breast (DCIS, stage I-IIIA) not currently receiving or planning to receive chemotherap	**Overall**: 222, 100% women, 54,4 ± 8,5 years; **IG: 110**, 100%	**IG:** Six discussion group sessions + 12 supervised exercise sessions + multiple home-based exercise sessions beginning in the third week + three face-to-	- Social Cognitive Theory	weekly minutes of ≥moderate intensity PA (MTI/ActiGraph accelerometer + GLTEQ) baseline, immediately post-intervention (month 3; M3),	Between group mean differences in PA was statistically significant at M3 (accelerometer, +41 weekly minutes, p = 0.010; self-report, +93 weekly minutes, p=0.001) and remained statistically significant at M6 for self-

	y or radiation therapy.	women, 54,9 ± 9,3 years; **CG:** 112, 100% women, 53,9 ± 7,7 years	face update counselling sessions **CG:** Usual care: printed American Cancer Society materials describing PA recommendations for cancer survivors 3 months		and 3 months post-intervention (month 6; M6)	reported PA (+74 weekly minutes, p=0.001), but not for accelerometery.
McGinnis et al., 2021	Multiple cancers at any stage, currently receiving or within six-months of receiving active cancer treatment (Breast 39,3; prostate,	**Overall:** 33, 63,6% women, 54,3 ± 12,4 years;	**IG:** Exercise Program + PA Behaviour Change Counselling **CG:** Exercise Program 3 months	- Social Cognitive Theory	PA (Adapted version of the GLTEQ) Baseline and post-program (3M)	Intervention Group reported an 81.3% increase in minutes per week of MVPA (M = 108.33 ± 166.5 min), compared to a 16.6% increase (M = 38.57 ± 114.6) in the control group. Intervention group 67% (n = 4) reported an increase of ≥ 60 min per week of MVPA, compared to 25% (n = 2) participants in the control group. p-value NA

	7,1%; ovarian, 7,1%; haematological, 17,9%; other, 28,6%)					
Courneya et al., 2016	Colon (stage II and III) who received adjuvant chemotherapy within the past 2–6 months,	**Overall:** 211; **IG:** 106, 57% women, <65 yrs (67%); ≥65 yrs (33%); **CG:** 10, 56% women, <65 yrs (68%); ≥65 yrs (32%);	**IG:** Behaviour support sessions + Supervised exercise sessions + exercise guidebook developed specifically for colon cancer **CG:** general health education materials promoting PA and healthy nutrition and standard surveillance follow-up. 3 years	- Theory of Planned Behaviour	Sel reported recreational PA (Total Physical Activity Questionnaire - TPAQ (converted to MET-hours/week)) Baseline, 6, 12, 18, 24, 30 and 36 months	The intervention group reported a significant increase in PA of 15.6 MET-hours/week from baseline to 1 year compared to the control group with an increase of 5.1 MET-hours/week (p=0.002).
Bélanger et al., 2014	Multiple cancers at any	**Overall:** 212, 60,8% women, 18-	**IG:** Thrive to Survive Guidebook: with information about the protective effect of	- Theory of Planned Behaviour	PA (Modified LSI from GLTEQ)	No differences at 1 and 3 months for all sample (p>0.05). But participants who reported ≤300 PA minutes/week

	stage/phase of treatment (Breast (16.0%), colorectal, lymphoma (17.0%), thyroid (13.7%), testes (12.3%), leukaemia (6.6%), cervix (6.1%), brain (6,1%), colorectal (3,8%) others (18,4%)	29 yrs (25,9%); 30-39 yrs (74,1%); **IG**: 106, 60,4% women, 18-29 yrs (24,5%); 30-39 yrs (75,5%); **CG**: 106, 61,3% women, 18-29 yrs (27,4%); 30-39 yrs (72,6%);	PA against chronic disease, tips on how to make PA enjoyable, how much PA is recommended, how to determine PA intensity, and practical tips such as how to dress for the weather. The Guidebook included participant-centred activities designed to facilitate participant engagement in the information as well as control over PA behaviour, including instructing the reader to scan their current physical environment for opportunities to be physically active, a time management worksheet, information about goal setting, and a PA tracking sheet. Throughout the Guidebook there were		Baseline, 1, and 3 months	and participate in the intervention group had significant differences in total PA at 3 months: mean change of +135 minutes/week vs +69 minutes/week on the CG (p=0.028); but not at 1 month

			motivational quotes from YACS with an accompanying picture of the person performing an activity, as well as motivational quotes from oncologists and exercise specialists. **CG:** Received Canadian PA Guidelines (CPAG). Does not specify intervention's duration			
Vallance et al., 2015	Breast (stages I-IIIA), scheduled to receive neoadjuvant or adjuvant chemotherapy	**Overall**: 95, 100% women, 52,8 ± 9,8 years; **IG:** 49, 100% women, 52,8 ± 9,6 years;	**IG:** PROACTIVE PA resource kit: PA print materials, a step pedometer, and a step logbook **CG:** Generic two-page public health PA resource: Canada's Physical Activity Guide to Healthy Active Living for	- Theory of Planned Behaviour	- Objective walking behaviour: Pedometer steps (3-day step test using the StepsCount SC-01 pedometer); - Self-reported PA (LSI from the GLTEQ);	Intervention was not statistically superior to a standard recommendation for daily average pedometer steps (P = 0.22), light intensity PA minutes (P = 0.70), moderate intensity PA minutes (P= 0.90), vigorous intensity PA minutes (P = 0.93) and total MVPA minutes (P = 0.90).

		CG: 46, 100% women, 52,9 ± 10,1 years	Healthy Adults or Canada's Physical Activity Guide for Older Adults. 4-6 months (during chemo)		Baseline (prior to second chemotherapy administration) and at post intervention (between 3 and 4 weeks after the last chemotherapy administration).	
Kong et al., 2021	Breast (stage I to III) who were planning to undergo radiation therapy (RT) after surgery	**Overall:** 152; **IG**: 76, 100% women, 47,3 ± 8,5 years; **CG**: 76, 100% women, 46,8 ± 7,6 years;	**IG:** Wearable Activity Tracker (WAT) + counselling* (weekly face-to-face by a exercise physiologist) + educational booklets **CG:** counselling* (weekly telephone by an exercise physiologist) + educational booklets during the 5-week radiotherapy treatment (RT) period	- Trans-theoretical Model	- Self-reported Leisure Time Physical Activities levels (Global Physical Activity Questionnaire (GPAQ)); before RT, immediately after RT, and 3 and 6 months after completion of RT.	- The IG had increased relative change in self-reported LTPA (102.8) compared with the CG (57.8) immediately after RT compared to baseline. Although the relative changes of self-reported LTPA of the IG were higher at three and six months after the end of RT compared to in the CG, the results were not significant. - The mean average daily step count of the IG was 9351.7, which increased to 11,592.2 during RT and 12,240.1 after RT

Weiner et al., 2019	Breast (diagnosed less than 5 years prior to study enrolment, had completed chemotherapy and/or radiation treatment)	**Overall:** 87; **IG**: 43, 100% women, 58,2 ± 11,4 years; **CG**: 44, 100% women, 56,2 ± 9,2 years	**IG:** face-to-face meeting with a trained interventionist (who used motivational interviewing techniques to help each participant set a specific, personalized PA goal and an action plan to gradually increase their activity) + received a Fitbit ® + two 20-min phone calls at the 2- and 6-week time points (to review Fitbit data and discussing progress toward the goal) + twice-weekly emails with theory-based content and reminders to wear and sync their Fitbit **CG:** Waitlist wellness contact control condition received standardized emails every 3 days on women's health	- Social Cognitive Theory; - Control Theory	PA: MVPA, LPA (ActiGraph GT3X+ accelerometer) baseline and 12 weeks	No differences between groups in LPA ($p = 0.48$) but positive significant differences in accelerometer-measured MVPA: mean increase 14.2 min per day (SD = 13.9) in the IG vs. −0.7 min per day (SD = 9.7) in the CG ($p < 0.001$).

			topics (e.g., healthy eating, stress management, and general brain health). 12 week			
Webb et al., 2019	Multiple cancers at any phase (breast 38.2%, prostate 6.8%, colorectal cancer 13.0%, others 42.0%)	**Overall**: 207, 73,9% women, 0-44 yrs (14,5%); 45-64 yrs (61,8%); ≥65 yrs (23,7%); **IG:** 104, 72,1% women, 0-44 yrs (14,4%); 45-64 yrs (65,4%); ≥65 yrs (20,2%);	**IG:** printed components and Internet tools and e-newsletters influenced by the stage of PA behaviour change model with content tailored by prediagnosis levels of PA, age and gender **CG:** standard letter recommendation 24 weeks (▪Intervention: 12 weeks + 12 weeks follow up ▪Control: 12 weeks standard letter + 12 weeks intervention)	- Social Cognitive Theory; - Theory of Planned Behaviour;	PA: GLTEQ 12 and 24 weeks	The intervention arm reports a mean PA improvement score of 9.58 (23.14) over 12 weeks, compared with 2.61 (24.10) in the control arm (p = 0.04). At 12 weeks: IG: 35.57 ±23.71 vs CG: 31.31± 22.65; p<0,05.

		CG: 103, 75,7% women, 0-44 yrs (14,6%); 45-64 yrs (58,3%); ≥65 yrs (27,2%);				
Short et al., 2015	Breast (stage 0-4), who completed active cancer treatment	**Overall**: 330, 100% women, 55 years; **Tailored IG:** 109, 100% women, 56 years; **Targeted IG**: 110, 100% women, 55 years;	**IG:** **Tailored-print intervention group** received three Social Cognitive Theory-based computer-tailored newsletters over a 12-week period (6 weeks apart); **Targeted-print intervention group** received a copy of the Theory of Planned Behaviour-based booklet 'Exercise for	- Social Cognitive Theory; - Theory of Planned Behaviour	- Self-reported PA and - Meeting the PA guidelines for aerobic and resistance-based activity (adapted version of the LSI from the GLTEQ); - Mean daily steps (Pedometer); baseline, 4 months	Allocation to the tailored intervention significantly reduced the odds of not doing any resistance-based PA ($p < 0.01$) relative to the control group and - increased the odds of meeting the resistance training guidelines. - Meeting aerobic guidelines was not significantly different between groups ($p>0.05$). - There were no other significant intervention effects.

		CG: 111, 100% women, 55 years	health: An exercise guide for breast cancer survivors. **CG:** Received the brochure 'An active way to better health' describing the national PA guidelines for Australian adults 12 weeks			
Pinto et al., 2013	Breast, stage 0-IV (completed primary and adjuvant treatment for breast cancer ≤ 5 years since treatment completion)	**Overall**: 192, 100% women, 60,0 ± 9,9 years; **IG:** 86, 92% women, 59,5 ± 9,7 years; **CG:** 106, 93% women, 62,8 ± 11,1 years	**IG:** health care provider advice for PA + 12 weeks of telephone counselling + Monthly PA calls for 3 months **CG:** health care provider advice for PA + 12 weeks of contact control + Monthly calls for 3 months 6 months	- Social Cognitive Theory - Trans-theoretical Model;	PA (7-day PAR) baseline, at 3 months, 6 and 12 months.	Intervention participants had more MPA than the control group at both 3 months (59,70 vs 30,82; p =0.048) and 6 months (56,64 vs 32,16; p = 0.032), but this beneficial telephone counselling effect dissipated at 12 month (p = 0.574).

Pinto et al., 2015	Breast (stage 0-3) who had completed surgery	**Overall:** 76, 100% women, 55,62 ± 9,55 years; **IG**: 39, 100% women, 55,64 ± 8,59 years; **CG**: 37, 100% women, 55,59 ± 10,59 years;	**IG:** PA + Reach to Recovery program: telephone-based PA counselling, a pedometer (Digiwalker) and a heart rate monitor + Reach to Recovery program informational booklets + 12 exercise tip sheets that focused on PA topics **CG:** Reach to Recovery program: 12 calls during which was administered the Weekly Symptom Questionnaire + Reach to Recovery program informational booklets. 12 weeks	- Social Cognitive; - Trans-theoretical Model	Self-reported MVPA (7-day PAR); Mean minutes of MVPA (Accelerometer (Actigraph GT3X)) baseline, 12, 24 weeks	For self-reported PA, there were significant group differences favouring the intervention group, compared to the control group in minutes of MVPA at 12 weeks (129,5±73,4 vs 25,0 ± 67,4; p<0.001) and at 24 weeks (98,4±83,2 vs 63,9 ± 82,9; p=0.03). For accelerometery significant group differences favouring the intervention group, compared to the control group in minutes of MVPA at 12 weeks (70,3±65.9 vs 16.5±31.9; p<0.01) and at 24 weeks (54,6±81,6 vs 13,4 ± 35,2; p<0.01)
Golsteijn et al., 2018	Colorectal, Prostate undergoing	478;	**IG:** pedometer + computer-tailored PA advice, both Web-based via an interactive	- Social Cognitive Theory;	Objective MVPA (ActiGraph GT3X-BT accelerometer) - baseline, 6 months;	At 3 months, participants in the OncoActive group improved their PA significantly in terms of both MVPA (B

	curative treatment or completed primary treatment up to one year ago.	**IG**: 249, 14,9% women, 66,55 ± 7,07 years; **CG**: 229, 10,9% women, 66,38 ± 8,21 years;	website and with printed materials. **CG:** usual care waiting-list 4 months	-Trans-theoretical Model; - HAPA; - I-Change Model; -Health Belief model; - goal setting theories; - theories of self-regulation - the Precaution Adoption Process Model:	Self-reported MVPA (SQUASH) - baseline, 3, 6 months;	= 133.55, p = 0.04) and days with at least 30 min of PA (B = 0.86, p < 0.001). At 6 months, results indicate significant improvements in self-reported PA (MVPA: B = 267.17, p < 0.001; Days ≥30 min PA: B = 0.98, p < 0.001). ActiGraph assessed MVPA also increased significantly (MVPA: B = 44.60, p = 0.006), whereas the increase in ActiGraph assessed days ≥30 min PA was borderline significant (B = 0.38, p = 0.05).

Appendix 6 - SURE Checklist

A - Identification, selection and appraisal of studies

A1) Were selection criteria reported?

Yes

A2) Was the search comprehensive?

Partially

A3) Is the review up-to-date?

Yes

A4) Was biased selection of articles avoided?

Yes

A5) Were appropriate criteria used to assess the risk of bias?

Yes

A6) Overall identification, selection and appraisal of studies

Reliable

B - Analysis of the findings

B1) Were characteristics and results of included studies reliably reported?

Yes

B2) Were methods used to analyse the findings reported?

Yes

B3) Was the extent of heterogeneity described?

Yes

B4) Were the findings combined (or not combined) appropriately?

Yes

B5) Were factors that could explain heterogeneity explored?

Not applicable

B6) Overall analysis of findings

Reliable

C - Overall assessment of the reliability of the review

C1) Other considerations

No other quality issues identified

C2) Overall reliability of the review

Reliable: This is a good quality systematic review with only minor limitations

Appendix 7 - Abstract ISBNPA

Title: Self-determination theory-based physical activity and/or nutrition behavior change interventions for cancer survivors – A systematic review

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Abstract draft (304 of 350 words)

Purpose: Theory-based interventions, using evidence-based behavior change techniques, aimed at promoting long-term health behavior change in cancer survivors are effective, but remain scarce. Prior research has shown that internal (better quality) motivations play an important role in long-term, sustained, behavior adoption, supporting the use of self-determination theory (SDT) as a valid framework. However, no previous systematic review has examined SDT-based PA and/or dietary behavior change interventions in cancer survivors. Therefore, this study aims to synthetize such information.

Methods: Scientific articles were identified through electronic database searches (PubMed, Web of Science and Psychology and Behavioral Sciences Collection) and reference scanning. Searches included various combinations of three sets of terms: 1) terms concerning the health condition or population of interest (e.g., cancer); 2) terms concerning the intervention (e.g., lifestyle/behavioral interventions); and 3) terms concerning the behavior change outcomes of interest (e.g., diet, physical activity). Clinical or community lifestyle/behavioral intervention studies targeting energy balance-related behaviors and weight loss and/or maintenance in adults (≥18y) diagnosed with any type of cancer (at any stage of disease/treatment) were included. Pharmacological and surgery-based intervention studies were excluded.

Results/findings: The search yielded 36 potentially relevant papers after title/abstract screening. Full-text screening and data extraction are currently being performed by two independent researchers, according to a data extraction form previously developed by the authors. The same two researchers are assessing study methodological quality using the Quality Assessment Tool for Quantitative Studies, developed by the Effective Public Health Practice Project. Results deriving from the narrative synthesis of the characteristics and effectiveness of the interventions will be summarized in tabular form and will be presented at the ISBNPA annual meeting.

Conclusions: Systematically identifying and summarizing relevant information on SDT-based physical activity and/or nutrition behavior change interventions for cancer survivors can contribute to the development of more effective interventions designed to promote adherence to lifestyle behaviors.

Keywords: Cancer, behavior change intervention, self-determination theory