

An assessment of study characteristics, quality and reporting in cancer prehabilitation literature: a scoping review

WELFARE, Samantha <<http://orcid.org/0009-0000-4071-5172>>, MADEN-WILKINSON, Thomas <<http://orcid.org/0000-0002-6191-045X>>, COPELAND, Robert <<http://orcid.org/0000-0002-4147-5876>>, HUMPHREYS, Liam John <<http://orcid.org/0000-0002-9279-1019>>, DALTON, Caroline <<http://orcid.org/0000-0002-1404-873X>> and MYERS, Anna <<http://orcid.org/0000-0001-6432-8628>>

Available from Sheffield Hallam University Research Archive (SHURA) at:

<https://shura.shu.ac.uk/35923/>

This document is the Published Version [VoR]

Citation:

WELFARE, Samantha, MADEN-WILKINSON, Thomas, COPELAND, Robert, HUMPHREYS, Liam John, DALTON, Caroline and MYERS, Anna (2025). An assessment of study characteristics, quality and reporting in cancer prehabilitation literature: a scoping review. *BMJ Open*, 15 (7), bmjopen-2024. [Article]

Copyright and re-use policy

See <http://shura.shu.ac.uk/information.html>

BMJ Open An assessment of study characteristics, quality and reporting in cancer prehabilitation literature: a scoping review

Samantha Welfare ^{1,2}, Thomas Maden-Wilkinson,^{1,2} Robert Copeland,² Liam John Humphreys ^{1,2}, Caroline Dalton,^{2,3} Anna Myers^{1,2}

To cite: Welfare S, Maden-Wilkinson T, Copeland R, *et al.* An assessment of study characteristics, quality and reporting in cancer prehabilitation literature: a scoping review. *BMJ Open* 2025;**15**:e093832. doi:10.1136/bmjopen-2024-093832

► Prepublication history and additional supplemental material for this paper are available online. To view these files, please visit the journal online (<https://doi.org/10.1136/bmjopen-2024-093832>).

Received 17 September 2024
Accepted 12 June 2025



© Author(s) (or their employer(s)) 2025. Re-use permitted under CC BY-NC. No commercial re-use. See rights and permissions. Published by BMJ Group.

¹Physical Activity, Wellbeing and Public Health Research Group, School of Sport and Physical Activity, Sheffield Hallam University, Sheffield, UK

²Advanced Wellbeing Research Centre, Sheffield Hallam University, Sheffield, UK

³Biomolecular Research Group, Sheffield Hallam University, Sheffield, UK

Correspondence to

Samantha Welfare;
sw2472@exchange.shu.ac.uk

ABSTRACT

Background Cancer and its treatment can negatively impact physical function, general well-being and quality of life. An evidence-based strategy to manage this is to prescribe exercise. One approach is to prescribe exercise prehabilitation to improve pretreatment health and function. However, current exercise prehabilitation programmes are under-researched, and the quality of their reporting has not been systematically assessed.

Objectives This review aimed to identify the following: the characteristics of prehabilitation exercise programmes; how intensity, physical function, patient-reported outcomes and treatment-related outcomes were measured; the quality of reporting and programme implementation.

Eligibility criteria Studies were eligible for inclusion if they reported a cancer prehabilitation exercise intervention, reported outcomes relating to physical function and patient-reported outcomes, and full-text copies were available in English.

Sources of evidence PubMed, Mednar and Scopus were screened for studies from inception until 4 of April 2024.

Charting methods Exercise characteristics were extracted and manually charted in Microsoft Excel using the Template for Intervention Description and Replication. The tool for the assessment of study quality and reporting in exercise (TESTEX) framework was used to assess study quality and intervention reporting.

Results 1495 results were retrieved, 28 of which were included. Exercise sessions lasted a mean of 42.5±21.9 min and were completed 3.7±1.3 times per week. 22 studies implemented concurrent exercise, five prescribed aerobic, and one prescribed resistance. High-intensity exercise was prescribed in four studies, moderate-high in 12, seven prescribed moderate, three prescribed low-moderate, and one was low intensity. 10 studies prescribed exercise intensity using the Borg Rating of Perceived Exertion Scale, five prescribed heart rate (HR) zones, six used a set workload, and seven did not monitor intensity. A mean TESTEX score of 9.3±2.3 out of 15 was achieved. The lowest scoring criterion (n=3) related to the reporting of the exercise dose.

Conclusions There was heterogeneity among studies regarding exercise intervention characteristics and measures of effectiveness. The overall quality of reporting was satisfactory, yet inconsistencies were apparent regarding quantifying and monitoring exercise dose,

STRENGTHS AND LIMITATIONS OF THIS STUDY

- ⇒ This study used a robust search strategy across multiple databases.
- ⇒ The combined use of tool for the assessment of study quality and reporting in exercise (TESTEX) and template for intervention description and replication (TiDier) frameworks provides a novel assessment of the quality of reporting and exercise characteristics.
- ⇒ Heterogeneity in outcomes, settings and exercise protocols meant that meta-analysis was not feasible

which limits the ability of researchers and clinicians to replicate, evaluate or scale cancer prehabilitation exercise interventions, impeding evidence-based practice. As such, to be able to optimise cancer prehabilitation exercise programmes, research must first focus on improving the quality of reporting and standardising outcome measures and methods of monitoring and prescribing exercise.

INTRODUCTION

Cancer is a highly prevalent disease, with one in two people receiving a cancer diagnosis within their lifetime.¹ Therefore, minimising the burden of cancer is critical to patient well-being. While treatments have been developed to ameliorate the disease, reduce its severity and improve mortality rates, they can be detrimental to physical function, well-being and quality of life (QoL).^{2,3} It is reported that during treatment, cancer patients often experience reduced physical function and weakened immune and anti-inflammatory mechanisms, which can result in an increased risk of treatment-related toxicity and mortality.^{4,5} Consequently, developing and optimising strategies that enhance pretreatment physical function and health are vital for managing post-treatment outcomes and preserving patient well-being.

A relatively new strategy is to prescribe interventions before acute treatment to physically and mentally prepare the patient

(prehabilitation). This is opposed to the more commonly acknowledged rehabilitation phase, where programmes are implemented after treatment to restore health and well-being.⁶ Prehabilitation often features baseline and post-treatment assessments alongside programmes designed to enhance physical and psychological well-being, thus minimising treatment-related impairment.^{7 8} A particularly promising strategy is exercise prehabilitation, which comprises exercise-based programmes that aim to improve physical function and prepare the patient for the demands of treatment.⁹

When implemented effectively, exercise prehabilitation proves highly beneficial in adults living with cancer and has been evidenced to reduce treatment complication rates, shorten hospital stays and improve aspects of physical and psychological well-being.¹⁰ Furthermore, by implementing exercises specifically designed to increase aerobic fitness and lean body mass before treatment, the risk of toxicity and the likelihood of treatment effectiveness significantly improve.^{11 12} However, the existing evidence may be threatened by a lack of adherence and no intention to treat analysis.^{13 14}

Furthermore, a consensus is lacking regarding the optimal approach to delivering prehabilitation, whereby programmes vary in location and supervision status.¹⁵ Exercise programmes are perceived as easier to implement, monitor and standardise when delivered in clinical settings, as a smaller reliance is placed on the participant's motivation to adhere.^{15 16} However, participants may be deterred by inconvenient exercise settings such as busy public gyms, and participant withdrawal is common.^{16 17} Other strategies aim to enhance adherence and remove barriers like travel time and distance using home-based delivery methods (virtual/video call delivery or prerecorded material), but safety and exercise intensity may be compromised.^{18 19} Most of these home-based programmes rely on patient-reported measures of adherence. Therefore, whether sessions were completed per protocol is unknown, and the reported adherence is likely to be an inflation of actual values.^{20 21} Accordingly, the methods used for assessing and reporting adherence must be systematically assessed to understand whether adherence rates are accurate and standardised across the literature.

The optimal intensity, modality and frequency of the exercise itself also remain unknown.²² Aerobic programmes are evidenced to significantly improve cardiorespiratory fitness, fatigue, depression and QoL.²³ Whereas the external load placed on the body by resistance-based programmes is theorised to induce adaptations that benefit muscular strength, bone mineral density, mobility and body composition.²⁴ Yet there are arguments that concurrent programmes (combining aerobic and resistance elements) are superior and provide the benefits of both aerobic and resistance-based exercises.²⁵

Current guidelines for adults living with cancer comprise three 30 min sessions of moderate-intensity

aerobic exercise each week, concurrent with two sessions of resistance training at $\geq 60\%$ of their one repetition maximum (1RM).²⁶ There is evidence advocating that the prescription of high-intensity interval training (HIIT) may improve cardiopulmonary fitness, muscular function and QoL in a more time-efficient manner.²⁷ Yet, quantifying and monitoring exercise intensity vary largely, meaning comparisons cannot be made between programmes.²⁸ Indeed, despite the increasing recognition of prehabilitation for people living with cancer within clinical practice guidelines, the most effective approach to prehabilitation is unknown, and the quality and characteristics of the current evidence require assessment.²⁹

Currently, comparisons between different studies and programmes cannot be made due to heterogeneity in effectiveness outcomes. Gold standard techniques, like cardiopulmonary exercise testing (CPET), are validated for determining clinically significant changes in health and fitness and are highly supported across the literature.¹¹ However, studies often opt for non-validated methods, design their own or use subjective measures.³⁰ By not using validated and objective measures, findings are open to reporter bias, measures may not accurately represent the values they are trying to assess, and discrepancies exist between perceived/reported and actual values, especially when assessing physiological variables like symptom burden or fitness levels.^{31 32} Indeed, without systematic assessment of programme implementation, evaluation and reporting, programme effectiveness cannot be identified and compared with any degree of certainty.

In summary, a consensus is lacking regarding the optimal approach to cancer prehabilitation. Furthermore, while systematic assessments of the characteristics and quality of reporting of all modalities of prehabilitation exist,³³ assessments that focus specifically on exercise prehabilitation among adults living with cancer are yet to be completed. Therefore, this scoping review aimed to map the characteristics of cancer prehabilitation exercise interventions and systematically assess their quality of reporting (using a validated tool). By doing so, this review identified areas which lacked consistency, were poorly reported and therefore prevented comparison, replication and optimisation.

AIMS

Cancer prehabilitation interventions are complex to design, implement and report. As such, there is a need to synthesise the evidence to understand the characteristics of such interventions and assess the quality of reporting of cancer prehabilitation exercise interventions. The aims of the current study are:

- ▶ To identify the characteristics of cancer prehabilitation exercise interventions: frequency, intensity, time and type of exercise, setting, part of a unimodal or multimodal intervention.

- ▶ To identify methods of measuring and assessing exercise intensity, physical function, adherence and patient-reported outcomes.
- ▶ To assess the quality of reporting of prehabilitation exercise interventions.

METHOD

This scoping review was reported according to the Preferred Reporting Items for Systematic reviews and Meta-Analysis (PRISMA) extension for Scoping Reviews³⁴ and the Joanna Briggs Institute framework.³⁵ The following steps were completed: (1) defining a review question; (2) refining the inclusion criteria; (3) creating and conducting the search strategy; (4) evidence screening; (5) data extraction; (6) data analysis; (7) presenting the results. The search strategy and protocol were not registered.

Inclusion criteria

The eligibility of identified studies was assessed according to the following criteria: (1) participants were ≥ 18 years of age living with any type or stage of cancer; (2) interventions featured a prehabilitation exercise programme of any modality. Studies featuring rehabilitation were eligible, providing that the results and protocols of the prehabilitation phase could be separated; (3) outcomes measured physical function, patient-reported or treatment-related; (4) full-text articles were available in English.

Search strategy

A final search of PubMed, Scopus, Mednar and the reference lists of relevant studies was completed on 4 of April 2024. The search strategy (described in online supplemental material 1) was applied to identify articles containing titles, abstracts and keywords that included predefined search terms relating to cancer, prehabilitation, exercise, physical function and patient-reported outcomes.

Evidence screening

The retrieved articles were exported to Covidence (an online system for storing and sorting articles) for eligibility screening (Covidence systematic review software, Veritas Health Innovation, Melbourne, Australia. Available at www.covidence.org). Initial screening of titles and abstracts identified relevant articles (SW). Full texts were screened and inclusion was confirmed/denied (SW). An independent assessor (AM) completed calibration checks for eligibility and data extraction in 10% of the retrieved studies.³⁶ No discrepancies occurred during the calibration. The number of articles at each stage of the screening process and the reasons for exclusion were tracked using the PRISMA flow chart (online supplemental material 2).³⁷

Data extraction and analysis

Data were manually extracted from Covidence and collated and tabulated to include aspects of the template

for intervention description and replication (TIDieR) framework (Microsoft Excel).³⁸ Information relating to the characteristics of the exercise intervention was extracted from each study (modality, intensity, frequency and duration). Data were also extracted regarding adherence, adverse events, recruitment/eligibility criteria and sample sizes. Guided by the American College of Sports Medicine (ACSM) definitions, exercise modality was divided into the following categories³⁹:

1. Aerobic: exercise that continuously requires the contraction of all major muscle groups in a rhythmic nature. This type of exercise relies on aerobic metabolism.
2. Resistance: exercise that requires the muscle to contract against an external resistance such as free weights, resistance bands or one's body weight.
3. Concurrent: programmes comprising components of resistance and aerobic exercise.

Programme settings were categorised into centre-based, home-based and a combination of centre and home-based sessions. Centre-based programmes took place in locations designated for exercise participation (eg, hospitals, community centres, gyms or leisure centres). Home-based programmes were completed either in the participant's dwelling or the surrounding outdoor environment (eg, walking around a local park). Further subgroups were created to separate supervised and unsupervised programmes. Supervision could be completed in either setting via face-to-face or remote/digital observation.

Information about the methods used to assess effectiveness was also extracted. For example, measures of physical function included the maximal volume of oxygen taken in during exercise (VO_2 max), grip strength, the distance walked in a timed 6-Minute Walk Test (6MWT) and body composition. Patient-reported outcomes featured subjective measures of general health and wellbeing like the European Organisation for Research and Treatment of Cancer – Quality of Life Questionnaire Core 30 (EORTC-QLQ-C30). Treatment-related outcomes included length of hospital stay, complication grade and hospital readmissions.

Following data extraction, all included studies were scored against the tool for the assessment of study quality and reporting in exercise (TESTEX) criteria.⁴⁰ TESTEX comprises 15 items that assess how interventions were conducted, monitored, assessed, analysed and reported.⁴⁰ If the criterion is satisfied, then a score of one is given; if not satisfied or insufficient information is reported, then a score of 0 is given. TESTEX scores were tabulated and displayed graphically. Descriptive analysis was completed to determine the mean exercise frequency, intensity, programme duration and TESTEX scores achieved. Differences in TESTEX scores were assessed depending on exercise modalities and settings, thus identifying potential disparities in the quality of implementation and reporting of each strategy. Therefore, it can be determined whether setting and modality impact factors like adherence and safety (incidence of adverse events).

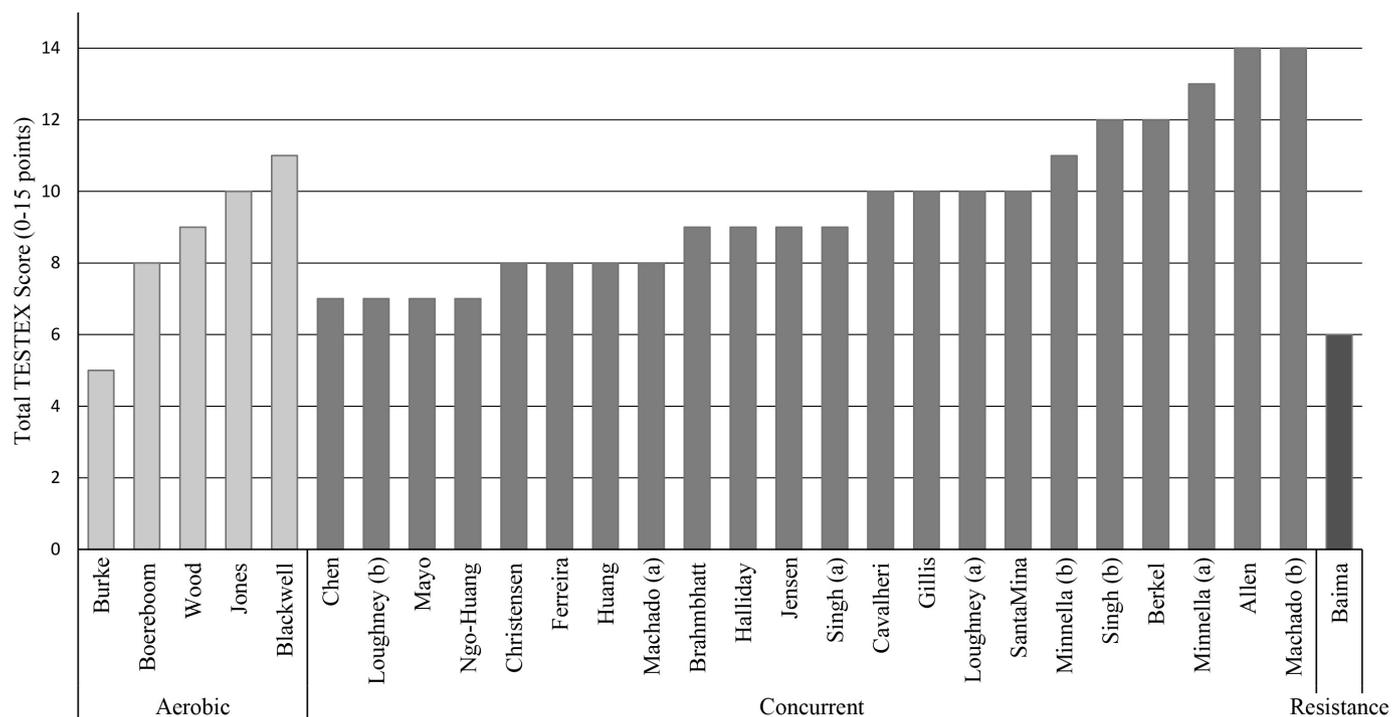


Figure 1 TESTEX quality assessment scores (scales 0–15) categorised by prehabilitation exercise modality. Bars display the total TESTEX score (0–15) achieved by each study. Total scores are categorised based on exercise modality: light grey bars, aerobic exercise; medium grey bars, concurrent exercise; dark grey bars, resistance exercise. TESTEX, tool for the assessment of study quality and reporting in exercise.

Patient and public involvement statement

There was no patient or public involvement in this study.

RESULTS

1495 articles were retrieved, 80 were duplicates and 1352 were deemed irrelevant based on their titles. 60 full texts

were screened, 28 of which were eligible for inclusion (online supplemental material 2).

Characteristics of the included cancer exercise prehabilitation studies are presented in online supplemental table 1 (supplementary material 3), and selected TIDieR characteristics of the exercise programmes are presented in online supplemental table 2 (supplementary material 4).

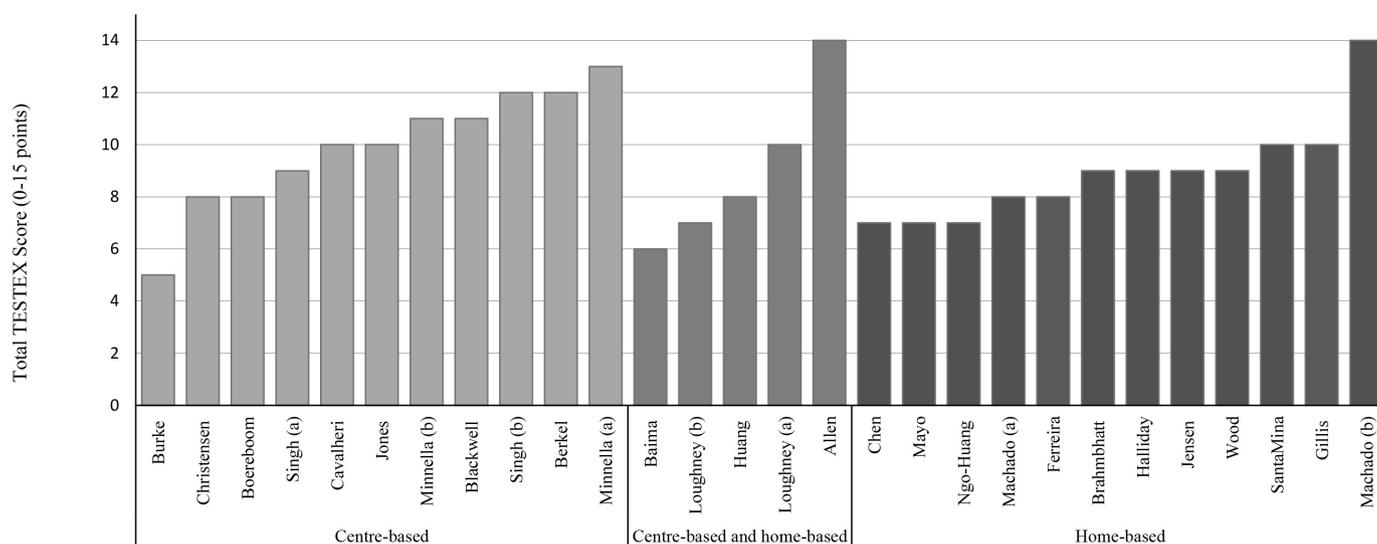


Figure 2 TESTEX quality assessment scores (scales 0–15) categorised by intervention setting. Bars display the total TESTEX score (0–15) achieved by each study. Total scores are categorised based on exercise setting: light grey bars, centre-based; medium grey bars, centre-based and home-based; dark grey bars, home-based. TESTEX, tool for the assessment of study quality and reporting in exercise.

TESTEX scores are displayed graphically and categorised by exercise modality (figure 1) and setting (figure 2).

Study and participant characteristics

Eight randomised control trials (RCTs) (30.8%)^{41–48} and one non-randomised control trial compared prehabilitation to usual care conditions.⁴⁹ Five studies (11.5%) compared participant responses to different exercise programmes,^{50–54} one study (3.9%) compared home and centre-based settings,⁵⁵ and 13 studies (50%) compared premeasures to post-measures from a single intervention.^{56–68} Study characteristics (online supplemental material 3) were heterogeneous in all variables, including sample size, cancer site, treatment types and inclusion criteria. A total of 1540 participants were included across the 28 studies. Eight studies recruited rectal/colorectal cancer patients.^{42 44 50 51 53 56 64 68} Two studies focused on breast cancer,^{55 67} and two studies recruited participants with oesophageal/gastro-oesophageal cancer.^{41 49} Lung cancer was the focus of five studies,^{45 47 57 60 63} three focused on prostate cancer,^{48 54 62} and two on bladder cancer.^{46 52} Urological and pancreatic cancer were featured in one study each.^{43 65} The remaining four studies included multiple or unspecified cancer types.^{58 59 61 66} 20 studies recruited participants scheduled to receive surgery. The remaining eight studies included combined-treatment programmes: surgery and chemotherapy (n=3),^{41 55 58} surgery and chemo-radiotherapy (n=4),^{42 49 56 65} and chemo-radiotherapy and haematopoietic cell transplantation (n=1).⁶⁶

Health, functionality and comorbidity status

Participant recruitment criteria were inconsistent. Six studies (21.4%) specified that participants must possess the capacity to exercise or complete physical assessments, and 23 studies (82.1%) excluded participants with co-morbidities or conditions that may preclude or contraindicate exercise participation (online supplemental material 3). Validated scale-based criteria for co-morbidity status included a WHO status lower than 1 (n=1),⁴⁹ the absence of a heart condition classified as class III or IV according to the New York Heart Association (n=1), and an American Society of Anaesthesiologists (ASA) health status grading scale <4 (n=1)⁵¹ or <3 (n=2).^{52 53} The ability to complete a CPET assessment was required for participation in five studies,^{41 42 57 59 68} one of which required a baseline CPET VO_2 at the ventilatory anaerobic threshold (VAT) of <11 mL/kg/min.⁴² One study required participants to achieve a veterans-specific activity questionnaire (VSAQ) score of ≤7 metabolic equivalent of tasks (METs).⁴²

Outcome measures

27 studies (96.4%) assessed physical function, comprising 33 unique measures (online supplemental material 4). Six-minute walk tests were the modal physical function-related outcome measure (n=14).^{44 45 48 50 51 53 54 57 60 61 64–67} Eight studies used CPETs, which generated values of VO_2 at the anaerobic threshold (AT), VO_2 max and O_2

pulse.^{41–43 53 58 60 66 68} Assessments of muscular strength, power and endurance included grip strength dynamometry (n=6)^{41 47 61 63 65 67} and sit-to-stand tests (n=4).^{47 61 63 65}

19 studies included patient-reported outcomes featuring 23 unique measures. The most frequently used measures were the EORTC-QLQ-C30 (n=6)^{41 47 54 61 63 64} and the 36-Item Short Form Survey (SF-36) (n=6).^{45 50–52 64 67} 12 studies reported treatment-related outcomes, which featured 18 different measures. The modal measure of treatment success was the duration of post-treatment hospital stays (n=6).^{42 45 48 49 63 64} Four studies used the Clavien-Dindo classification of post-treatment complications severity (n=4).^{42 45 49 50}

The programme duration, exercise modality, session frequency and session length varied across the included studies (online supplemental material 4). The mean programme duration was 6.36±5.01 weeks. The most frequently prescribed modality was concurrent exercise (n=22, 78.6%), followed by aerobic (n=5, 17.9%) and resistance (n=1, 3.6%). The mean length of each exercise session was 42.50 min (SD=21.92), prescribed for an average of 3.60 days a week (SD=1.32). 11 (39.3%) studies were centre-based,^{42 43 49 52–54 56 57 60 64} 12 (42.86%) were home-based,^{44–48 50 51 58 63 65–67} and five (17.9%) were home and centre-based.^{41 55 59 61 62} High-intensity exercise was prescribed in four studies (14.3%), moderate-high in 12 (42.9%), seven prescribed moderate (25%), three prescribed low-moderate (10.7%), and one was low intensity (3.6%). 10 studies monitored and prescribed exercise intensity using the Borg Rating of Perceived Exertion Scale (35.7%), five prescribed heart rate (HR) zones (17.9%), six used a set workload (21.4%), and seven did not monitor intensity (25%).

10 studies (35.7%) implemented exercise as the sole prehabilitation strategy. The remaining 18 studies (64.3%) prescribed exercise as the main component of a multimodal programme (online supplemental material 4). Among the multimodal programmes, behaviour change techniques (BCTs) were implemented in 11 studies,^{46–48 51 56–58 63 65–67} nutritional counselling in eight,^{41 42 44 45 50 52 53 65} relaxation and anxiety relief in five,^{44 45 50 52 53} psychological counselling in one,⁴¹ and smoking cessation in one.⁴²

Figure 1 shows the total TESTEX scores for each study included in this review, categorised according to exercise modality. The mean total TESTEX score was 9.32±2.29 (figure 1). The lowest scoring criteria related to the reporting of exercise dose, volume and intensity, which was met by three studies.^{41 58 66} Two studies that both implemented concurrent exercise^{41 47} received the highest TESTEX score (14 points). The lowest score (six points) was achieved by one aerobic exercise-based study⁵⁶ and one resistance-based study.⁵⁵ When comparing modalities, the greatest mean score was received by concurrent exercise protocols (M=9.59, SD=2.24), followed by aerobic exercise (M=8.80, SD=2.39). Only one study prescribed resistance exercise and scored six points.

Figure 2 shows the TESTEX scores for each study based on the setting in which the programme was delivered. Home-based programmes received a mean total TESTEX score of 8.90 ± 2.08 (figure 2). Centre-based programmes received a mean of 10.36 points (SD=2.20), and the combined centre and home-based programmes achieved a mean score of 9 (SD=3.16). The lowest-scoring studies (6 points) featured centre-based elements, one being completed in a clinical centre and the other including home and centre-based components.^{55 56} The highest-scoring studies (14 points) were completed in either home-based only or home and centre-based settings.^{41 47}

Adherence and adverse events

Across all 28 studies, nine met the TESTEX criteria for adherence ($\geq 85\%$ adherence).^{42 47 52 53 58 61–63 67} All of which implemented concurrent exercise. Satisfactory adherence ($\geq 85\%$ adherence rate) was achieved in 40% (n=2) of the studies implemented in centre and home-based settings.^{61 62} The adherence criterion was also met by 27.3% of centre-based studies (n=3)^{42 52 53} and 33.3% of home-based studies (n=4).^{47 58 63 67} Methods for assessing adherence were researcher-reported completion rates (n=7),^{42 43 49 52 57 60 68} participant-reported completion rates (n=16)^{41 44–48 50 51 55 58 59 61–63 67} and smartwatch-derived accelerometry (n=2).^{65 66} The protocols of 18 studies included adverse events as an outcome. No serious adverse events were reported, but two studies reported non-serious exercise-related events, one reported nine⁶³ and the other reported six events.⁴⁷ These events included muscle pain, foot pain, knee pain and the exacerbation of pre-existing musculoskeletal conditions.

DISCUSSION

The importance of prehabilitation for improving post-treatment outcomes is becoming increasingly recognised within cancer care.⁶⁹ However, the optimal approach remains unknown due to heterogeneity in exercise characteristics and a lack of systematic assessment regarding the quality of reporting.⁷⁰ Accordingly, this review aimed to identify the exercise characteristics and quality of reporting of cancer exercise prehabilitation programmes, thus highlighting areas that lack consistency and quality.

What is the quality of reporting of prehabilitation exercise interventions?

Across all 28 included studies, the average TESTEX quality score was 9.32 ± 2.29 , below the minimum 'satisfactory' score of 10.⁴⁰ However, this threshold is not explicitly defined, and when interpreting TESTEX scores in cardiovascular rehabilitation, a score above 9 is considered 'good'.⁷¹ Indeed, the mean quality of studies in the present review is similar to that achieved in other clinical contexts such as the rehabilitation of patients with Parkinson's disease.⁷² Furthermore, the average quality achieved in the present review exceeds that of exercise programmes prescribed for adults with multiple sclerosis

where a systematic review reported a mean TESTEX score of 7.5.⁷³ However, these studies focused on rehabilitation and may have different quality standards. It should also be noted that the quality of the included studies varied depending on characteristics like modality, setting and the specific TESTEX criteria being assessed.

TESTEX adherence criteria ($\geq 85\%$ achieved according to the study's criteria) were reportedly met by nine studies. It is accepted by researchers and healthcare providers that adherence is mediated by the setting in which the exercise is delivered.⁷⁴ Thus, it is vital to understand whether a relationship between setting and adherence exists within the literature.¹⁶ 50 per cent of studies that delivered exercise in centre and home-based settings and 33.33% of those delivered in home-based settings met adherence criteria, greater than that achieved in a solely centre-based setting (30%). Respectively, it could be assumed that removing the need to travel and offering participants flexibility in exercise settings increases adherence.¹⁴

However, adherence measures were unstandardised, comprising attendance rates, completion per protocol, exercise diary tracking and step counts. Indeed, only 16% of home-based and none of the home and centre-based programmes used objective measures and instead relied on self-reported attendance and exercise completion. Meanwhile, 70% of centre-based programmes used objective attendance measures or completion reported by the researcher. Similarly, a significant disadvantage of home-based interventions is that adherence is difficult to control.¹⁶ Therefore, the finding that a greater proportion of supervised exercise programmes (37.5%) met adherence criteria compared with unsupervised programmes (25%) is not surprising. Indeed, when exercise is unsupervised, a greater reliance is placed on the individual's motivations and behavioural factors become more potent mediators of adherence.^{16 75} It must also be considered that unsupervised studies rely on participant-reported adherence rates. Therefore, as self-reported measures are known to be an inflation of actual values, it is possible that actual adherence was lower than the rates reported.⁷⁶

Another outcome that used self-reported measures in home-based settings was the incidence of adverse events, where some studies relied on participants to report the occurrence of any exercise-related events themselves. In the context of cardiovascular treatment, comparisons between the number of events reported by patients and healthcare professionals indicated that patients often did not report an event or underestimated its severity.⁷⁷ Hence, the same misreporting could be expected in the present review, explaining why of the 18 studies that met TESTEX criteria for reporting adverse events, only two studies reported any incidences occurring. Additionally, the lack of adverse events may also be attributed to the fact that 23 studies specified that participants must be free from contraindications or conditions that preclude exercise. The ACSM list of contraindications includes hypertension, anaemia and recent strokes.³⁹ Yet, individuals living with these conditions are at the highest

risk of treatment-related complications and have the greatest need for prehabilitation.⁷⁸ Similarly, five studies required participants to be able to complete a CPET, thus preventing lower functioning and more at-risk patients from participating, despite them being mostly in need of prehabilitation. Accordingly, by excluding these individuals, the reporting of adverse events may not be a true representation of the incidences that occur in a real-world setting, and many patients are denied the opportunity to receive prehabilitation.⁷⁹

Concurrent with findings from Engel *et al.*,³³ detailed descriptions of the intervention content were lacking and when looking specifically at exercise interventions, the reporting of the exercise dose and volume was poor. Indeed, the lowest scoring TESTEX criteria related to the reporting and monitoring of the exercise duration and intensity, meaning that the exact exercise dose and energy expenditure could only be determined for three studies. All three of these studies monitored participants using wearable technology that measured HR and accelerometry data. Importantly, if the exercise dose is poorly reported and monitored, it cannot be determined whether the stimulus was sufficient to induce beneficial adaptations, enhance physical function and improve patient-reported outcomes.⁸⁰ Alternatively, if the dose is too intense, recovery is compromised, and patients are at risk of injury or illness.⁸¹ Accordingly, for the balance between adaptation and recovery to be understood and optimised, programmes must report objective and valid measures of the type, intensity and volume of exercise completed in each session.

What are the characteristics of cancer prehabilitation exercise interventions?

The characteristics of the exercise programmes were heterogeneous and unstandardised. Most studies implemented concurrent exercise (78.6% of studies), 17.9% prescribed aerobic exercise and 3.6% were resistance-based. The highest mean quality was achieved by concurrent exercise protocols (9.64±2.22), which scored marginally higher than aerobic exercise (8.60±2.30).

The higher quality of reporting and greater research focus on concurrent programmes has led to findings that concurrent exercise reduces hospital stay durations, cardiorespiratory fitness, full body strength and muscular capillarisation.^{82 83} Similarly, concurrent exercise is theorised to enhance psychosocial outcomes, like diminishing feelings of distress, anxiety and depression.⁵⁸ Contemporary evidence suggests that enhanced psychosocial outcomes occur as exercise improves the efficiency of depression-related biomarker clearance (eg, cortisol and proinflammatory cytokines) and antineurodegenerative chemical regulation in the hypothalamic-pituitary-adrenal axis.⁸⁴ As a result, depleted levels of the neurotransmitters responsible for negative mental states circulate, and self-esteem, pain and depressive symptoms improve.^{85 86} Alternative theories suggest that the aerobic component of exercise elevates postexercise serotonin,

a neurotransmitter that mediates mental state.⁸⁷ For example, regular walking was reported to increase serotonin, improve sleep quality and reduce feelings of fatigue among breast cancer patients.⁸⁸ Nonetheless, as concurrent exercise programmes tend to prescribe a higher volume of aerobic than resistance components, the benefits of resistance exercise are unoptimised.

The justification for prescribing higher volumes of aerobic exercise within concurrent programmes may be that the ability of aerobic exercise to enhance cardiopulmonary fitness is vital to anaesthetists, as cardiorespiratory function limits a patient's ability to withstand anaesthesia and surgery.⁸⁹ Aerobic exercise is also evidenced to improve VO₂ max, lean body mass and cancer-related fatigue.⁹⁰⁻⁹² Additionally, regular aerobic exercise may aid in regulating tumour vasculature remodelling, thus enabling tissues to form structures that mirror healthy models and augmenting perfusion and oxygenation properties.⁹³ Subsequently, treatment tolerance, energy availability and immune function increase.⁹⁴ Nonetheless, it must be noted that robust evidence is lacking concerning cancer prehabilitation, and research efforts have hitherto prioritised rehabilitation.⁹⁵ Moreover, while aerobic exercise elicits many beneficial responses, musculoskeletal adaptations are potentially limited and predominantly occur in response to the weight-bearing aspects of the exercise.⁹⁶

Conversely, resistance exercise stimulates muscle synthesis, consequently enhancing physical function, muscular strength and insulin sensitivity.⁹⁷ Previous research states that resistance-based programmes improve post-treatment limb strength, muscle mass, contractile force and bone density.⁹⁸ Subsequent improvements, particularly in muscle mass, are also hypothesised to improve survival.⁹⁹ Other observed adaptations occur in response to resistance exercise-induced muscular contractions, which regulate the release of interleukin-6 and other cytokines¹⁰⁰ which could be antitumourigenic.¹⁰¹ Yet, while resistance exercise appears to be a potent mediator of muscular conditioning, research is scarce and poorly reported.

Most studies implemented moderate (n=7) or moderate to high (n=12) intensity exercise. However, the most common method for monitoring and prescribing intensity was rating of perceived exertion (RPE), which is a subjective measure of perceived exercise intensity and is at risk of bias from feelings of psychological distress, cancer-related pain and fatigue.¹⁰² Indeed, while validated in healthy populations, there is little evidence to support the use of RPE among cancer patients, and treatments like chemotherapy or radiotherapy to the chest and cancer-related medications may impact the perception of physical exertion.^{103 104} Attempts to validate RPE among patients on beta-blockers are inconclusive¹⁰⁵ as beta-blockers reduce tissue perfusion and cardiac output, thus distorting perceptions of physical exertion.¹⁰⁶ Therefore, as beta-blockers are frequently prescribed among those living with cancer to regulate blood pressure and

HR and to block tumourigenesis and metastasis, it can be argued that RPE values do not truly represent exercise intensity.^{107 108} Subsequently, while most studies reported implementing a moderate to high-intensity exercise, the lack of objectivity means that the actual intensity is unknown.

Notably, for beneficial adaptations to occur, the exercise intensity must be at a sufficient level to induce an oxidative stress response and catalyse adaptations in the body that defend against future physical stress.^{80 109} For example, Nichols *et al*⁸⁰ implemented a cardiac rehab intervention among 70 patients but observed no improvements in VO_2 max, concluding that the peak values of 46%–54% of HR reserve observed during the exercise were insufficient to cause beneficial adaptations and were likely an overestimation of the intensity achieved throughout the session. Accordingly, for exercise prehabilitation to be optimised, studies must systematically and objectively measure and report exercise intensity, thus ensuring that the correct stimulus for adaptation is provided.

Across the included studies, 74 unique outcome measures were reported. As such, the extensive range and the poor detail in which measures were described inhibit comparison and data synthesis. Hence, without a core set of outcomes, the efficacy and effectiveness of cancer prehabilitation programmes are not well understood.¹¹⁰ Common outcome measures included 6MWT and CPET scores, which assessed physical function in 14 and eight studies, respectively. The CPET is the ‘gold standard’ tool for evaluating functional capacity, exercise limitations and clinical responses.^{111 112} Hence, CPET scores often inform the intensity and modality of exercise protocols.¹¹³ However, while CPET and 6MWT assessments provide outcomes relating to physical function, they are not validated among populations with comorbidities or advanced-stage cancers and cannot detect changes in complex physiological processes.^{114 115} For example, physiological symptoms like cachexia require assessment via alternative means, often biomarker analysis or body composition imaging.^{116 117} For this reason, it must be considered whether exercise programmes can truly be optimised if complex physiological outcomes are not being assessed at a mechanistic level.

Strengths and limitations

A limitation in the strength of evidence is the heterogeneity of outcomes, settings and exercise protocols. Accordingly, meta-analysis was not feasible, and comparisons between studies could not be made. Additional limitations occurred as a risk of bias assessment was not completed. The present review opted for a narrow search strategy, which included outcome measures and thus retrieved fewer results. However, this strategy was adopted to maintain feasibility and ensure relevance to the research objectives.¹¹⁸ Risk of bias assessments typically focus on the reporting of the results themselves; this did not apply to the present review. Hence, any inaccuracy in the estimated effectiveness of each study was not

considered.¹¹⁹ The combined use of TESTEX and TIDier frameworks is a key strength of the present review and provides a novel assessment of the quality of reporting and exercise characteristics and creates a balanced and fully representative strategy for data extraction and synthesis.⁴⁰

Future guidance

In future, research must address the heterogeneity in exercise characteristics by creating standardised programmes that optimise the beneficial effects of exercise.¹²⁰ To do so, further investigation into the role of the exercise type, intensity and frequency is needed. For example, novel evidence suggests that high-intensity interval training induces more profound improvements in VO_2 max than moderate-intensity exercise.¹²¹ Yet, in the current review, most protocols were prescribed at a moderate to high intensity, potentially to find a balance between overload and recovery.¹²²

Furthermore, methods of quantifying intensity are unstandardised, poorly reported and subjective, meaning that the actual intensity achieved is ambiguous. Similarly, as there was large heterogeneity in effectiveness outcomes, programmes cannot be compared. Hence, studies should assess programme effectiveness using objective and validated measures (like HR and biomarker analysis).¹¹⁰

Indeed, while the amount of research relating to cancer exercise prehabilitation is rapidly increasing, the quality of these studies and the consistency in how they are designed, monitored and evaluated is lacking.¹²³ Therefore, areas of weakness highlighted within the current review, like methods of monitoring the exercise dose and the range and validity of the selected outcome measures used, must be addressed in order to standardise programmes and facilitate optimisation. Finally, validated frameworks, such as TESTEX or the Consensus on Exercise Reporting Template, should be used to assess the quality of reporting and implementation, therefore facilitating replication, comparison and optimisation.^{33 124}

Conclusion

This scoping review describes the characteristics and quality of reporting of prehabilitation exercise interventions for adults living with cancer. Cancer prehabilitation is a relatively new concept that lacks homogeneity. Most studies implemented concurrent exercise, with only one study focusing on resistance exercise. On average, the included studies were of satisfactory quality, yet there were clear disparities between exercise modalities and settings. Large variability was seen regarding the outcome measures used and methods of prescribing and monitoring exercise dose. Furthermore, by identifying common reporting gaps and variability, this review will provide a foundation for standardised intervention design, which is essential to improving intervention quality, comparability and effectiveness to enhance patient outcomes.

Contributors SW, TM-W, RC and AM conceived the study idea. SW performed the literature search, performed the data analysis, interpreted the data and wrote the first draft of the manuscript. AM performed calibration checks. TM-W, RC, AM, LJH and CD critically revised the manuscript. SW had full access to all the data, takes responsibility for the integrity and the accuracy of the data analysis, and is the guarantor. The corresponding author attests that all listed authors meet authorship criteria and that no others meeting the criteria have been omitted.

Funding The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, conduct, reporting or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval Ethical approval was granted by the Sheffield Hallam University ethics committee (Ref: ER51277591).

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement All data relevant to the study are included in the article or uploaded as supplementary information.

Supplemental material This content has been supplied by the author(s). It has not been vetted by BMJ Publishing Group Limited (BMJ) and may not have been peer-reviewed. Any opinions or recommendations discussed are solely those of the author(s) and are not endorsed by BMJ. BMJ disclaims all liability and responsibility arising from any reliance placed on the content. Where the content includes any translated material, BMJ does not warrant the accuracy and reliability of the translations (including but not limited to local regulations, clinical guidelines, terminology, drug names and drug dosages), and is not responsible for any error and/or omissions arising from translation and adaptation or otherwise.

Open access This is an open access article distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited, appropriate credit is given, any changes made indicated, and the use is non-commercial. See: <http://creativecommons.org/licenses/by-nc/4.0/>.

ORCID iDs

Samantha Welfare <http://orcid.org/0009-0000-4071-5172>

Liam John Humphreys <http://orcid.org/0000-0002-9279-1019>

REFERENCES

- Smittenaar CR, Petersen KA, Stewart K, *et al*. Cancer incidence and mortality projections in the UK until 2035. *Br J Cancer* 2016;115:1147–55.
- Eakin EG, Youlden DR, Baade PD, *et al*. Health Status of Long-term Cancer Survivors: Results from an Australian Population-Based Sample. *Cancer Epidemiol Biomarkers Prev* 2006;15:1969–76.
- Saghatchian M, Lesur A. Gestion des effets secondaires de l'hormonothérapie du cancer du sein chez la femme jeune. *Bull Cancer* 2019;106:S37–42.
- Arends J, Strasser F, Gonella S, *et al*. Cancer cachexia in adult patients: ESMO Clinical Practice Guidelines[®]. *ESMO Open* 2021;6:100092.
- Bonomi PD, Walsh D, Currow DC, *et al*. Cancer cachexia impact on chemotherapy dose reduction, treatment discontinuation, and survival: A qualitative systematic review. *JCO* 2022;40:e24103.
- Mayer RS, Engle J. Rehabilitation of Individuals With Cancer. *Ann Rehabil Med* 2022;46:60–70.
- Santa Mina D, Clarke H, Ritvo P, *et al*. Effect of total-body prehabilitation on postoperative outcomes: a systematic review and meta-analysis. *Physiotherapy* 2014;100:196–207.
- Silver JK, Baima J. Cancer prehabilitation: an opportunity to decrease treatment-related morbidity, increase cancer treatment options, and improve physical and psychological health outcomes. *Am J Phys Med Rehabil* 2013;92:715–27.
- Durrand JW, Moore J, Danjoux G. Prehabilitation and preparation for surgery: has the digital revolution arrived? *Anaesthesia* 2022;77:635–9.
- Steffens D, Beckenkamp PR, Hancock M, *et al*. Preoperative exercise halves the postoperative complication rate in patients with lung cancer: a systematic review of the effect of exercise on complications, length of stay and quality of life in patients with cancer. *Br J Sports Med* 2018;52:344.
- Steffens D, Ismail H, Denehy L, *et al*. Preoperative Cardiopulmonary Exercise Test Associated with Postoperative Outcomes in Patients Undergoing Cancer Surgery: A Systematic Review and Meta-Analyses. *Ann Surg Oncol* 2021;28:7120–46.
- Pin F, Couch ME, Bonetto A. Preservation of muscle mass as a strategy to reduce the toxic effects of cancer chemotherapy on body composition. *Curr Opin Support Palliat Care* 2018;12:420–6.
- Irwin ML, Cadmus L, Alvarez-Reeves M, *et al*. Recruiting and retaining breast cancer survivors into a randomized controlled exercise trial: the Yale Exercise and Survivorship Study. *Cancer* 2008;112:2593–606.
- Ferreira V, Agnihotram RV, Bergdahl A, *et al*. Maximizing patient adherence to prehabilitation: what do the patients say? *Support Care Cancer* 2018;26:2717–23.
- Shen C, Gu L, Li N, *et al*. Attitudes and perceptions of cancer patients and healthcare providers towards prehabilitation: A thematic synthesis. *Br J Health Psychol* 2024;29:395–429.
- Ormel HL, van der Schoot GGF, Sluiter WJ, *et al*. Predictors of adherence to exercise interventions during and after cancer treatment: A systematic review. *Psychooncology* 2018;27:713–24.
- Waterland JL, Chahal R, Ismail H, *et al*. Implementing a telehealth prehabilitation education session for patients preparing for major cancer surgery. *BMC Health Serv Res* 2021;21:443.
- Mina DS, Alibhai SMH, Matthew AG, *et al*. Exercise in Clinical Cancer Care: A Call to Action and Program Development Description. *Curr Oncol* 2012;19:136–44.
- Tay SS, Zhang F, Neo EJ. The use of technology in cancer prehabilitation: a systematic review. *Front Oncol* 2024;14:1321493.
- Nicolson PJA, Hinman RS, Wrigley TV, *et al*. Self-reported Home Exercise Adherence: A Validity and Reliability Study Using Concealed Accelerometers. *J Orthop Sports Phys Ther* 2018;48:943–50.
- Zandwijk P, Van Koppen B, Van Mameren H, *et al*. The accuracy of self-reported adherence to an activity advice. *Eur J Physiother* 2015;17:183–91.
- Shun SC. Cancer Prehabilitation for Patients Starting from Active Treatment to Surveillance. *Asia Pac J Oncol Nurs* 2016;3:37–40.
- Courneya KS, Sellar CM, Stevinson C, *et al*. Randomized controlled trial of the effects of aerobic exercise on physical functioning and quality of life in lymphoma patients. *J Clin Oncol* 2009;27:4605–12.
- Champ CE, Carpenter DJ, Diaz AK, *et al*. Resistance Training for Patients with Cancer: A Conceptual Framework for Maximizing Strength, Power, Functional Mobility, and Body Composition to Optimize Health and Outcomes. *Sports Med* 2023;53:75–89.
- Small SD, Bland KA, Rickard JN, *et al*. Exercise-based Multimodal Programming: A Treatment Gap for Older Adults with Advanced Cancer. *Oncologist* 2022;27:1–3.
- Campbell KL, Winters-Stone KM, Wiskemann J, *et al*. Exercise Guidelines for Cancer Survivors: Consensus Statement from International Multidisciplinary Roundtable. *Med Sci Sports Exerc* 2019;51:2375–90.
- Palma S, Hasenoehrl T, Jordakieva G, *et al*. High-intensity interval training in the prehabilitation of cancer patients—a systematic review and meta-analysis. *Support Care Cancer* 2021;29:1781–94.
- Stout NL, Baima J, Swisher AK, *et al*. A Systematic Review of Exercise Systematic Reviews in the Cancer Literature (2005-2017). *PM&R* 2017;9:S347–84.
- Carli F, Silver JK, Feldman LS, *et al*. Surgical Prehabilitation in Patients with Cancer: State-of-the-Science and Recommendations for Future Research from a Panel of Subject Matter Experts. *Phys Med Rehabil Clin N Am* 2017;28:49–64.
- Chen L, Peng P, Xu Z, *et al*. The effects of exercise on the quality of life of patients with breast cancer: a systematic review and meta-analysis based on the QLQ-C30 quality of life scale. *Gland Surg* 2023;12:633–50.
- Hutchinson AD, Hosking JR, Kichenadasse G, *et al*. Objective and subjective cognitive impairment following chemotherapy for cancer: A systematic review. *Cancer Treat Rev* 2012;38:926–34.
- Robins RW, Beer JS. Positive illusions about the self: Short-term benefits and long-term costs. *J Pers Soc Psychol* 2001;80:340–52.
- Engel D, Testa GD, McIsaac DI, *et al*. Reporting quality of randomized controlled trials in prehabilitation: a scoping review. *Perioper Med (Lond)* 2023;12:48.
- Tricco AC, Lillie E, Zarin W, *et al*. PRISMA Extension for Scoping Reviews (PRISMA-ScR): Checklist and Explanation. *Ann Intern Med* 2018;169:467–73.
- Peters MDJ, Marnie C, Tricco AC, *et al*. Updated methodological guidance for the conduct of scoping reviews. *JBI Evid Synth* 2020;18:2119–26.

- 36 Thomas A, Lubarsky S, Durning SJ, *et al.* Knowledge Syntheses in Medical Education: Demystifying Scoping Reviews. *Acad Med* 2017;92:161–6.
- 37 Page EJ, Massey AS, Prado-Romero PN, *et al.* The Use of Self-Monitoring and Technology to Increase Physical Activity: A Review of the Literature. *Perspect Behav Sci* 2020;43:501–14.
- 38 Hoffmann TC, Glasziou PP, Boutron I, *et al.* Better reporting of interventions: template for intervention description and replication (TIDieR) checklist and guide. *BMJ* 2014;348:bmj.g1687.
- 39 American College of Sports M. *ACSM's guidelines for exercise testing and prescription*. Lippincott Williams & Wilkins, 2013.
- 40 Smart NA, Waldron M, Ismail H, *et al.* Validation of a new tool for the assessment of study quality and reporting in exercise training studies: TESTEX. *Int J Evid Based Healthc* 2015;13:9–18.
- 41 Allen SK, Brown V, White D, *et al.* Multimodal Prehabilitation During Neoadjuvant Therapy Prior to Esophagogastric Cancer Resection: Effect on Cardiopulmonary Exercise Test Performance, Muscle Mass and Quality of Life—A Pilot Randomized Clinical Trial. *Ann Surg Oncol* 2022;29:1839–50.
- 42 Berkel AEM, Bongers BC, Kotte H, *et al.* Effects of Community-based Exercise Prehabilitation for Patients Scheduled for Colorectal Surgery With High Risk for Postoperative Complications: Results of a Randomized Clinical Trial. *Ann Surg* 2022;275:e299–306.
- 43 Blackwell J, Boereboom C, Doleman B, *et al.* High intensity interval training is a safe and effective way to improve fitness before surgery for cancer: a randomised control trial. *Br J Surg* 2019;106:39.
- 44 Chen BP, Awasthi R, Sweet SN, *et al.* Four-week prehabilitation program is sufficient to modify exercise behaviors and improve preoperative functional walking capacity in patients with colorectal cancer. *Support Care Cancer* 2017;25:33–40.
- 45 Ferreira V, Minnella EM, Awasthi R, *et al.* Multimodal Prehabilitation for Lung Cancer Surgery: A Randomized Controlled Trial. *Ann Thorac Surg* 2021;112:1600–8.
- 46 Jensen BT, Laustsen S, Jensen JB, *et al.* Exercise-based prehabilitation is feasible and effective in radical cystectomy pathways—secondary results from a randomized controlled trial. *Support Care Cancer* 2016;24:3325–31.
- 47 Machado P, Pimenta S, Garcia AL, *et al.* Effect of Preoperative Home-Based Exercise Training on Quality of Life After Lung Cancer Surgery: A Multicenter Randomized Controlled Trial. *Ann Surg Oncol* 2024;31:847–59.
- 48 Santa Mina D, Hilton WJ, Matthew AG, *et al.* Prehabilitation for radical prostatectomy: A multicentre randomized controlled trial. *Surg Oncol* 2018;27:289–98.
- 49 Christensen JF, Simonsen C, Banck-Petersen A, *et al.* Safety and feasibility of preoperative exercise training during neoadjuvant treatment before surgery for adenocarcinoma of the gastro-oesophageal junction. *BJO Open* 2019;3:74–84.
- 50 Gillis C, Li C, Lee L, *et al.* Prehabilitation versus rehabilitation: a randomized control trial in patients undergoing colorectal resection for cancer. *Anesthesiology* 2014;121:937–47.
- 51 Mayo NE, Feldman L, Scott S, *et al.* Impact of preoperative change in physical function on postoperative recovery: argument supporting prehabilitation for colorectal surgery. *Surgery* 2011;150:505–14.
- 52 Minnella EM, Awasthi R, Bousquet-Dion G, *et al.* Multimodal Prehabilitation to Enhance Functional Capacity Following Radical Cystectomy: A Randomized Controlled Trial. *Eur Urol Focus* 2021;7:132–8.
- 53 Minnella EM, Ferreira V, Awasthi R, *et al.* Effect of two different preoperative exercise training regimens before colorectal surgery on functional capacity. *Eur J Anaesthesiol* 2020;37:969–78.
- 54 Singh F, Newton RU, Taaffe DR, *et al.* Prehabilitative versus rehabilitative exercise in prostate cancer patients undergoing prostatectomy. *J Cancer Res Clin Oncol* 2023;149:16563–73.
- 55 Baima J, Reynolds S-G, Edmiston K, *et al.* Teaching of Independent Exercises for Prehabilitation in Breast Cancer. *J Cancer Educ* 2017;32:252–6.
- 56 Burke SM, Brunet J, Sabiston CM, *et al.* Patients' perceptions of quality of life during active treatment for locally advanced rectal cancer: the importance of preoperative exercise. *Support Care Cancer* 2013;21:3345–53.
- 57 Cavalheri V. Critically appraised paper: Short-term preoperative exercise training improves exercise capacity and reduces postoperative pulmonary complications in people undergoing lung cancer surgery [synopsis]. *J Physiother* 2018;64:S1836–9553(18)30107-3.
- 58 Halliday LJ, Doganay E, Wynter-Blyth V, *et al.* Adherence to Pre-operative Exercise and the Response to Prehabilitation in Oesophageal Cancer Patients. *J Gastrointest Surg* 2021;25:890–9.
- 59 Huang GH, Ismail H, Murnane A, *et al.* Structured exercise program prior to major cancer surgery improves cardiopulmonary fitness: a retrospective cohort study. *Support Care Cancer* 2016;24:2277–85.
- 60 Jones LW, Peddle CJ, Eves ND, *et al.* Effects of presurgical exercise training on cardiorespiratory fitness among patients undergoing thoracic surgery for malignant lung lesions. *Cancer* 2007;110:590–8.
- 61 Loughney L, Cahill R, O'Malley K, *et al.* Compliance, adherence and effectiveness of a community-based pre-operative exercise programme: a pilot study. *Perioper Med (Lond)* 2019;8:17.
- 62 Loughney L, McGowan R, O'Malley K, *et al.* Perceptions of wellbeing and quality of life following participation in a community-based pre-operative exercise programme in men with newly diagnosed prostate cancer: A qualitative pilot study. *PLoS One* 2021;16:e0253018.
- 63 Machado P, Pimenta S, Garcia AL, *et al.* Home-Based Preoperative Exercise Training for Lung Cancer Patients Undergoing Surgery: A Feasibility Trial. *J Clin Med* 2023;12:2971.
- 64 Singh F, Newton RU, Baker MK, *et al.* Feasibility and Efficacy of Presurgical Exercise in Survivors of Rectal Cancer Scheduled to Receive Curative Resection. *Clin Colorectal Cancer* 2017;16:358–65.
- 65 Ngo-Huang A, Parker NH, Bruera E, *et al.* Home-Based Exercise Prehabilitation During Preoperative Treatment for Pancreatic Cancer Is Associated With Improvement in Physical Function and Quality of Life. *Integr Cancer Ther* 2019;18:1534735419894061.
- 66 Wood WA, Phillips B, Smith-Ryan AE, *et al.* Personalized home-based interval exercise training may improve cardiorespiratory fitness in cancer patients preparing to undergo hematopoietic cell transplantation. *Bone Marrow Transplant* 2016;51:967–72.
- 67 Brahmabhatt P, Sabiston CM, Lopez C, *et al.* Feasibility of Prehabilitation Prior to Breast Cancer Surgery: A Mixed-Methods Study. *Front Oncol* 2020;10:571091.
- 68 Boereboom CL, Blackwell JEM, Williams JP, *et al.* Short-term pre-operative high-intensity interval training does not improve fitness of colorectal cancer patients. *Scand J Med Sci Sports* 2019;29:1383–91.
- 69 MacMillan Cancer S. Principles and guidance for prehabilitation within the management and support of people with cancer. 2019.
- 70 Cuijpers ACM, Linskens FG, Bongers BC, *et al.* Quality and clinical generalizability of feasibility outcomes in exercise prehabilitation before colorectal cancer surgery – A systematic review. *Eur J Surg Oncol* 2022;48:1483–97.
- 71 Fuertes-Kenneally L, Manresa-Rocamora A, Blasco-Peris C, *et al.* Effects and Optimal Dose of Exercise on Endothelial Function in Patients with Heart Failure: A Systematic Review and Meta-Analysis. *Sports Med Open* 2023;9:8.
- 72 Gamborg M, Hvid LG, Dalgas U, *et al.* Parkinson's disease and intensive exercise therapy - An updated systematic review and meta-analysis. *Acta Neurol Scand* 2022;145:504–28.
- 73 Dennett R, Madsen LT, Connolly L, *et al.* Adherence and drop-out in randomized controlled trials of exercise interventions in people with multiple sclerosis: A systematic review and meta-analyses. *Mult Scler Relat Disord* 2020;43:S2211–0348(20)30245-5.
- 74 Shaw KL. Patient education, motivation, compliance, and adherence to physical activity, exercise, and rehabilitation. *Pathol Intervent Musculoskeletal Rehabil* 2015;3:1–24.
- 75 Courneya KS, Segal RJ, Gelmon K, *et al.* Predictors of adherence to different types and doses of supervised exercise during breast cancer chemotherapy. *Int J Behav Nutr Phys Act* 2014;11:1–9.
- 76 Yuen HK, Wang E, Holthaus K, *et al.* Self-reported versus objectively assessed exercise adherence. *Am J Occup Ther* 2013;67:484–9.
- 77 Bolland MJ, Barber A, Doughty RN, *et al.* Differences between self-reported and verified adverse cardiovascular events in a randomised clinical trial. *BMJ Open* 2013;3:e002334.
- 78 Flynn DE, Mao D, Yerkovich ST, *et al.* The impact of comorbidities on post-operative complications following colorectal cancer surgery. *PLoS One* 2020;15:e0243995.
- 79 De Lazzari N, Niels T, Tewes M, *et al.* A Systematic Review of the Safety, Feasibility and Benefits of Exercise for Patients with Advanced Cancer. *Cancers (Basel)* 2021;13:4478.
- 80 Nichols S, Taylor C, Goodman T, *et al.* Routine exercise-based cardiac rehabilitation does not increase aerobic fitness: A CARE CR study. *Int J Cardiol* 2020;305:25–34.
- 81 Mallard J, Hucteau E, Schott R, *et al.* Early skeletal muscle deconditioning and reduced exercise capacity during (neo) adjuvant chemotherapy in patients with breast cancer. *Cancer* 2023;129:215–25.
- 82 Kirkham AA, Gelmon KA, Van Patten CL, *et al.* Impact of Exercise on Chemotherapy Tolerance and Survival in Early-Stage Breast

- Cancer: A Nonrandomized Controlled Trial. *J Natl Compr Canc Netw* 2020;18:jncn20121:1670–7.
- 83 Mijwel S, Bolam KA, Gerrevall J, *et al.* Effects of Exercise on Chemotherapy Completion and Hospitalization Rates: The OptiTrain Breast Cancer Trial. *Oncologist* 2020;25:23–32.
- 84 Archer T, Josefsson T, Lindwall M. Effects of physical exercise on depressive symptoms and biomarkers in depression. *CNS & Neurological Disorders-Drug Targets (Formerly Current Drug Targets-CNS & Neurological Disorders)* 2014;1640–53.
- 85 Fox K. The effect of exercise on self-perceptions and self-esteem. 2000;88–111.
- 86 Shakoor E, Salesi M, Koushki M. The Effect of Concurrent Aerobic and Anaerobic Exercise on Stress, Anxiety, Depressive Symptoms, and Blood Pressure in Renal Transplant Female Patients: A Randomized Control Trial. *IJKSS* 2016;4:25–31.
- 87 Ferioli M, Zauli G, Martelli AM, *et al.* Impact of physical exercise in cancer survivors during and after antineoplastic treatments. *Oncotarget* 2018;9:14005–34.
- 88 Payne JK, Held J, Thorpe J, *et al.* Effect of exercise on biomarkers, fatigue, sleep disturbances, and depressive symptoms in older women with breast cancer receiving hormonal therapy. *Oncol Nurs Forum* 2008;35:635–42.
- 89 Della Rocca G, Vetrugno L, Coccia C, *et al.* Preoperative Evaluation of Patients Undergoing Lung Resection Surgery: Defining the Role of the Anesthesiologist on a Multidisciplinary Team. *J Cardiothorac Vasc Anesth* 2016;30:530–8.
- 90 Scott JM, Li N, Liu Q, *et al.* Association of Exercise With Mortality in Adult Survivors of Childhood Cancer. *JAMA Oncol* 2018;4:1352–8.
- 91 Tian L, Lu HJ, Lin L, *et al.* Effects of aerobic exercise on cancer-related fatigue: a meta-analysis of randomized controlled trials. *Support Care Cancer* 2016;24:969–83.
- 92 Zopf EM, Schulz H, Poeschko J, *et al.* Effects of supervised aerobic exercise on cardiorespiratory fitness and patient-reported health outcomes in colorectal cancer patients undergoing adjuvant chemotherapy—a pilot study. *Support Care Cancer* 2022;30:1945–55.
- 93 Garcia E, Becker VGC, McCullough DJ, *et al.* Blood flow responses to mild-intensity exercise in ectopic vs. orthotopic prostate tumors: dependence upon host tissue hemodynamics and vascular reactivity. *J Appl Physiol (1985)* 2016;121:15–24.
- 94 Jia N, Zhou Y, Dong X, *et al.* The antitumor mechanisms of aerobic exercise: A review of recent preclinical studies. *Cancer Med* 2021;10:6365–73.
- 95 Silver JK, Stout NL, Fu JB, *et al.* The State of Cancer Rehabilitation in the United States. *J Cancer Rehabil* 2018;1:1–8.
- 96 Ozaki H, Loenneke JP, Buckner SL, *et al.* Muscle growth across a variety of exercise modalities and intensities: Contributions of mechanical and metabolic stimuli. *Med Hypotheses* 2016;88:22–6.
- 97 Montalvo RN, Hardee JP, VanderVeen BN, *et al.* Resistance Exercise's Ability to Reverse Cancer-Induced Anabolic Resistance. *Exerc Sport Sci Rev* 2018;46:247–53.
- 98 De Backer IC, Van Breda E, Vreugdenhil A, *et al.* High-intensity strength training improves quality of life in cancer survivors. *Acta Oncol* 2007;46:1143–51.
- 99 Bradshaw PT. Body composition and cancer survival: a narrative review. *Br J Cancer* 2024;130:176–83.
- 100 Schiaffino S, Dyar KA, Ciciliot S, *et al.* Mechanisms regulating skeletal muscle growth and atrophy. *FEBS J* 2013;280:4294–314.
- 101 Fiuza-Luces C, Valenzuela PL, Gálvez BG, *et al.* The effect of physical exercise on anticancer immunity. *Nat Rev Immunol* 2024;24:282–93.
- 102 Fernandez C, Firdous S, Jehangir W, *et al.* Cancer-Related Fatigue: Perception of Effort or Task Failure? *Am J Hosp Palliat Care* 2020;37:34–40.
- 103 D'Ascenzi F, Anselmi F, Fiorentini C, *et al.* The benefits of exercise in cancer patients and the criteria for exercise prescription in cardiology. *Eur J Prev Cardiol* 2021;28:725–35.
- 104 Jones LW, Eves ND, Scott JM. Bench-to-Bedside Approaches for Personalized Exercise Therapy in Cancer. *Am Soc Clin Oncol Educ Book* 2017;37:684–94.
- 105 Levinger I, Bronks R, Cody DV, *et al.* Perceived exertion as an exercise intensity indicator in chronic heart failure patients on Beta-blockers. *J Sports Sci Med* 2004;3:23–7.
- 106 Scherr J, Wolfarth B, Christle JW, *et al.* Associations between Borg's rating of perceived exertion and physiological measures of exercise intensity. *Eur J Appl Physiol* 2013;113:147–55.
- 107 Arif M, Hardianti MS, Tyagita N, *et al.* Benefits of β -blockers in cancer treatment. *Oncol Clin Pract* 2023;19:90–100.
- 108 Peixoto R, Pereira M de L, Oliveira M. Beta-Blockers and Cancer: Where Are We? *Pharmaceuticals (Basel)* 2020;13:105.
- 109 Radak Z, Chung HY, Koltai E, *et al.* Exercise, oxidative stress and hormesis. *Ageing Res Rev* 2008;7:34–42.
- 110 Treanor C, Kyaw T, Donnelly M. An international review and meta-analysis of prehabilitation compared to usual care for cancer patients. *J Cancer Surviv* 2018;12:64–73.
- 111 Levett DZH, Jack S, Swart M, *et al.* Perioperative cardiopulmonary exercise testing (CPET): consensus clinical guidelines on indications, organization, conduct, and physiological interpretation. *Br J Anaesth* 2018;120:484–500.
- 112 American Thoracic S. ATS/ACCP Statement on Cardiopulmonary Exercise Testing. *Am J Respir Crit Care Med* 2003;167:211–77.
- 113 Minnella EM, Awasthi R, Loissele S-E, *et al.* Effect of Exercise and Nutrition Prehabilitation on Functional Capacity in Esophagogastric Cancer Surgery: A Randomized Clinical Trial. *JAMA Surg* 2018;153:1081–9.
- 114 Ferrão B, Neves PM, Santos T, *et al.* Body composition changes in patients with head and neck cancer under active treatment: a scoping review. *Support Care Cancer* 2020;28:4613–25.
- 115 Win T, Jackson A, Sharples L, *et al.* Cardiopulmonary exercise tests and lung cancer surgical outcome. *Chest* 2005;127:1159–65.
- 116 Levett DZH, Grocott MPW. Cardiopulmonary exercise testing, prehabilitation, and Enhanced Recovery After Surgery (ERAS). *Can J Anaesth* 2015;62:131:131–42.
- 117 Maddocks M, Jones LW, Wilcock A. Immunological and hormonal effects of exercise: implications for cancer cachexia. *Curr Opin Support Palliat Care* 2013;7:376–82.
- 118 Lockwood C, Dos Santos KB, Pap R. Practical Guidance for Knowledge Synthesis: Scoping Review Methods. *Asian Nurs Res (Korean Soc Nurs Sci)* 2019;13:287–94.
- 119 Viswanathan M, Patnode CD, Berkman ND, *et al.* Recommendations for assessing the risk of bias in systematic reviews of health-care interventions. *J Clin Epidemiol* 2018;97:26–34.
- 120 Loughney L, West MA, Kemp GJ, *et al.* Exercise intervention in people with cancer undergoing neoadjuvant cancer treatment and surgery: A systematic review. *Eur J Surg Oncol* 2016;42:28–38.
- 121 Coderre D, Brahmabhatt P, Hunter TL, *et al.* Cancer Prehabilitation in Practice: the Current Evidence. *Curr Oncol Rep* 2022;24:1569–77.
- 122 Franssen RFW, Janssen-Heijnen MLG, Barberan-Garcia A, *et al.* Moderate-intensity exercise training or high-intensity interval training to improve aerobic fitness during exercise prehabilitation in patients planned for elective abdominal cancer surgery? *Eur J Surg Oncol* 2022;48:3–13.
- 123 Ma W, Liu Y, Liu J, *et al.* Prehabilitation of surgical patients: a bibliometric analysis from 2005 to 2023. *Perioper Med (Lond)* 2024;13:48.
- 124 Slade SC, Dionne CE, Underwood M, *et al.* Consensus on Exercise Reporting Template (CERT): Explanation and Elaboration Statement. *Br J Sports Med* 2016;50:1428–37.