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SYSTEMATIC REVIEW

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Individualisation of Exercise Prescription in Cancer: A Systematic Review and Meta-Analysis

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Abstract

Background The importance of prescribing individualised exercise programs for all people with cancer has been echoed across the literature. However, there is a notable gap in our understanding of how exercise individualisation is applied in oncology research, what the common individualisation practises of exercise prescription for people with cancer are, and the effects of these practises on common symptoms such as fatigue.

Objectives The aims of this systematic review and meta-analysis were to elucidate the individualisation prescription methods employed in exercise oncology research, determine whether current studies employ best-practice autoregulatory prescription for people with and following treatment for cancer, and conduct subgroup analyses to determine the influence of exercise individualisation methodology on fatigue severity.

Methods A systematic literature search was conducted in PubMed, EMBASE, CINAHL, and Web of Science databases. Studies written in English stating they prescribed any form of 'individualised' exercise for people ≥ 18 years with a histologically confirmed diagnosis of cancer were included in this review. Pooled meta-analysis and subgroup meta-analysis were performed using a random-effects model.

Results Sixty-three studies involving 4472 participants were included. The rationale underpinning why exercise was individualised was predominantly based on objective reasons (41%). Most commonly, exercise was individualised pre-session, and inter-session (25%) via modulation of the exercise prescription, whereby exercise prescriptions were adapted in various heterogenous ways (22%). Autoregulation was only explicitly reported in two (3%) studies. Individualising exercise using subjective reasoning was significantly associated with reduced fatigue severity (SMD = – 0.355, 95% CI – 0.631 to – 0.079; $p = 0.0116$). Timing exercise individualisation inter-session had a moderate and significant pooled effect on reducing fatigue severity (SMD = – 0.616, 95% CI – 0.962 to – 0.271; $p = 0.0005$).

Conclusions This review highlights most exercise oncology studies individualise exercise at baseline only, with this being broadly reported via modulation of the exercise prescription, which may not meet the needs of people with cancer, given their often-fluctuating symptoms and clinical status. Fatigue severity may be reduced by individualising exercise prescription using subjective assessments and by timing the individualisation between sessions.

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Protocol registration: **The original protocol was registered with the Open Science Framework on 28 April 2022 (https://osf.io/d6tkv/).**

Key Points

1Individualisation of exercise prescription within the exercise oncology literature has been poorly described, with only 49% of studies providing sufficient information for replication of the approach.2Most studies reporting that they individualised the exercise prescription did so pre-session, and inter-session (25%) using objective reasons (41%); autoregulation was only explicitly reported in two (3%) studies.3Individualising exercise using subjective reasoning or performed inter-session were significantly associated with reduced fatigue severity.

Introduction

Globally, the incidence of cancer continues to rise [1]. Given the significant health impacts of cancer such as fatigue, pain, and subsequent psychological distress [2–4], addressing the detrimental disease- and treatment-related side effects following a cancer diagnosis is a global public health priority [5]. Exercise improves numerous health outcomes including physical function [6, 7], mental well-being [8, 9] and fatigue [10, 11] for people across the disease and treatment continuum [12, 13]. However, in the provision of exercise to people living with and beyond cancer, it is essential that exercise programming is individualised – that is, tailored and adjusted to suit the disease- and treatment-related side effects and subsequent daily fluctuations that differ among individuals [14, 15].

The importance of prescribing individualised exercise programs for all people with cancer to minimise injury risk and optimise therapeutic benefit has been highlighted in national exercise and cancer position statements around the globe, including Australia [16] and the United States [12]. Whilst there are several possible exercise individualisation techniques, one technique is autoregulation, which may represent a feasible way of monitoring and adjusting exercise more appropriately for individuals across the cancer control continuum [17, 18]. However, there is a notable gap in our understanding of how exercise is being individualised, and what are the common individualisation practises for people with cancer. Thus, exploring the various methods of exercise individualisation, including autoregulation, and the potential differential effects on cancer-related side effects such as fatigue, is an important step to address this gap.

Therefore, this systematic review aims to (1) elucidate the individualisation prescription methods employed in exercise oncology research, (2) determine whether current studies employ best-practice autoregulatory prescription for people with and following treatment for cancer, and (3) to exploratorily examine the relationship between aspects of exercise individualisation (subjective/objective reasoning and inter/intra-session adjustment) and fatigue severity, as a proxy outcome for understanding symptom management in people on the cancer continuum.

Methods

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement [19]. The protocol was registered with the Open Science Framework on 28 April 2022 (https://osf.io/d6tkv/).

Search Strategy

Searches were conducted by B.J.C in four databases (PubMed, EMBASE, CINAHL, Web of Science) until 23 March 2024. Search terms included combinations of thesaurus terms (MeSH in PubMed, EMtree in EMBASE) and free-text terms. Search terms for exercise (exercise*, exertion, 'fitness training', 'fitness workout*', 'physical conditioning', 'physical work-out*', 'physical workout*', 'weight training', 'aerobic', workout*, 'resistance training', 'resistance-training', 'Exercise', 'Resistance Training', 'Circuit-Based Exercise', 'Exercise Therapy', 'Weight Lifting'), were used in AND-combination with the search terms expressing the target population (Cancer*, oncology, malignan*, neoplas*, tumour*, tumor*, 'Neoplasms'), and individualisation of exercise ('Individualis*', 'personalis*', 'personaliz*', 'Individualiz*', 'customiz*', 'customis*', 'patient-specific', 'targeted exercise*', 'tailored', 'patient-focused', 'patient-centred', 'patient-focussed', 'autoregula*', 'readiness-to-train').

Study Inclusion

The inclusion criteria were as follows: (1) population: adults aged 18 years or older with a histologically-confirmed diagnosis of cancer; (2) intervention: any structured exercise intervention that stated or implied it was individualised or a synonymous term. Studies were included based on the claim of individualisation within the reported methods. This approach was intentional, as a key aim of the review was to examine the extent to which studies that described their interventions as individualised actually reported individualisation procedures, with or without supervision; (3) comparison: usual care, control group receiving no exercise, an exercise protocol of a lesser intensity than the exercise group, or exercise after a delay (wait list/delayed care control), or no control group (pre-post outcomes compared); (4) outcome: intervention fidelity (e.g., recruitment, attendance, adherence, attrition), and/or patient health and wellbeing (i.e., quality of life, symptom improvement, medication use, physical activity). Studies included were randomised controlled trials (RCT), controlled trials (CT), and pre-post trials. Included studies were required to have full text available in English.

Study Screening, Data Extraction, and Quality Appraisal

Systematic review management software (Covidence, Veritas Health Innovation, Melbourne, Australia) was used to support article title and abstract screening identified through the search process. After duplicates were removed, articles were screened by B.J.C and J.E.C. to exclude those outside of the scope of the review. Following screening, full text articles were retrieved and independently assessed by B.J.C. and J.E.C. for eligibility according to the outlined inclusion criteria, with a third arbiter included as necessary (G.L.R). Reference lists of eligible articles were examined to identify potential additional studies that met the inclusion criteria. Extraction of data pertaining to the study population, outcome measures and exercise program was completed by B.J.C. Only fidelity outcomes reported across > 1 study were included in qualitative synthesis.

Methodological quality of all studies was assessed by B.J.C and J.E.C using a derivation of the Delphi list developed by Verhagen et al. [20]. Two of the nine quality criteria from the Delphi list (blinding of the trainers and blinding of the participants) were not appropriate for the type of interventions included and were subsequently excluded [12]. All criteria were equally rated using a 'yes' (1 point), 'no' (0 points) or 'unclear' (0 points) answer format; a quality score for the seven criteria was generated as a percentage of the maximum score for each included study.

Data Synthesis and Analysis

Due to the heterogeneity of the study designs and subject characteristics, data were analysed individually in a descriptive method. Data were first extracted and categorised based on the underpinning rationale for 'why' exercise was individualised (e.g., baseline assessment results, exercise preferences), 'when' individualisation of exercise prescription occurred (e.g., pre-session, intra-session), and 'how' individualisation was implemented (e.g., modulation of intensity, volume, autoregulation). Furthermore, intervention characteristics, adherence, attrition, recruitment, and adverse events were presented as number, mean and percentage.

Data Extraction for Meta-Analysis

When studies reported multiple fatigue measures (e.g., sub-scales), the total fatigue score was used. If both fatigue and its inverse (vitality) were reported, the fatigue score was selected. Using a single primary outcome per study minimised bias from over-weighting. To ensure all scales were aligned in the same direction, effect sizes were adjusted so that higher values always indicated greater fatigue severity. If a scale measured fatigue in the opposite direction (i.e., higher scores indicated lower fatigue), the sign of Cohen's d was reversed (i.e., multiplied by − 1). Of the included studies, only fatigue was selected for meta-analysis due to there being an insufficient amount of outcome measures from other studies relevant to the fluctuations of symptoms and side-effects of interest.

Meta-Analysis

Random-effects meta-analysis was performed in R using the *metafor* package [21]. Meta-analysis was limited to randomised controlled trials as these provide the best estimate of the treatment effect. We estimated the effect of exercise compared to control on fatigue using the standardised mean difference (95% CI). Separate meta-analyses were performed based on (1) the reason for and (2) timing of exercise individualisation, with subgroup analysis conducted to explore potential sources of heterogeneity (reason: objective, subjective, combination; timing: pre-intra or inter-session). Significant differences between subgroups were assessed using moderation analysis. Heterogeneity was quantified using a restricted estimate maximum likelihood model with the 95% prediction interval, Cochran Q, tau (τ^2), I^2, and H^2. Publication bias was assessed via visual inspection of funnel plots were, and Egger's regression test.

Results

Study Eligibility and Design

Details of the search process are displayed in Fig. 1. The systematic search resulted in 3138 records. Checking the reference lists of eligible articles did not result in any additional articles. Full text review resulted in the inclusion of 63 articles [22–70], describing 63 interventions (25 CT and 38 pre-post comparison studies) [22–70]. Across controlled trials, most comparison groups received usual care (n = 18), where groups were asked to maintain their usual physical activity (n = 6), were provided with information and advice in reference to the national physical activity guidelines (n = 5), had contact with medical staff for general advice but not directly exercise-related (n = 2), were asked to document and report any exercise (n = 1), continued to attend normal outpatient care including rehabilitation (n = 1), or no further information was reported (n = 4). The remaining controlled trials provided exercise to participants following the intervention period in the form of a waitlist-delayed intervention (n = 5) or home exercise program (n = 2).

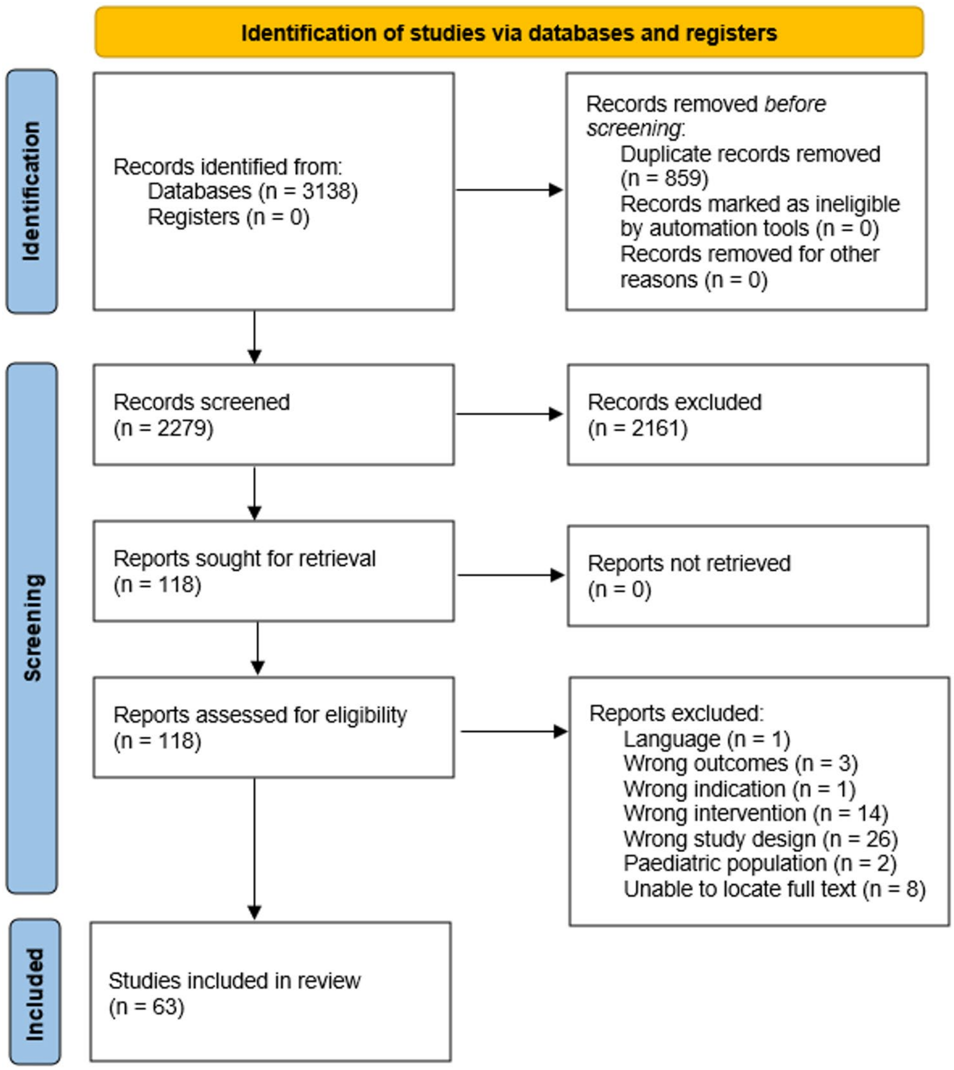

Fig. 1 Study inclusion and screening, using the PRISMA framework [19]

Methodological Quality

Quality scores ranged from 14% to 100%, with a mean of 50%. Methodological assessment identified that point estimates and group similarity at baseline had the highest quality ratings (49% and 39%). Blinding of the outcome assessor had the lowest quality rating (6%; Supplementary Table 1).

Participant Characteristics

Participant characteristics are shown in Supplementary Table 2. When all studies were combined, a total of 4472 individuals participated in the trials, where 68.5% of the included participants were female. The most common cancer diagnosis across 44 interventions reporting a single cancer was breast cancer (*n* = 20 studies, 32%) [25, 26, 33, 34, 36, 38–40, 44, 45, 47–49, 53, 56–58, 62, 63, 65–67, 69, 71, 72], followed by haematological cancers (*n* = 9 studies, 14%) [24, 31, 32, 35, 39, 42, 48, 50, 53, 57, 58, 61, 62, 64, 73–75]. Mixed cancer populations (e.g., prostate, and colorectal) were included in 15 studies (24%). Study sample sizes ranged from 7 to 299, with a median of 30 participants per study. Participants had a mean age of 58 years, ranging from 29 to 79 years. Cancer stage was reported in 32 studies (51%) and, when clearly defined, stage II disease was the most common (44%), followed by stage I (33%), stage III (12%) and stage IV (11%). Some studies grouped cancer stages for all participants (e.g., stage I-III and advanced), which were not included in the above totals. Most studies included participants that received more than one treatment type (63%). Treatment primarily included chemotherapy (76%), where other adjunct or isolated treatments of the studies included radiotherapy (58%) and surgery (51%). There were 24 studies that included participants on active treatment during the intervention, in 19 studies participants were off-treatment or undergoing maintenance treatment, 16 studies reported a mixed treatment status, and four studies did not report on treatment status. A mean of two years post-diagnosis at time of participation was observed (reported in 20 studies: range 0–241 months).

Intervention Characteristics

Full intervention characteristics, including intervention duration, supervision, and details of exercise session mode, frequency, duration and intensity, and individualisation method are shown in Supplementary Table 3. Where the prescription was modified across the intervention or only provided a range (e.g., sets per week), a mean was reported. Duration of the exercise intervention was reported in 61 studies [22–54, 56, 58–84], where interventions ranged from 3 to 96 weeks, with a mean of 14 weeks. In-person exercise supervision was reported in 45 studies [22–25, 27, 31–34, 36, 38–41, 43, 46–48, 50–53, 55, 57–72, 74, 75, 77, 78, 82, 83] where up to three sessions per week were supervised by an exercise physiologist or physical therapist (20–100% session supervision). The amount of supervision could not be determined in five studies. Across all studies, 16 interventions were unsupervised [26, 28–30, 35, 37, 42, 44, 45, 49, 73, 76, 79–81, 84] and two studies did not report on supervision characteristics [54, 56].

The type of prescribed exercise was reported in 62 studies, where most studies (*n* = 50, 79%) included a combination of resistance training and aerobic exercise [23, 24, 26–31, 34, 35, 37–42, 44, 46–54, 56–64, 66–69, 71–80, 82, 83], and the remaining 12 studies (17%) included aerobic exercise alone [22, 25, 27, 33, 36, 65, 81], with six of those including walking only [32, 36, 43, 45, 55, 84]. Exercise session frequency was reported in 55 studies (87%) [22–24, 26, 27, 31–45, 47–54, 57–69, 71–77, 79, 80, 81, 82, 83, 84, 85] and ranged from one to five sessions per week (average 2 days/week). The duration/time of exercise sessions was reported in 57 studies (90%) [1, 12, 14, 16, 17, 19–95], and ranged from 10 to 90 min per session (average 32 min/session).

Exercise intensity prescription (aerobic) was reported in 57 studies (90%), where exercise was prescribed at an overall light intensity on average (very light 6%, light 39%, moderate 25%, vigorous 8%) [22–37, 39–45, 47–54, 57–70, 72–79, 81–84] using heart rate or rating of perceived exertion (RPE) [12, 96]. A combination of both objective and subjective prescription techniques was used in 14 studies (22%) [24, 27, 30, 36, 37, 40, 43, 48, 54, 58, 65, 72, 74, 79]. Aerobic exercise intensity was prescribed using an objective physiological metric in 41 studies [22, 24, 25, 27, 30, 33, 34, 36, 37, 39–52, 54, 57–59, 61–63, 65, 67, 69, 70, 72, 74, 75, 79, 81–84] (65%), including heart rate reserve (30–85%; *n* = 14) [22, 24, 41, 42, 44, 45, 47–49, 58, 61–63, 67], percentage of heart rate maximum (50–85%; *n* = 15) [30, 37, 39, 43, 51, 52, 54, 59, 65, 72, 74, 79, 81–83], threshold and maximum wattage (ventilatory threshold 1/2 and 50–80% maximum; *n* = 2) [27, 40], measured or predicted volume of consumed oxygen (VO_2 30–80%; *n* = 4) [33, 34, 69, 84], units of metabolic equivalent of task (3 and 15 (MET hours/week; *n* = 2)) [36, 70], and lactate threshold (60–115%; *n* = 1) [50]; 2 & 6-minute walk test results indicating prescribed steps per day and intensity and duration respectively (*n* = 2) [28, 46]; sustaining a zone 2 heart rate for as long as possible within the prescribed duration (*n* = 1) [57]. Subjective measures of aerobic exercise prescription were used in 23 studies (36.5%) [24, 26, 27, 29, 30, 32, 35–37, 40, 43, 48, 53, 54, 58, 60, 62, 65, 66, 68, 75, 77, 78], including RPE (10–16 on Borg© 6–20 scale and 4–8 on modified Borg© 1–10 scale; *n* = 14) [26, 29, 32, 35, 53, 60, 66, 68, 72, 74, 75, 77–79]. Two studies reported the 'American College of Sports Medicine guidelines' as intensity prescription [38, 80].

For resistance training, intensity prescription was reported in 29 studies, objectively as a percentage of one-repetition maximum (1RM) (*n* = 12; [30, 37, 39, 40, 47, 54, 57–59, 68, 82, 83], and a RM of 10, 6–12, and 10–12 (*n* = 9; [34, 48, 51, 52, 64, 69, 72, 74, 78]. Subjectively, five studies [35, 53, 60, 62, 75] used rating of perceived exertion (RPE) as a sole method of intensity prescription. The studies used the modified Borg© RPE [97] or OMNI perceived exertion scale of resistance exercise (OMNI-RES) [98] with a range between 1 and 5, 3 to 6, and 6 to 7. A combination of both prescriptive methods was used in nine studies [24, 26, 30, 37, 47, 48, 54, 66, 74]. Brooks et al. [77] and Spence et al. [66] were the only included studies to report using repetitions in reserve, with a range between two to four. The methods of intensity prescription were provided but unclear in eight studies [23, 28, 29, 31, 38, 46, 73, 76], with light to moderate, moderate, minimum, maximum, yellow band, red band, green band, and American College of Sports Medicine (ACSM) guidelines being reported. In 13 studies [24, 41, 42, 44, 49, 50, 56, 61, 63, 67, 70, 79, 80] an intensity prescription method was not reported. Resistance training set prescription from 23 studies included, a single set (*n* = 2; [47, 48], two sets (*n* = 4; [29, 34, 40, 75], three sets (*n* = 7; [24, 26, 37, 41, 54, 59, 69], with the remaining studies reporting a set range of two to five (*n* = 7; [35, 39, 52, 57, 60, 62, 66, 72, 74, 77, 78, 82]. Repetition prescription was reported in 24 studies with a specific repetition target (*n* = 8; [24, 30, 34, 39, 40, 54, 69, 72] being 8, 10, 12 and 15 respectively, and repetition ranges between 6–20+ (*n* = 16; [26, 35, 37, 41, 47, 48, 52, 57–59, 62, 66, 74, 77, 78, 82].

Method of Exercise Individualisation

The exercise prescription individualisation methods used for all 63 studies included are summarised in Table 1, with the specifics of each study's individualisation

Table 1 Summary of exercise individualisation parameters within the included studies

Why[1]			When[1]			How[1]		
Classification	***n*[2]**	**%[2]**	**Classification[3]**	***n*[2]**	**%[2]**	**Classification**	***n*[2,4]**	**%[2,4]**
Objective	26	41	Pre-intervention	3	5	Frequency	0	0
Subjective	19	30	Inter-session	16	25	Intensity	19	12
Combined	17	27	Pre-session	16	25	Duration	1	0
Not reported	1	2	Intra-session	6	10	Type	3	5
			Inter- and intra-session	1	2	Volume	13	5
			Not reported	21	33	Prescription	14	22
						Autoregulation	2	3
						Pre-determined	2	3
						Not reported	20	32
Total	62	98		42	67		43	68

[1] Why: Reason underpinning individualisation. When: Timing of individualisation. How: individualisation component/s

[2] Numbers and percentages relative to the total number of included studies

[3] Pre-intervention: individualisation determined according to baseline results, preferences or pre-determined protocol. Inter-session: individualisation determined according to assessment conducted between exercise sessions. Pre-session: individualisation determined prior to each training session. Intra-session: individualisation determined during the exercise session itself

[4] Where multiple prescription parameters are modified per study, these were counted within each parameter

method in Supplementary Table 3. Overall, 31 studies (49%) [23, 24, 27, 29, 30, 32, 35, 36, 39, 41, 43, 45–48, 50, 52, 53, 55, 59, 66, 68, 71–73, 75, 77, 78, 81, 82, 99] included details for all three aspects of why, when and how they individualised the exercise prescription.

Why Exercise was Individualised

Exercise individualisation is a cornerstone of clinical exercise physiology practice, reflecting the inherent need to tailor prescription to individual capacity and response. However, the rationale and mechanisms through which studies operationalised this individualisation varied considerably. The rationale underpinning exercise individualisation was reported in 62 studies (98%). To understand how individualisation was operationalised in research contexts, reasons for exercise individualisation were classified as subjective (i.e., patient-reported, clinician observed) or objective (i.e., physiological outcome-based) rationales, reflecting approaches commonly employed in clinical practice. Most studies (n = 26, 41%) utilised an objective approach [22, 24, 26–28, 33, 35–37, 39, 42–44, 46, 47, 49, 54–56, 58, 66, 67, 72, 78, 81, 84] focused on physiological results from baseline assessment (i.e., cardiopulmonary exercise test, 6-minute walk test, 1RM testing), and objective data gathered from participants to determine exercise prescription. Meanwhile, 19 studies (30%) [23, 31, 38, 40, 41, 45, 48, 50, 52, 57, 59, 60, 65, 74, 75, 79, 82] used a subjective approach based on individual factors such as patient ability, goals, clinical status, clinician decision, tailoring, and preferences to determine exercise prescription. A combination of objective and subjective rationale was used in 16 studies (25%) [25, 29, 30, 32, 34, 51, 53, 61–64, 69–71, 73, 77, 80, 83] accounting for factors such as patient preferences, health and exercise history, observed abilities, guidelines, baseline assessments, and specific needs to determine exercise prescription.

When Exercise was Individualised

The timing of when individualisation was applied was reported in 42 studies (63%). The timing of individualisation was categorised into (1) pre-intervention/pre-determined, (2) pre-session, (3) intra-session, (4) inter-session, or (5) a combination of intra- and inter-session. Pre-intervention/pre-determined studies (n = 3) [36, 46, 81] individualised exercise prescription based on baseline assessment results. Two pre-intervention/pre-determined studies [36, 46] individualised exercise based on predetermined plans, guidelines, or protocols (e.g., not scheduling sessions during specific periods such as the first week of each course of chemotherapy). Pre-session studies (n = 16) [29, 30, 32, 39, 44, 47, 51–53, 59, 61, 63, 68, 71, 78, 82, 83], individualised exercise prescription prior to each training session. This may have included assessments, questions, or evaluations conducted to determine readiness, health condition, need for adjustments, or reviewing diaries, logs, or records before each session to assess behaviour, progress, or potential difficulties. Intra-session studies (n = 7) [28, 31, 48, 57, 72, 74, 77] individualised exercise based on real-time active feedback provided during the session (i.e., monitoring, assessment, or feedback provided during the exercise session itself to guide intensity, technique, or progression) to ensure proper execution and optimise results. Inter-session studies (n = 15) [23, 27, 35, 37, 41, 43, 45, 50, 54, 55, 66, 73, 75, 80, 84] individualised exercise based on monitoring, assessment, or follow-up conducted between exercise sessions to ensure progress, adherence, safety, or adjustments (e.g. weekly or fortnightly contact, or regular phone calls to monitor adherence, progress, provide feedback, or address any concerns). One study [24] individualised exercise based on a combination of intra- and inter-session timing approaches (i.e., a combination of predetermined scheduling, pre-session assessments, and inter-session follow-up).

How Exercise was Individualised

A total of 44 studies (70%) reported how exercise prescription was individualised. The majority of interventions applied their reported individualisation methods via modulation of intensity, volume, type, a combination of these variables, or other components of exercise prescription. Studies individualising exercise via modulation of intensity (n = 8) [26, 27, 32, 35, 45, 47, 59, 72] typically increased or decreased intensity based on factors such as heart rate, RPE, or blood lactate concentration, adjusting based on individualised targets or thresholds. Studies modulating based on exercise volume (n = 2) [23, 50] increased or decreased the duration or number of repetitions based on individual needs or goals. Studies individualising exercise by exercise type (n = 3) [25, 33, 67] changed or modified the type of exercise based on individual preferences, abilities, or suitability. Eleven studies individualised the exercise prescription using a combination of intensity and volume modulation (n = 11) [22, 24, 29, 30, 34, 39, 41, 46, 52, 53, 69], whilst only one study combined exercise intensity and duration [43]. Modulation of exercise prescription categorised studies where prescriptions were adapted in various ways (n = 14) [36, 39, 40, 48, 55, 66, 68, 70, 71, 73, 75, 77, 79, 99]. These adaptations included modulation of progression rate (e.g., load adjusted to maintain RIR targets), flexible session formats (e.g., unscheduled rest days to accommodate fatigue), participant-centred tailoring (e.g., weekly walking targets based on individual feedback), and symptom-responsive modifications (e.g., addressing dizziness, muscular stiffness, and treatment-related side effects).

One study modulated exercise sessions by not scheduling exercise during the first week of chemotherapy [36], another had predetermined intensities set based on participant health status [58], and another modulated by allowing participants to choose their rest days [79]. Notably, only two studies individualised exercise prescription using autoregulation e.g., on presentation for a given exercise session, the clinical exercise physiologist would consult with the patient to determine their capacity to exercise and subsequently regress or progress the planned session accordingly [78, 82].

Study Fidelity Outcomes

Adverse Events

A total of 357 adverse events were reported across 13 studies (Supplementary Table 4). Zero adverse events were reported in 23 studies (36.5%). The remaining 26 studies (41%) did not report adverse events.

Adherence

A measure of adherence was reported in 37 studies [23, 24, 26, 33–42, 44, 45, 47, 48, 52–57, 61–65, 68, 69, 72, 74, 75, 80–82, 84]. Adherence was calculated as a measure of meeting exercise intensity, duration and/or volume by 15 studies [23, 26, 35, 37, 45, 47, 54, 57, 72, 74, 75, 80–82, 84]. Of the remaining 22 studies, adherence was calculated as a percentage of the number of exercise sessions attended out of total number prescribed (i.e., attendance). The method for reported adherence was not defined in nine studies [42–44, 50, 56, 61–63, 65], and 19 studies [25, 27–31, 46, 48, 49, 57–59, 64, 66, 67, 70, 73, 78, 79] did not report adherence.

Adherence to components of the exercise prescription was reported in 28 studies (55%), but 10 of those studies reported adherence as session attendance rate only. Of the 20 studies that reported adherence to an exercise protocol, mean adherence was 60%. Participant attrition ranged from 0% [65] to 69% [56] in the 50 studies (79%) that reported attrition. Recruitment uptake was reported in 43 studies with a range of 25.4% [24] to 100% [28, 43] with mean of 70%.

Outcome Measures

There was a large heterogeneity in the primary study outcomes included within this review. Primarily, these were feasibility studies ($n = 19$). A measure of cardiorespiratory fitness was the most common primary outcome of included studies ($n = 10$), followed by quality of life ($n = 5$), and fatigue ($n = 4$). Notably, there was an assortment of measures used to assess these outcomes.

Meta-Analyses

Average and point-estimate data of all included studies are summarised in Supplementary File 1. The pooled effect size (SMD) was − 0.27 ($SE = 0.12$, $z = 2.26$, $p = 0.024$, 95% CI [− 0.51, − 0.04]), indicating a small-to-moderate effect of exercise on fatigue severity. A moderate-to-high heterogeneity (I^2 = 65.86%, τ^2 = 0.0963, H^2 = 2.93), suggests that a significant portion of variability was due to differences among studies rather than sampling error. Egger's regression test did not indicate significant publication bias ($z = 1.40$, $p = 0.162$). The estimated intercept was 0.0414 (95% CI [− 0.45, 0.53]), suggesting that smaller studies did not systematically report larger effect sizes.

Within the separate analyses, 12 studies were included in the "why" moderator analysis (combination, subjective, objective), whereas only 10 studies had sufficient data for the "timing" moderator analysis (inter-session and pre-intra session). The moderator analysis of the influence of the reason for exercise individualisation on fatigue severity (Fig. 2) found that objective assessments to determine individualisation demonstrated moderate effect but with imprecise 95% CI (standardized mean difference [SMD] = – 0.504, 95% CI – 1.016 to 0.007; $p = 0.0532$), meanwhile, subjective assessments were significantly associated with reduced fatigue (SMD = – 0.355, 95% CI – 0.631 to – 0.079; $p = 0.0116$). The combination of both approaches did not yield a significant effect (SMD = 0.041, 95% CI – 0.321 to 0.403; $p = 0.8234$).

A further moderator analysis of the timing of exercise individualisation (Fig. 3) showed that exercise individualisation that was determined between sessions had a significant pooled effect on fatigue (SMD = – 0.616, 95% CI – 0.962 to – 0.271; $p = 0.0005$), whereas pre-intra session individualisation showed no significant effect (SMD = – 0.031, 95% CI – 0.265 to 0.203; $p = 0.7974$).

Discussion

This is the first review to explore and summarise the individualisation methods of exercise prescription for people living with and beyond cancer, including autoregulatory prescription. Overall, the precise methods of exercise individualisation were poorly reported, with only 49% of studies reporting sufficient information across *why*, *when* and *how* domains that would enable replication of the individualisation approach.

The most common method of exercise individualisation was based on objective outcomes at baseline only (35%). Given documented fluctuations in symptoms experienced by people along the cancer continuum [111], this approach likely fails to meet the daily exercise prescription needs of these people. Pre-session and inter-session individualisation—each observed in 25% of included studies—and intra-session adjustment (11%) allow prescription modification based on real-time clinical presentation. Our meta-analysis found inter-session individualisation timing was associated with a statistically discernible reduction in fatigue severity, suggesting that adaptations based on prior session responses may hold value for optimising outcomes, which supports the hypothesis that individualising exercise prescription, particularly between sessions, may enhance intervention responsiveness. However, as pre- and intra-session individualisation were not significantly associated with fatigue severity, this does not negate the potential relevance of other non-analysed factors (e.g., mood, sleep, pain, stress, or energy levels) given the multifactorial aetiology and interconnectedness of these factors in the complex symptom of cancer-related fatigue. That said, the limited number of studies employing these

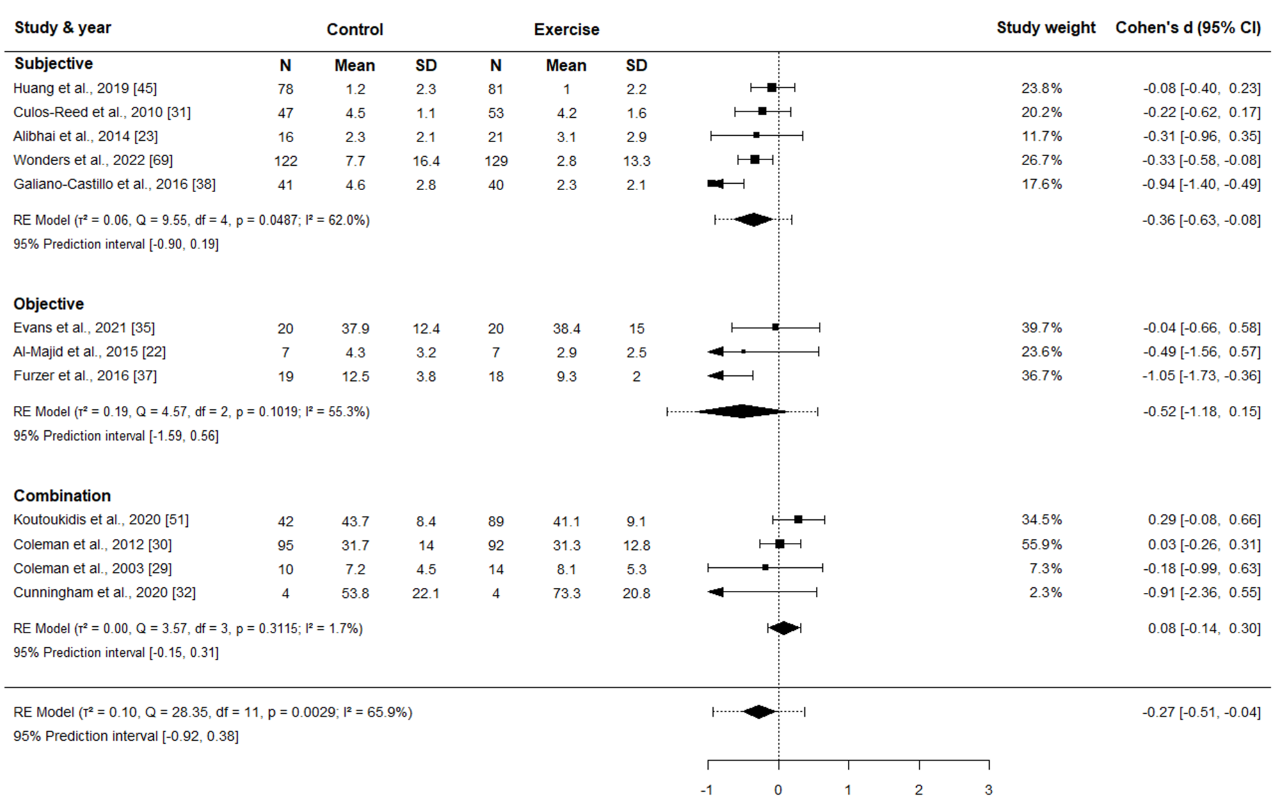

Fig. 2 Moderator analysis of reason for exercise individualisation and fatigue severity

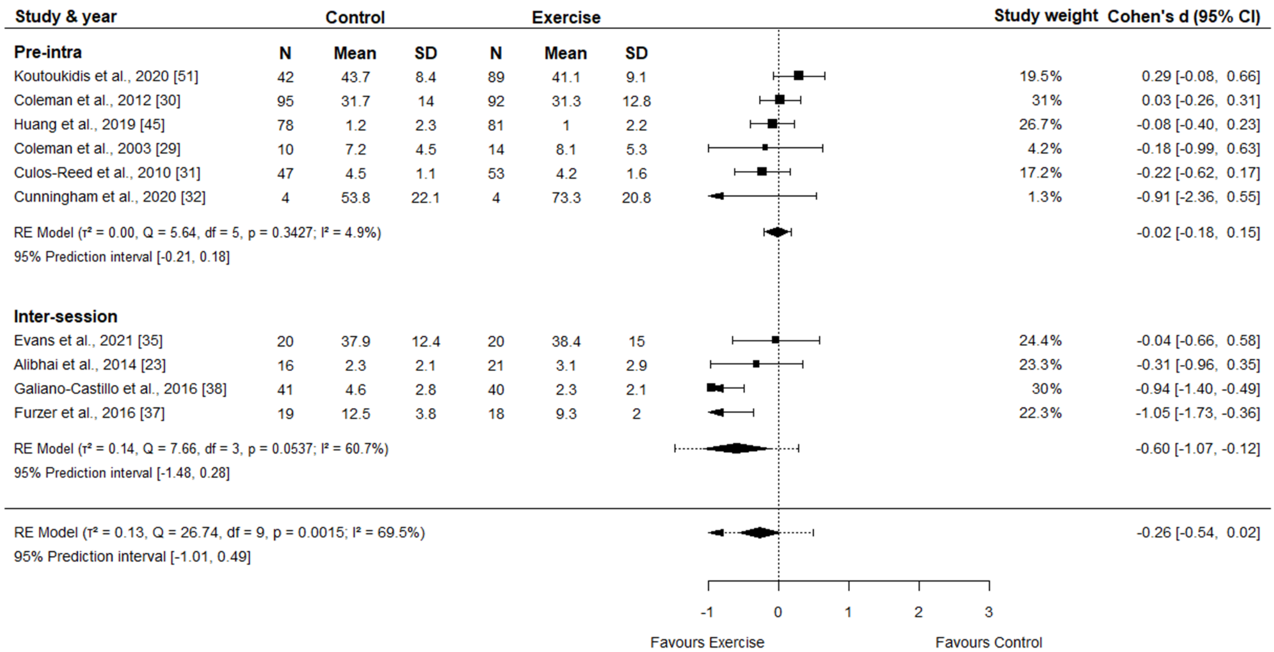

Fig. 3 Moderator analysis of timing of exercise individualisation and fatigue

methods precludes firm conclusions about their comparative effectiveness. Future research should investigate whether combining individualisation timepoints (e.g., both before/between and during sessions) can improve symptom management and functional outcomes in cancer populations. It is important to acknowledge that certain dimensions of exercise individualisation—particularly the clinician's capacity to make responsive, in-the-moment decisions based on real-time patient cues, contextual barriers, and adherence needs—are difficult to operationalise and fully study in controlled research settings. While our analysis identified inter-session individualisation as a significant contributor to fatigue reduction, this should not be interpreted as evidence that all individualisation strategies are equally effective for all, nor that increased frequency of individualisation universally improves outcomes.

The rationale for individualising exercise prescriptions was well-reported in (97% of included studies) with 39% of studies describing objective data as the rationale for exercise individualisation. However, this approach has been critiqued [100] on the basis that objective assessment alone is limited in responding to daily fluctuations in symptoms. In contrast, subjective measures (30%) yielded reduced fatigue severity. A combination of both objective and subjective rationales in 26% of studies further highlights the need for a holistic approach that integrates multiple facets of the individual's experience, ensuring a more comprehensive and responsive exercise prescription. In the 12 studies we meta-analysed a mean intervention adherence of 22% was achieved in the four studies which reported on this. Further, ten studies reported frequency adherence (attendance) with a mean of 66%. A previous meta-analysis [101] exploring effects of exercise on cancer-related fatigue highlighted that higher intervention adherence resulted in the larger improvements. It may be that irrespective of the reason for exercise individualisation fatigue severity may not be meaningfully improved if an ample exercise dose is not achieved via the levels of frequency and intensity prescribed by the intervention.

Autoregulation provides a framework for exercise individualisation within a rigorously designed exercise protocol by modifying exercise prescription according to an individual's 'readiness to train'. Of 24 studies (38%) individualising either pre-or intra-session, seven studies' [44, 47, 52, 59, 71, 78, 82] methods met the definition of autoregulation as defined by Fairman et al. [17], although only two studies explicitly reported using autoregulation [78, 82]. These studies had a quality rating ranging between 14.3 and 71.4, with three being controlled trials. Yet none empirically evaluated the utility of autoregulation [52, 78, 82] compared to a traditional exercise prescription. Autoregulation has recently been recommended by international governing bodies of exercise physiology [16] as a means to ward off staleness, improve enjoyment, and ultimately foster the long-term maintenance of activity [17]. In addition, Bettariga et al. [18] proposed autoregulatory programming strategies allow exercise intensity and volume to be modulated in response to patients' symptoms and fatigue, ensuring safety and adherence. Despite this, there is a lack of evidence specifically testing

Table 2 Example of reporting individualisation of exercise prescription

Criteria	Details to Report	Example
Why (Rationale for individualisation)	Reason for adjusting exercise prescription, who makes the decision, and whether it is based on *objective* (e.g., outcome assessment results to achieve a specific adaptation) or *subjective* (e.g., participant-reported health history, comorbidities, capacity, disease/treatment effects) information	Resistance training intensity adjusted to maximise strength based on objective assessments (1RM testing) and providing an accompanying RPE range based on subjective reports of fatigue from chemotherapy side effects, as determined by the exercise physiologist
When (Timing of individualisation)	Point in the intervention when adjustments are made, who implements the change, and whether it is based on *objective* (e.g., regular fitness assessments) or *subjective* (e.g., participant feedback) information	Prior to each session based on weekly fatigue assessments (objective) and daily participant-reported symptoms (subjective), with the exercise professional modifying the session
How (Method and extent of individualisation)	Specific method used to adjust training (*RIR*, *autoregulation*, *RPE*, *%RM*, *increasing or decreasing volume*), who applies it, and to what extent adjustments are made	Load adjusted using an autoregulated approach: if RPE > 7 or RIR < 2, load reduced by smallest available increment; if RPE < 5 or RIR > 4, load increased by smallest available increment. Adjustments made by the participant under supervision
Who (person responsible for individualising exercise prescription)	Detail the individual that was overseeing and directing the individualisation approach	The exercise physiologist individualised the exercise as required based on participants' feedback throughout the session
What (what happened because of individualisation)	The effect of individualising the exercise prescription on the participant's exercise session or outcome	The participant was able to continue exercising in the presence of high fatigue levels, albeit with a reduced 'dose' of exercise than previously planned for the session

RPE Rating of perceived exertion, *RIR* Repetitions in reserve, *RM* Repetition maximum

different autoregulation strategies. Therefore, further research specifically designed to understand its empirical utility and potential for application is warranted.

Our findings support a clinical practice model in which exercise professionals have access to multiple individualisation methods—objective assessment-driven prescription, subjective clinical reasoning, responsive adjustment between sessions, and real-time in-session modification—and the skill to select and apply the most appropriate strategy for each individual in their specific context. Optimal patient outcomes may depend less on rigid adherence to a single individualisation approach and more on the clinician's ability to judiciously apply the right adjustment at the right time to support engagement, safety, and symptom management.

To improve future research, the authors propose future exercise oncology study investigators refer to Table 2 regarding the design and reporting of exercise individualisation, alongside the CERT [102] and ExRDI guidelines [103]. Widespread adoption of these standards will enhance the ability of future research to quantify, evaluate and replicate exercise prescription in cancer individualisation methods for translation into clinical practice.

Although the findings of this review present important information and a contribution to the exercise oncology literature, several limitations are present, particularly with respect to the heterogeneity of the research participants and exercise interventions. The included studies included participants with varying cancer types, disease stages, and treatment regimes, and prescribed a diverse range of exercise prescriptions. As such, the FITT-VP principles were diversely applied. Finally, the heterogeneity of study measures, individualisation methods reporting, and primary outcomes precluded some of the preplanned meta-analysis of the influence of other factors associated with fluctuations with respect to individualisation methods. Nonetheless, these findings are meaningful in further understanding exercise prescription individualisation for cancer populations.

Conclusion

The importance of exercise individualisation within oncology is undisputed [18, 87, 104–106, 112]. As a result, there has been advocacy across the literature and field of exercise oncology for improvements to contemporary practice, reporting, and monitoring [100, 107–110]. This review highlights considerable variability in how individualisation of exercise is implemented and reported in cancer exercise trials. Our meta-analysis found that certain individualisation strategies—particularly inter-session modifications—were associated with significant improvements in fatigue, underscoring the potential clinical value of individualising exercise over time. However, pre-session and intra-session approaches remain underutilised and inconsistently reported, limiting the ability to determine their independent effects. To advance the field, future research should systematically incorporate and report the key components of individualisation outlined in Table 2. Purpose-built trials—including those using autoregulated or adaptive programming methods—are needed to evaluate the added value of individualisation and to support translation into flexible, patient-centred clinical models of care.

Supplementary Information

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Supplementary Material 1.

Supplementary Material 2.

Supplementary Material 3.

Supplementary Material 4.

Supplementary Material 5.

Author Contributions

GLR, TLS and BC contributed to the conception and design of the study and development of the search strategy. BC conducted the systematic review and completed the acquisition of data. GLR, MJ and BC performed the data analysis. Together, GLR, TLS, CMF, MJ and BC contributed to the interpretation of results. BC drafted the manuscript, which was edited by GLR, TLS, CMF, MJ and BC. All authors read and approved the final submitted version of the manuscript.

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Data Availability

The datasets generated analysed with R studio and script are available in the Open Science Framework repository, [https://osf.io/d6tkv/]. All data generated or analysed during this study are included in this published article [and its supplementary information files].

Declarations

Ethics Approval and Consent to Participate

Not applicable.

Consent for Publication

Not applicable.

Competing Interests

No competing interests to report

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