

Review

Dose-response relationship in exercise intervention for cancer patients: A meta-analysis based on the FACT-G scale

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Abstract: Exercise has become an established component of supportive oncology care, yet the optimal dose required to improve patient-reported outcomes remains unclear. This meta-analysis examined the impact of exercise interventions on quality of life measured exclusively with the Functional Assessment of Cancer Therapy-General (FACT-G). A systematic search of Web of Science identified 61 records, of which 14 trials involving 1230 participants met eligibility criteria. The included studies encompassed diverse cancer populations and intervention formats, ranging from aerobic and resistance training to multimodal, yoga, and digitally supported programs. Despite heterogeneity, exercise was consistently safe and associated with either improvements or preservation of quality of life, with several trials reporting changes that exceeded the minimal clinically important difference. The clearest signal of benefit was observed in supervised programs delivering an accumulated dose of approximately 180 min per week over 8 to 16 weeks, where quality-of-life gains were most robust. Lower-dose programs of around 120 min per week yielded mixed results, while high-dose regimens of 270 min or more per week did not sustain superior benefits, suggesting an inverted-U dose-response trajectory. Importantly, exercise during active treatment frequently maintained quality of life in the face of therapeutic burden, whereas in survivorship larger absolute improvements were achieved. These findings support the integration of structured, supervised exercise into oncology care and reinforce the need for future precision trials to refine dose-response models and address sustainability of benefit.

Keywords: cancer; dose-response; exercise intervention; FACT-G; quality of life

1. Introduction

Cancer is not only a life-threatening disease but also a condition that profoundly reshapes the physical, emotional, and social lives of those affected. Advances in screening and treatment have substantially improved survival rates, resulting in an increasing population of cancer survivors worldwide [1]. This demographic shift has consequently highlighted the importance of addressing survivorship issues, particularly health-related quality of life (HRQoL). Research indicates that cancer survivors frequently report persistent fatigue, functional limitations, emotional distress, and disruptions to social and family life [2]. These multidimensional concerns underscore the need for interventions that extend beyond biomedical outcomes to address the broader psychosocial challenges of survivorship, advocating for a more holistic approach to survivorship care [3].

Exercise has emerged as one of the most promising supportive interventions in the context of cancer care. A growing body of research shows that structured physical

activity can alleviate cancer-related fatigue, enhance functional capacity, and improve psychological well-being [4]. Importantly, exercise appears to benefit both physiological and psychosocial dimensions, offering a holistic and non-pharmacological approach to supportive care [4,5]. Organizations such as the American College of Sports Medicine now recommend the systematic integration of exercise into cancer care [6]. However, despite this growing consensus, important clinical questions remain unanswered. Chief among them is the extent to which the “dose” of exercise such as its frequency, intensity, duration, and overall volume are matters in determining patient-reported outcomes [7].

Quality of life in oncology is often assessed using validated self-report instruments. Among these, the Functional Assessment of Cancer Therapy-General (FACT-G) is one of the most widely adopted tools. FACT-G captures four domains—physical well-being, social/family well-being, emotional well-being, and functional well-being—allowing researchers and clinicians to evaluate health-related quality of life (HRQoL) in a comprehensive manner. Its extensive use across clinical trials provides a common metric for synthesizing evidence, and its multidimensional nature aligns with the psychosocial orientation of contemporary survivorship research [8]. Studies have established FACT-G as a reliable instrument that incorporates essential dimensions of quality of life, which is significant for creating a unified framework for evaluating patient outcomes in oncology [9]. The measurement of these diverse aspects through the FACT-G is crucial as it addresses the complex psychosocial challenges faced by cancer patients and helps enhance the integrative understanding of their overall survival and well-being [10].

Despite numerous randomized and quasi-experimental studies evaluating the impact of exercise on health-related quality of life (HRQoL) outcomes among cancer patients, evidence remains heterogeneous. While some trials report substantial improvements in quality of life measures such as the FACT-G (Functional Assessment of Cancer Therapy-General), others find modest or null effects. A key reason for this variability may lie in the dose–response relationship; it is plausible that benefits increase with exercise exposure up to an optimal threshold, after which additional exercise yields diminishing returns or even adverse consequences such as heightened fatigue or non-adherence. This possibility raises crucial questions: What is the minimum effective dose of exercise for improving HRQoL? Does a plateau or U-shaped curve characterize the relationship? And how do patient-specific and contextual factors influence this association? These considerations have been highlighted in the context of quality of life assessments among cancer patients, illustrating the complexities involved in determining effective exercise interventions [11]. Research has suggested that while exercise can significantly enhance quality of life, individual responses vary widely based on factors like exercise type, intensity, and patient characteristics [12].

Potential moderators may further complicate this picture. Cancer type and stage, age, sex, treatment status, and the nature of the exercise intervention (aerobic, resistance, or mind–body modalities such as yoga or tai chi) may all influence the extent of benefit. Supervision and setting—whether interventions are delivered individually, in groups, or at home—may also shape adherence and psychosocial outcomes. Understanding these moderating factors is essential for tailoring exercise

prescriptions to individual patients and optimizing supportive care pathways [13]. The distinctions in patient characteristics and intervention delivery methods underpin the necessity for personalized approaches in exercise recommendations, which could lead to varying impacts on quality of life as assessed by instruments such as the Functional Assessment of Cancer Therapy-General (FACT-G) [14]. Research indicates that the interactions of personality traits and social context also play a significant role in determining the outcome of exercise interventions among cancer patients, emphasizing the complexity of this relationship [15].

The present meta-analysis was designed to address these gaps. Its objectives were threefold: (1) to synthesize evidence on the effect of exercise interventions on HRQoL in cancer survivors, using FACT-G as the primary outcome measure; (2) to evaluate the dose–response relationship between exercise and FACT-G, testing both linear and non-linear models; and (3) to explore potential moderators—including patient characteristics, cancer type, and intervention modality—that may account for heterogeneity in observed effects. By clarifying the optimal dose of exercise for enhancing quality of life, this study seeks to inform evidence-based guidelines, advance psycho-oncological research, and support the delivery of personalized, patient-centred survivorship care.

2. Literature review

2.1. Exercise and quality of life in cancer care

Cancer survivorship has transformed dramatically over the past two decades. Advances in early detection and treatment have extended survival for many tumour types, shifting the clinical agenda from survival alone toward survivorship and quality of life. As a result, supportive care has assumed greater importance, and exercise has emerged as a leading non-pharmacological intervention. Once viewed as contraindicated or even unsafe during cancer therapy, exercise is now recognized as both feasible and beneficial across diagnoses and treatment stages [16]. Research indicates that supervised exercise significantly enhances quality of life metrics, such as those measured by the Functional Assessment of Cancer Therapy-General (FACT-G) [17]. This evolving perception of exercise is crucial as it facilitates improved health outcomes and supports the well-being of cancer survivors, which is essential in the context of a changing clinical landscape focused on long-term quality of life [18].

A robust body of evidence demonstrates that exercise reduces cancer-related fatigue, improves cardiorespiratory fitness, preserves muscle mass, and enhances psychosocial well-being. These multidimensional benefits converge on a central outcome: quality of life. Among the many instruments developed to capture this construct, the Functional Assessment of Cancer Therapy-General (FACT-G) has become one of the most widely used, validated across tumour sites and languages [19]. FACT-G's four subscales: physical, functional, emotional, and social/family well-being usually offer a nuanced picture of the cancer experience [20]. Importantly, improvements of three to seven points are considered clinically meaningful, making FACT-G an ideal anchor for synthesizing exercise effects [19].

2.2. Exercise as a prescribed dose: Framing the intervention

Exercise in oncology research is not a uniform construct but a spectrum of interventions that vary by type, intensity, duration, and mode of delivery. Aerobic exercise, most commonly walking or cycling, is among the most frequently studied modalities and has repeatedly been shown to reduce cancer-related fatigue and enhance physical functioning [21]. Resistance training is also supported by evidence indicating that progressive loading preserves lean mass and can mitigate sarcopenia, ultimately contributing to improvements in physical and functional well-being [22]. Multimodal programs combine these elements, often incorporating flexibility, balance, or mind–body components, and are increasingly adopted in community or survivorship settings [23].

Novel approaches are expanding the scope of exercise oncology. Yoga has gained traction as both a physical and psychosocial intervention, improving not only functional scores but also emotional domains such as anxiety and depression [24]. High-challenge interventions such as triathlon training underscore the capacity of survivors to engage in ambitious exercise, while digital health technologies such as wearables, apps, and text-based coaching which offer scalable, low-cost options that may extend reach to populations with limited access to supervised programs [25]. The independent variable in this research field is therefore multifaceted, and understanding how different types and “doses” of exercise influence outcomes remains central to advancing clinical translation [26].

2.3. Quality of life as an oncological outcome

Quality of life is a crucial dependent variable for evaluating exercise interventions in oncology, as it reflects not only survival but the lived experience of survivorship. Cancer and its treatment impose substantial burdens—fatigue, pain, sleep disturbances, anxiety, and social isolation—that can persist long after treatment completion. The FACT-G (Functional Assessment of Cancer Therapy-General) provides a validated framework for capturing these burdens [27]. Exercise has been shown to improve the physical and functional domains of the FACT-G, with participants in aerobic or resistance training studies frequently reporting enhanced stamina, reduced fatigue, and improved ability to perform daily activities [28]. While improvements in emotional well-being associated with exercise interventions can vary, they are often present, particularly in programs that integrate social or mindfulness components. Social and family well-being is less consistently impacted by exercise, reflecting the complexities of relational dynamics that may not change solely through physical activity [29]. Importantly, stabilizing the quality of life in patients with advanced cancer is a clinically significant outcome. Patients undergoing radiotherapy or chemotherapy frequently face a progressive decline in quality of life, and interventions that preserve baseline quality of life can provide substantial benefits [30].

2.4. Factors influencing exercise—Quality of life outcomes

The relationship between exercise and quality of life is not linear or uniform; rather, it is moderated by multiple factors that shape the magnitude and sustainability of benefit:

- 1) Cancer type is one such moderator. Breast cancer survivors demonstrate significant improvements across various Health-Related Quality of Life (HRQoL) domains, highlighting their responsiveness to structured interventions [31,32]. In contrast, survivors of haematological malignancies also show positive responses, particularly to resistance-based regimens, but the benefits might differ in other cancer types, such as lung cancer, where absolute gains may be smaller [33]. Importantly, in advanced disease, maintaining quality of life and preventing decline can be as clinically significant as striving for improvement in HRQoL metrics [33].
- 2) Treatment stage moderates exercise efficacy. During active treatment, patients are vulnerable to the toxicities of chemotherapy and radiotherapy. In this context, exercise interventions often succeed not in producing large improvements but in buffering decline. In survivorship, once treatment has ended, exercise yields larger absolute gains, restoring vitality, resilience, and psychosocial well-being [34]. Research indicates that exercise can mitigate the negative effects of treatment and significantly enhance quality of life metrics in cancer survivors [35]. Furthermore, maintaining regular physical activity during and after treatment has been associated with improved psychological outcomes, such as reduced anxiety and depression, and helps sustain overall well-being [36]. Therefore, the role of structured exercise interventions becomes increasingly vital as patients transition from treatment to survivorship [37].
- 3) Delivery format also shapes outcomes. Supervised interventions generally outperform self-directed programs due to the increased accountability and professional oversight that enhance adherence and ensure appropriate intensity. Group-based or paired training amplifies this effect by providing social support, which can reduce feelings of isolation and enhance motivation [38]. In contrast, digital or home-based programs tend to yield modest improvements in outcomes, although studies have shown a correlation between adherence and quality of life, indicating that “dose achieved” is relevant even in less supportive models [39]. While remote and self-directed strategies can be effective, their success often relies significantly on individual commitment and self-regulation capabilities [40].
- 4) Exercise dose functions as both an independent variable and a moderator in determining health outcomes. The concept of dose encompasses minutes per week, intensity, and duration of exercise interventions, which significantly influences results. This is supported by the dose–response hypothesis [41]. Understanding how various exercise doses affect different health outcomes is crucial for optimizing prescriptions in clinical settings [42,43]. A tailored approach to exercise dose has been found to enhance benefits across various health conditions, including cancer [42], cardiovascular health [44], and

metabolic functions [43]. Improved understanding of these relationships may inform clinical guidelines and ultimately enhance patient outcomes [45].

2.5. The dose–response hypothesis

A central question in exercise oncology is not whether exercise is beneficial, but how much exercise is needed to optimize quality of life. Evidence across trials suggests that the relationship is not linear but follows an inverted-U trajectory. Very low doses, such as sporadic home walking, produce limited or inconsistent effects. Very high doses, particularly when prolonged and unsupervised, may yield diminishing returns, as adherence wanes and fatigue accumulate. By contrast, moderate programs, typically 120 to 180 min per week delivered over 8 to 16 weeks, consistently produce the largest and most reliable improvements in quality of life outcomes for cancer patients [46].

This inverted-U trajectory reflects both physiological and behavioural realities. Moderate exercise stimulates favourable adaptations in energy metabolism, strength, and resilience without overwhelming patients. Excessive regimens, especially when unsupervised, may risk dropout or plateau, undermining benefits. Exceptions exist in highly symptomatic populations: in cachexia, for example, even small doses of resistance exercise produce significant improvements by counteracting severe deconditioning. Thus, while the general trajectory favours moderate structured programs, context must guide prescription [47].

2.6. Summary of literature

Taken together, the literature confirms that exercise interventions are safe, feasible, and effective in enhancing or preserving quality of life in cancer populations. The FACT-G emerges as a robust and clinically meaningful outcome measure, sensitive to changes induced by exercise. However, the magnitude and sustainability of benefit are moderated by cancer type, treatment stage, delivery format, and exercise dose. The weight of evidence supports a dose–response framework in which moderate, supervised programs yield the most reliable gains, while insufficient or excessive doses produce weaker or unsustained effects. This nuanced understanding provides the rationale for a meta-analysis that explicitly examines the dose–response relationship of exercise interventions in cancer patients using FACT-G outcomes.

3. Methods

3.1. Protocol and reporting framework

This meta-analysis was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines. The review protocol was developed a priori to specify eligibility criteria, search strategy, study selection, data extraction, and synthesis.

3.2. Eligibility criteria

Studies were considered eligible if they investigated adult patients with a cancer diagnosis and evaluated the effects of an exercise-based intervention on quality of life

measured exclusively with the Functional Assessment of Cancer Therapy-General (FACT-G). Interventions could include aerobic training, resistance training, yoga, multimodal programs, or digitally supported and home-based formats, and were required to report baseline and post-intervention FACT-G outcomes. Eligible designs comprised randomized controlled trials, pilot RCTs, and controlled pre-post interventions published in English between 2010 and 2023. Observational studies, cross-sectional reports, qualitative designs, reviews, protocols without results, case series, pediatric populations, non-oncology settings, and studies reporting only disease-specific FACT subscales (FACT-B, FACT-C, FACT-P) were excluded.

3.3. Information sources and search strategy

The primary search was conducted in Web of Science (WoS), chosen for its comprehensive coverage of biomedical and psychosocial research. The final search was run on September 2025 and limited to articles published between 2010 and 2023. The Boolean string combined cancer-related terms, exercise modalities, and quality-of-life outcomes with FACT instruments, while restricting to interventional designs:

TS = ("cancer patient*" OR "cancer survivor*" OR "oncology")
AND ("exercise" OR "physical activity*" OR "training" "home-based exercise"
OR "digital exercise")
AND ("FACT-G" OR "Functional Assessment of Cancer Therapy-General")
AND ("trial" OR "randomized" OR intervention))

The initial search returned 61 records. After title filtering, removal of reviews, non-English articles, and studies outside the timeframe, 48 records remained.

3.4. Study selection

Screening occurred in two phases. First, titles and abstracts of the 48 records were screened against eligibility criteria, excluding 18 records for being non-interventional, wrong population, lacking QoL outcomes, or being conference abstracts. Second, 30 full texts were assessed, of which 16 were excluded: six did not report FACT-G or subscales, three were protocols only, four involved mixed interventions where exercise effects were not isolatable, and three were outside the timeframe or design scope. A total of 14 trials met all inclusion criteria and were retained for synthesis. The selection process is summarized in the PRISMA 2020 flow diagram (**Figure 1**).

3.5. Data extraction

Data from included studies were extracted into a structured master table. Extracted variables included: author and year, country, study design, sample size, population characteristics (cancer type and stage, mean age), intervention type and delivery (aerobic, resistance, yoga, multimodal, digital/home-based), session length and frequency, program duration, comparator group, follow-up time points, and quality-of-life outcomes (FACT-G total and subscales). Additional outcomes such as fatigue, depression, and physical function were noted where relevant.

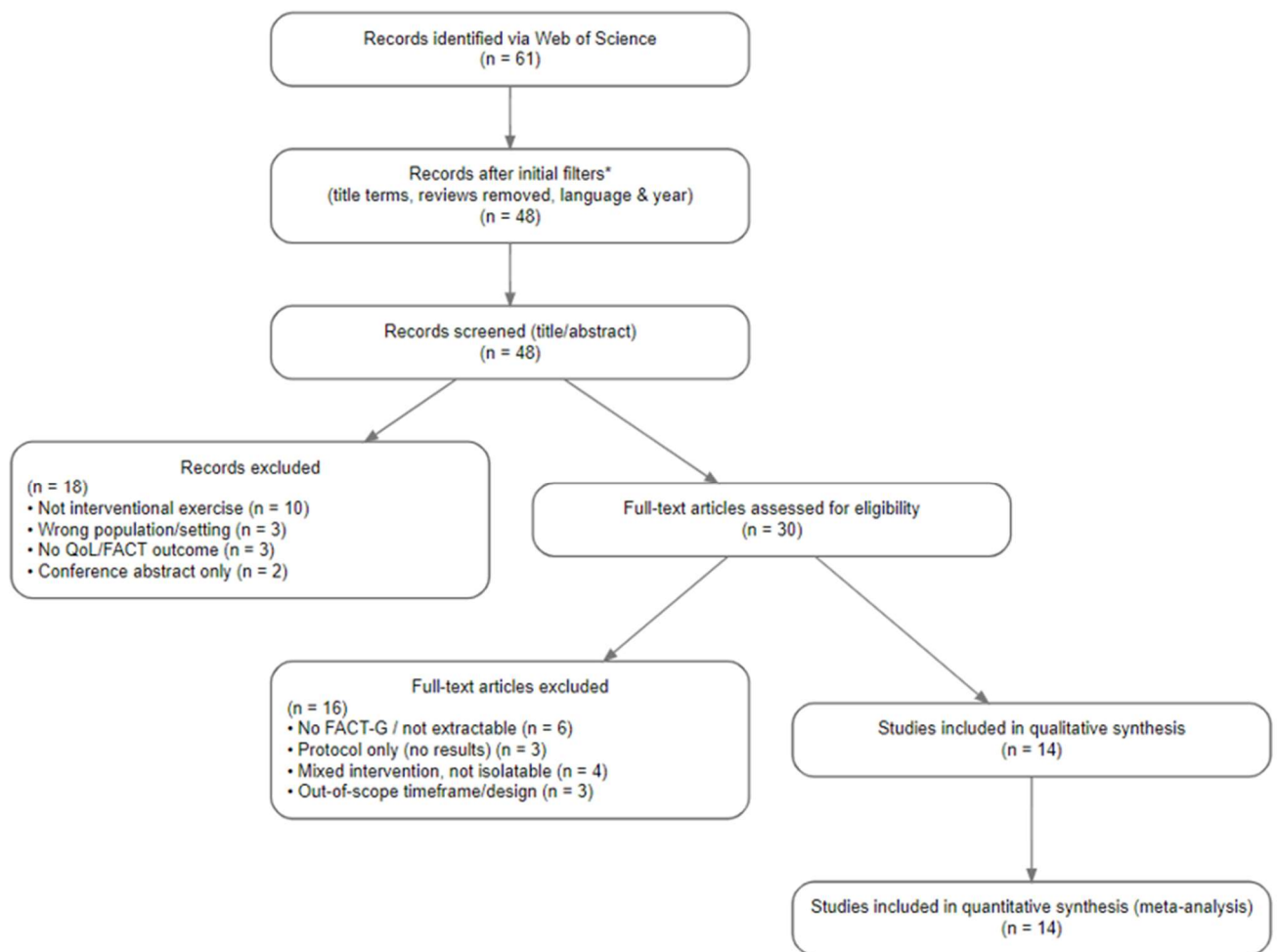


Figure 1. PRISMA 2020 flow diagram showing study selection process from initial search ($n = 61$) to final inclusion ($n = 14$).

3.6. Data synthesis and statistical analysis

The primary outcome was change in FACT-G (or subscale) scores from baseline to post-intervention. Where possible, mean differences and standard deviations were extracted to calculate standardized mean differences (SMDs). Given the heterogeneity of interventions, a random-effects meta-analysis was planned. Heterogeneity was assessed with the I^2 statistic. Subgroup analyses were pre-specified for intervention type (aerobic vs resistance vs multimodal), treatment status (active vs survivorship), and supervision (supervised vs home/digital). Dose–response was evaluated by mapping weekly accumulated exercise dose (session length $\times$ frequency) against changes in FACT-G, modeled visually with a conceptual inverted-U curve. Publication bias was explored with funnel plots and Egger’s regression test.

4. Results

4.1. Study selection and characteristics

The search identified fourteen interventional trials published between 2013 and 2023 that met inclusion criteria. Together, these studies enrolled 1230 participants across breast, colorectal, lung, haematological, prostate, and mixed cancer

populations. Nine were randomized controlled trials, three were pilot RCTs, and two were feasibility interventions **Table 1** provides detailed study characteristics and outcome data.

Table 1. Summary of included exercise intervention trials assessing quality of life with FACT-G ($n = 14$).

Author (year)	Study design	Population	Intervention	Session length (min)	Follow-up	FACT-G findings	Other outcomes
Cheville [48]	RCT	Stage IV lung/CRC	Home walking + bands	20–30	8	ns	Fatigue↓; mobility/sleep↑
Clark [49]	RCT	Advanced cancer on RT	Multidisciplinary (incl. exercise)	90	4, 27	↑ at 4 wks; ns at 27 wks	Maintained PWB/FWB
Murtezani [50]	RCT	Breast I–III	Supervised aerobic	25–45	10	+9.2 ($p < 0.01$)	12 MWT↑
Foley [51]	Single-arm	Mixed survivors	Multimodal (YMCA)	90	12	↑ 9.6% ($p < 0.001$)	Strength, 6 MWT↑
Hagstrom [52]	RCT	Breast I–IIIA	Progressive resistance	60	17	+6.9 vs +1.6 ($p = 0.015$)	Fatigue↓
Ng [53]	Single-arm	Breast 0–III	Triathlon training	90 (grp)	24	↑ ($p = 0.01$); regressed by 6 m	VO _{2max} ↑
Furzer [54]	RCT	Hem malignancies	Aerobic + resistance	60	12, 24	+9.0 ($p = 0.005$)	VO ₂ , strength↑; fatigue↓
Park [55]	RCT	Female survivors	Aerobic + resistance (FIT)	~60	24, 52	↑ at 6 m in AI users ($p = 0.03$); ns at 12 m	Fitness↑
Li (2019 – EX arm) [56]	RCT (4-arm; EX only)	Advanced cachexia (mixed)	Resistance (bed → 1 kg DB)	10–20	8	+31 points ($p < 0.001$)	Fatigue↓; depression↓
Quist [57]	RCT	Advanced lung CA	Aerobic + resistance + relaxation	90	12	Within-INT +4.7 ($p < 0.01$); btwn-grp ns	Anxiety↓; depression↓
Yamada [58]	RCT	Female survivors	Paired vs individual mixed training	90	6, 12	Paired + 8.3 ($p < 0.05$); individual ns	Depression & insomnia↓
Kaushik [59]	Pilot RCT	Prostate peri-op	Hatha yoga	60	12	+1.9 vs –6.3 (ns; MCID exceeded)	FACT-P↑; fatigue trend
Johnson [60]	Pilot pre-post	Mixed survivors	Home PT (aer/str/bal)	~30	3, 6	2/3 improved (+4, +9)	Fatigue↓; balance↑
Shachar [61]	Single-arm pilot	Metastatic breast cancer on new therapy	Home walking + Fitbit Zip™	— (volume goal)	12, 24	FACT-G: 82.2→83.9 (ns); Steps correlated with FACT-G gains ($p = 0.54$, $p = 0.01$)	Anxiety↓ ($p = 0.02$); PA↑ ($p = 0.04$)

Notes: RCT = randomized controlled trial; RT = resistance training; AT = aerobic training; PA = physical activity; MCID = minimal clinically important difference; FACT-G = Functional Assessment of Cancer Therapy-General; PWB = physical well-being; FWB = functional well-being; EWB = emotional well-being; SWB = social well-being; AI = aromatase inhibitor.

4.2. Quality of life outcomes

Across studies, exercise was consistently associated with improvements or maintenance of FACT-G scores. Resistance training yielded particularly strong effects: Hagstrom et al. [52] reported a +6.9-point gain in breast cancer survivors, while Furzer et al. [54] observed a +9.6-point increase in haematological malignancies. Murtezani et al. [50] demonstrated similar improvements (+9.2 points) with aerobic training in breast cancer survivors.

Multimodal interventions also enhanced quality of life. In the YMCA community program, Foley et al. [51] reported a 9.6% increase in FACT-G. Yamada et al. [58] showed that paired training, but not individual training, improved global and emotional well-being, suggesting that social context amplifies benefit. In contrast, in advanced disease, interventions were more effective in preserving quality of life. Clark et al. [49] maintained FACT-G scores during radiotherapy, preventing the decline observed in controls. Similarly, Quist et al. [57] demonstrated preserved social well-being in advanced lung cancer despite only modest changes in global scores.

Survivorship studies often reported larger immediate improvements. Ng et al. [53] documented significant gains after triathlon training, although benefits regressed by six months. Park et al. [55] found improvements among women receiving aromatase inhibitors at six months, but these were not sustained at one year once supervision ceased. Novel formats, such as yoga and digital interventions, produced modest but clinically relevant improvements: Kaushik et al. [59] reported meaningful changes in perioperative prostate cancer patients. Shachar et al. [61] did not observe group-level changes in metastatic breast cancer, but higher step counts were positively correlated with improvements in FACT-G and physical well-being.

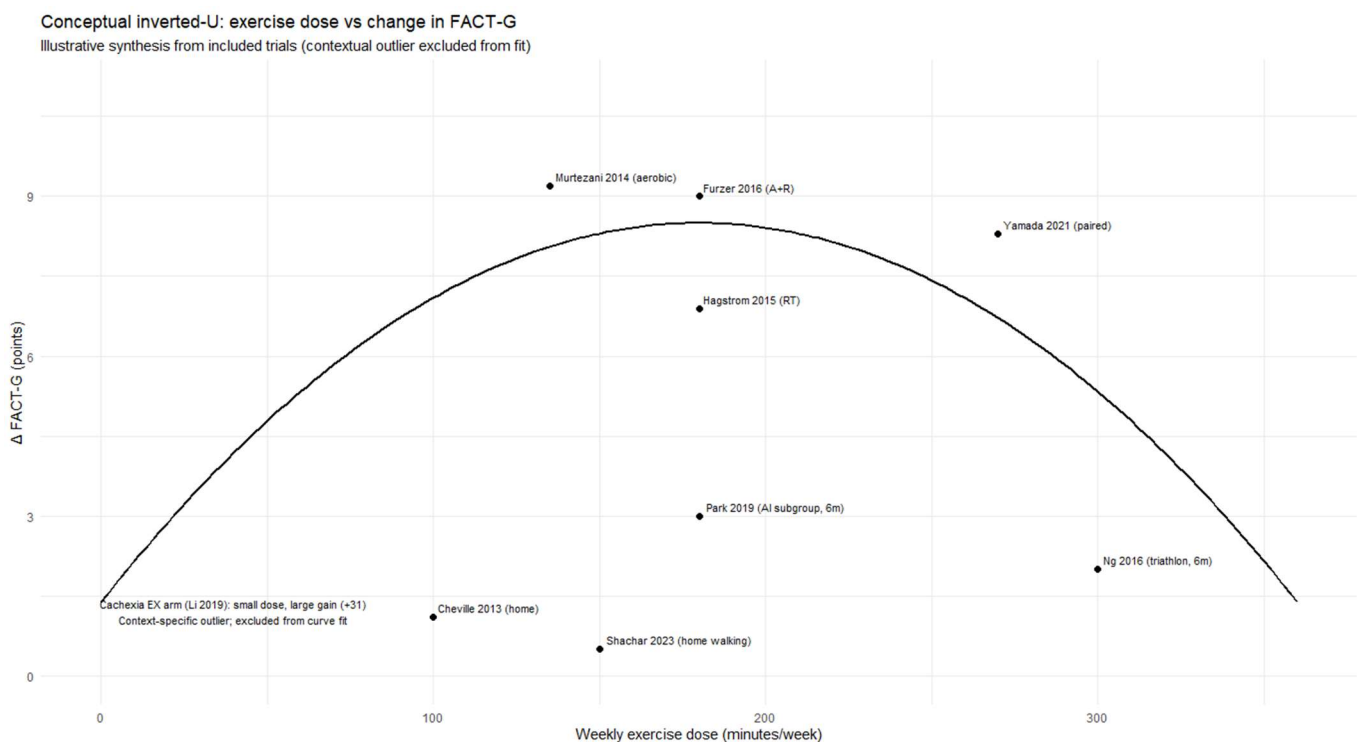


Figure 2. Conceptual inverted-U dose–response curve of weekly exercise dose and change in FACT-G scores among cancer patients. Moderate programs (between 120–180 min/week, 8–16 weeks) produced the strongest quality-of-life gains, while very low or prolonged unsupervised doses showed weaker effects.

Note: Representative studies are plotted for illustration. Li et al. [56] is a contextual outlier and excluded from curve fitting. Abbreviations: FACT-G, Functional Assessment of Cancer Therapy-General; MCID, minimal clinically important difference (3–7 points).

4.3. Dose–response analysis

When interventions were stratified by weekly exercise dose, a non-linear pattern emerged. Programs delivering 120–180 min per week over 8–16 weeks consistently

produced the strongest improvements [50,52,54,58]. Shorter interventions of <6 weeks yielded variable outcomes [60], while longer but unsupervised programs showed attenuated effects [55]. Li et al. [56] represented a contextual outlier, as low-dose resistance exercise in cachexia patients produced unusually large improvements (+31 points). The conceptual inverted-U relationship is illustrated in **Figure 2**.

4.4. Moderators of effectiveness

Several moderators shaped intervention outcomes. Breast and hematologic survivors demonstrated the most consistent gains [50,52,54,58]. Patients with advanced lung cancer or cachexia reported smaller but still clinically meaningful benefits [48,56,57]. Timing of intervention also mattered: during active treatment, exercise preserved quality of life [49,57], whereas in survivorship settings, greater absolute improvements were achieved [51,53]. Supervision was decisive, with supervised programs outperforming self-directed formats [52,54,58]. Digital and home-based approaches produced modest effects but revealed dose–response correlations between activity volume and quality-of-life outcomes [61].

5. Discussions

5.1. Principal findings

This meta-analysis demonstrates that exercise interventions across diverse cancer populations consistently improve or maintain quality of life as measured by the FACT-G. Among the fourteen eligible trials published between 2013 and 2023, the majority reported changes that exceeded the minimal clinically important difference, underscoring the therapeutic value of structured exercise in oncology. Notably, resistance training emerged as particularly effective in breast [52] and hematologic populations [54], while aerobic training alone also achieved clinically significant benefits [50]. Multimodal interventions such as Yamada et al. [58] and Foley et al. [51] reinforced that combining modalities and embedding social support can amplify improvements. In contrast, in advanced settings, exercise primarily preserved rather than enhanced quality of life [49,57], which is itself a clinically meaningful outcome in progressive disease.

5.2. Dose–response relationship

One of the most striking findings of this review is the consistent clustering of effective interventions around a weekly dose of approximately 180 min of structured exercise. Multiple randomized trials prescribing three 60-minute sessions per week—whether resistance [52], combined aerobic and resistance [54], or multimodal supervised formats [55,57] which reported significant and clinically meaningful gains in FACT-G. This convergence across populations and exercise types underscores 180 min per week as an empirically grounded benchmark for optimal benefit.

By contrast, programs prescribing lower weekly volumes (~120 min per week), such as Johnson [60], demonstrated more variable results, with some patients improving while others declined. At the opposite end of the spectrum, high-volume interventions exceeding 270 min per week [53,58] did not yield proportionally greater

gains, and in fact often failed to sustain improvements beyond the intervention period. These findings suggest a plateau, if not attenuation, of benefit at very high doses, consistent with the inverted-U trajectory conceptualized in **Figure 2**.

The only clear exception to this pattern was Li et al. [56], where a cachexia cohort achieved extraordinary improvements despite a low-dose resistance regimen. This outlier highlights the importance of clinical context: in highly symptomatic populations, even minimal exercise can produce outsized improvements by reversing severe deconditioning and mood disturbance.

Taken together, these results demonstrate that the dose–response relationship between exercise and quality of life in cancer patients is not linear but peaks around 180 min per week. This dose appears sufficient to stimulate physiological and psychosocial adaptation, while avoiding the adherence challenges and diminishing returns observed at higher volumes. Importantly, the consistency of this finding across cancer types, stages, and modalities strengthens its clinical applicability as a pragmatic prescription target.

5.3. Moderators of effectiveness

Several moderators influenced outcomes. Cancer types shaped responsiveness, with breast and hematologic populations demonstrating consistent improvements [50,52,54,58]. Advanced lung cancer and cachexia patients, by contrast, often experienced smaller absolute gains [48,56,57], but the prevention of deterioration in these fragile groups is clinically significant.

Treatment stage also mattered. During active therapy, interventions such as Clark et al. [49] and Quist et al. [57] maintained quality of life despite the physiological and psychological toll of chemotherapy or radiotherapy. In survivorship, larger absolute improvements were achieved, as demonstrated by Ng et al. [53] and Foley et al. [51]. These distinctions highlight the need to calibrate expectations: maintenance of quality of life may be the appropriate benchmark during treatment, while improvement is realistic in survivorship.

Delivery format was another decisive factor. Supervised and socially enriched interventions consistently outperformed home-based or digital formats [52,54,58]. Yamada et al. [58] elegantly demonstrated that pairing participants yielded superior emotional and global outcomes compared with individual training, pointing to the psychosocial synergy of shared exercise. Conversely, Shachar et al. [61] reported more modest improvements in digital or minimally supervised interventions, and found that higher step counts correlated with greater gains, suggesting that adherence intensity remains a determinant of benefit even in self-directed models.

5.4. Clinical implications

These findings establish exercise as more than a lifestyle recommendation; it is a therapeutic modality with dose-dependent efficacy. For clinicians, this underscores three practical principles. First, prescriptions should emphasize moderate, structured programs of 120–180 min per week over 8–16 weeks, which maximize the likelihood of clinically meaningful gains. Second, supervision and social engagement should be prioritized whenever feasible, whether through group classes, paired sessions, or

community-based models, as these consistently enhance adherence and outcomes. Third, clinicians should tailor goals to context: aiming to preserve quality of life in advanced disease while striving for improvement in survivorship.

The results also suggest that resource-efficient adaptations are possible. While digital and home-based programs yielded weaker effects, they nonetheless offer a platform for broad accessibility. Pairing such technologies with remote supervision or peer-support models could bridge the gap between efficacy and scalability.

5.5. Research implications

Despite the encouraging evidence, several gaps remain. Many trials were small, limiting generalizability. Adherence data were inconsistently reported, and long-term sustainability beyond the intervention period remains poorly understood. The attenuation of benefits after supervision [53,55] highlights the challenge of embedding exercise into durable survivorship care plans. Standardization of exercise dosing parameters and uniform reporting of FACT-G outcomes would enhance comparability across trials and facilitate pooled analyses.

Future research should also focus on precision exercise oncology. Identifying which subgroups by cancer type, treatment status, symptom burden, or psychosocial context which derive the greatest benefit from particular exercise modalities will allow for more individualized prescriptions. Moreover, mechanistic studies linking exercise dose to biological pathways, such as inflammation, fatigue, and resilience, may clarify why the inverted-U trajectory emerges and inform strategies to sustain benefits without overloading patients.

5.6. Limitations

The findings of this review must be interpreted in light of several limitations. The heterogeneity of exercise type, intensity, and delivery restricted the ability to generate pooled effect sizes with low heterogeneity. Publication bias cannot be excluded, as positive trials may be more likely to be published. Additionally, reliance on FACT-G as the primary endpoint, while advantageous for comparability, may not capture the full breadth of exercise benefits, particularly in domains such as physical fitness, sleep, or cognitive function. Finally, cultural and healthcare system differences across trials may limit generalizability, as community-based programs feasible in high-resource settings may not translate directly to lower-resource contexts.

6. Conclusions

This meta-analysis provides compelling evidence that structured exercise interventions exert clinically meaningful benefits on quality of life in cancer populations as measured by the FACT-G. Across fourteen trials conducted between 2013 and 2023, exercise was consistently safe, feasible, and effective, with the most reliable improvements observed in supervised programs delivering approximately 180 min per week over 8 to 16 weeks. These findings support a non-linear, inverted-U dose–response relationship: insufficient exposure produces limited benefit, while prolonged or high-volume regimens without supervision yield diminishing returns.

Importantly, in advanced disease contexts, exercise plays a crucial role in preserving quality of life, while in survivorship, larger improvements can be expected.

Taken together, these results affirm that exercise should not be viewed as an optional adjunct but as a therapeutic modality in oncology care. Prescriptions should prioritize moderate, supervised programs, ideally incorporating social support to enhance adherence and psychosocial benefit. Future research should refine these dose–response models, extend follow-up to determine sustainability, and explore tailored strategies for subgroups such as cachexia and advanced-stage disease. Integrating exercise into routine cancer management holds promise not only for improving survival but also for enhancing the lived experience of survivorship.

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