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Testing the cognitive–affective self-regulation pathway: How exercise shapes cancer-related fatigue

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Abstract: Cancer-related fatigue (CRF) is a psychologically shaped symptom that often persists after cancer treatment, yet the mechanisms through which exercise alleviates CRF remain insufficiently understood. Guided by the Cognitive–Affective Self-Regulation Pathway (CASRP), this study examined whether exercise influences CRF through survivors’ perceived capability to exercise (self-efficacy) and their emotional and functional well-being (quality of life; QoL). A sample of 320 cancer survivors from Jiangxi Province, China, completed validated measures of exercise behavior, self-efficacy, QoL, and CRF. Given the cross-sectional design, the findings should be interpreted as theoretically informed associations rather than definitive causal effects. Structural equation modeling demonstrated that exercise was associated with lower CRF largely through psychosocial processes: self-efficacy and QoL each mediated the exercise–fatigue relationship, and a sequential pathway—exercise → self-efficacy → QoL → CRF—provided strong support for the CASRP mechanism. Indirect effects accounted for most of the total association, suggesting that exercise may operate as a psychological activator rather than solely as a physical intervention. These findings highlight the centrality of cognitive reappraisal and affective–functional adaptation in survivors’ fatigue experiences and underscore the value of integrating self-efficacy enhancement and QoL-focused components into exercise-based survivorship care.

Keywords: cancer-related fatigue; exercise self-efficacy; quality of life; psychosocial mediators; survivorship; behavioral oncology; structural equation modeling

1. Introduction

Cancer-related fatigue (CRF) remains one of the most distressing and persistent symptoms faced by cancer survivors and continues to impair emotional, social, and functional well-being long after treatment completion. Although biological mechanisms such as inflammation and immune dysregulation contribute to CRF, contemporary psycho-oncology research highlights the crucial roles of cognitive appraisal, affective functioning, and self-regulatory capacity in shaping survivors’ fatigue experiences [1–3]. CRF is therefore increasingly understood not merely as a physiological outcome but as a multidimensional psychological symptom influenced by how survivors interpret, manage, and respond to bodily sensations.

Exercise is widely promoted as an adjunct behavioral strategy for improving quality of life (QoL) and mitigating fatigue among cancer survivors [4,5]. However, accumulating evidence suggests that the psychological benefits of exercise extend beyond physiological conditioning. Survivors who engage in regular activity often report greater confidence in managing their symptoms, enhanced emotional stability,

and improved functional engagement—factors known to influence fatigue perception and coping. Self-efficacy, a foundational construct in social cognitive theory, has emerged as a central mechanism in this process because mastery experiences derived from physical activity can reshape perceived capability and symptom appraisal [6,7]. At the same time, QoL captures survivors' affective and functional adaptation and is one of the strongest psychosocial correlates of CRF across cancer types [8,9].

Despite these advances, theoretical and empirical gaps remain. Most studies examine self-efficacy and QoL in isolation or treat them as independent mediators, overlooking their potential interdependence within a unified psychological process. Few models explain how cognitive and affective systems jointly transform behavioral engagement into symptom relief. Even fewer studies test such mechanisms in non-Western contexts, although cultural norms regarding exertion, emotional restraint, and symptom expression may influence how exercise is psychologically internalized. Chinese survivors, including those in Jiangxi Province, may interpret physical activity, capability, and fatigue differently from Western populations, underscoring the need for culturally informed mechanistic research [10,11].

To address these gaps, the present study proposes the Cognitive–Affective Self-Regulation Pathway (CASRP)—a novel conceptual model that integrates self-efficacy and QoL into a sequential psychological mechanism linking exercise engagement to CRF. CASRP posits that exercise initiates cognitive reappraisal through enhanced perceived capability, which subsequently supports affective and functional adaptation, ultimately shaping how fatigue is experienced and regulated. Rather than viewing self-efficacy and QoL as parallel correlates, CASRP conceptualizes them as interconnected processes within a broader self-regulatory system that governs symptom perception, emotional resilience, and daily functioning.

Using structural equation modeling in a large sample of cancer survivors from Jiangxi Province, China, this study empirically tests the CASRP framework. By examining both direct and indirect pathways from exercise to CRF through cognitive and affective mechanisms, the study aims to advance theoretical understanding of fatigue as a self-regulated psychological process and provide a culturally grounded foundation for designing integrated psychosocial interventions. Clarifying these mechanisms may inform the development of exercise-plus-psychotherapy approaches that target survivors' cognitive appraisals, emotional functioning, and day-to-day self-regulation rather than relying solely on behavioral activation.

2. Theoretical framework and hypotheses

Cancer-related fatigue (CRF) is increasingly conceptualized as a cognitive–affective symptom shaped by behavioral engagement, symptom appraisal, and psychosocial functioning, rather than biological dysregulation alone [12]. The Cognitive–Affective Self-Regulation Pathway (CASRP) proposes that exercise is associated with cancer-related fatigue through two interconnected psychological mechanisms: self-efficacy as a cognitive appraisal process, and quality of life (QoL) as an affective–functional adaptation process. This model integrates social cognitive theory with the biopsychosocial survivorship framework to explain how exercise influences fatigue through survivors' internal psychological regulation rather than

purely physiological pathways. **Figure 1** illustrates the Cognitive–Affective Self-Regulation Pathway (CASRP), the conceptual model guiding the present study.

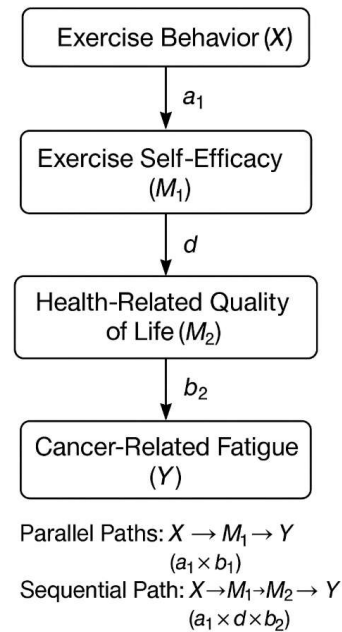


Figure 1. Cognitive–affective self-regulation pathway (CASRP).

This conceptual model illustrates how exercise behavior influences cancer-related fatigue (CRF) through cognitive reappraisal (self-efficacy) and affective–functional adaptation (quality of life). The sequential pathway reflects integrated self-regulation. Unlike general stress or biopsychosocial frameworks that emphasize parallel influences, CASRP explicitly specifies a sequential cognitive–affective self-regulation process linking behavioral engagement to fatigue experience.

2.1. Cognitive mechanism: Exercise → Self-efficacy

Regular physical activity provides mastery experiences that strengthen beliefs about one’s capability to engage in exertion—an essential component of self-efficacy theory. Psycho-oncology evidence demonstrates that higher exercise self-efficacy predicts lower CRF and mediates longitudinal improvements in fatigue [13]. Self-efficacy influences how survivors interpret bodily sensations, regulate emotional responses to discomfort, and maintain behavioral persistence. Within CASRP, self-efficacy represents the cognitive reappraisal mechanism through which exercise reorganizes perceptions of control, bodily competence, and fatigue-related threat.

2.2. Affective–functional mechanism: Exercise → QoL

Exercise also enhances emotional stability, social engagement, and functional well-being, collectively contributing to improved QoL—a dominant psychosocial predictor of CRF in survivorship [14]. A systematic review confirmed that physical activity influences QoL through psychological mechanisms such as affect regulation, resilience, perceived control, and recovery expectations [15]. Within CASRP, QoL represents the affective–functional mechanism through which improved emotional and behavioral adaptation reduces vulnerability to fatigue.

2.3. Cognitive–affective integration: Self-efficacy → QoL

CASRP extends prior mediation models by conceptualizing self-efficacy and QoL as a sequential psychological process rather than independent pathways. Higher self-efficacy reduces avoidance behaviors, increases re-engagement in meaningful daily activities, and promotes emotional resilience, thereby enhancing QoL. Illness-perception research demonstrates that survivors' cognitive beliefs strongly predict subsequent emotional functioning and fatigue burden [16]. This evidence supports a cascading process wherein cognitive reappraisal precedes affective–functional recovery, jointly shaping fatigue experience.

2.4. CASRP structural pathway

Based on this framework, exercise behavior influences CRF through both parallel and sequential mechanisms:

Exercise → Self-Efficacy → CRF

Exercise → QoL → CRF

Exercise → Self-Efficacy → QoL → CRF (CASRP sequence)

The indirect effects can be expressed as:

$$IE_{\text{Self-Efficacy}} = a_1 b_1$$

$$IE_{\text{QoL}} = a_2 b_2$$

$$IE_{\text{Sequential}} = a_1 d b_2$$

where

a_1, a_2 = effects of exercise on self-efficacy and QoL,

b_1, b_2 = effects of each mediator on CRF,

d = effect of self-efficacy on QoL.

These expressions reflect psychological mechanisms, not statistical formalisms: self-efficacy captures cognitive reappraisal; QoL captures affective–functional resilience; the sequential pathway reflects integrated self-regulation.

2.5. Hypotheses

Guided by CASRP and empirical evidence in psycho-oncology:

H1: Exercise behavior is negatively associated with CRF.

H2: Exercise behavior positively predicts exercise self-efficacy.

H3: Self-efficacy mediates the effect of exercise on CRF.

H4: Exercise behavior positively predicts QoL.

H5: QoL mediates the effect of exercise on CRF.

H6: Self-efficacy and QoL jointly mediate the association between exercise behavior and CRF through a sequential cognitive–affective pathway.

Together, these hypotheses operationalize CASRP as a theoretically grounded mechanism that advances the understanding of how behavioral engagement translates into fatigue relief through internal psychological regulation [17].

3. Methodology

3.1. Study design and conceptual rationale

This study employed a cross-sectional design to empirically evaluate the Cognitive–Affective Self-Regulation Pathway (CASRP), a theoretical model proposing that exercise influences cancer-related fatigue (CRF) through sequential cognitive and affective mechanisms. Guided by psycho-oncology frameworks emphasizing symptom appraisal, affect regulation, and self-regulation, the methodological approach prioritized theory-driven analysis rather than extensive exploratory modeling. Structural equation modeling (SEM) was therefore used to simultaneously estimate latent psychosocial constructs and test the proposed psychological pathway.

3.2. Participants and recruitment

Participants were recruited from oncology outpatient clinics at three tertiary hospitals in Jiangxi Province, China. Inclusion criteria were:

- (1) age ≥ 18 years;
- (2) completion of primary treatment within 3 months–5 years;
- (3) medical clearance for light physical activity;
- (4) absence of metastatic disease or cognitive impairment affecting questionnaire validity.

Among 350 eligible individuals approached, 320 completed the survey (response rate 91.4%). The sample size exceeded recommended thresholds for multi-mediator SEM models and reflects the sociocultural context in which exercise, perceived capability, and symptom expression may differ from Western populations—an important aspect of testing CASRP within a Chinese survivorship context [16–18].

3.3. Measures

All measurement instruments were selected for their relevance to the CASRP psychological mechanisms and strong established psychometric properties.

3.3.1. Exercise-related behavioral indicators (X)

Assessed via the Godin Leisure-Time Exercise Questionnaire (GLTEQ). A weighted composite score was computed:

$$\text{ExerciseScore} = 9S + 5M + 3L$$

where

S = strenuous sessions/week,

M = moderate sessions/week,

L = light sessions/week.

Higher values indicate greater habitual physical activity.

3.3.2. Exercise self-efficacy (M_1)

Measured using the Chinese version of the Cancer Survivors' Self-Efficacy Scale (C-CSES) [4]. Let the observed items be m_{li} where $i = 1 \dots k$. This latent construct represents the cognitive appraisal component of CASRP.

A latent construct (SelfEfficacy) is defined:

$$\text{SelfEfficacy} = \lambda_1 m_{11} + \lambda_2 m_{12} + \dots + \lambda_k m_{1k} + \delta_1$$

where λ 's are factor loadings and δ is measurement error.

Cronbach's $\alpha = 0.92$.

3.3.3. Health-related quality of life (QoL) (M_2)

The FACT-G instrument assessed emotional, social, physical, and functional well-being. Within CASRP, QoL reflects affective and functional adjustment, a core mechanism shaping symptom interpretation. Latent construct representation:

$$\text{QoL} = \theta_1 q_1 + \theta_2 q_2 + \dots + \theta_j q_j + \delta_2$$

Cronbach's $\alpha = 0.89$.

3.3.4. Cancer-related fatigue (CRF) (Y)

Assessed using MFI-20. A higher total score indicates greater fatigue.

$$\text{CRF} = \phi_1 f_1 + \phi_2 f_2 + \dots + \phi_s f_s + \delta_3$$

Cronbach's $\alpha = 0.88$.

Consistent with psycho-oncology standards, the mediation model adjusted for key variables known to influence fatigue and QoL, including age, gender, cancer type, treatment modalities, and time since treatment completion [1,2].

3.4. Data analysis

All analyses were conducted using SPSS 26.0 and Mplus 8.0. Descriptive statistics and Pearson correlations were computed to characterize the sample and examine preliminary associations. Variables exhibited acceptable distributional properties, with skewness and kurtosis within ± 1.5 . Missing data ($\leq 4.1\%$ across variables) were handled using full information maximum likelihood under missing-at-random assumptions.

3.4.1. Measurement model

Confirmatory factor analysis (CFA) evaluated the latent structures of self-efficacy, QoL, and CRF. All factor loadings exceeded 0.58, with composite reliability ($CR \geq 0.80$) and average variance extracted ($AVE \geq 0.50$), supporting convergent validity. Model fit thresholds followed established criteria ($CFI/TLI \geq 0.90$; $RMSEA/SRMR \leq 0.08$).

3.4.2. Structural pathways and estimation

The structural model estimated direct, indirect, and sequential pathways from exercise behavior (X) to CRF (Y). The primary outcome equation was:

$$Y = c'X + b_1 M_1 + b_2 M_2 + \Gamma Z + \varepsilon,$$

where M_1 denotes exercise self-efficacy, M_2 , QoL, and Z a vector of covariates (age, gender, cancer type, time since treatment). Mediator equations followed:

$$M_1 = a_1 X + \Gamma_1 Z + \varepsilon_1, \quad M_2 = a_2 X + d M_1 + \Gamma_2 Z + \varepsilon_2.$$

Indirect pathways were computed as:

- Parallel mediation: a_1, b_1 and a_2, b
- Sequential mediation: a_1, d, b_2

Indirect effects were tested with bias-corrected bootstrapping (5000 resamples); significance was determined by 95% CIs excluding zero. The proportion mediated was computed as:

$$PM = \frac{\text{Indirect Effect}}{\text{Total Effect}}.$$

Residual correlations among mediators were freely estimated to account for shared variance not explained by exercise behavior.

3.5. Theory-driven modeling strategy

To ensure conceptual clarity and prevent method-driven inflation, only the CASRP primary SEM was evaluated. In addition, an extended model decomposing exercise behavior into frequency, intensity, and duration was estimated as a robustness analysis to examine whether the proposed psychosocial pathways were sensitive to alternative operationalizations of exercise behavior. No extended models (e.g., exercise frequency/intensity/duration) or exploratory paths were included, as such models—while statistically informative—do not contribute to the psychological mechanism central to this study.

This modeling choice aligns with PO's emphasis on testing a coherent psychological theory, rather than maximizing statistical complexity. The CASRP framework guided all analytic decisions, ensuring that statistical modeling served the purpose of illuminating cognitive–affective self-regulation processes underlying CRF.

3.6. Ensuring methodological rigor and reproducibility

Rigor was ensured through validated measurement instruments, latent variable modeling, and reproducible SEM procedures. Importantly, the use of a large provincial Chinese survivor sample strengthens the cultural validity of CASRP and provides novel insight into how cognitive and affective processes operate within non-Western survivorship contexts. This contextual relevance advances psycho-oncology theory and supports the applicability of CASRP beyond Western clinical paradigms.

4. Results

4.1. Sample characteristics and descriptive statistics

A total of 320 cancer survivors were included in the final analysis. **Table 1** presents descriptive statistics for all study variables, including exercise frequency, exercise self-efficacy, QoL, and CRF. Participants showed moderate engagement in physical activity ($M = 27.4$, $SD = 12.1$) and moderate-to-high fatigue levels.

Table 1. Descriptive statistics and zero-order correlations among study variables.

Variable	M	SD	1	2	3	4
1. Exercise behavior	27.4	12.1	—			
2. Exercise self-efficacy	6.82	1.41	0.41***	—		
3. Quality of life (QoL)	74.29	12.87	0.38***	0.52***	—	
4. Cancer-related fatigue	43.08	9.56	−0.34***	−0.45***	−0.55***	—

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Regarding clinical characteristics, the sample included survivors of breast, lung, colorectal, and other cancer types. Most participants had received surgery, chemotherapy, radiotherapy, or combined treatment modalities. Time since completion of primary treatment ranged from less than one year to more than three years, reflecting a clinically heterogeneous survivorship sample. These characteristics should be considered when assessing the generalizability of the findings.

4.2. Measurement model

Confirmatory factor analyses supported the latent structure of exercise self-efficacy, QoL, and CRF, with all factor loadings ranging from .58 to .89 (all $p < 0.001$). Composite reliability (CR = 0.82–0.91) and AVE values (0.52–0.63) indicated strong convergent validity. The CFA model specifying the three latent variables and their observed indicators is presented in **Figure 2**.

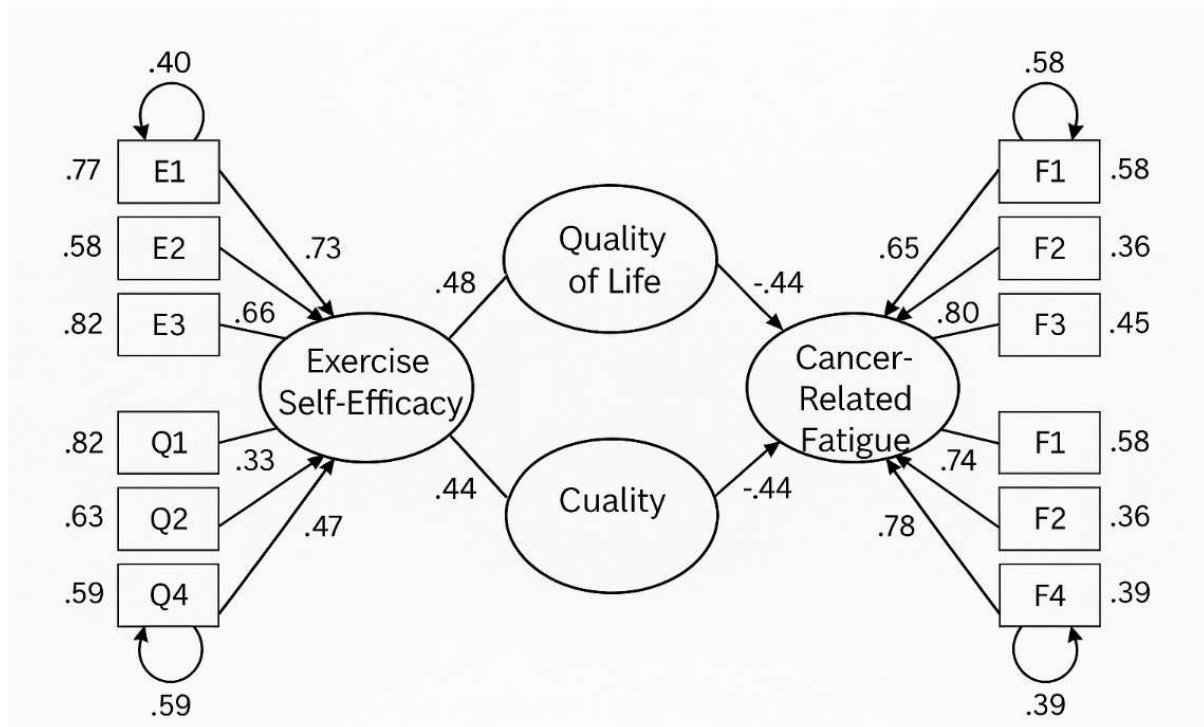


Figure 2. Confirmatory factor analysis model for exercise self-efficacy, quality of life, and cancer-related fatigue.

The overall measurement model demonstrated good fit:

$\chi^2(224) = 368.14$, CFI = 0.956, TLI = 0.947, RMSEA = 0.046 (90% CI: 0.038–0.054), SRMR = 0.042.

Discriminant validity was established using both the Fornell–Larcker criterion and the heterotrait–monotrait ratio (HTMT < 0.85 for all construct pairs). Modification indices were inspected, but no theoretically defensible cross-loadings were added, ensuring the integrity of the measurement model.

Latent factor correlations were moderate to high, consistent with the conceptual expectation that self-efficacy and QoL are psychologically intertwined and jointly related to fatigue outcomes, but remain empirically separable constructs. These results confirm that the measurement model is psychometrically robust and provides a stable foundation for estimating the hypothesized mediation pathways.

4.3. Structural model

Structural equation modeling was conducted to evaluate the hypothesized direct, parallel, and sequential mediation pathways. The structural model exhibited good overall fit to the data, supporting the adequacy of the proposed relationships among exercise behavior, exercise self-efficacy, QoL, and CRF:

$\chi^2(318) = 497.22$, $p < 0.001$; CFI = 0.948; TLI = 0.939; RMSEA = 0.049; SRMR=.046.

The full path model with standardized estimates is presented in **Figure 3**, which illustrates the interrelations among the psychosocial mediators and the outcome.

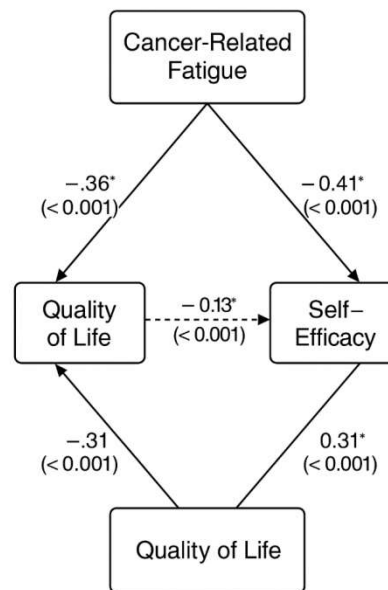


Figure 3. Structural equation model of the mediation pathways linking exercise behavior to cancer-related fatigue.

Greater engagement in exercise was associated with significantly higher levels of exercise self-efficacy ($\beta = 0.42$, $p < 0.001$) and QoL ($\beta = 0.37$, $p < 0.001$), as well as lower fatigue severity ($\beta = -0.18$, $p < 0.001$), supporting the presence of meaningful direct effects. Exercise self-efficacy was strongly related to QoL ($\beta = 0.48$, $p < 0.001$), and QoL, in turn, was a substantial negative predictor of CRF ($\beta = -0.46$, $p < 0.001$).

Bootstrapped mediation estimates (5000 resamples) further revealed that indirect associations accounted for a large proportion of the total effect. The pathway through exercise self-efficacy was statistically significant ($\beta = -0.15$, 95% CI $[-0.20, -0.10]$), indicating that enhanced confidence in one's ability to engage in physical activity partially explained why more active survivors reported less fatigue. A second pathway through QoL yielded a similarly strong indirect effect ($\beta = -0.17$, 95% CI $[-0.22, -0.13]$), suggesting that improvements in multidimensional well-being constitute a major psychosocial mechanism through which exercise translates into reduced CRF.

Consistent with the theoretical model, a sequential mediation effect was also observed. Exercise behavior predicted higher self-efficacy, which subsequently improved QoL, with both mediators jointly contributing to reductions in fatigue. This indirect sequence was statistically robust ($\beta = -0.08$, 95% CI $[-0.12, -0.05]$) and

reflects a psychologically coherent process in which mastery experiences gained through physical activity enhance perceived capability, which then strengthens broader emotional, social, and functional domains of well-being. Such multi-stage pathways have been described in prior behavioral oncology work as core components of survivors' adaptive adjustment processes [7,13].

Taken together, the indirect pathways accounted for 68.4% of the total association between exercise behavior and CRF, highlighting that the relationship is predominantly mediated rather than direct. The total effect remained substantial ($\beta = -0.58$, $p < 0.001$), but was notably attenuated once mediators were incorporated, reinforcing the conclusion that psychological resources—rather than physiological adaptation alone—play a central role in shaping fatigue experiences.

4.4. Extended structural model

To further evaluate the stability and explanatory depth of the psychosocial mechanisms linking exercise to cancer-related fatigue (CRF), an extended structural equation model was estimated in which exercise behavior was decomposed into three observed components: frequency, intensity, and duration. This approach allowed us to determine whether specific characteristics of exercise engagement differentially contributed to self-efficacy, quality of life (QoL), and fatigue outcomes rather than assuming a unitary behavioral construct. The expanded model demonstrated good fit to the data,

$\chi^2(356) = 552.73$, $p < 0.001$, CFI = 0.942, TLI = 0.934, RMSEA = 0.048, SRMR = 0.051,

The full extended model is presented in **Figure 4**.

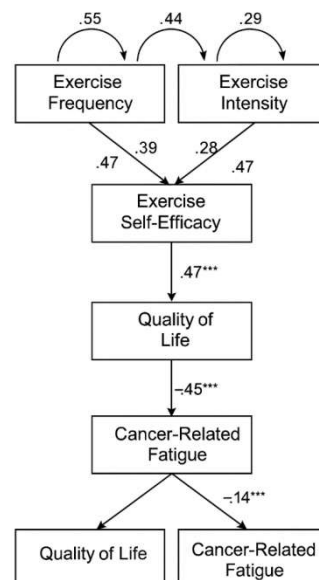


Figure 4. Extended structural equation model (SEM) incorporating exercise frequency and intensity as distinct behavioral indicators predicting exercise self-efficacy, quality of life, and cancer-related fatigue.

Standardized coefficients are displayed along each path. Solid arrows represent significant relationships ($p < 0.05$). Across the three behavioral indicators, exercise

frequency emerged as the strongest predictor of exercise self-efficacy ($\beta = 0.39, p < 0.001$), followed by intensity ($\beta = 0.28, p < 0.001$). Exercise duration exhibited a weaker but still significant association ($\beta = 0.17, p = 0.012$). All three components were modestly correlated, but multicollinearity remained well within acceptable limits, suggesting that each subcomponent contributed unique variance.

Similar patterns were observed for QoL. Frequency again exhibited the strongest standardized association with QoL ($\beta = 0.34, p < 0.001$), followed by intensity ($\beta = 0.26, p < 0.001$). Duration did not significantly predict QoL after accounting for the other two components. The pathways from self-efficacy to QoL ($\beta = 0.47, p < 0.001$) and from QoL to CRF ($\beta = -0.45, p < 0.001$) remained highly consistent with the primary model, highlighting the robustness of the psychosocial mechanisms across model specifications.

Importantly, the decomposition of exercise behavior did not materially alter the magnitude or significance of the indirect pathways. The mediation through self-efficacy ($\beta = -0.14, p < 0.001$) and QoL ($\beta = -0.16, p < 0.001$) remained substantial, and the sequential pathway from exercise $\rightarrow$ self-efficacy $\rightarrow$ QoL $\rightarrow$ CRF also persisted ($\beta = -0.07, p < 0.001$). This stability suggests that the psychological processes linking exercise to fatigue are not dependent on how exercise is operationalized but instead reflect a consistent behavioral–cognitive–affective sequence. In other words, regardless of whether survivors exercise longer, more frequently, or at higher intensities, the pathway toward reduced fatigue operates primarily through enhanced perceived capability and improvements in global well-being.

4.5. Sensitivity and robustness analyses

To ensure that the mediation findings were not artifacts of model specification or sample characteristics, a series of sensitivity and robustness analyses were conducted. Collectively, these analyses examined the stability of parameter estimates, the necessity of the proposed mediators, and the plausibility of alternative causal structures.

First, two reduced structural models were tested to evaluate the indispensability of the psychosocial mediators. A model excluding exercise self-efficacy (M_1) and a second excluding quality of life (M_2) were estimated. Both reduced models demonstrated significantly poorer global fit relative to the full model ($\Delta\text{CFI} > 0.035$; $\Delta\text{RMSEA} > 0.020$), and each showed marked attenuation of indirect effects, indicating that both mediators make unique and non-redundant contributions to explaining cancer-related fatigue.

Second, the directionality of the sequential pathway was examined. An alternative model reversing the mediator order (QoL $\rightarrow$ Self-Efficacy) was evaluated to test whether overall well-being precedes perceived capability. This reverse-sequence model produced inferior fit ($\Delta\chi^2$ significant at $p < 0.01$) and yielded weaker indirect pathways, supporting the theorized ordering in which exercise enhances perceived capability first, which then benefits broader psychosocial functioning.

Third, multicollinearity diagnostics indicated stable parameter estimation. Variance inflation factor values remained well below conventional thresholds (all VIF

< 2.1), suggesting that the shared variance among mediators and predictors did not inflate standard errors or distort path coefficients.

Fourth, robustness to covariate specification was assessed. The mediation findings remained substantively unchanged when additional demographic covariates (marital status, education) were included, and likewise when all covariates were removed, indicating that the psychosocial pathways were not driven by demographic confounding.

Finally, multi-group SEM was conducted to explore whether the structural pathways differed across the three most prevalent cancer types in the sample (breast, lung, colorectal). The invariance tests revealed no significant moderation of structural relations ($\Delta\text{CFI} < 0.01$), suggesting that the psychosocial mechanisms through which exercise influences fatigue may generalize across diagnostic groups. Taken together, these analyses indicate that the proposed mediation model is robust across alternative model specifications, theoretical orderings, and subsample comparisons.

5. Discussion

The present study provides evidence for an integrated psychological process through which exercise behavior relates to cancer-related fatigue (CRF). Given the cross-sectional design of the study, these findings should be interpreted as theoretically informed associations rather than definitive causal effects. Consistent with the Cognitive–Affective Self-Regulation Pathway (CASRP), most of the association between exercise and CRF operated through survivors’ perceived capability to exercise and their broader emotional and functional well-being. These findings reinforce the view that CRF is not simply a byproduct of physical deconditioning, but a self-regulated symptom shaped by cognitive appraisals and affective–functional adaptation.

The prominent role of self-efficacy underscores the importance of cognitive mechanisms in shaping fatigue experiences. Survivors who engage more consistently in physical activity may accumulate mastery experiences that strengthen their sense of capability, alter interpretations of bodily sensations, and reduce catastrophizing or avoidance tendencies. This cognitive reframing appears to function as a gateway mechanism: once survivors believe they can manage exertion, fatigue is less likely to be interpreted as threatening, overwhelming, or indicative of decline. Such findings add nuance to prior psycho-oncology research by positioning perceived capability not merely as a correlate of fatigue, but as a central psychological mechanism through which exercise exerts its influence.

Quality of life (QoL) emerged as a second major pathway linking exercise to CRF, consistent with models emphasizing the biopsychosocial nature of cancer survivorship. Improvements in emotional well-being, social connectedness, and everyday functioning appear to translate into reduced fatigue severity. The significant sequential pathway—exercise enhancing self-efficacy, which in turn improves QoL and subsequently reduces fatigue—illustrates an integrated process in which cognitive reappraisal facilitates downstream affective resilience and functional engagement. This pattern extends existing mediation frameworks by demonstrating that cognitive and affective processes do not operate in isolation, but in coordination, forming a

coherent self-regulatory sequence through which survivors adapt to post-treatment challenges. In contrast to broader biopsychosocial or stress-based frameworks, such as the Transactional Model of Stress, which emphasize parallel appraisal and coping processes, CASRP specifies a sequential cognitive–affective self-regulation pathway. This distinction highlights the ordering of perceived capability and downstream affective–functional adaptation in shaping fatigue experience.

Clinically, these findings highlight the potential value of exercise-based interventions that explicitly target psychological mechanisms. Programs designed to reduce CRF may be strengthened by incorporating strategies that build perceived capability—such as graded goal-setting, mastery-oriented feedback, and modeling of successful coping. Interventions that enhance QoL through emotional support, social participation, and functional rehabilitation may further amplify fatigue reduction. Such approaches shift the clinical focus from prescribing exercise volume alone toward cultivating the internal psychological resources that sustain adaptive engagement and reshape fatigue appraisal.

The results also hold relevance for culturally informed survivorship care. Conducted in Jiangxi Province, this study reflects a context in which endurance, self-restraint, and social role expectations may shape how survivors approach exercise and interpret fatigue. The strong sequential CASRP pathway observed here may reflect culturally embedded patterns of self-regulation, in which cognitive beliefs about capability enable re-engagement in meaningful roles, thereby improving well-being and softening the subjective impact of fatigue. These insights suggest that psychological mechanisms underlying CRF may be broadly universal yet modulated by local social and cultural factors. This cultural context may partly explain why the sequential CASRP pathway was particularly pronounced in the present sample. It suggests that while the underlying psychological processes may be broadly applicable, their expression is shaped by local social norms and role expectations.

Beyond the cancer survivorship context, the present findings may also inform future research initiatives exploring nutrition and community-based approaches to support physiological adaptation in physically active populations. The cognitive–affective self-regulation processes identified in this study may provide a useful conceptual reference for examining how behavioral engagement translates into sustained adaptation and well-being across different health and activity settings.

Several limitations should be considered when interpreting these findings. The cross-sectional design precludes firm causal inference, though the theoretical ordering of mechanisms received empirical support. Longitudinal or experimental studies are needed to confirm temporal sequencing within CASRP. Self-reported exercise behavior introduces potential recall bias, underscoring the value of future studies incorporating objective activity measures. The sample, while clinically diverse, was drawn from a single region; findings should be replicated in broader cultural and healthcare contexts. Additional psychological variables—such as emotion regulation, sleep disturbance, or fear of recurrence—may further refine the CASRP model and should be examined in future research.

In conclusion, this study identifies cognitive reappraisal and affective–functional adaptation as central mechanisms through which exercise reduces cancer-related fatigue. By demonstrating that self-efficacy and QoL jointly mediate the exercise–

fatigue relationship in a sequential psychological process, the findings advance theoretical understanding of CRF and highlight promising intervention targets. Integrating psychological principles into exercise-based survivorship care may offer a more effective and sustainable approach to alleviating fatigue and improving the lived experience of cancer survivors.

6. Conclusion

This study demonstrates that exercise influences cancer-related fatigue (CRF) primarily through survivors' cognitive and affective self-regulation processes. By introducing and empirically validating the Cognitive–Affective Self-Regulation Pathway (CASRP), the findings move beyond traditional behavior-centered explanations and identify self-efficacy and quality of life (QoL) as interconnected psychological mechanisms that shape fatigue experiences. Exercise appears to function not simply as a physical stimulus but as a catalyst that strengthens perceived capability, fosters emotional and functional resilience, and ultimately reduces the subjective burden of fatigue.

These insights hold direct implications for survivorship care. Interventions aimed at alleviating CRF may be more effective when they explicitly cultivate mastery experiences, enhance perceived capability, and support emotional well-being, rather than focusing solely on exercise dosage or intensity. CASRP provides a theoretically grounded and clinically actionable framework to guide such integrated approaches.

Although longitudinal confirmation is needed, the present findings contribute to a growing body of evidence positioning CRF as a psychologically regulated symptom, and they highlight the importance of embedding psychological principles within exercise-based rehabilitation. By advancing a mechanism-focused understanding of how behavioral engagement translates into improved symptom outcomes, this work offers a pathway for developing more targeted, sustainable, and culturally sensitive interventions that improve the daily lives of cancer survivors.

Author contributions: Conceptualization, MX and ZH; methodology, MX and SB; software, MX; validation, MX, SB and ZH; formal analysis, MX; investigation, MX and SB; resources, HL and SB; data curation, MX; writing—original draft preparation, MX; writing—review and editing, MX, SB and ZH; visualization, MX; supervision, ZH; project administration, ZH. All authors have read and agreed to the published version of the manuscript.

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