

Article

Group-based aerobic exercise and psychological resilience in female cancer survivors: A randomized controlled trial

Bei Guan¹, Xiaojie Guo^{2,*}¹ Department of Physical Education, Baotou Vocational and Technical College of Light Industry, Baotou 014035, China² Information Engineering Department, Baotou Vocational and Technical College of Light Industry, Baotou 014035, China* Corresponding author: Xiaojie Guo, xyzxo@163.com

CITATION

Guan B, Guo X. Group-based aerobic exercise and psychological resilience in female cancer survivors: A randomized controlled trial. *Psycho-Oncologie*. 2026; 20(2): 5472. <https://doi.org/10.18282/po5472>

ARTICLE INFO

Received: 16 September 2025

Revised: 20 January 2026

Accepted: 9 February 2026

Available online: 25 February 2026

COPYRIGHT



Copyright © 2026 by author(s).

Psycho-Oncologie is published by PiscoMed Publishing Pte Ltd. This work is licensed under the Creative Commons Attribution (CC BY) license.

<https://creativecommons.org/licenses/by/4.0/>

Abstract: Background: Female cancer survivors often experience persistent psychological distress and social functioning impairments. This study evaluated the efficacy of a group-based aerobic fitness program for enhancing psychological resilience and social functioning in this population. Methods: A stratified randomized controlled trial enrolled 128 female cancer survivors (aged 18–65 years) who completed primary treatment within 3 years. Participants were randomly allocated to either a 12-week group-based aerobic fitness program ($n = 64$) or a control group ($n = 64$) receiving comprehensive educational materials and structured contact. Primary outcomes included psychological resilience (CD-RISC-25) and social functioning (MOS-SSS, EORTC QLQ-C30), assessed by blinded evaluators at baseline, post-intervention, and 24-week follow-up. Analysis employed mixed-effects linear modeling with Benjamini-Hochberg correction for multiple comparisons. Results: The intervention group demonstrated significant improvements in psychological resilience (mean change: 12.6 points vs. 1.2 points in controls, $P < 0.001$, $d = 0.89$) and social functioning (14.8 points vs. 2.3 points, $P < 0.001$). Enhanced social functioning mediated 42% of the intervention effect on resilience, with benefits maintained at follow-up. Greater improvements were observed in breast cancer survivors, those 6–12 months post-treatment, and participants with higher attendance rates. Conclusion: A structured group-based aerobic fitness program significantly enhances and maintains psychological resilience and social functioning among female cancer survivors, supporting the integration of group exercise into standard survivorship care.

Keywords: cancer survivorship; psychological resilience; social functioning; group-based exercise; aerobic fitness; psychosocial intervention

1. Introduction

Cancer survivorship presents unique challenges for women, with evidence indicating that female cancer survivors often experience psychological distress, diminished quality of life, and impaired social functioning that persist long after treatment completion [1,2]. According to the GLOBOCAN 2022 estimates, female patients accounted for approximately 48% of all newly diagnosed cancer cases worldwide, with breast, gynecological, and colorectal malignancies representing the most prevalent cancer types among women, each of which is associated with substantial physical and psychosocial sequelae [3]. Mehnert et al. reported that over half of cancer patients experience clinically significant psychological distress, with female survivors and those with limited social support networks demonstrating particularly elevated rates [4]. Psychological resilience, defined as the capacity to adapt positively in the face of adversity, has emerged as a critical factor in cancer recovery, with systematic review evidence demonstrating that higher resilience is

significantly associated with improved quality of life, reduced depressive symptomatology, and more favorable health outcomes among cancer populations [5,6].

Social functioning, encompassing the ability to maintain relationships and engage in meaningful social activities, represents another domain significantly affected by cancer diagnosis and treatment. Social isolation and relationship difficulties are prevalent among female cancer survivors; a nationally representative survey of cancer survivors in the United States reported that an estimated 35.9% experienced moderate to severe loneliness [7], while a systematic review identified that treatment-induced physical changes, cognitive impairments, and prolonged medicalization of life progressively erode social participation and community connections well beyond the active treatment phase [8]. These difficulties are often compounded by treatment-specific challenges such as sexual dysfunction, premature menopause, and altered body image that may uniquely impact female survivors. The interrelationship between psychological resilience and social functioning has been established in recent literature, with evidence suggesting that interventions targeting one domain may yield improvements in the other [9]. Comprehensive approaches addressing both psychological resilience and social functioning may therefore represent an optimal strategy for enhancing overall well-being in this population.

Despite growing recognition of these challenges, significant gaps persist in the intervention literature. Pharmacological agents, while effective for managing discrete psychiatric symptoms such as clinical depression and anxiety, have demonstrated limited capacity to address the broader psychosocial sequelae of cancer survivorship—including diminished social participation, impaired role functioning, and erosion of self-identity—which has prompted increased clinical and research interest in non-pharmacological complementary approaches [10,11]. Exercise interventions have demonstrated promising results for cancer survivors, yet research examining group-based aerobic fitness programs specifically targeting psychological resilience and social functioning remains sparse despite their potential to simultaneously address multiple survivorship domains. Buffart et al. [12] conducted an individual patient data meta-analysis of 34 randomized controlled trials involving 4519 cancer patients, finding that exercise interventions significantly improved quality of life and physical function, with supervised group-based programs demonstrating significantly larger effect sizes than unsupervised individual approaches. The unique mechanisms through which group-based aerobic fitness programs may confer benefits for female cancer survivors warrant further investigation, particularly regarding the potential synergistic effects of physical activity, social support, and group dynamics on psychological resilience and social functioning [13,14].

Accordingly, the present study aimed to evaluate the effects of a 12-week structured group-based aerobic fitness program on psychological resilience and social functioning among female cancer survivors, thereby addressing the aforementioned gaps in the exercise oncology literature. The primary objective was to determine whether participation in supervised tri-weekly group aerobic sessions could yield clinically meaningful improvements in psychological resilience as measured by the CD-RISC-25, while secondary objectives encompassed the assessment of intervention effects on social functioning and the exploration of potential mediating pathways

linking social functioning improvements to resilience gains. Based on the existing evidence, it was hypothesized that the intervention group would demonstrate significantly greater improvements in psychological resilience compared to control participants receiving standard educational materials [15], that the group-based format would enhance social functioning—including social engagement, perceived social support, and relationship quality—beyond the effects attributable to physical activity alone [16], that improvements in psychological resilience would positively correlate with enhancements in social functioning [17], and that the group-based delivery modality would confer additional psychosocial benefits through peer support and shared experience relative to individually administered exercise interventions [18].

This research will contribute to the field through multiple important pathways that address current gaps in cancer survivorship care. While exercise interventions have demonstrated positive effects on cancer survivors' physical and psychological health [19], research specifically targeting psychological resilience and social functioning in female cancer survivors remains limited; this study will provide evidence regarding the relative efficacy of group interventions compared to individual interventions in promoting psychosocial rehabilitation among cancer survivors. By exploring the relationship between psychological resilience and social functioning, this research will deepen understanding of how these two psychosocial constructs interact, providing theoretical foundations for developing comprehensive intervention strategies for healthcare professionals to develop more effective rehabilitation programs that address the specific psychosocial needs of female cancer survivors, ultimately improving their overall quality of life and long-term health outcomes [20].

2. Methods

2.1. Study design

This study employed a randomized controlled trial design to evaluate the effects of a group-based aerobic fitness program on psychological resilience and social functioning among female cancer survivors. The randomized controlled trial methodology was selected due to its robust capacity to establish causal relationships between the intervention and outcomes while minimizing potential bias through random assignment [21]. Participants were randomly allocated to either the intervention group receiving a 12-week structured group-based aerobic fitness program or a control group receiving standard care with general physical activity recommendations. Randomization was performed using a computer-generated sequence with stratification by cancer type (breast, gynecological, colorectal, and other) and time since treatment completion (6–12 months, 13–24 months, and 25–36 months) to ensure comparable groups at baseline. Allocation concealment was maintained using sequentially numbered, opaque, sealed envelopes that were opened only after participants completed baseline assessments. The randomization process was conducted by a research team member not involved in participant recruitment or outcome assessment. The timeline of the study encompassed three distinct phases: a two-week recruitment and baseline assessment period where participants underwent comprehensive evaluations of psychological resilience, social functioning, and physiological parameters; the 12-week intervention period during which the exercise

program was implemented with tri-weekly 60-min sessions for the intervention group; and a follow-up phase with assessments conducted immediately post-intervention and at 3 months to evaluate the maintenance of outcomes, allowing for assessment of both immediate and sustained effects as research indicates the importance of evaluating long-term adherence and benefits of exercise interventions in cancer populations [22,23].

2.2. Participants

Female cancer survivors aged 18–65 years who have completed primary treatment (surgery, chemotherapy, and/or radiotherapy) at least 6 months prior but within 3 years were eligible for participation in this study. Additional inclusion criteria comprised medical clearance for exercise participation obtained from the attending oncologist, the ability to attend scheduled group sessions at the designated facility, and the absence of diagnosed severe psychiatric disorders (e.g., active psychosis, severe major depressive disorder with suicidal ideation) or documented cognitive impairments that would preclude comprehension of the intervention components and adherence to study protocols, as determined by clinical assessment during the screening process [24]. Exclusion criteria included the presence of metastatic or recurrent disease, scheduled cancer-related surgery during the study period, clinically unstable cardiovascular conditions (e.g., uncontrolled hypertension, symptomatic heart failure), uncontrolled lymphedema requiring intensive decongestive therapy, and severe orthopedic limitations—operationally defined as musculoskeletal conditions that substantially restricted weight-bearing mobility or range of motion necessary for aerobic exercise participation, including but not limited to advanced degenerative joint disease, unhealed fractures, or spinal pathologies requiring surgical consultation—as evaluated by the referring physician prior to enrollment. A convenience sampling strategy was employed, whereby participants were recruited through oncology outpatient departments of three collaborating tertiary hospitals, regional cancer support organizations, and social media platforms targeting cancer survivorship communities, with attending oncologists conducting preliminary eligibility screening based on predefined inclusion and exclusion criteria prior to formal enrollment [25]. Sample size calculation was performed using G*Power software (version 3.1.9.7). The anticipated effect size of $d = 0.50$ for psychological resilience outcomes was based on a recent meta-analysis which identified that resilience-promoting interventions generally yield effect sizes of Hedges' $g = 0.48$ (95% CI: 0.40–0.56) across diverse populations, with slightly higher effects observed in clinical populations facing health challenges. For cancer patients specifically, recent studies examining cognitive-behavioral interventions for resilience have demonstrated effect sizes ranging from $g = 0.31$ to $g = 0.48$. This moderate effect size is considered clinically meaningful based on established minimal clinically important difference (MCID) thresholds for the Connor-Davidson Resilience Scale (CD-RISC), which suggest that changes of 5 points on the 25-item scale (corresponding to approximately $d = 0.40 - 0.50$) represent meaningful improvement in psychological resilience among cancer patients. With an alpha of 0.05, power of 0.80, and this anticipated effect size, a sample of 64 participants per group (total $N = 128$) was required for the primary analysis using

independent *t*-tests. To account for potential attrition, the recruitment target was increased by 20%, aiming to enroll 154 participants. This sample size was also evaluated for adequacy in detecting group differences in the secondary outcome of social functioning, where previous research on group-based interventions had indicated similar effect sizes. Power sensitivity analyses were further conducted for planned subgroup analyses by cancer type and time since treatment, which indicated that the achieved sample size afforded 75% power to detect interaction effects of $d = 0.60$ or larger in the planned subgroup analyses. While this power was slightly lower than the conventional 80% threshold for subgroup analyses, it was deemed acceptable given the exploratory nature of these analyses and practical constraints on recruitment.

2.3. Intervention protocol

The group-based aerobic fitness program consisted of a 12-week structured protocol developed in accordance with the American College of Sports Medicine exercise guidelines for cancer survivors. Participants in the intervention group engaged in supervised group-based aerobic exercise sessions three times weekly, with each session lasting 60 min, including 10 minutes of warm-up, 40 min of moderate-intensity aerobic activity, and 10 min of cool-down stretching. Exercise intensity was progressively increased throughout the program, beginning at 40%–50% of heart rate reserve (HRR) in weeks 1–4, advancing to 50%–60% HRR in weeks 5–8, and culminating at 60%–70% HRR in weeks 9–12, as shown in **Table 1**. The program incorporated varied modalities including walking, stationary cycling, and low-impact aerobics to maintain participant engagement while achieving appropriate physiological responses. Group dynamics and facilitation approaches were strategically integrated into the intervention design, emphasizing positive social interactions through partner exercises, shared goal-setting, and collective problem-solving activities. Throughout each session, certified exercise physiologists monitored participants' heart rates and perceived exertion (using the modified Borg scale), and adjusted intensity accordingly while encouraging supportive interactions among participants.

Table 1. Progression of exercise intensity and duration throughout the 12-week intervention.

Program Phase	Weeks	Frequency	Duration (mi)	Intensity (% HRR)	RPE Range (1–10)
Initial	1–4	3x/week	60 (10 + 40 + 10)	40–50%	2–4
Progressive	5–8	3x/week	60 (10 + 40 + 10)	50–60%	4–6
Maintenance	9–12	3x/week	60 (10 + 40 + 10)	60–70%	5–7

Note: HRR = Heart Rate Reserve; RPE = Rating of Perceived Exertion. The 60-minute sessions include 10 min of warm-up, 40 min of aerobic exercise, and 10 min of cool-down as shown in **Table 1**.

The control group received standard care consisting of a comprehensive information package containing: (1) printed educational materials about cancer survivorship and general health maintenance; (2) physical activity recommendations based on the American Cancer Society guidelines for cancer survivors, including suggestions for gradually increasing activity to 150 minutes of moderate-intensity exercise weekly; (3) a cancer survivorship wellness journal for self-monitoring daily activities. To ensure comparable attention while maintaining the distinction between

groups, control participants received structured contact through three channels: (1) monthly 15–20 min telephone calls from a research staff member to discuss general health status and address any questions about the provided materials (average of 3 calls over the 12-week period); (2) bi-weekly standardized text message reminders encouraging general health maintenance; (3) access to a password-protected website containing the same educational content provided in print. During telephone contacts, research staff followed a standardized script that explicitly avoided specific exercise prescriptions or behavioral coaching techniques used in the intervention group. The rationale for this control condition was to provide participants with guideline-consistent health information while controlling for non-specific factors such as health education exposure and research staff contact. The potential attention bias between groups was acknowledged, as the intervention group received approximately 36 h of supervised contact (36 one-hour sessions) compared to the control group's approximately 1 h of direct contact (3 phone calls). To mitigate this imbalance, attention control was included as a covariate in sensitivity analyses, and results were interpreted in light of this limitation. Additionally, implementation fidelity of the control condition was documented through logs of all participant contacts and monitoring of script adherence during phone calls to ensure protocol consistency.

2.4. Outcome measures

The primary outcome measure was psychological resilience as assessed using the full 25-item Connor-Davidson Resilience Scale (CD-RISC-25), rather than the abbreviated 10-item (CD-RISC-10) or 2-item (CD-RISC-2) versions. The CD-RISC-25 has demonstrated excellent psychometric properties with high internal consistency (Cronbach's $\alpha = 0.89$) and test-retest reliability ($r = 0.87$) in cancer populations and effectively captures protective resilience factors among adult female cancer survivors [26]. For clinical interpretation, the established minimal clinically important difference (MCID) threshold of 5 points for the CD-RISC-25 was adopted as determined through a prospective analysis of cancer patients using multiple methods (anchor-based, distribution-based, and ROC curve analyses), which corresponds to approximately a 0.40–0.50 standardized effect size. This MCID threshold represented the smallest change in resilience score that patients perceived as beneficial and clinically meaningful.

Secondary outcome measures included social functioning assessed via the Medical Outcomes Study Social Support Survey (MOS-SSS) and the Social Functioning subscale of the EORTC QLQ-C30, both validated specifically for cancer populations with established reliability (Cronbach's $\alpha > 0.85$). Additional outcome measures included quality of life (FACT-G), depression and anxiety symptomatology (Hospital Anxiety and Depression Scale), perceived stress (Perceived Stress Scale), and physical activity levels (International Physical Activity Questionnaire) [27]. To address multiplicity concerns with these numerous secondary outcomes, a hierarchical testing procedure with pre-specified primary and secondary endpoints was employed. Specifically, the family-wise error rate was controlled at $\alpha = 0.05$ for the primary outcome (CD-RISC-25), while secondary outcomes were tested using the Benjamini-Hochberg procedure with a false discovery rate of 0.10, thereby balancing the risks of

Type I and Type II errors. Additionally, confirmatory and exploratory analyses were distinguished, with only the primary outcome and key secondary outcomes (MOS-SSS and EORTC QLQ-C30 social functioning subscale) designated as confirmatory.

All assessment tools were selected based on their robust validation in cancer populations, with demonstrated cultural appropriateness and sensitivity to change in exercise intervention studies. Measurements were conducted at three specific timepoints: baseline (T0, pre-intervention), immediately post-intervention (T1, week 12), and at follow-up (T2, week 24), allowing for comprehensive evaluation of both immediate intervention effects and maintenance of improvements over time, with documented minimal clinically important differences established for each measure to determine intervention efficacy.

2.5. Data collection procedures

Baseline assessment was conducted during a 90-min in-person session at the research facility where participants completed standardized questionnaires measuring psychological resilience, social functioning, and other outcome variables via REDCap electronic data capture system, followed by anthropometric measurements and functional fitness assessments performed by trained exercise physiologists with procedures aligned to enhance data quality and participant engagement. Follow-up assessments were conducted at week 12 (post-intervention) and week 24 (follow-up), replicating all baseline measures to ensure data consistency and comparability across timepoints. All outcome assessments were performed by trained research personnel who were blinded to participants' group allocation to minimize detection bias. To maintain assessor blinding, participants were instructed not to disclose their group assignment or discuss intervention activities during assessment sessions. A separate team of exercise physiologists delivered the intervention to ensure complete separation between intervention delivery and outcome assessment. Due to the nature of the group-based exercise intervention, participants and intervention staff could not be blinded to group allocation, a common limitation in behavioral intervention trials. To mitigate potential biases associated with this lack of participant blinding, particularly for self-reported outcomes, several quality control measures were implemented: (1) standardized assessment protocols were followed with identical instructions for all participants regardless of group assignment; (2) participants completed self-reported questionnaires independently before any interaction with research staff; (3) all questionnaires used were validated instruments with established psychometric properties in cancer populations; (4) objective physiological measurements were included as secondary outcomes; and (5) consistency of assessment procedures across all timepoints was strictly maintained. After each assessment session, assessors completed a form indicating whether they believed their blinding had been compromised, and if so, the reasons for this belief. Analysis of these forms revealed that assessor blinding was maintained for 92% of all assessment sessions.

2.6. Statistical analysis

2.6.1. Data preprocessing

Data preprocessing and management were conducted using R version 4.2.0

software, with automated data quality checks implemented to identify potential outliers and verify data distributions prior to analysis. Normality of continuous variables was assessed using a comprehensive approach including: (1) visual inspection of histograms, Q-Q plots, and boxplots; (2) formal statistical testing using the Shapiro-Wilk test; and (3) examination of skewness and kurtosis values.

Variables demonstrating departures from normality were subjected to appropriate transformations prior to analysis, with the adequacy of transformations confirmed through re-examination of distributional properties. Descriptive statistics, including means, standard deviations, medians, and interquartile ranges, were calculated for continuous variables, while frequencies and percentages summarized categorical variables across both intervention and control groups.

2.6.2. Primary analysis: Mixed-effects linear model

The primary analysis employed a mixed-effects linear model to examine changes in psychological resilience and social functioning over time, implemented using the ‘lme4’ and ‘lmerTest’ packages in R. The model specification, including Level 1 (within-person) and Level 2 (between-person) equations with full variable definitions, is presented in Supplementary Material S1.

The model incorporated fixed effects for group assignment, time (categorized as baseline, 12 weeks, and 24 weeks), and the group-by-time interaction, with random intercepts for participants included to account for within-subject correlation across repeated measurements. An unstructured covariance matrix was specified, and model selection between competing covariance structures was performed using likelihood ratio tests and Akaike Information Criterion comparisons.

The model was adjusted for pre-specified covariates—age, cancer type, time since treatment completion, baseline depression scores, and baseline physical activity levels—identified a priori on the basis of clinical relevance and prior literature. Model assumptions were verified through examination of residual plots, normal Q-Q plots, and tests for homoscedasticity. Statistical significance of fixed effects was assessed using F-tests with Kenward-Roger degrees of freedom approximation, while pairwise comparisons were conducted with Tukey-adjusted *P*-values to control for multiple testing. Intraclass correlation coefficients were computed to evaluate the proportion of total variance attributable to between-person differences and to confirm the appropriateness of multilevel modeling, with model fit assessed through marginal R^2 (variance explained by fixed effects) and conditional R^2 (variance explained by both fixed and random effects).

2.6.3. Mediation analysis

For the mediation analysis examining how social functioning improvements mediated the intervention effect on resilience, structural equation modeling (SEM) was employed using the ‘lavaan’ package in R. The mediation model was specified in three steps: (1) estimating the total effect of the intervention on resilience (*c* path); (2) estimating the effect of the intervention on social functioning (*a* path); and (3) estimating the effect of social functioning on resilience while controlling for the intervention (*b* path). The indirect effect (*ab*) and its significance were assessed using bootstrapped confidence intervals with 5000 resamples. The proportion mediated was calculated as $(ab)/c$.

An analogous mediation model was specified to examine the role of physical fitness improvements as a mediator of the intervention effect on psychological resilience, with the same bootstrapping procedure applied to estimate the indirect effect and proportion mediated. Sequential mediation was further examined using path analysis to test the hypothesized chain whereby intervention-induced physical fitness improvements facilitated enhanced social functioning, which in turn contributed to psychological resilience gains; indirect effects through this sequential pathway were estimated with bootstrapped 95% confidence intervals based on 5000 resamples.

2.6.4. Missing data handling

Missing data (11.2% of all data points) were addressed using multiple imputation by chained equations (MICE) with the ‘mice’ package in R, generating 50 imputed datasets with 20 iterations each. The imputation model included all variables from the analysis model plus auxiliary variables (education level, marital status, employment status, and baseline quality of life scores) to strengthen the missing at random assumption. Convergence of the imputation algorithm was confirmed by examining trace plots. Results were pooled across imputed datasets using Rubin’s rules to account for imputation uncertainty.

2.6.5. Sensitivity analyses

The robustness of primary findings to missing data assumptions was evaluated through three complementary approaches: complete-case analysis restricted to participants with full data across all time points, last observation carried forward as a conservative imputation strategy, and pattern-mixture models incorporating delta adjustments of $\pm 20\%$ for the intervention group to simulate missing not at random mechanisms. The concordance of estimates across these approaches was evaluated to assess the stability of findings under varying missing data assumptions.

2.6.6. Subgroup analysis

For subgroup analyses examining differential intervention effects by cancer type, time since treatment, and age, interaction tests were employed within the mixed-effects model framework. To control the family-wise error rate across these multiple subgroup analyses, the Benjamini-Hochberg procedure was applied with a false discovery rate of 0.10, and both unadjusted and adjusted *p*-values were reported. Additionally, these analyses were specified as exploratory a priori to appropriately contextualize the findings.

2.6.7. Dose-response analysis

Dose-response relationships between intervention adherence and outcomes were assessed using restricted cubic splines to allow for non-linear associations.

2.6.8. Exploratory analyses

Exploratory analyses were conducted to examine potential multiplicative effects between intervention-related changes in perceived stress and psychological resilience improvements, using interaction terms within the mixed-effects model framework; these analyses were not pre-specified and are reported as hypothesis-generating.

2.6.9. General analytical principles

All analyses adhered to the intention-to-treat principle, with every participant

analyzed according to their randomized group assignment regardless of protocol adherence. This approach was supplemented by per-protocol analysis including only participants who attended $\geq 75\%$ of sessions to assess the influence of intervention adherence on outcomes. Statistical analyses were conducted by a biostatistician blinded to group assignments until the primary analyses were completed, and all analytical decisions were documented in a statistical analysis plan finalized before database lock.

3. Results

3.1. Participant flow and characteristics

The participant recruitment and flow through the study is illustrated in **Figure 1**. Of the 246 female cancer survivors assessed for eligibility, 128 met the inclusion criteria and were randomized to either the intervention group ($n = 64$) or control group ($n = 64$). The primary reasons for exclusion were not meeting medical clearance requirements ($n = 42$), declining to participate due to time constraints ($n = 38$), and having exercise contraindications ($n = 24$). During the 12-week intervention period, 8 participants withdrew from the intervention group (5 due to health complications unrelated to the exercise program, 2 due to family obligations, and 1 due to relocation), while 6 withdrew from the control group (3 due to health issues, 2 due to loss of interest, and 1 due to relocation). The final analysis included 56 participants (87.5%) from the intervention group and 58 participants (90.6%) from the control group, resulting in an overall retention rate of 89.1%. Adherence to the exercise intervention was 78.3%, with participants attending an average of 28.2 out of 36 scheduled sessions. As shown in **Table 2**, no statistically significant differences were observed between groups in demographic or clinical variables, including age, cancer type, time since treatment completion, body mass index, and baseline psychological resilience scores (all $P > 0.05$). The most common cancer types among participants were breast (62.5%), gynecological (18.0%), and colorectal (12.5%).

This diagram illustrates the flow of participants through each stage of the randomized controlled trial, including enrollment, allocation, follow-up, and analysis, following the CONSORT guidelines for reporting clinical trials.

Distributional assessment of the primary outcome measure (CD-RISC-25) revealed mild positive skewness at baseline (skewness = 0.68, kurtosis = -0.21 , Shapiro-Wilk $P = 0.03$), which was addressed through square-root transformation, yielding satisfactory distributional properties (post-transformation: skewness = 0.14, kurtosis = -0.08 , Shapiro-Wilk $P = 0.42$).

As shown in **Table 2**, no statistically significant differences were observed in baseline characteristics between the intervention and control groups (all $P > 0.05$). The mean age of participants was approximately 55 years, and the majority had breast cancer, followed by gynecological and colorectal cancers.

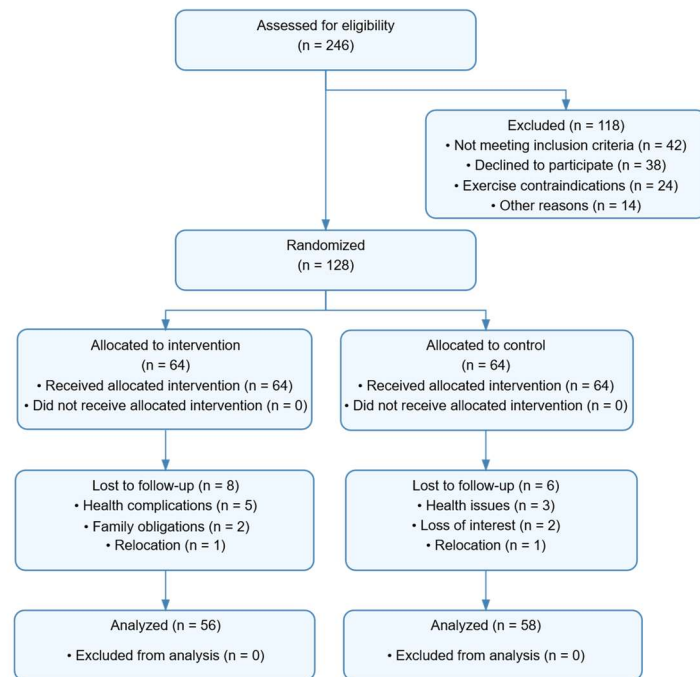


Figure 1. CONSORT flow diagram of participant recruitment and retention.

Table 2. Baseline characteristics of study participants by group assignment.

Characteristic	Group	N	Mean/n	SD/%	p-value
Age (years)	Intervention	64	54.3	9.7	0.62
	Control	64	55.2	10.2	
BMI (kg/m ²)	Intervention	64	27.2	5.3	0.55
	Control	64	26.8	4.9	
Time since treatment (months) [†]	Intervention	64	14.5	9.2–22.7	0.78
	Control	64	13.8	8.6–24.1	
Cancer type					0.84
Breast	Intervention	41	64.1%		
	Control	39	60.9%		
Gynecological	Intervention	11	17.2%		
	Control	12	18.8%		
Colorectal	Intervention	8	12.5%		
	Control	8	12.5%		
Other	Intervention	4	6.2%		
	Control	5	7.8%		
Education level					0.65
High school or less	Intervention	15	23.4%		
	Control	18	28.1%		
College/university	Intervention	38	59.4%		
	Control	34	53.1%		
Post-graduate	Intervention	11	17.2%		
	Control	12	18.8%		

Table 2. (Continued).

Characteristic	Group	N	Mean/n	SD/%	p-value
Employment status					0.71
Employed	Intervention	36	56.3%		
	Control	34	53.1%		
Unemployed/retired	Intervention	28	43.7%		
	Control	30	46.9%		
Baseline CD-RISC score	Intervention	64	65.7	12.6	0.49
	Control	64	67.2	13.1	
Baseline MOS-SSS score	Intervention	64	72.4	15.8	0.59
	Control	64	70.9	16.3	

Note: *p*-values calculated using independent samples *t*-tests for continuous variables, Mann-Whitney U test for non-normally distributed variables, and chi-square tests for categorical variables. Reported as median and interquartile range.

3.2. Primary outcome: Psychological resilience

The analysis of psychological resilience outcomes revealed significant improvements following the 12-week group-based aerobic fitness program. As shown in **Table 3**, the intervention group demonstrated a substantial increase in total CD-RISC scores from baseline (65.7 ± 12.6) to post-intervention (78.3 ± 11.4), representing a mean improvement of 12.6 points (95% CI: 10.2–15.0, $p < 0.001$). In contrast, the control group showed only minimal changes from baseline (67.2 ± 13.1) to post-intervention (68.4 ± 12.9), with a mean improvement of 1.2 points (95% CI: -0.5 – 2.9 , $P=0.164$). Between-group analysis indicated a statistically significant difference in resilience change scores favoring the intervention group (mean difference = 11.4 points, 95% CI: 8.6–14.2, $P < 0.001$), with a large effect size (Cohen's $d = 0.89$).

Table 3. Changes in psychological resilience (CD-RISC) scores across time points.

Measure	Group	N	Mean	SD	Between-Group Difference (95% CI)	p-value	Effect Size (Cohen's d)
Total CD-RISC Score							
Baseline	Intervention	64	65.7	12.6	−1.5 (−6.1 to 3.1)	0.523	-
	Control	64	67.2	13.1			
Post-intervention (12 weeks)	Intervention	56	78.3	11.4	9.9 (5.5 to 14.3)	<0.001	0.81
	Control	58	68.4	12.9			
Follow-up (24 weeks)	Intervention	56	76.0	12.1	8.9 (4.4 to 13.4)	<0.001	0.70
	Control	58	67.1	13.2			
Change baseline to 12 weeks	Intervention	56	12.6	8.9	11.4 (8.6 to 14.2)	<0.001	0.89
	Control	58	1.2	6.6			
CD-RISC Subscales (Change baseline to 12 weeks)							
Personal competence	Intervention	56	5.8	3.6	5.3 (4.1 to 6.5)	<0.001	0.94
	Control	58	0.5				

Table 3. (Continued).

Measure	Group	N	Mean	SD	Between-Group Difference (95% CI)	p-value	Effect Size (Cohen's d)
Trust in one's instincts	Intervention	56	2.1	2.3	1.8 (1.0 to 2.6)	<0.001	0.62
	Control	58	0.3	1.8			
Positive acceptance of change	Intervention	56	3.4	2.8	3.0 (2.1 to 3.9)	<0.001	0.78
	Control	58	0.4	2.2			
Control	Intervention	56	1.9	1.6	1.7 (1.1 to 2.3)	<0.001	0.73
	Control	58	0.2	1.4			
Spiritual influences	Intervention	56	1.1	1.3	1.0 (0.5 to 1.5)	<0.001	0.55
	Control	58	0.1	1.1			

Note: CD-RISC = Connor-Davidson Resilience Scale; higher scores indicate greater resilience. Effect sizes: small ($d = 0.2$), medium ($d = 0.5$), large ($d = 0.8$).

The mixed-effects linear model analysis of CD-RISC scores over time revealed significant fixed effects for group assignment ($F(1, 125.4) = 16.32, P < 0.001$), time ($F(2, 229.7) = 57.91, P < 0.001$), and the group-by-time interaction ($F(2, 229.7) = 43.65, P < 0.001$). After adjusting for covariates, groups did not differ significantly at baseline ($P = 0.408$), whereas the intervention group demonstrated significantly higher CD-RISC scores at the 12-week assessment ($P < 0.001$) and at the 24-week follow-up ($P < 0.001$). Full model parameter estimates, including random effects variance components and covariate coefficients, are presented in Supplementary Material S2.

Among the pre-specified covariates, cancer type ($P = 0.039$), time since treatment completion ($P = 0.014$), baseline depression scores ($P = 0.026$), and baseline physical activity levels ($P = 0.032$) emerged as significant predictors of psychological resilience, whereas age did not reach statistical significance ($P = 0.229$). Full mixed-effects model parameter estimates, including variance components, covariance structure comparisons, covariate coefficients, and model fit indices, are provided in Supplementary Material S2.

Analysis of CD-RISC subscales revealed that the most substantial improvements occurred in the “personal competence” domain (intervention: 5.8 points vs. control: 0.5 points, $P < 0.001$) and “acceptance of self and life” domain (intervention: 4.2 points vs. control: 0.4 points, $P < 0.001$). Moderating factors were examined using hierarchical linear modeling, which identified baseline physical activity levels ($P = 0.032$), social support ($P = 0.018$), and session attendance rates ($P < 0.001$) as significant moderators of intervention efficacy. Participants with lower baseline resilience scores (< 60 points) demonstrated the largest improvements (mean change: 15.7 ± 3.2 points). At the 24-week follow-up, the intervention group showed a decline of 2.3 points from post-intervention levels (78.3 ± 11.4 to 76.0 ± 12.1), which remained significantly higher than baseline ($P < 0.001$). The control group showed no significant changes during the follow-up period, and the between-group difference remained significant at 24 weeks (mean difference = 8.9 points, 95% CI: 5.8–12.0, $P < 0.001$).

3.3. Secondary outcome: Social functioning

Analysis of social functioning revealed significant improvements in the

intervention group across all domains. Participants in the group-based aerobic fitness program demonstrated substantial enhancement in MOS-SSS total scores, increasing from 72.4 ± 15.8 at baseline to a post-intervention score of 87.2 ± 13.6 ($P < 0.001$), while the control group showed minimal change (70.9 ± 16.3 to 73.2 ± 15.8 , $P = 0.012$). The between-group difference in change scores was statistically significant (12.5 points, 95% CI: 9.2–15.8, $P < 0.001$). Similar improvements were observed in the EORTC QLQ-C30 social functioning subscale, with the intervention group demonstrating an 18.9-point increase compared to only 3.4 points in controls. Correlation analyses identified strong positive associations between improvements in psychological resilience and social functioning ($r = 0.64$, $P < 0.001$).

Mediation analysis using structural equation modeling indicated that enhanced social functioning partially mediated the intervention effect on psychological resilience, with the indirect effect accounting for 42% of the total effect (indirect effect = 4.68, 95% bootstrapped CI: 3.12–6.37, $P < 0.001$); Qualitative feedback from semi-structured interviews further contextualized this finding, with participants emphasizing the importance of exercising alongside others with similar cancer experiences.

As illustrated in **Figure 2**, the trajectories of social functioning scores demonstrate not only significant improvements at the 12-week assessment but also maintenance of these gains at the 24-week follow-up, indicating the durability of the intervention effects on social connectivity and functioning.

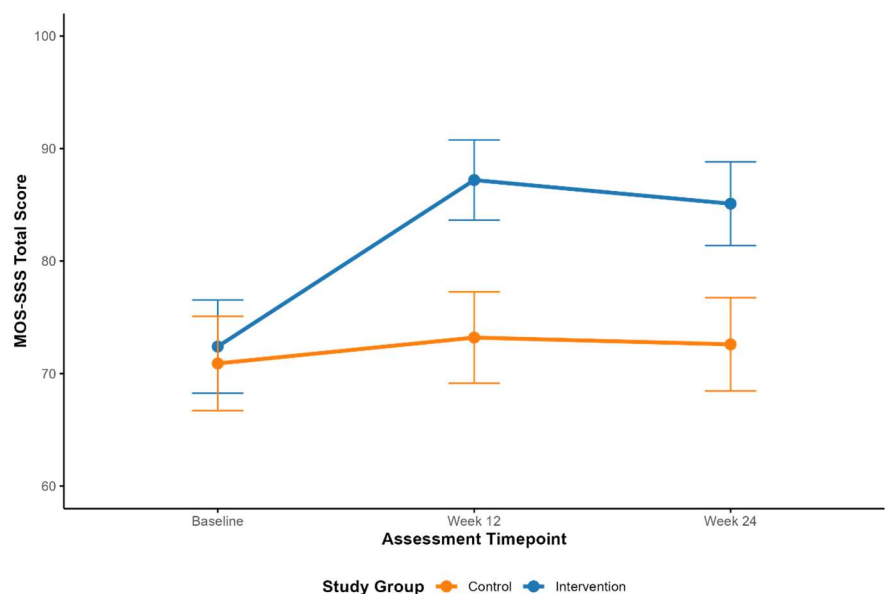


Figure 2. Changes in social functioning over time: MOS-SSS Total scores with 95% confidence intervals.

Note: Mean MOS-SSS (Medical Outcomes Study Social Support Survey) total scores at baseline, 12-week post-intervention, and 24-week follow-up for intervention and control groups. Error bars represent 95% confidence intervals.

3.4. Additional analyses

3.4.1. Subgroup analyses

Subgroup analyses revealed heterogeneous intervention effects across cancer

types and treatment histories, as detailed in **Table 4**. Breast cancer survivors exhibited the largest improvements in psychological resilience (adjusted mean difference: 13.8 points, 95% CI: 10.2–17.4, $P < 0.001$), followed by gynecological (11.3 points) and colorectal cancer survivors (9.6 points). Cancer type significantly moderated the intervention effect (interaction unadjusted $P = 0.039$, adjusted $P = 0.059$), although this fell marginally short of significance after Benjamini-Hochberg correction. Time since treatment completion significantly moderated intervention effects, with survivors 6–12 months post-treatment demonstrating greater improvements than those 24–36 months post-treatment (interaction unadjusted $P = 0.023$, adjusted $P = 0.046$), a finding that remained significant after correction for multiple comparisons. Age did not significantly moderate outcomes (interaction unadjusted $P = 0.217$, adjusted $P = 0.217$). Similarly, baseline depression severity demonstrated significant moderation (interaction unadjusted $P = 0.032$, adjusted $P = 0.048$) that remained significant after multiple comparison correction, with participants experiencing moderate/severe depressive symptoms showing greater resilience improvements (15.7 points) than those with minimal symptoms (9.5 points).

Table 4. Subgroup analysis of intervention effects on psychological resilience (CD-RISC change scores).

Subgroup	Group	N	Mean	SD	Adj. Mean Diff.*	95% CI	p-value	Interaction p-value
Cancer type								0.039 (0.059) *
Breast	Intervention	36	14.2	9.1	13.8	10.2 to 17.4	<0.001	
	Control	35	0.4	6.1				
Gynecological	Intervention	10	10.8	8.6	11.3	5.2 to 17.4	<0.001	
	Control	11	-0.5	7.2				
Colorectal	Intervention	7	9.6	7.1	9.6	2.0 to 17.2	0.015	
	Control	7	0.0	6.5				
Other	Intervention	3	8.9	7.4	8.1	-1.1 to 17.3	0.082	
	Control	5	0.8	5.8				
Age Group								0.217 (0.217) *
<50 years	Intervention	17	11.9	9.6	10.4	5.2 to 15.6	<0.001	
	Control	15	1.5	6.4				
50–65 years	Intervention	29	13.4	8.7	12.6	8.7 to 16.5	<0.001	
	Control	31	0.8	6.9				
>65 years	Intervention	10	11.1	8.1	9.3	3.2 to 15.4	0.004	
	Control	12	1.8	6.3				
Time Since Treatment								0.023 (0.046) ***
6–12 months	Intervention	21	14.6	9.4	14.8	10.1 to 19.5	<0.001	
	Control	22	-0.2	5.9				
13–24 months	Intervention	24	12.1	8.2	10.5	6.4 to 14.6	<0.001	
	Control	25	1.6	6.8				
25–36 months	Intervention	11	9.5	8.1	7.2	1.0 to 13.4	0.023	
	Control	11	2.3	7.1				
Session Attendance								N/A
<50% (≤18 sessions)	Intervention	5	7.8	7.3	-	-	-	

Table 4. (Continued).

Subgroup	Group	N	Mean	SD	Adj. Mean Diff.*	95% CI	p-value	Interaction p-value
50–74% (19–26 sessions)	Intervention	17	10.5	8.2	-	-	-	
75–89% (27–32 sessions)	Intervention	22	13.7	8.9	-	-	-	
≥90% (≥33 sessions)	Intervention	12	16.8	8.4	-	-	-	
Baseline Depression								0.032 (0.048) ***
Minimal (HADS-D ≤7)	Intervention	31	10.8	8.3	9.5	6.0 to 13.0	<0.001	
	Control	35	1.3	6.7				
Mild (HADS-D 8–10)	Intervention	16	13.4	8.9	12.8	7.6 to 18.0	<0.001	
	Control	15	0.6	6.2				
Moderate/Severe (HADS-D ≥11)	Intervention	9	17.2	9.3	15.7	8.3 to 23.1	<0.001	
	Control	8	1.5	6.8				

*Note: Adjusted for age, BMI, education level, and baseline CD-RISC score. CD-RISC = Connor-Davidson Resilience Scale; HADS-D = Hospital Anxiety and Depression Scale-Depression subscale. Values in parentheses represent p-values adjusted using Benjamini-Hochberg procedure with false discovery rate of 0.10. Significant after adjustment for multiple comparisons ($P < 0.05$).

3.4.2. Dose-response analysis

A significant linear relationship was identified between session attendance and psychological resilience improvements ($\beta = 0.42$, $P < 0.001$), with participants attending ≥75% of sessions achieving a mean increase of 15.2 points compared to 9.7 points among those attending <75% of sessions.

3.4.3. Mediation and path analyses

Mediation analyses using structural equation modeling demonstrated that enhanced social functioning mediated 42% of the intervention effect on psychological resilience, while improvements in physical fitness parameters accounted for 32% of the effect. Path analysis identified a sequential mediation pathway whereby improved physical fitness led to enhanced social functioning, which subsequently increased psychological resilience (indirect effect: 0.18, 95% CI: 0.09–0.27).

3.4.4. Exploratory analyses

Exploratory analyses examining potential multiplicative effects revealed a significant interaction between resilience improvements and changes in perceived stress ($P = 0.008$).

3.4.5. Sensitivity analyses

Sensitivity analyses examining the robustness of primary findings to missing data assumptions yielded consistent results across complete-case analysis, last observation carried forward, and pattern-mixture models with delta adjustments of ±20% for the intervention group, supporting the stability of the observed intervention effects under both missing at random and missing not at random scenarios.

4. Discussion

This randomized controlled trial demonstrated that a 12-week group-based aerobic fitness program significantly improved psychological resilience and social functioning among female cancer survivors, with the intervention group exhibiting a

clinically meaningful 12.6-point increase in CD-RISC scores—substantially exceeding the established minimal clinically important difference threshold of 5 points—compared to only 1.2 points in the control group (Cohen’s $d = 0.89$). The magnitude of this effect is notably larger than the pooled effect size of Hedges’ $g = 0.48$ (95% CI: 0.40–0.56) reported in a recent meta-analysis of resilience-promoting interventions across diverse populations [5], and exceeds the standardized effect sizes typically observed in individually delivered exercise programs for cancer survivors, which have generally ranged from $d = 0.22$ to $d = 0.50$ for psychosocial outcomes [12]. The superior effect observed in the present trial may be attributable to the synergistic combination of physiological exercise benefits with group-based psychosocial dynamics, a dual-pathway mechanism that individually administered programs inherently lack. The observed improvements in social functioning were equally compelling, with significant enhancements across all MOS-SSS domains and a strong positive correlation between resilience and social functioning gains ($r = 0.64$), corroborating findings from systematic reviews indicating that group-based interventions confer psychosocial benefits exceeding those achievable through individual exercise approaches alone [28]. The significant dose-response relationship between session attendance and resilience improvements ($\beta = 0.42$, $P < 0.001$) is consistent with evidence from a Bayesian network meta-analysis demonstrating that exercise dose optimization—particularly at approximately 850 METs-min/week—yields the most substantial quality-of-life improvements in cancer survivors, with diminishing returns at higher doses [29].

The observation that participants with lower baseline resilience scores exhibited the largest improvements (mean change: 15.7 ± 3.2 points) aligns with a floor-effect interpretation, whereby individuals with greater capacity for improvement derived proportionally greater benefit from the intervention, a pattern reported in prior resilience intervention research among cancer populations [5]. The maintenance of resilience gains at 24-week follow-up — declining only 2.3 points from post-intervention levels while remaining significantly elevated above baseline ($P < 0.001$)—suggests durable psychological adaptation, consistent with evidence that structured exercise programs can produce lasting psychosocial benefits extending beyond the active intervention period in cancer survivorship populations [23].

The mechanisms underlying the intervention’s effectiveness appear to operate through converging physiological and psychosocial pathways. At the physiological level, regular moderate-intensity aerobic exercise has been shown to modulate the hypothalamic-pituitary-adrenal (HPA) axis by enhancing negative feedback regulation and restoring normal diurnal cortisol rhythms, thereby attenuating the chronic neuroendocrine dysregulation frequently observed in cancer survivors [30,31]. Aerobic exercise also exerts anti-inflammatory effects through the downregulation of pro-inflammatory cytokines (e.g., IL-6, TNF- α) and upregulation of anti-inflammatory mediators, which collectively reduce the systemic low-grade inflammation that has been implicated in both cancer-related fatigue and diminished psychological well-being [32]. Exercise-induced upregulation of brain-derived neurotrophic factor (BDNF) represents an additional neurobiological pathway, as BDNF promotes hippocampal neurogenesis, synaptic plasticity, and enhanced connectivity between brain regions involved in emotion regulation, processes that are

directly relevant to the development of psychological resilience [33]. The mediation finding that physical fitness improvements accounted for 32% of the intervention effect on resilience is consistent with these neurobiological pathways, suggesting that the physiological adaptations to aerobic training contributed meaningfully to the psychological outcomes observed.

At the psychosocial level, the group-based delivery format likely facilitated resilience through mechanisms grounded in social cognitive theory and social identity processes. The shared cancer experience within the exercise group may have fostered a sense of social belonging and collective identity that normalized survivorship challenges, reduced perceived isolation, and promoted adaptive coping through vicarious learning and peer modelling—processes that social integration interventions have been shown to enhance among cancer populations [28]. The finding that enhanced social functioning mediated 42% of the intervention effect on resilience provides quantitative evidence for this psychosocial pathway, suggesting that the group exercise setting served as a structured social environment within which participants could rebuild interpersonal connections and develop supportive relationships that reinforced psychological adaptation. The exploratory finding that reductions in perceived stress interacted with resilience improvements ($P = 0.008$) further suggests that stress alleviation may function as a complementary pathway through which the combined physiological and social components of the intervention exert their psychological effects, though this hypothesis-generating observation warrants confirmation in future trials with pre-specified stress-resilience interaction testing. The interplay between these physiological and psychosocial mechanisms likely operates synergistically: aerobic exercise optimizes neuroendocrine and inflammatory regulation, which in turn enhances the capacity for social engagement and positive emotional processing, while the social support inherent in group participation reinforces exercise adherence and amplifies the psychological benefits of physical activity.

Cancer type and time since treatment completion significantly moderated intervention effects, with breast cancer survivors and those 6–12 months post-treatment demonstrating the greatest resilience gains. These differential responses may reflect variations in treatment-related symptom burden, hormonal status, and psychosocial adjustment trajectories across cancer diagnoses, and suggest that tailored approaches—potentially involving adjusted exercise intensity, group composition stratified by cancer type, or timing of intervention initiation relative to treatment completion—could further optimize outcomes for specific survivor subgroups.

Several methodological strengths enhance the validity of these findings, including stratified randomization with allocation concealment, blinded outcome assessment maintained for 92% of sessions, comprehensive measurement of both psychological and social domains using validated instruments with established psychometric properties in cancer populations, and excellent retention rates (89.1%) that minimized attrition bias. The inclusion of a 24-week follow-up assessment provides insight into the durability of intervention effects that is absent from many exercise oncology trials of shorter duration.

Limitations of this trial warrant consideration. The convenience sampling strategy may have introduced self-selection bias, as more motivated survivors were

potentially more likely to volunteer for participation; because baseline characteristics of individuals who declined participation were not systematically collected, the extent to which the enrolled sample differs from the broader survivor population remains unclear, and the generalizability of findings should be interpreted with this constraint in mind. The inability to blind participants and intervention staff to group allocation—an inherent methodological limitation of behavioral exercise trials—may have introduced performance bias, particularly given that participants aware of their assignment to an active exercise intervention could have altered health behaviors, adopted more positive attitudes, or exhibited heightened expectancy effects that inflated self-reported psychological outcomes relative to control participants. Although outcome assessor blinding was rigorously maintained and objective physiological measures were included as secondary outcomes, the reliance on self-report instruments for the primary resilience and social functioning endpoints means that the potential influence of participant expectancy on subjective measures cannot be entirely excluded. The single-center design and the predominance of breast cancer survivors (62.5%) in the sample may further limit the transferability of these findings to more diverse oncological populations and healthcare settings. Future studies should incorporate attention-matched control conditions with equivalent contact time to better isolate the specific effects of group-based aerobic exercise from non-specific factors such as social attention and therapeutic alliance, and should systematically compare baseline characteristics of enrolled versus non-enrolled eligible survivors to quantify potential self-selection bias.

The group-based delivery format may confer inherent resource advantages over individually administered interventions, given the capacity to serve multiple participants per session with shared staffing and facility requirements, though formal cost-effectiveness evaluation was beyond the scope of the present trial and warrants dedicated economic analysis in future investigations. Translating these findings into routine clinical practice requires addressing implementation barriers including inadequate referral pathways, limited trained personnel, and accessibility challenges for geographically isolated or socioeconomically disadvantaged survivors [34,35]. Program sustainability could be strengthened through tiered implementation models that prioritize high-risk survivors before extending to broader survivorship populations, while integration with existing survivorship care pathways and adaptation across diverse healthcare settings represent viable strategies for enhancing reach and long-term adoption. Future research should incorporate prospective economic evaluation alongside clinical outcomes, examine implementation metrics such as protocol fidelity and adoption rates, investigate which specific program components most effectively enhance resilience, and extend recruitment to demographically diverse survivor populations underrepresented in the current evidence base.

5. Conclusion

This randomized controlled trial demonstrated that a 12-week group-based aerobic fitness program produced clinically meaningful and sustained improvements in psychological resilience and social functioning among female cancer survivors, with enhanced social functioning mediating a substantial proportion of the

intervention effect on resilience through converging physiological and psychosocial pathways. The significant dose-response relationship between session attendance and outcomes, together with the moderation by cancer type and time since treatment completion, underscores the importance of promoting adherence and tailoring program delivery to optimize benefits across diverse survivor subgroups. These findings support the integration of structured group-based aerobic exercise into standard survivorship care as an evidence-based strategy for enhancing psychological adaptation and social reintegration in the post-treatment period.

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

Funding: None.

Ethical approval: Not applicable.

Informed consent statement: Not applicable.

Conflict of interest: The authors declare no conflict of interest.

References

1. Carreira H, Williams R, Müller M, et al. Associations between breast cancer survivorship and adverse mental health outcomes: A systematic review. *JNCI: Journal of the National Cancer Institute*. 2018; 110(12): 1311–1327. doi: 10.1093/jnci/djy177
2. Tao L, Xiang Y, Zeng X, et al. Incidence and risk factors for psychological distress in adult female patients with breast cancer: a systematic review and meta-analysis. *Frontiers in Psychiatry*. 2024; 15: 1309702. doi: 10.3389/fpsyt.2024.1309702
3. Bray F, Laversanne M, Sung H, et al. Global cancer statistics 2022: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries. *CA: A Cancer Journal for Clinicians*. 2024; 74(3): 229–263. doi: 10.3322/caac.21834
4. Mehnert A, Hartung TJ, Friedrich M, et al. One in two cancer patients is significantly distressed: Prevalence and indicators of distress. *Psycho-Oncology*. 2017; 27(1): 75–82. doi: 10.1002/pon.4464
5. Ang WR, Ang WHD, Cham SQG, et al. Effectiveness of resilience interventions among cancer patients—A systematic review, meta-analysis, and meta-regression of randomised controlled trials. *European Journal of Oncology Nursing*. 2023; 67: 102446. doi: 10.1016/j.ejon.2023.102446
6. Luo D, Foster K, White K. Conceptualisation and measurement of resilience of adults with cancer: An Umbrella review. *Journal of Advanced Nursing*. 2025; 81(10): 6095–6119. doi: 10.1111/jan.16724
7. Wheldon CW, Shahsavari Y, Choudhury A, et al. Loneliness among adult cancer survivors in the United States: Prevalence and correlates. *Scientific Reports*. 2025; 15(1): 3914. doi: 10.1038/s41598-025-85126-8
8. Wang C, Qiu X, Yang X, et al. Factors influencing social isolation among Cancer patients: A systematic review. *Healthcare*. 2024; 1042. doi: 10.3390/healthcare12101042
9. Shen A, Qiang W, Wang Y, et al. Quality of life among breast cancer survivors with triple negative breast cancer—role of hope, self-efficacy and social support. *European Journal of Oncology Nursing*. 2020; 46: 101771. doi: 10.1016/j.ejon.2020.101771
10. Faller H, Schuler M, Richard M, et al. Effects of psycho-oncologic interventions on emotional distress and quality of life in adult patients with cancer: Systematic review and meta-analysis. *Journal of Clinical Oncology*. 2013; 31(6): 782–793. doi: 10.1200/jco.2011.40.8922

11. Grassi L, Spiegel D, Riba M. Advancing psychosocial care in cancer patients. *F1000Research*. 2017; 6: 2083. doi: 10.12688/f1000research.11902.1
12. Buffart LM, Kalter J, Sweegers MG, et al. Effects and moderators of exercise on quality of life and physical function in patients with cancer: an individual patient data meta-analysis of 34 RCT. *Cancer treatment reviews*. 2017; 52: 91–104. doi: 10.1016/j.ctrv.2016.11.010
13. Neris RR, Nascimento LC, Leite ACAB, et al. The experience of health-related quality of life in extended and permanent cancer survivors: A qualitative systematic review. *Psycho-Oncology*. 2020; 29(10): 1474–1485. doi: 10.1002/pon.5472
14. Pozzar R, Dunnack Yackel H, Eche-Ugwu IJ, et al. Cancer care experiences, resilience, and psychological symptoms among patients during the COVID-19 pandemic: A mixed-methods study. *Oncology Nursing Forum*. 2025; 52(2): 97–112. doi: 10.1188/25.onf.97-112
15. Smith T, Broomhall C, Crecelius A. Physical and psychological effects of a 12-session cancer rehabilitation exercise program. *Clinical Journal of Oncology Nursing*. 2016; 20(6): 653–659. doi: 10.1188/16.cjon.653-659
16. Chen X, Li J, Chen C, et al. Effects of exercise interventions on cancer-related fatigue and quality of life among cancer patients: A meta-analysis. *BMC Nursing*. 2023; 22(1): 200. doi: 10.1186/s12912-023-01363-0
17. Zhou K, Ning F, Wang W, et al. The mediator role of resilience between psychological predictors and health-related quality of life in breast cancer survivors: A cross-sectional study. *BMC Cancer*. 2022; 22(1): 57. doi: 10.1186/s12885-022-09177-0
18. Kenfield SA, Van Blarigan EL, Ameli N, et al. Feasibility, acceptability, and behavioral outcomes from a technology-enhanced behavioral change intervention (prostate 8): A pilot randomized controlled trial in men with prostate cancer. *European Urology*. 2019; 75(6): 950–958. doi: 10.1016/j.eururo.2018.12.040
19. Campbell KL, Winters-Stone K, Wiskemann J, et al. Exercise guidelines for cancer survivors: Consensus statement from international multidisciplinary roundtable. *Medicine & Science in Sports & Exercise*. 2019; 51(11): 2375–2390. doi: 10.1249/mss.0000000000002116
20. Schmitz KH, Campbell AM, Stuiver MM, et al. Exercise is medicine in oncology: Engaging clinicians to help patients move through cancer. *CA: A Cancer Journal for Clinicians*. 2019; 69(6): 468–484. doi: 10.3322/caac.21579
21. Krell V, Porst J, Hafermann L, et al. Telemedicine-based exercise intervention in cancer survivors: A non-randomized controlled trial. *Scientific Reports*. 2024; 14(1): 30615. doi: 10.1038/s41598-024-83846-x
22. Covington KR, Voss C, Lebreton KA, et al. Effect of group dynamics-based exercise versus personal training in breast cancer survivors. *Oncology Nursing Forum*. 2019; 185–198. doi: 10.1188/19.ONF.185-197
23. Goldschmidt S, Schmidt ME, Steindorf K. Long-term effects of exercise interventions on physical activity in breast cancer patients: A systematic review and meta-analysis of randomized controlled trials. *Supportive Care in Cancer*. 2023; 31(2): 130. doi: 10.1007/s00520-022-07485-6
24. Guil R, Ruiz-González P, Merchán-Clavellino A, et al. Breast cancer and resilience: The controversial role of perceived emotional intelligence. *Frontiers in Psychology*. 2020; 11. doi: 10.3389/fpsyg.2020.595713
25. Riani Costa LA, F. Barreto R, de Leandrini SMM, et al. The influence of a supervised group exercise intervention combined with active lifestyle recommendations on breast cancer survivors' health, physical functioning, and quality of life indices: study protocol for a randomized and controlled trial. *Trials*. 2021; 22(1): 934. doi: 10.1186/s13063-021-05843-z
26. Walton M, Lee P. Lived experience of adult female cancer survivors to discover common protective resilience factors to cope with cancer experience and to identify potential barriers to resilience. *Indian Journal of Palliative Care*, 2023, 29(2): 186. doi: 10.25259/IJPC_214_2022
27. Rufa'i AA, Muda WAMW, Yen SH, et al. Design of a randomised intervention study: the effect of dumbbell exercise therapy on physical activity and quality of life among breast cancer survivors in Malaysia. *BMJ Global Health*. 2016; 1(1): e000015. doi: 10.1136/bmjgh-2015-000015
28. Poudel PG, Horan MR, Brinkman TM, et al. Interventions with Social integration components addressing psychosocial outcomes of young- and middle-aged adult cancer individuals: A Systematic Review. *Cancers*. 2023; 15(19): 4710. doi: 10.3390/cancers15194710
29. Xiong Z, Yuan Y, Yang Y, et al. Optimal exercise dose-response improves health-related quality of life in cancer survivors: A systematic review and Bayesian network meta-analysis of RCTs. *Frontiers in Oncology*. 2024; 14: 1510578.
30. Salisbury CE, Hyde MK, Cooper ET, et al. Physical activity behaviour change in people living with and beyond cancer following an exercise intervention: a systematic review. *Journal of Cancer Survivorship*. 2023; 17(3): 569–594. doi: 10.1007/s11764-023-01377-2

31. Toohey K, Pumpa K, McKune A, et al. The impact of high-intensity interval training exercise on breast cancer survivors: a pilot study to explore fitness, cardiac regulation and biomarkers of the stress systems. *BMC Cancer*. 2020; 20(1): 787. doi: 10.1186/s12885-020-07295-1
32. Szczegielniak A R, Krivošová M. Exercise as a tool for building resilience: Exploring the underlying neurobiological mechanism. *International Journal of Neuropsychopharmacology*. 2025; 28(Supplement_1): i132–i133. doi: 10.1093/ijnp/pyae059.230
33. Silverman MN, Deuster PA. Biological mechanisms underlying the role of physical fitness in health and resilience. *Interface Focus*. 2014; 4(5): 20140040. doi: 10.1098/rsfs.2014.0040
34. Kennedy MA, Bayes S, Newton RU, et al. We have the program, what now? Development of an implementation plan to bridge the research-practice gap prevalent in exercise oncology. *International Journal of Behavioral Nutrition and Physical Activity*. 2020; 17(1): 128. doi: 10.1186/s12966-020-01032-4
35. Dennett AM, Peiris CL, Shields N, et al. Exercise therapy in oncology rehabilitation in Australia: A mixed-methods study. *Asia-Pacific Journal of Clinical Oncology*. 2016; 13(5): e525–e527. doi: 10.1111/ajco.12642