


ORIGINAL ARTICLE OPEN ACCESS

Effects of Individualized High-Intensity Online Concurrent Exercise Guided by Autonomic Modulation on the Mental Health and Quality of Life of Breast Cancer Survivors

Ana Myriam Lavín-Pérez^{1,2}  | Daniel Collado-Mateo¹ | Inés Nieto¹ | Xián Mayo¹ | Carmen Hinojo González^{3,4} | Ana de Juan Ferré^{3,4} | Alfonso Jiménez^{1,2}

¹Sport Sciences Research Centre, King Juan Carlos University, Madrid, Spain | ²GO Fit LAB, GO Fit Life, Science and Technology, S.A., Madrid, Spain | ³Oncology Department, Hospital Universitario Marqués de Valdecilla, Santander, Spain | ⁴Instituto de Investigación Marqués de Valdecilla (IDIVAL), Santander, Spain

Correspondence: Daniel Collado-Mateo (daniel.collado@urjc.es)

Received: 8 August 2025 | **Revised:** 7 November 2025 | **Accepted:** 26 November 2025

Keywords: home-based exercise | HRQoL | HRV | interval training | oncology | psychological factors | strength training

ABSTRACT

Background: Exercise has been shown to improve mental well-being and health-related quality of life (HRQoL) in breast cancer survivors. However, there is no evidence on the effects of online interventions tailored using heart rate variability (HRV).

Aims: This study analyzed the effects of online high-intensity interval and strength training, guided daily by autonomic modulation, compared to pre-planned moderate to high-intensity concurrent training and control, on HRQoL, pain, fatigue, anxiety, depression, life satisfaction, self-esteem, and fear of movement in breast cancer survivors.

Methods: A 16-week randomized controlled trial was conducted with 54 participants assigned to HRV-guided exercise, pre-planned exercise, or usual care. Participants trained aerobic and strength three times per week under real-time online supervision. Intensity was adjusted based on HRV for the HRV-guided group. HRQoL, anxiety, depression, life satisfaction, self-esteem and fear of movement were assessed pre- and post-intervention.

Results: Significant time-by-group interactions were found for HRQoL functional domains (physical $p = 0.004$, role $p = 0.005$, emotional $p = 0.013$, social $p = 0.001$) and symptoms (fatigue $p < 0.001$, pain $p < 0.001$, dyspnea $p = 0.004$, insomnia $p = 0.012$, constipation $p = 0.014$), as well as depression ($p < 0.001$), anxiety ($p = 0.002$), life satisfaction ($p = 0.003$), self-esteem ($p = 0.024$), and fear of movement ($p = 0.015$). HRV-guided exercise led to greater improvements, while the control group worsened. Moreover, the exploratory analysis suggested a higher degree of interconnected changes in the HRV-guided group, and that dyspnea and fatigue might be the variables most strongly connected with anxiety, depression, and functioning-related variables.

Conclusion: Individualized online concurrent exercise, especially autonomic modulation-guided, improves HRQoL and mental health in breast cancer survivors, representing a promising personalized rehabilitation strategy.

1 | Introduction

The number of breast cancer survivors is increasing [1], which can be attributed to improvements in early diagnosis and

treatment effectiveness, as well as an overall rise in the number of cases [2]. This situation is alarming, with approximately 40.8% of women experiencing the disease from 2020 to 2024 [1]. After finishing hospital treatments, women who have breast

This is an open access article under the terms of the [Creative Commons Attribution](https://creativecommons.org/licenses/by/4.0/) License, which permits use, distribution and reproduction in any medium, provided the original work is properly cited.

© 2025 The Author(s). *Psycho-Oncology* published by John Wiley & Sons Ltd.

cancer face a range of physical, clinical, and psychological challenges that greatly affect their mental well-being and overall quality of life [3].

Women who have undergone primary surgery, chemotherapy, and radiation therapy carry psychological difficulties that they have to cope with. These difficulties can include distressing emotions such as anger, anxiety, despair, helplessness, fear of death, and even suicidal thoughts, among others [3]. The cumulative effects of long-term treatments can exacerbate these difficulties, further impacting their mental health and survivorship [4]. Numerous studies have demonstrated the high incidence of anxiety and depression in these women, even years after the treatment process, and its relation with the risk of mortality [5]. Additionally, aspects such as self-esteem and self-concept are often damaged due to the drastic changes in breast anatomy or even the impact on libido as a side effect of the treatments [5]. Moreover, most detected cancers are hormone-related, requiring ongoing treatment for at least 5 years after chemotherapy which often comes with limiting side effects, such as cancer-related fatigue and joint pain [6]. The accumulation of all these psychological effects ends up affecting women's life satisfaction and their health-related quality of life (HRQoL) [7], which decreases drastically in this population and is related to mortality [8].

Therefore, it is important to find strategies and therapies that help women in this process to improve their HRQoL in the short and long term. Exercise is emerging as one of the best tools to mitigate some of the mentioned side effects as well as to reduce the risk of sarcopenia, obesity, cancer recurrence, and mortality [9]. Recent literature has mainly focused on these physical and clinical aspects [10], but there are still many unanswered questions regarding its effectiveness on mental health. Meta-analyses of the effect of exercise interventions on psychological parameters, such as life satisfaction, depression, anxiety, fear of movement, self-esteem and HRQoL, are highly heterogeneous in the type of exercise employed, the intensity, or even in the way they are carried out [11, 12].

Regarding the type, intensity, and frequency of exercise, there is a consensus in recommending a combination of aerobic and resistance training performed at moderate-to-vigorous intensities, typically around 60%–80% HRmax for aerobic exercise and 65%–85% 1RM for resistance training, at a frequency of 2–3 sessions per week to improve HRQoL, physical function, and psychological outcomes such as depression and anxiety [11, 13, 14]. These guidelines also highlight some variability in the recommended volume of resistance training depending on the target outcomes, generally ranging from 2 to 3 sets per exercise and 8 to 15 repetitions, reflecting heterogeneous dose and the need to adapt the workload according to patients' needs [13, 14]. However, when analyzing fatigue intensity, general recommendations decline to 65% of HRmax and 60% of 1RM (RPE \approx 12) [13, 14]. In contrast, recent studies suggest that higher resistance loads (\geq 70% 1RM) can also be safe and effective in this population, potentially leading to greater gains in muscle strength and reductions in fatigue [15]. So, there is controversy regarding the implementation of high intensity in women with breast cancer who are experiencing the effects of fatigue or joint pain [6]. This variability indicates that a single,

universal prescription may not be optimal for all breast patients, especially given the heterogeneity in treatment side effects, fatigue levels, and recovery capacity. In this context, individualized prescription strategies that account for day-to-day physiological fluctuations may be particularly useful to tailor intensity, ensuring safety while maximizing the benefits of exercise. Therefore, an individualized intervention based on objective parameters related to exercise recovery, such as heart rate variability (HRV), could be beneficial in prescribing high-intensity exercise, particularly by examining the relationship between this variable and depression, anxiety, fatigue, and pain perception [16].

Concerning the mode of exercise implementation, telemedicine, home-based, or digital interventions are gaining increasing importance and frequency thanks to the development of technologies [17]. However, many of these exercise programs have been based on physical activity recommendations or low or moderate-intensity exercise, in contrast to applying the intensities and weights more commonly used in face-to-face training [17]. In order to get similar benefits, remote training should have similar characteristics to face-to-face exercise. Finally, supervision is highly relevant for achieving a greater sense of security, providing corrections, promoting social support, and exercising adherence [18, 19]. Online and remote exercise programs can be as effective as face-to-face programs by including real-time connections between trainers and patients, which allows trainers to provide instructions and corrections to participants.

Currently, there is limited research on online exercise programs for breast cancer patients. The few existing studies included supervised aerobic and/or strength training [20, 21], but did not prescribe training according to patients' baseline levels. Additionally, technology can enhance the personalization of exercise programs by adjusting daily routines based on objective physiological imbalances. One promising tool, as mentioned above, is the daily prescription of exercises based on parasympathetic modulation, a technique previously used in sports performance [22]. This approach may help to further individualize patients' training and achieve significant mental and psychological benefits. Thus, the present research aimed to analyze the effects of an online high-intensity interval and strength exercise program, prescribed based on daily parasympathetic modulation, compared to pre-planned exercise of moderate to high intensity and usual care in HRQoL, pain, fatigue, anxiety, depression, life satisfaction, self-esteem, and fear of movement in breast cancer survivors.

2 | Methods

2.1 | Study Design

This randomized controlled trial was registered on [ClinicalTrials.gov](https://clinicaltrials.gov) (ID: NCT05040867), recognized by the WHO and ICMJE. The study adhered to the 2014 Declaration of Helsinki and received ethical approval from Universidad Rey Juan Carlos (No. 1901202103121) and Hospital Universitario Marqués de Valdecilla (IDIVAL, No. 42//2021). Moreover, the study was

designed and reported in accordance with the CONSORT (Consolidated Standards of Reporting Trials) guidelines. All participants were informed of the study's purpose, potential risks, and benefits, and provided written informed consent prior to participation.

2.2 | Participants

Recruitment occurred in two phases. First, the oncology team at Marqués de Valdecilla University Hospital identified eligible women aged 18–65 with luminal or triple-negative breast cancer who had completed chemotherapy and radiotherapy 1–5 months prior, minimizing cardiotoxicity risks. Exclusion criteria included scheduled surgeries, metastases, prior cancers, and HER2+ status.

In the second phase, the research team contacted candidates. Those without access to a smartphone with internet, incompatible schedules, or injuries preventing exercise were excluded. All eligible participants underwent to an echocardiogram to examine severe heart conditions previously undiagnosed before random and blind assignment to one of three groups: HRV-guided high-intensity exercise, pre-planned moderate-to-high-intensity exercise, or usual care. Participants were enrolled by the medical team and allocated to intervention groups based on a predetermined randomization sequence, following the order in which they completed radiotherapy. The sample size was calculated using G*Power for a repeated measures ANOVA (3 groups, 2 time points), estimating a moderate effect size ($f = 0.25$) based on Kotte, Bolam [23] with $\alpha = 0.05$ and power 0.80, resulting in 16 participants per group. To compensate for possible losses, 68 women were recruited.

The final sample had a mean age of 50.3 years (SD = 8). Cancer types included luminal B (44.44%), luminal A (37.04%), and triple-negative (18.52%). Group characteristics are detailed in Table 1.

2.3 | Procedure

Participants were randomized into three groups. Two of them performed online supervised exercises with intensity guided by

daily individual HRV (HRVG) or with pre-planned exercise intensity (PEG) and the other one continued with usual care.

2.3.1 | Online and Supervised Concurrent Exercise Programs

Participants trained 3 days per week for 16 weeks, with each session lasting 60–70 min and conducted by a certified exercise professional specialized in oncology populations. Equipment necessary for the exercises was provided to each participant during the pre-intervention evaluation. All sessions were supervised and conducted online. Participants connected via video call with an exercise professional and other participants, seeing as well real-time heart rate, monitored by MZ-Remote platform. Intensity adjustments were made based on heart rate for cardiovascular exercises and weightlifting load for strength exercises. Posture and technique were monitored and corrected during sessions.

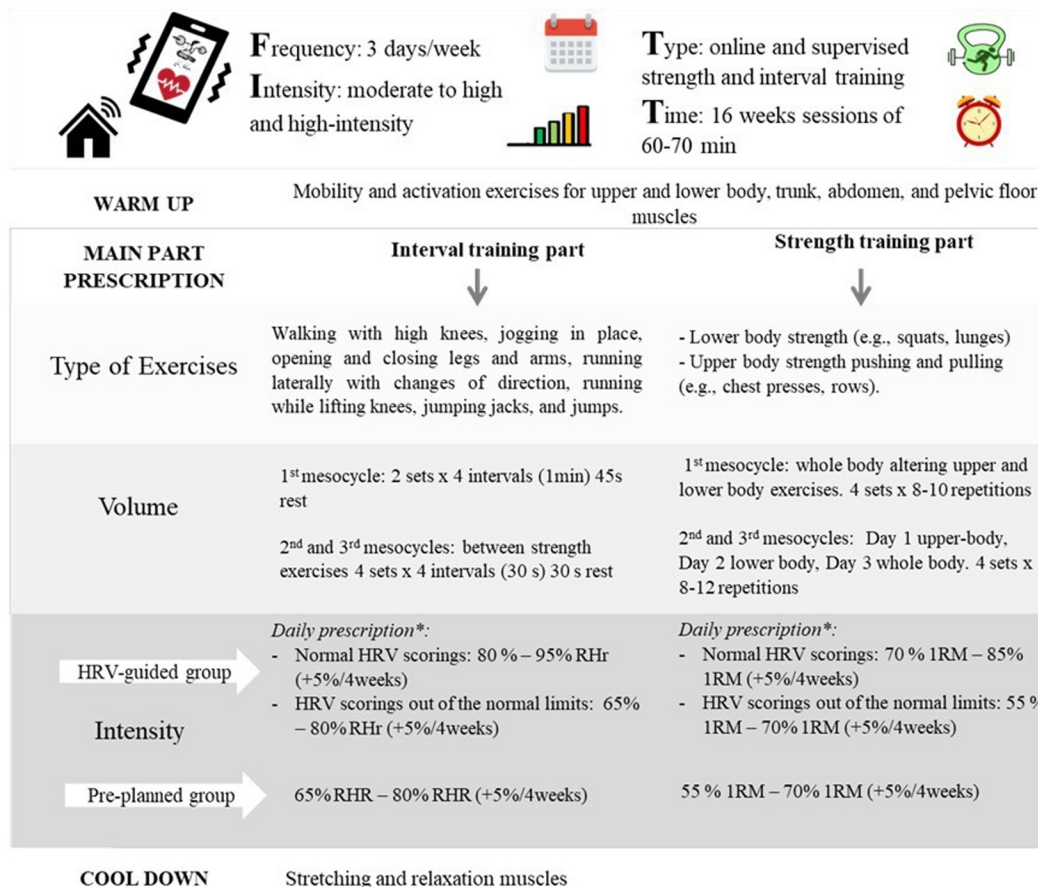
Sessions were structured into three phases: warm-up, main exercise, and cool-down. The warm-up lasted 5–10 min and included mobility and activation exercises for upper and lower body, trunk, abdomen, and pelvic floor muscles to prepare participants for the main exercise. The main phase lasted 45–50 min and included interval and strength training with increasing technical and biomechanical difficulty in each session. Finally, the cool-down phase lasted around 5 min and involved stretching muscles, focusing on relaxation, and muscle lengthening during exhalation. All phases are explained in Figure 1.

In both exercise groups, intensity was prescribed according to the values achieved in the initial evaluation. However, the way of prescription was different between groups. In the PEG, the exercise prescription was prefixed following a blocked progression, whereas in the HRVG, the intensity varied based on individual daily HRV. This way of tailoring exercise allowed the trainer to adjust the training load according to the individual's physiological stress (rMSSD) measured by an HRV photoplethysmography. More detailed information on the exercise programs is presented in Figure 1 and explained elsewhere [24].

TABLE 1 | Participants' characteristics.

	HRV-guided exercise group	Pre-planned exercise group	Control group	p-value
Sample size	18	18	18	
Nationality (%)				
European	100	100	84.61	0.985
South American	0	0	5.18	0.859
Mean age (SD)	50.56 (7.56)	48.94 (9.27)	51.39 (7.19)	0.656
Type of breast cancer (%):				
Luminal phenotype A	38.89	33.33	38.89	0.928
Luminal B phenotype	38.89	50.00	44.44	0.931
Triple negative	22.22	16.67	16.67	0.89

Abbreviations: HRV: Heart rate variability; SD: Standard deviation.



Legend: * HRVG intensity decision. Based on every morning smartphone photoplethysmography rMSSD. A seven-day rolling average measure (lnrMSSD7day-roll-avg) was used for decision-making and setting training intensity and load. The score obtained for each specific day was compared with the smallest worthwhile change (SWC) to analyze if it fell within the upper and lower limits of the SWC, calculated (lnrMSSD ± 0.5 × standard deviation). Reference values for the first four weeks were established based on a one-week baseline measurement before starting training and in the rest of the program was updated every 4 weeks.

HRV: heart rate variability; 1RM:1-repetition maximum; RHR: reserve heart rate

FIGURE 1 | Online supervised concurrent exercise programs of the HRV-guided group and the pre-planned group.

2.3.2 | Usual Care

The control group continued with the usual care including the treatments and without any exercise restriction.

2.4 | Instruments and Variables

Evaluations took place 2 weeks before the intervention and immediately after the 16-week program. All three groups completed self-administered questionnaires. Sociodemographic data, including age, country of origin, and clinical information related to cancer diagnosis and treatment, were also collected.

2.4.1 | Measurement of Health-Related Quality of Life

To assess HRQoL, participants were asked to complete the EORTC QLQ-C30 questionnaire [25], designed to evaluate functionality (physical, role, emotional, cognitive, and social functioning), cancer-related symptoms (fatigue, nausea and vomiting, pain, dyspnea, insomnia, loss of appetite, constipation, diarrhea, and financial difficulties), and overall health

status [26]. The questionnaire uses a temporal scope of 1 week and a 4-point Likert scale, ranging from “not at all” to “very much.”, except for the two items evaluating overall health status, which range from 1 to 7.

Following the manual, scores were transformed to a 0–100 scale, where higher scores indicate stronger responses [26]. On functional and global health status/quality of life scales, higher scores reflect better functioning or well-being. In contrast, higher scores on symptom scales indicate greater symptom severity or problems [25].

2.4.2 | Measurement of Anxiety and Depression

Anxiety and depression were assessed using the Hospital Anxiety and Depression Scale (HADS) following established guidelines [27]. The 14-item scale evaluates symptoms over the past week, with odd-numbered items assessing anxiety (HADS-A) and even-numbered items assessing depression (HADS-D). Each item is rated on a 4-point Likert scale (0–3), yielding subscale scores from 0 to 21. Higher scores indicate greater symptom severity. A score of ≥ 8 suggests clinical anxiety or

depression, with HADS-A showing 0.90 sensitivity and 0.78 specificity, and HADS-D 0.83 sensitivity and 0.79 specificity [28]. Scores are classified as normal (0–7), mild [8–10], moderate [11–14], or severe [15–21].

2.4.3 | Measurement of Life Satisfaction

Life satisfaction was measured using the Satisfaction With Life Scale (SWLS), a 5-item questionnaire rated on a 7-point Likert scale (1 = strongly disagree, 7 = strongly agree) [29]. Total scores range from 5 to 35, with higher scores indicating greater satisfaction. Based on Pavot and Diener's (1993) guidelines, scores are categorized as follows: 31–35 (very satisfied), 26–30 (satisfied), 21–25 (slightly satisfied), 20 (neutral), 15–19 (slightly dissatisfied), 10–14 (dissatisfied), and 5–9 (very dissatisfied) [29].

2.4.4 | Measurement of Self-Esteem

The Rosenberg Self-Esteem Scale assesses global self-worth using 10 items rated on a 4-point Likert scale (1 = strongly agree to 4 = strongly disagree) [30]. Items 2, 5, 6, 8, and 9 are reverse-scored, as they are negatively worded. Total scores range from 10 to 40, with higher scores indicating greater self-esteem [30]. Based on total scores, participants are classified as having high [30–40], medium [26–29], or low (< 26) self-esteem. Medium scores suggest the need for some improvement, while low scores indicate significant problems [30].

2.4.5 | Measurement of Fear of Movement

Fear of movement was assessed using the Tampa Kinesiophobia Scale (TKS-11) [31]. Participants were asked to assess their level of agreement with 11 items from 1 (totally disagree) to 4 (totally agree) [31]. Total scores ranged from 11 to 44 points, with higher scores indicating greater fear of pain, movement, and injury [31]. The intensity of fear could be categorized into: absence of fear (≤ 17 points), slight fear (18–24 points), moderate fear (25–31 points), severe fear (32–38 points), and maximum fear (39–44 points) [32].

2.4.6 | Measurement of Weekly Physical Activity

Physical activity was assessed using the Spanish version of the International Physical Activity Questionnaire (IPAQ) [33, 34]. Participants reported the number of days and minutes per day spent walking, performing moderate-intensity activities, and performing vigorous-intensity activities during the previous 7 days. From these data, the total weekly minutes of physical activity were calculated. The Spanish version used in this study was validated by Roman-Viñas et al. [34], showing good reliability for total physical activity ($r = 0.82$, $p < 0.05$), vigorous activity ($r = 0.79$, $p < 0.05$), moderate activity ($r = 0.83$, $p < 0.05$), and walking time ($r = 0.73$, $p < 0.05$).

2.5 | Statistical Analysis

Statistical analyses were conducted using IBM SPSS Statistics (Version 28). Repeated measures ANOVA was applied to compare pre- and post-intervention data across all participants who received the intervention in each group (HRVG, PEG, CG), after normalizing variables using the two-step transformation method [35]. Bonferroni post-hoc tests were used for pairwise comparisons. Partial eta squared (η^2) was calculated to assess the variance explained by each predictor. Clinical changes were assessed by counting participants who shifted levels in fatigue, pain, anxiety, depression, self-esteem, life satisfaction, and fear of movement, based on validated cut-off points. Pearson correlations were used to perform exploratory associations between variable changes within each group, following normalization and without Bonferroni correction due to the exploratory character and small sample size in each group to prevent Type II errors and potential significant interactions [36, 37]. Statistical significance was set at $p < 0.05$.

3 | Results

3.1 | Participants' Characteristics

Of the 68 participants evaluated for eligibility, 62 started the intervention, and 54 completed the study (18 in each group). Dropout reasons are presented in Figure 2. Of the 5 participants excluded for not meeting eligibility criteria, 2 were excluded due to lack of a smartphone, 2 due to scheduling conflicts with the exercise program, and 1 due to cardiac abnormalities, according to the combined cardiac evaluation and criteria of the hospital's oncology and cardiology teams. The small number of participants excluded for smartphone access suggests that this criterion did not meaningfully affect the generalizability of the study findings.

3.2 | Effects on Health-Related Quality of Life

In the assessment of HRQoL, significant differences were observed in the overall health subscale between groups and evaluation times, with significant differences between CG and HRVG, as well as between CG and PEG. Intragroup differences revealed significant differences between pre- and post-evaluation in all groups, increasing by 36.7% in HRVG and 15.61% in PEG, while decreasing by 20.34% in CG.

As shown in Table 2, physical, emotional, social, and role functioning showed significant differences across groups and time points, while cognitive functioning did not. Pairwise comparisons for physical functioning revealed significant intragroup changes in the control group (CG: -12.73%), HRV-guided group (HRVG: $+13.96\%$), and pre-planned exercise group (PEG: $+5.83\%$), with significant differences between CG–HRVG and PEG–CG. In role functioning, significant intragroup changes were observed only in HRVG, with differences between HRVG–CG and HRVG–PEG. For emotional functioning, both HRVG and CG showed significant intragroup changes, with improvements of 16.55% in HRVG and 10.51% in

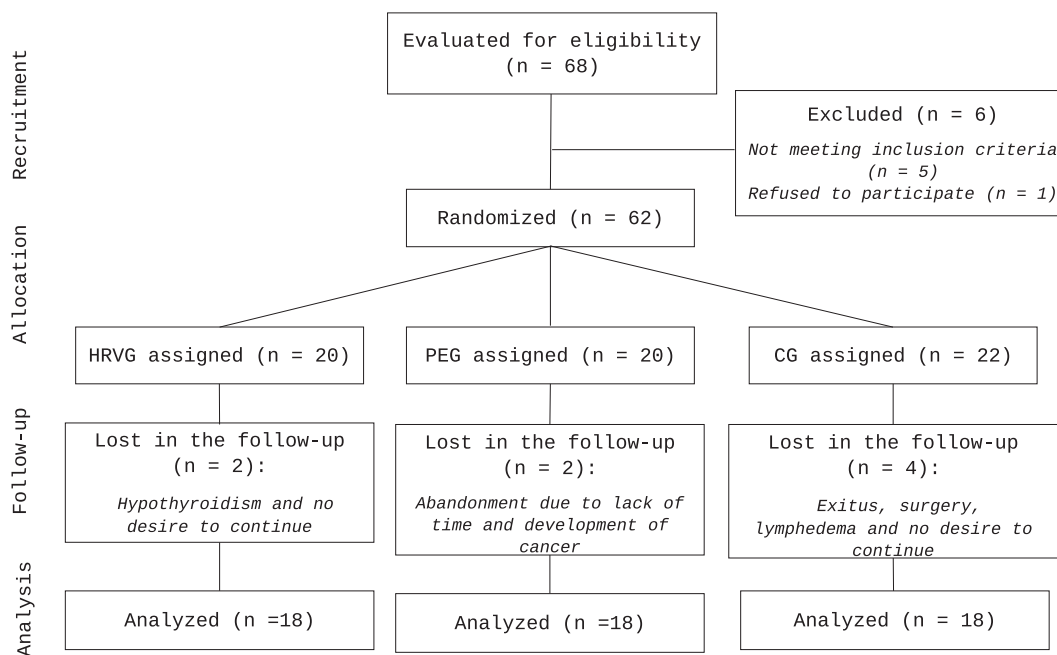


FIGURE 2 | Flow diagram of the participants following CONSORT guidelines.

PEG. Significant group differences were noted between HRVG–CG and PEG–CG. Social functioning improved significantly within both HRVG and PEG, with increases of 33.8% and 22.53%, respectively.

Significant differences were found between groups and over time (pre–post) in fatigue, pain, dyspnea, insomnia, and constipation, but not in appetite loss, diarrhea, nausea, or financial difficulties ($p > 0.05$). Pairwise comparisons revealed that the HRVG group showed significant intragroup improvements in fatigue (–50.81%), pain (–64.10%), dyspnea, and insomnia. In the PEG group, only pain improved significantly (–37.14%). In contrast, the CG group experienced a significant 37.49% increase in fatigue. Detailed results are presented in Table 3.

Clinical changes in fatigue and pain are illustrated in Supporting Information S1: Figure S1, showing the number of participants in each group with scores above and below the clinical cut-off at baseline and post-intervention.

3.3 | Effects on Anxiety and Depression

As shown in Table 4, significant differences in anxiety and depression were observed between groups and over time. Post hoc analyses revealed significant within-group improvements in the HRVG for both anxiety ($p = 0.001$) and depression ($p = 0.005$). In the CG, depression worsened significantly ($p = 0.002$). Figure S2 illustrates that both HRV-guided and pre-planned groups improved, with more participants reaching normal anxiety and depression levels, especially in the HRVG. In contrast, the control group showed increased severity across both variables.

3.4 | Effects on Life Satisfaction, Self-Esteem and Fear of Movement

Results for life satisfaction, self-esteem, and fear of movement (Table 4) showed significant differences across time and groups. Life satisfaction improved by 37.1% in HRVG ($p < 0.001$) and 17.51% in PEG ($p = 0.002$), while CG declined by 16.86% ($p = 0.003$). Between-group comparisons showed significant differences between CG and both HRVG and PEG ($p < 0.001$). Self-esteem increased by 27.88% in HRVG ($p < 0.001$) and 9.84% in PEG ($p = 0.01$). Fear of movement decreased by 23.27% in HRVG ($p < 0.001$) and 13.37% in PEG ($p = 0.002$). Figure S3 illustrates that HRVG showed the greatest improvements across all measures. PEG also improved, while CG declined in all three variables.

3.5 | Effects on Weekly Physical Activity

Significant differences were obtained in the interaction time and group minutes of physical activity per week. Although all groups significantly increased their physical activity level (HRVG: $p < 0.001$; PEG: $p < 0.01$; CG: $p = 0.017$), differences between groups were only shown between the HRVG and the CG.

3.6 | The Relationship Between Psychological Parameters Regarding the Effects of Different Exercise Programs

Pearson correlations (presented in Figure 3 and in Supporting Information S1: Table S1 of the supporting information) revealed in this exploratory analysis that HRV-guided exercise

TABLE 2 | Descriptive and interaction results of global health and functional HRQoL dimensions of effects of exercise and usual care groups.

Variable	HRV group mean (SD)		PE group mean (SD)		Control group mean (SD)		ANOVA Time*group p-value (ES)	Between-group	Within group
	Baseline	After	Baseline	After	Baseline	After			
Global health	4.39 (0.50)	6.00 (0.62)	4.81 (1.11)	5.56 (0.87)	4.92 (1.23)	3.92 (1.03)	18.25; p < 0.001 (0.417)	HRVG-CG: p < 0.001 HRVG-PEG: p = 0.008 PEG-CG: p < 0.001	HRVG: p < 0.001 PEG: p = 0.001 CG: p = 0.002
Physical functioning	82.22 (13.53)	93.70 (11.08)	88.89 (9.70)	94.07 (7.88)	86.67 (13.33)	75.29 (18.07)	6.36; p = 0.004 (0.206)	HRVG-CG: p < 0.001 HRVG-PEG: <i>p = 0.092</i> PEG-CG: p = 0.006	HRVG: p = 0.004 PEG: p = 0.042 CG: p = 0.008
Role functioning	78.70 (22.00)	93.52 (8.36)	86.11 (20.81)	89.81 (15.27)	79.63 (23.26)	70.59 (27.97)	1.33; p = 0.005 (0.190)	HRVG-CG: p < 0.001 HRVG-PEG: p = 0.040 PEG-CG: <i>p = 0.137</i>	HRVG: p = 0.002 PEG: <i>p = 0.357</i> CG: <i>p = 0.234</i>
Emotional functioning	74.07 (24.23)	83.33 (24.25)	75.46 (22.59)	83.39 (24.72)	74.54 (27.63)	62.25 (28.89)	4.76; p = 0.013 (0.161)	HRVG-CG: p < 0.001 HRVG-PEG: <i>p = 0.760</i> PEG-CG: p < 0.001	HRVG: p = 0.028 PEG: <i>p = 0.072</i> CG: p = 0.006
Cognitive functioning	70.37 (25.28)	81.48 (27.35)	77.78 (19.80)	77.83 (25.39)	75.00 (34.42)	68.63 (29.98)	2.82; <i>p = 0.085</i> (0.092)	HRVG-CG: p = 0.004 HRVG-PEG: <i>p = 0.302</i> PEG-CG: <i>p = 0.069</i>	HRVG: <i>p = 0.066</i> PEG: <i>p = 0.282</i> CG: <i>p = 0.166</i>
Social functioning	65.74 (20.98)	87.96 (25.35)	71.30 (28.47)	85.29 (17.56)	70.37 (32.11)	65.69 (30.88)	17.94; p = 0.001 (0.234)	HRVG-CG: <i>p = 0.740</i> HRVG-PEG: <i>p = 1.00</i> PEG-CG: <i>p = 0.676</i>	HRVG: p < 0.001 PEG: p = 0.002 CG: <i>p = 0.544</i>

Note: Bold font: *p*-value < 0.05.

Abbreviations: ES: Effect size; HRV: Heart rate variability; PE: Pre-planned; SD: Standard deviation.

might have more significant associations than PEG or CG. Exact *p*-values for all correlations are reported in Supporting Information S1: Table S1 to allow better and more complete interpretation. In the HRVG, reductions in fatigue seemed to be associated with improvements in role functioning and life satisfaction, and might also relate to changes in dyspnea. Gains in self-esteem may suggest a relationship with higher life satisfaction and global health, while also appearing inversely related to dyspnea. Increases in dyspnea might be linked to higher levels of depression, anxiety, and pain, as well as lower role and cognitive functioning. Changes in pain seemed inversely related to physical and role functioning, which in turn may also show associations with depression.

In the PEG, fatigue appeared to correlate positively with dyspnea. Dyspnea might be associated with anxiety and fatigue, and may show inverse relationships with cognitive and social functioning, as well as life satisfaction. Changes in pain seemed negatively associated with global health and life satisfaction, while anxiety might be related to self-esteem.

As for the CG, dyspnea may be inversely associated with global health and physical functioning, and could show a positive association with fear of movement. Global health seemed inversely related to depression, and fatigue might be linked to lower emotional functioning.

TABLE 3 | Descriptive and interaction results of HRQoL symptoms dimensions of effects of exercise and usual care groups.

Variable	HRV group mean (SD)		PE group mean (SD)		Control group mean (SD)		ANOVA Time*group p-value (ES)	Between-group	Within group
	Baseline	After	Baseline	After	Baseline	After			
Fatigue	37.65 (25.32)	18.52 (24.70)	30.86 (28.66)	23.46 (23.15)	34.57 (28.49)	47.53 (24.34)	18.34; p < 0.001 (0.413)	HRVG-CG: p < 0.001 HRVG-PEG: p = 0.082 PEG-CG: p = 0.002	HRVG: p = 0.001 PEG: p = 0.065 CG: p = 0.004
Nausea	0.93 (3.96)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.93 (3.93)	0.93 (3.93)	1.047; p = 0.374 (0.038)	HRVG-CG: p = 0.220 HRVG-PEG: p = 0.221 PEG-CG: p = 1.000	HRVG: p = 0.316 PEG: p = 1.00 CG: p = 1.00
Pain	36.11 (29.29)	12.96 (24.64)	32.41 (23.20)	20.37 (19.43)	36.11 (27.56)	40.74 (38.87)	12.57; p < 0.001 (0.331)	HRVG-CG: p < 0.001 HRVG-PEG: p = 0.185 PEG-CG: p = 0.008	HRVG: p < 0.001 PEG: p = 0.034 CG: p = 0.282
Dyspnea	24.07 (25.06)	9.26 (25.06)	18.52 (26.13)	7.41 (18.28)	20.37 (23.26)	31.48 (15.71)	6.14; p = 0.004 (0.194)	HRVG-CG: p < 0.001 HRVG-PEG: p = 0.405 PEG-CG: p = 0.011	HRVG: p = 0.012 PEG: p = 0.053 CG: p = 0.058
Insomnia	42.59 (33.96)	25.93 (31.43)	35.19 (31.25)	24.07 (27.55)	33.33 (34.30)	42.59 (29.83)	4.79; p = 0.012 (0.158)	HRVG-CG: p = 0.009 HRVG-PEG: p = 0.782 PEG-CG: p = 0.020	HRVG: p = 0.045 PEG: p = 0.055 CG: p = 0.096
Appetite loss	20.37 (25.92)	5.56 (12.78)	1.85 (7.86)	1.85 (7.86)	16.67 (30.78)	20.37 (34.56)	2.717; p = 0.082 (0.093)	HRVG-CG: p = 0.005 HRVG-PEG: p = 0.023 PEG-CG: p = 0.647	HRVG: p = 0.010 PEG: p = 1.00 CG: p = 0.608
Constipation	22.22 (28.01)	9.26 (19.15)	14.81 (23.49)	11.11 (16.17)	29.63 (39.42)	40.74 (38.87)	4.68; p = 0.014 (0.155)	HRVG-CG: p = 0.004 HRVG-PEG: p = 0.304 PEG-CG: p = 0.066	HRVG: p = 0.053 PEG: p = 0.527 CG: p = 0.034
Diarrhea	0.00 (0.00)	5.56 (23.57)	7.41 (14.26)	1.85 (7.86)	0.00 (0.00)	3.70 (15.71)	2.056; p = 0.148 (0.072)	HRVG-CG: p = 0.981 HRVG-PEG: p = 0.027 PEG-CG: p = 0.030	HRVG: p = 0.314 PEG: p = 0.082 CG: p = 0.157

(Continues)

TABLE 3 | (Continued)

Variable	HRV group mean (SD)		PE group mean (SD)		Control group mean (SD)		ANOVA Time*group p-value (ES)	Between-group	Within group
	Baseline	After	Baseline	After	Baseline	After			
Financial difficulties	9.26 (15.36)	7.41 (18.28)	5.56 (12.78)	9.26 (19.15)	29.63 (34.09)	33.33 (36.16)	0.707; <i>p</i> = 0.511 (0.026)	HRVG-CG: <i>p</i> = 0.278 HRVG-PEG: <i>p</i> = 0.288 PEG-CG: <i>p</i> = 0.982	HRVG: <i>p</i> = 0.680 PEG: <i>p</i> = 0.317 CG: <i>p</i> = 0.157

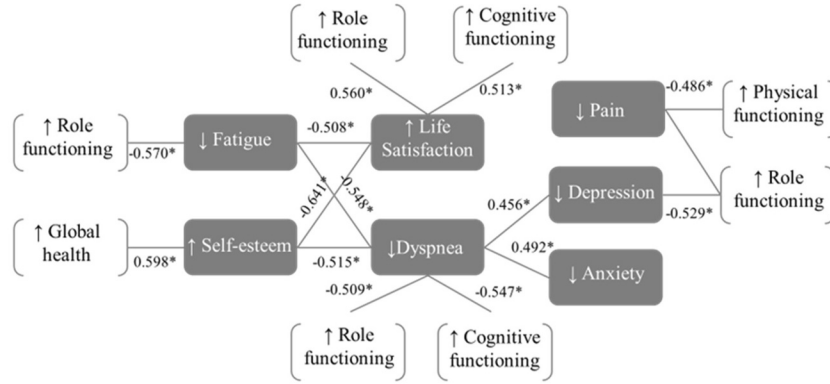
Note: Bold font: *p*-value < 0.05.
Abbreviations: ES: Effect size; HRV: Heart rate variability; PE: Pre-planned; SD: Standard deviation.

TABLE 4 | Mental health and weekly minutes of physical activity descriptive and interaction results of effects of exercise and usual care groups.

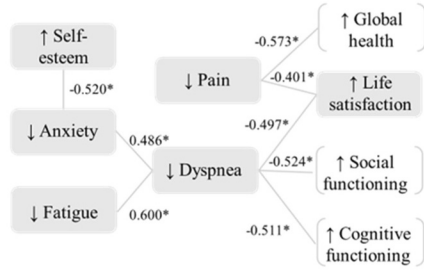
Variable	HRV group mean (SD)		PE group mean (SD)		Control group mean (SD)		ANOVA Time*group p-value (ES)	Between-group	Within group
	Baseline	After	Baseline	After	Baseline	After			
Anxiety	8.33 (4.53)	4.83 (3.65)	7.56 (3.82)	6.22 (3.21)	7.17 (5.04)	8.00 (4.35)	8.81; <i>p</i> = 0.002 (0.257)	HRVG-CG: <i>p</i> < 0.001 HRVG-PEG: <i>p</i> = 0.052 PEG-CG: <i>p</i> = 0.061	HRVG: <i>p</i> = 0.001 PEG: <i>p</i> = 0.086 CG: <i>p</i> = 0.230
Depression	5.78 (4.53)	2.89 (2.91)	4.00 (3.43)	3.33 (1.18)	4.33 (5.18)	6.17 (5.07)	12.93; <i>p</i> < 0.001 (0.336)	HRVG-CG: <i>p</i> < 0.001 HRVG-PEG: <i>p</i> = 0.080 PEG-CG: <i>p</i> = 0.003	HRVG: <i>p</i> = 0.005 PEG: <i>p</i> = 0.117 CG: <i>p</i> = 0.002
Life satisfaction	20.22 (5.95)	27.72 (5.33)	22.22 (12.78)	26.11 (5.30)	22.78 (6.61)	18.94 (4.99)	7.22; <i>p</i> = 0.003 (0.221)	HRVG-CG: <i>p</i> < 0.001 HRVG-PEG: <i>p</i> = 0.055 PEG-CG: <i>p</i> < 0.001	HRVG: <i>p</i> < 0.001 PEG: <i>p</i> = 0.002 CG: <i>p</i> = 0.003
Self-esteem	19.33 (3.09)	24.72 (3.56)	22.56 (5.94)	24.78 (4.43)	22.22 (4.36)	21.22 (2.88)	4.7; <i>p</i> = 0.023 (0.156)	HRVG-CG: <i>p</i> = 1.00 HRVG-PEG: <i>p</i> = 0.576 PEG-CG: <i>p</i> = 0.369	HRVG: <i>p</i> < 0.001 PEG: <i>p</i> = 0.010 CG: <i>p</i> = 0.236
Fear of movement	29.61 (6.08)	22.72 (5.39)	26.17 (8.40)	22.67 (7.19)	27.50 (8.35)	29.11 (8.19)	5.6; <i>p</i> = 0.015 (0.180)	HRVG-CG: <i>p</i> = 1.00 HRVG-PEG: <i>p</i> = 1.000 PEG-CG: <i>p</i> = 0.304	HRVG: <i>p</i> < 0.001 PEG: <i>p</i> = 0.002 CG: <i>p</i> = 0.143
Physical activity (minutes/week)	175 (71.50)	771.67 (492.92)	130 (94.1)	693.61 (331.74)	147.22 (78.7)	347.78 (273.87)	7.34; <i>p</i> = 0.002 (0.224)	HRVG-CG: <i>p</i> = 0.007 HRVG-PEG: <i>p</i> = 1.00 PEG-CG: <i>p</i> = 0.073	HRVG: <i>p</i> < 0.001 PEG: <i>p</i> < 0.001 CG: <i>p</i> = 0.017

Note: Bold font: *p*-value < 0.05.
Abbreviations: ES: Effect size; HRV: Heart rate variability; PE: Pre-planned; SD: Standard deviation.

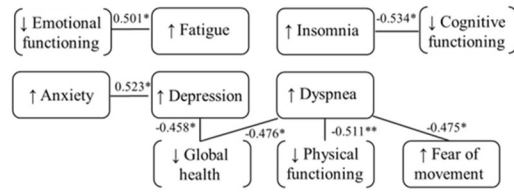
HRV-guided exercise group



Pre-planned exercise group



Control group



*p-value <0.05; ** p-value<0.01.

FIGURE 3 | Pearson correlations of the changes in the psychological, functional and symptoms variables.

4 | Discussion

The purpose of this research was to analyze the effects of online supervised high-intensity interval training and high-load strength training, prescribed based on daily individual HRV, compared to pre-planned interval and strength training of moderate to high intensity/load and usual care on different psychological variables that influence the mental health of breast cancer survivors.

In terms of HRQoL, both intervention groups improved in physical and social functioning, but only physical functioning differed significantly from the control group, highlighting the general value of exercise for supporting daily activities in cancer survivors. However, role and emotional functioning improved only with HRV-guided training, offering greater benefits for managing work, hobbies, and emotional symptoms like anxiety and depression. The control group showed a decline in emotional functioning. Cognitive functioning showed no significant change, possibly due to the absence of a specific cognitive intervention [38]. Regarding symptoms, HRV-guided exercise significantly improved fatigue, pain, dyspnea, appetite loss, and insomnia, while pre-planned training improved only pain. Fatigue, a major concern in this population [39], decreased by 50.81% in the HRV group but rose by 37.49% in controls. Patients with higher fatigue often show reduced HRV, reflecting autonomic imbalance and inflammation [16]. Lower RMSSD scores were linked to greater fatigue, suggesting rMSSD-based exercise may better manage fatigue and related symptoms.

After the completion of in-hospital treatments, women with hormone-dependent cancers typically continue adjuvant therapy with oral medications and/or injections for at least 5 years. This prolonged therapy may contribute to the persistence or even exacerbation of certain symptoms or side effects from previous treatments, such as fatigue and pain [40]. This trend is evident in the control group findings of the present study, in which, consistent with other research, women who continued with the usual care reduced their overall health, physical and emotional function, and satisfaction with life, increasing their fatigue and depression [3]. Diarrhea, nausea, and financial difficulties did not show significant improvement with any of the programs, which was expected, as patients were not under chemotherapy.

In terms of emotional symptoms, the HRVG significantly improved anxiety and depression between times and in comparison to the control group in both variables. These results suggest that personalizing exercise based on individual HRV may be more effective than standardized programs. Prior research indicates that anxiety mediates the link between sympathetic activation and quality of life and that exercise helps regulate mood disorders [41]. Physiologically, exercise promotes neurogenesis and cognitive function by releasing chemicals like beta-endorphins, serotonin, vascular endothelial growth factor, and brain-derived neurotrophic factor [42]. It also influences the hypothalamic-pituitary-adrenal axis, reducing anxiety by lowering cortisol levels and improving hormonal regulation through increased endorphin production and serotonergic system changes [43].

In line with these findings, Li et al. (2024) reported reduced anxiety and depression through online aerobic programs in cancer patients [44]. Similarly, Courneya et al. (2014) found that higher volumes of exercise during chemotherapy were particularly effective for breast cancer patients with significant depressive symptoms [45]. In our study, only the group performing higher intensity and volume of exercise showed significant reductions in both anxiety and depression, shifting from severe to more normal levels. This suggests that increased exercise intensity, even delivered online, can improve mental health outcomes through both biological and psychosocial mechanisms. Given that over 30% of women with breast cancer experience depression [46], these results are socially significant. Moreover, anxiety and depression can worsen cancer-related symptoms such as fatigue, highlighting the importance of addressing mental health in this population [39].

Findings on life satisfaction, self-esteem, and fear of movement suggest that both pre-planned and HRV-modulated exercise can significantly improve these psychological variables. However, personalized approaches showed greater percentage changes and clinically meaningful improvements. Although less studied than quality of life or anxiety, these factors are crucial for understanding individual differences and barriers to exercise participation, as seen in other health conditions [47]. In breast cancer, for example, fear of movement may hinder exercise initiation and adherence due to concerns about injury, lymphedema, fatigue, or joint pain, all of which affect exercise self-efficacy [47]. Similarly, low self-esteem, often stemming from physical changes post-treatment or low perceived competence [48], may make exercising in shared spaces challenging, especially when surrounded by individuals without similar experiences. Understanding these psychological barriers is essential for designing effective, inclusive exercise programs. Careful planning, clear explanations, tailored correction, and supportive feedback can help foster safety, confidence, and sustained engagement in physical activity for women with breast cancer [18].

The associations between variables revealed exploratory patterns, indicating that the highest degree of connectivity between changes might be observed in the HRV-guided group. Network theory in mental health suggests that symptoms are interrelated and influence one another [49]. Applying this approach to exercise interventions in cancer patients could help identify central symptoms and their impact. For example, exercise-related reductions in pain, reported by 48.17% of this population [50], appeared to occur together with increases in overall health in the pre-planned group and with higher role and physical function in the HRVG group. Better physical condition tended to coincide with lower pain levels and increases in overall well-being, a significant aspect given that high pain levels are associated with discontinuation of hormone therapy [51]. Similarly, variations in dyspnea and fatigue seem to be associated with differences in depression scores, functionality, and cognitive function, whereas unfavorable changes in these symptoms might be related to declines in health measures in the usual care group. Focusing on these interconnected symptoms through exercise-based strategies could be important for understanding quality of life dynamics among breast cancer survivors.

Although the benefits of physical exercise are well-studied, few investigations have examined supervised online exercise programs, and none have achieved the present level of success [21]. This may be due to the real-time supervision provided in all sessions, which ensures proper execution, adherence, and safe progression of high-intensity exercise, while also promoting social interaction, self-efficacy, and self-esteem, further supporting mental health [18]. Integrating technology and personalized approaches can enhance adherence and outcomes by enabling specific monitoring of HRV, exercise frequency, and intensity. This allows for tailored exercise prescriptions, real-time feedback, and communication between professionals and patients, enhancing confidence and control [52]. This enhances confidence and a sense of control in participants, as trainers can personalize intensity based on feedback about recovery, fatigue, stress, or discomfort, ensuring the program meets their needs. However, success may depend on participants' willingness to use the technology, access to devices, and trainers' ability to implement and explain the tools. Combining these technologies with adherence strategies like the PADEX scale [19], as done in this study, can improve supervision, support, and outcomes, especially in managing chronic diseases.

4.1 | Clinical Implications

This study represents a clinical advance by implementing, for the first time, parasympathetic modulation as an objective tool to adjust training intensity based on recovery and fatigue in female breast cancer survivors. This methodology allows for safer and more personalized exercise prescription, reducing the potential risks associated with overload and increasing the effectiveness of exercise, as the significant results in most of the psychological variables showed. From a research perspective, future lines of study are opening about its application in different training contexts and the analysis of the interaction between autonomic control and psychological factors, to enhance the effectiveness of exercise-based clinical interventions, which are very necessary to contrast the findings.

5 | Limitations

This study has some limitations. First, it included women with both triple-negative and luminal breast cancer, leading to varied prior treatments that may affect their perceptions of quality of life and psychological factors when beginning the exercise program. Second, only women with luminal cancer were on hormone therapy during the study, making side effects like fatigue and pain more noticeable. Third, the small sample size prevented subgroup analysis by severity level. Moreover, the within-group sample size was insufficient to support robust association analyses; therefore, these results should be considered exploratory and secondary to the main interaction analysis, without implying a causal relationship. Future research should explore how exercise benefits vary with initial levels of anxiety, depression, self-esteem, life satisfaction, or fear of movement.

6 | Conclusion

This study shows that online supervised concurrent exercise improves HRQoL and psychological outcomes in breast cancer survivors. Both personalized HRV-guided high-intensity training and pre-planned moderate to high-intensity exercise enhanced self-esteem, life satisfaction, and reduced fear of movement. However, the HRV-guided group experienced greater improvements in physical, emotional, and global health, along with significant reductions in pain, fatigue, and dyspnea. Individualized training also led to larger decreases in anxiety and depression. Conversely, the control group showed declines in HRQoL, depression, and life satisfaction. These results highlight the benefits of personalized exercise based on parasympathetic modulation, supporting its role in recovery and quality of life, and call for further research on tailored exercise interventions for breast cancer survivors.

Author Contributions

A.M.L.-P. and D.C.-M. wrote the original manuscript. I.N., X.M., C.H.G., A.d.J.F., G.L., and A.J. revised the manuscript. A.M.L.-P., D.C.-M., and X.M. analyzed and interpreted the data. A.M.L.-P., C.H.G., A.d.J.F., G.L., and A.J. conceptualized the study and defined the methods. A.M.L.-P. collected the data. I.N. and G.L. were responsible for data curation. All authors approved the final version of the manuscript.

Acknowledgments

This research received financial support through the Spanish National Industrial Doctorate grant program (A.M.L.-P.), which is part of the Strategic Plan for Science and Innovation Promotion by the Ministry of Science, Innovation, and Universities. The specific predoctoral industry grant is identified by the code DIN2018-010129. Additionally, A.M.L.-P. is supported by a postdoctoral fellowship aimed at recruiting research personnel for projects related to the implementation of clinical exercise in non-clinical contexts, under the Go Fit URJC Chair of Active Life, Physical Exercise, and Happiness (grant code VCA13-5082). The authors also acknowledge the support of the Spanish Association Against Cancer (AECC) through the project CTDRS247455JIME. The funding bodies had no involvement in the study's design, execution, or the decision to write and submit this manuscript for publication.

Ethics Statement

The study adhered to the ethical standards outlined in the Declaration of Helsinki. Ethical approval was obtained from the Ethics Committee of King Juan Carlos University (reference number 1901202103121) and from the Ethics Committee of the Hospital Universitario Marqués de Valdecilla, affiliated with the Valdecilla Health Research Institute (IDIVAL), under registration number 42//2021. All participants provided informed consent prior to their inclusion in the study.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

References

1. M. Arnold, E. Morgan, H. Rumgay, et al., "Current and Future Burden of Breast Cancer: Global Statistics for 2020 and 2040," *Breast* 66 (2022): 15–23, <https://doi.org/10.1016/j.breast.2022.08.010>.
2. A. J. Kerr, D. Dodwell, P. McGale, et al., "Adjuvant and Neoadjuvant Breast Cancer Treatments: A Systematic Review of Their Effects on Mortality," *Cancer Treatment Reviews* 105 (2022): 102375, <https://doi.org/10.1016/j.ctrv.2022.102375>.
3. P. Aggeli, G. Fasoi, A. Zartaloudi, et al., "Posttreatment Anxiety, Depression, Sleep Disorders, and Associated Factors in Women Who Survive Breast Cancer," *Asia-Pacific Journal of Oncology Nursing* 8, no. 2 (2021): 147–155, https://doi.org/10.4103/apjon.apjon_65_20.
4. H. Carreira, R. Williams, G. Funston, S. Stanway, and K. Bhaskaran, "Associations Between Breast Cancer Survivorship and Adverse Mental Health Outcomes: A Matched Population-Based Cohort Study in the United Kingdom," *PLoS Medicine* 18, no. 1 (2021): e1003504, <https://doi.org/10.1371/journal.pmed.1003504>.
5. Lee S. K., Park S., and Park S. M., "Depression and Long-term Mortality Among 5-year Breast Cancer Survivors in Korea: A Population-Based Cohort Study," (2024).
6. A. Davie, G. C. Carter, A. Rider, et al., "Real-World Patient-Reported Outcomes of Women Receiving Initial Endocrine-Based Therapy for HR+/HER2– Advanced Breast Cancer in Five European Countries," *BMC Cancer* 20, no. 1 (2020): 1–15, <https://doi.org/10.1186/s12885-020-07294-2>.
7. D. Liu, J.-S. Weng, X. Ke, X.-Y. Wu, and S.-T. Huang, "The Relationship Between Cancer-Related Fatigue, Quality of Life and Pain Among Cancer Patients," *International Journal of Nursing Science* 10, no. 1 (2023): 111–116, <https://doi.org/10.1016/j.ijnss.2022.12.006>.
8. D. Kang, H. Kim, J. Cho, et al., "Prediction Model for Postoperative Quality of Life Among Breast Cancer Survivors Along the Survivorship Trajectory From Pretreatment to 5 Years: Machine Learning–Based Analysis," *JMIR public health and surveillance* 9, no. 1 (2023): e45212, <https://doi.org/10.2196/45212>.
9. A. Salam, A. Woodman, A. Chu, et al., "Effect of Post-Diagnosis Exercise on Depression Symptoms, Physical Functioning and Mortality in Breast Cancer Survivors: A Systematic Review and Meta-Analysis of Randomized Control Trials," *Cancer Epidemiology* 77 (2022): 102111, <https://doi.org/10.1016/j.canep.2022.102111>.
10. C. García-Chico, S. López-Ortiz, S. Peñín-Grandes, et al., "Physical Exercise and the Hallmarks of Breast Cancer: A Narrative Review," *Cancers* 15, no. 1 (2023): 324, <https://doi.org/10.3390/cancers15010324>.
11. A. M. Lavín-Pérez, D. Collado-Mateo, X. Mayo, et al., "Effects of High-Intensity Training on the Quality of Life of Cancer Patients and Survivors: A Systematic Review With Meta-Analysis," *Scientific Reports* 11, no. 1 (2021): 15089, <https://doi.org/10.1038/s41598-021-94476-y>.
12. M. Sun, C. Liu, Y. Lu, F. Zhu, H. Li, and Q. Lu, "Effects of Physical Activity on Quality of Life, Anxiety and Depression in Breast Cancer Survivors: A Systematic Review and Meta-analysis," *Asian Nursing Research* 17, no. 5 (2023): 276–285, <https://doi.org/10.1016/j.anr.2023.11.001>.
13. A. Avancini, A. Borsati, L. Toniolo, et al., "Physical Activity Guidelines in Oncology: A Systematic Review of the Current Recommendations," *Critical Reviews In Oncology-Hematology* 210 (2025): 104718, <https://doi.org/10.1016/j.critrevonc.2025.104718>.
14. K. L. Campbell, K. Winters-Stone, J. Wiskemann, et al., "Exercise Guidelines for Cancer Survivors: Consensus Statement From International Multidisciplinary Roundtable," *Medicine & Science in Sports & Exercise* 51, no. 11 (2019): 2375–2390, <https://doi.org/10.1249/mss.0000000000002116>.

15. F. M. Martins, S. B. Santagnello, G. N. de Oliveira Junior, et al., "Lower-Body Resistance Training Reduces interleukin-1 β and Transforming Growth Factor- β 1 Levels and Fatigue and Increases Physical Performance in Breast Cancer Survivors," *Journal of Strength & Conditioning Research* 37, no. 2 (2023): 439–451, <https://doi.org/10.1519/jsc.0000000000004270>.
16. A. D. Crosswell, K. G. Lockwood, P. A. Ganz, and J. E. Bower, "Low Heart Rate Variability and Cancer-Related Fatigue in Breast Cancer Survivors," *Psychoneuroendocrinology* 45 (2014): 58–66, <https://doi.org/10.1016/j.psycheneu.2014.03.011>.
17. H. Kang and M. Moon, "Effects of Digital Physical Activity Interventions for Breast Cancer Patients and Survivors: A Systematic Review and Meta-Analysis," *Healthcare Informatics Research* 29, no. 4 (2023): 352–366, <https://doi.org/10.4258/hir.2023.29.4.352>.
18. D. Collado-Mateo, A. M. Lavín-Pérez, C. Peñacobá, et al., "Key Factors Associated With Adherence to Physical Exercise in Patients With Chronic Diseases and Older Adults: An Umbrella Review," *International Journal of Environmental Research and Public Health* 18, no. 4 (2021): 2023, <https://doi.org/10.3390/ijerph18042023>.
19. A. M. Lavín-Pérez, J. Del Coso, A. Luque-Casado, et al., "Development and Validation of the Spanish Version of the PADEX Checklist to Promote Adherence to Physical Exercise in People With Long-Term Health Conditions and Older Adults," *Disability & Rehabilitation* (2024): 1–8.
20. G. Mavropalias, P. Cormie, C. J. Peddle-McIntyre, et al., "The Effects of Home-Based Exercise Therapy for Breast Cancer-Related Fatigue Induced by Radical Radiotherapy," *Breast Cancer* 30, no. 1 (2023): 139–150, <https://doi.org/10.1007/s12282-022-01408-3>.
21. A. Andrioti, A. Papadopetraki, M. Maridaki, and A. Philippou, "The Effect of a Home-based Tele-Exercise Training Program on the Quality of Life and Physical Performance in Breast Cancer Survivors," *Sports* 11, no. 5 (2023): 102, <https://doi.org/10.3390/sports11050102>.
22. A. Manresa-Rocamora, J. M. Sarabia, A. Javaloyes, A. A. Flatt, and M. Moya-Ramon, "Heart Rate Variability-Guided Training for Enhancing Cardiac-Vagal Modulation, Aerobic Fitness, and Endurance Performance: A Methodological Systematic Review With Meta-Analysis," *International Journal of Environmental Research and Public Health* 18, no. 19 (2021): 10299, <https://doi.org/10.3390/ijerph181910299>.
23. M. Kotte, K. A. Bolam, R. Altena, P. Cormie, Y. Wengström, and S. Mijwel, "Effects of live-remote Exercise on Quality of Life and Other Health-Related Outcomes in Cancer Survivors: A Randomised Controlled Trial," *Journal of Cancer Survivorship* (2025): 1–16, <https://doi.org/10.1007/s11764-025-01845-x>.
24. A. M. Lavín-Pérez, D. Collado-Mateo, C. Hinojo González, et al., "High-Intensity Exercise Prescription Guided by Heart Rate Variability in Breast Cancer Patients: A Study Protocol for a Randomized Controlled Trial," *BMC Sports Science, Medicine and Rehabilitation* 15, no. 1 (2023): 28, <https://doi.org/10.1186/s13102-023-00634-2>.
25. N. K. Aaronson, S. Ahmedzai, B. Bergman, et al., "The European Organization for Research and Treatment of Cancer QLQ-C30: A Quality-of-Life Instrument for Use in International Clinical Trials in Oncology," *Journal of the National Cancer Institute* 85, no. 5 (1993): 365–376, <https://doi.org/10.1093/jnci/85.5.365>.
26. P. Fayers, *The EORTC QLQ-C30 Scoring Manual* (European Organisation for Research and Treatment of Cancer, 2001).
27. A. S. Zigmond and R. P. Snaith, "The Hospital Anxiety and Depression Scale," *Acta Psychiatrica Scandinavica* 67, no. 6 (1983): 361–370, <https://doi.org/10.1111/j.1600-0447.1983.tb09716.x>.
28. I. Bjelland, A. A. Dahl, T. T. Haug, and D. Neckelmann, "The Validity of the Hospital Anxiety and Depression Scale. An Updated Literature Review," *Journal of Psychosomatic Research* 52, no. 2 (2002): 69–77, [https://doi.org/10.1016/s0022-3999\(01\)00296-3](https://doi.org/10.1016/s0022-3999(01)00296-3).
29. W. Pavot and E. Diener, "The Affective and Cognitive Context of Self-Reported Measures of Subjective well-being," *Social Indicators Research* 28 (1993): 1–20, <https://doi.org/10.1007/bf01086714>.
30. M. Rosenberg, "Rosenberg Self-Esteem Scale," *Journal of Religion and Health* (1965).
31. G. A. Tkachuk and C. A. Harris, "Psychometric Properties of the Tampa Scale for Kinesiophobia-11 (TSK-11)," *Journal of Pain* 13, no. 10 (2012): 970–977, <https://doi.org/10.1016/j.jpain.2012.07.001>.
32. A. M. Jiménez-Cebrián, R. Becerro-de-Bengoa-Vallejo, M. E. Losa-Iglesias, et al., "Kinesiophobia Levels in Patients With Parkinson's Disease: A Case-Control Investigation," *International Journal of Environmental Research and Public Health* 18, no. 9 (2021): 4791, <https://doi.org/10.3390/ijerph18094791>.
33. C. L. Craig, A. L. Marshall, M. Sjöström, et al., "International Physical Activity Questionnaire: 12-Country Reliability and Validity," *Medicine & Science in Sports & Exercise* 35, no. 8 (2003): 1381–1395, <https://doi.org/10.1249/01.mss.0000078924.61453.fb>.
34. B. Roman-Viñas, L. Serra-Majem, M. Hagströmer, L. Ribas-Barba, M. Sjöström, and R. Segura-Cardona, "International Physical Activity Questionnaire: Reliability and Validity in a Spanish Population," *European Journal of Sport Science* 10, no. 5 (2010): 297–304, <https://doi.org/10.1080/17461390903426667>.
35. G. F. Templeton, "A Two-Step Approach for Transforming Continuous Variables to Normal: Implications and Recommendations for IS Research," *Communications of the Association for Information Systems* 28, no. 1 (2011): 4, <https://doi.org/10.17705/1cais.02804>.
36. D. L. Streiner and G. R. Norman, "Correction for Multiple Testing: Is There a Resolution?," *Chest* 140, no. 1 (2011): 16–18, <https://doi.org/10.1378/chest.11-0523>.
37. R. A. Armstrong, "When to Use the B Onferroni Correction," *Ophthalmic and Physiological Optics* 34, no. 5 (2014): 502–508, <https://doi.org/10.1111/opo.12131>.
38. E. W. Koevoets, S. B. Schagen, M. B. de Ruiter, et al., "Effect of Physical Exercise on Cognitive Function After Chemotherapy in Patients With Breast Cancer: A Randomized Controlled Trial (PAM Study)," *Breast Cancer Research* 24, no. 1 (2022): 36, <https://doi.org/10.1186/s13058-022-01530-2>.
39. A. Ruiz-Casado, A. Álvarez-Bustos, C. G. de Pedro, M. Méndez-Otero, and M. Romero-Eliás, "Cancer-Related Fatigue in Breast Cancer Survivors: A Review," *Clinical Breast Cancer* 21, no. 1 (2021): 10–25, <https://doi.org/10.1016/j.clbc.2020.07.011>.
40. Y. Andreu, A. Soto-Rubio, M. Ramos-Campos, A. Escriche-Saura, M. Martínez, and J. Gavilá, "Impact of Hormone Therapy Side Effects on Health-Related Quality of Life, Distress, and Well-Being of Breast Cancer Survivors," *Scientific Reports* 12, no. 1 (2022): 18673, <https://doi.org/10.1038/s41598-022-22971-x>.
41. D.-W. Wu, L.-H. Chang, P.-C. Yang, et al., "Anxiety Is a Mediator Between Heart Rate Variability and Quality of Life in Chronic Obstructive Pulmonary Disease," *Journal of Personalized Medicine* 12, no. 6 (2022): 960, <https://doi.org/10.3390/jpm12060960>.
42. R. R. Kraemer and B. R. Kraemer, "The Effects of Peripheral Hormone Responses to Exercise on Adult Hippocampal Neurogenesis," *Frontiers in Endocrinology* 14 (2023): 1202349, <https://doi.org/10.3389/fendo.2023.1202349>.
43. R. E. Ross, C. J. VanDerwerker, M. E. Saladin, and C. M. Gregory, "The Role of Exercise in the Treatment of Depression: Biological Underpinnings and Clinical Outcomes," *Molecular Psychiatry* 28, no. 1 (2023): 298–328, <https://doi.org/10.1038/s41380-022-01819-w>.
44. H. Li, D. Sang, L. Gong, et al., "Improving Physical and Mental Health in Women With Breast Cancer Undergoing Anthracycline-Based Chemotherapy Through Wearable Device-Based Aerobic Exercise: A

Randomized Controlled Trial,” *Frontiers in Public Health* 12 (2024): 1451101, <https://doi.org/10.3389/fpubh.2024.1451101>.

45. K. S. Courneya, D. C. McKenzie, K. Gelmon, et al., “A Multicenter Randomized Trial of the Effects of Exercise Dose and Type on Psychosocial Distress in Breast Cancer Patients Undergoing Chemotherapy,” *Cancer Epidemiology, Biomarkers & Prevention* 23, no. 5 (2014): 857–864, <https://doi.org/10.1158/1055-9965.epi-13-1163>.

46. C. S. Y. Leo, L. J. Cheng, X. R. Lam, and H. He, “Global Prevalence and Factors Associated With Preoperative Depression in Women Undergoing Breast Surgery: A Meta-Analysis and Meta-Regression,” *Breast Cancer Research and Treatment* 205, no. 3 (2024): 425–438, <https://doi.org/10.1007/s10549-023-07216-3>.

47. M. Michael, J. Goble, M. Hawk, and D. J. Kujawa, “Reported Barriers Impeding Adherence to a Physical Exercise Program in Patients With Breast Cancer: A Systematic Review,” *Rehabilitation Oncology* 39, no. 2 (2021): 88–102, <https://doi.org/10.1097/01.reo.0000000000000220>.

48. L. Morales-Sánchez, V. Luque-Ribelles, P. Gil-Olarte, P. Ruiz-Gonzalez, and R. Guil, “Enhancing self-esteem and Body Image of Breast Cancer Women Through Interventions: A Systematic Review,” *International Journal of Environmental Research and Public Health* 18, no. 4 (2021): 1640, <https://doi.org/10.3390/ijerph18041640>.

49. G. E. Doppenberg-Smit, F. Lamers, M. E. van Linde, et al., “Network Analysis Used to Investigate the Interplay Among Somatic and Psychological Symptoms in Patients With Cancer and Cancer Survivors: A Scoping Review,” *Journal of Cancer Survivorship* 19, no. 4 (2024): 1–14, <https://doi.org/10.1007/s11764-024-01543-0>.

50. M. Divella, L. Vetrugno, S. Bertozzi, L. Seriau, C. Cedolini, and T. Bove, “Patient-Reported Pain and Other Symptoms Among Breast Cancer Survivors: Prevalence and Risk Factors,” *Tumori Journal* 106, no. 6 (2020): 480–490, <https://doi.org/10.1177/0300891620908930>.

51. A. A. Lemij, N. A. de Glas, M. G. Derks, et al., “Discontinuation of Adjuvant Endocrine Therapy and Impact on Quality of Life and Functional Status in Older Patients With Breast Cancer,” *Breast Cancer Research and Treatment* 193, no. 3 (2022): 567–577, <https://doi.org/10.1007/s10549-022-06583-7>.

52. S. M. Phillips, D. E. Conroy, S. K. Keadle, et al., “Breast Cancer Survivors’ Preferences for Technology-Supported Exercise Interventions,” *Supportive Care in Cancer: official journal of the Multinational Association of Supportive Care in Cancer* 25, no. 10 (2017): 3243–3252, <https://doi.org/10.1007/s00520-017-3735-3>.

Supporting Information

Additional supporting information can be found online in the Supporting Information section.

Supporting Information S1: pon70348-sup-0001-suppl-data.docx.