



# The impact of prescribed versus achieved resistance training intensity on strength, body composition, and psychological health in women survivors of breast cancer: Protocol for the EFICAN 2.0 randomized trial

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## ABSTRACT

**Background:** Strength training (ST) is recommended for survivors of breast cancer due to its health-related benefits. However, the optimal method for prescribing ST intensity in this population remains unexplored.

**Objective:** To compare the effects of three intensity prescription methods on muscular strength, body composition, physical function and psychological health in survivors of breast cancer; and to examine how the training intensity progresses over time according to each method.

**Methods:** A three-arm randomized trial will be conducted with 60 women survivors of breast cancer randomly allocated to: (1) daily estimated one-repetition maximum (1RM) using individual load-velocity relationship; (2) initial 1RM estimation via load-velocity relationship, without daily updates; or (3) initial 1RM estimation via a 10RM test, without daily updates. The intervention includes a 2-week familiarization phase and an 8-week intervention phase. Training intensity will be prescribed between 60 and 75% 1RM, following the American College of Sports Medicine guidelines. Primary outcomes include muscle strength, physical function, cardiorespiratory fitness, fatigue, pain, quality of life, anxiety, and depressive symptoms. The secondary outcome is the difference between prescribed and achieved training intensity, which will be continuously monitored in all groups using a linear velocity transducer, and analyzed over time. Adherence, adverse events, and deviations from the protocol will be recorded.

**Conclusion:** This trial will provide novel insights into the effects of different ST intensity prescription methods on physical and psychological outcomes in survivors of breast cancer. It will also determine whether traditional approaches achieve intended training intensities, thereby advancing knowledge on exercise prescription in oncology.

## 1. Introduction

Strength training has emerged as a key component in the rehabilitation and long-term care of individuals after cancer, producing a wide range of physical and psychological benefits. Among cancer populations, survivors of breast cancer represent a distinct clinical population due to the cumulative and often interacting effects of surgery,

chemotherapy, radiotherapy, and long-term endocrine therapy. These treatments are frequently associated with cardiotoxicity, neuromuscular impairments, joint pain, and persistent upper-limb dysfunction, particularly following axillary surgery. In addition to these physiological sequelae, survivors of breast cancer frequently experience heightened symptom variability, uncertainty regarding physical limits, and exercise-related fear, which may influence mental health and training

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tolerance and adherence to exercise programs [1]. In this context, strength training has been shown to counteract these side effects in cancer patients and survivors [2–4]. According to the American College of Sports Medicine (ACSM), breast cancer survivors should engage in strength training at least two days per week, involving all major muscle groups. Initial prescription should include 2 sets of 8–15 repetitions per exercise, starting around 60–70% of one-repetition maximum (1RM), and progressively increasing the load based on individual tolerance and adaptation [2]. Importantly, according to the ACSM, exercise programs should be tailored and, when possible, supervised by qualified professionals, especially for individuals at risk of or experiencing lymphedema. While these guidelines provide a solid foundation for exercise prescription in breast cancer survivors, they rely primarily on traditional intensity prescription methods (i.e., training intensity is prescribed based on an initially determined 1RM). These approaches, although widely endorsed, may not fully capture daily fluctuations in training status and neuromuscular readiness [5], especially relevant in clinical populations. Consequently, there is a need to explore alternative, more responsive strategies that could complement or refine current ACSM recommendations by offering more individualized and adaptive load prescription approaches.

Exercise intensity is a key variable in strength training prescription, as it governs the extent and specificity of the resulting physiological adaptations [6]. In the context of cancer survivorship, appropriately dosing intensity is essential to balance safety with the therapeutic benefits of exercise [2]. Traditionally, the most common methods for prescribing strength training intensity include percentages of the 1RM and perceived exertion scales (such as the Borg scale) [2]. While these prescription methods are widely implemented, they exhibit significant limitations. In women survivors of breast cancer, testing 1RM presents clinical challenges. Upper-limb surgeries, including mastectomy and axillary lymph node dissection, may compromise tissue integrity and increase the risk of lymphedema exacerbation when exposed to high or poorly adjusted mechanical loads [1,2]. Furthermore, endocrine therapies commonly prescribed in this population are associated with reductions in bone mineral density and alterations in muscle-tendon properties, increasing susceptibility to musculoskeletal injury [7]. In this context, both maximal strength testing and the subsequent prescription of fixed relative loads may not adequately reflect the participant's day-to-day physical readiness, specifically in the presence of fluctuating treatment-related symptoms such as pain, fatigue, or joint stiffness [7–9]. On the other hand, subjective measures such as Rate of Perceived Exertion (RPE) may be influenced by psychological or emotional states, particularly in clinical populations [10,11]. Given these limitations, the present study compares three commonly used, yet methodologically distinct, approaches for prescribing strength-training intensity: (a) daily 1RM estimation using movement velocity, (b) initial 1RM estimation via individual load-velocity relationship, and (c) a traditional 1RM estimation using an initial 10RM test. These three methods represent feasible strategies for prescribing resistance training load in clinical and exercise settings; vary substantially in their demands for precision and individualization; and reflect the most widely used modalities in both research and applied sports science practice [12–14]. Thus, their comparison is essential to advance knowledge on safe and effective strength-training prescription for breast cancer survivors.

In recent years, velocity-based strength training has emerged as a more precise and objective method for prescribing and monitoring strength training intensity, based on the measurement of the lifting velocity during resistance training. Although still relatively novel in clinical settings, growing literature supports the use of load-velocity relationship to adjust loads according to an individual's daily physical and psychological status, which influences daily training readiness [15]. This emerging velocity-based prescription method offers a potential advantage in breast cancer survivorship setting, thereby reducing reliance on maximal testing and limiting exposure to excessive or poorly tolerated loads. This adaptive approach may be particularly relevant for

survivors of breast cancer, whose physical capacity can vary substantially across sessions due to ongoing or late treatment effects [1,7,9]. Beyond its effects on muscular strength, the objective and adaptive nature of velocity-based prescription may have implications for several multidimensional outcomes commonly affected after breast cancer treatment. By adjusting training loads to daily neuromuscular performance, velocity-based training may help limit excessive fatigue and improve tolerance to exercise across sessions. Improved regulation of training intensity may also facilitate safer and more consistent exposure to mechanical loading, supporting functional capacity and overall physical functioning in breast cancer survivorship, which are closely linked to improvements in mood, anxiety, and health-related quality of life [16]. In this line, velocity-based prescription highlights a critical gap in literature, as it may enhance safety, adherence, and strength training effectiveness among clinical populations.

To the best of our knowledge, while the load-velocity relationship has been increasingly studied in healthy individuals and certain clinical populations [12,13,17,18], there are no intervention studies specifically targeting breast cancer survivors. As a result, the feasibility, safety, and efficacy of velocity-based strength training remain unknown in this population. Addressing this gap could inform clinical practice by providing evidence-based guidance on safe and effective strength training intensity prescription for breast cancer survivors, potentially optimizing rehabilitation outcomes and survivorship care models. Nonetheless, research conducted in other clinical contexts such as older adults, individuals with cardiovascular disease, and patients undergoing rehabilitation has shown promising outcomes. These studies suggest that velocity-based training is feasible and provides a more adaptive and individualized method for load prescription [14,19,20]. Additionally, although intervention data are lacking in breast cancer survivors, some investigations have already described the load-velocity relationship in exercises commonly used in this population, such as the leg press [21], bench press [22], box squat [23] or row [24]. These studies provide normative data and regression models that allow knowing the relative intensity (i.e., %1RM) the person is lifting by measuring how fast the weight is moved. Clarifying the feasibility and effectiveness of different intensity prescription strategies in this population may offer clinically relevant insights for exercise oncology practice. A more precise and adaptive approach could enhance the safety, tolerability, and personalization of strength training programs implemented in survivorship care.

Therefore, the primary aim of the present study is to compare the effects of a strength training program using three different intensity prescription methods on muscular strength, muscular function, functional capacity, body composition, health-related quality of life, fatigue, depressive symptoms, and anxiety in women survivors of breast cancer. The secondary aim is to determine the differences between prescribed and actual exercise intensity through the daily estimation of the 1RM in all study groups.

We hypothesize that the velocity-based training (VBT) group will exhibit greater improvements in muscular strength, as training loads are adjusted daily to participants' training status, resulting in higher and more consistent relative intensities throughout the intervention. Based on the principle of specificity, this more precise exposure to high-intensity loading is expected to elicit greater gains in maximal isometric strength compared with traditional prescription methods [25], in which the relative training load may progressively deviate from the intended intensity over time. Regarding the secondary aim of the study, we hypothesize that the velocity-based method will enable a more precise control of training intensity, as daily 1RM estimation is expected to ensure that participants consistently train at the prescribed relative load. In contrast, greater discrepancies between prescribed and actual intensity may occur when using either the initial velocity-based estimation of the 1RM or the 10RM-derived prescription.

## 2. Methods

### 2.1. Study design

A three-arm randomized trial will be conducted. The study protocol was prospectively registered in April 2025 (NCT06940310) before the enrolment of participants started. This study adheres to the Declaration of Helsinki and has been approved by the University of Almería Bioethics Commission (REF: UALBIO2025/041). The study protocol follows the standard protocol items: recommendations for interventional trials (SPIRIT) reporting guideline [26] (Supplementary Table 1), and the results will be reported according to the consolidated standards of reporting trials (CONSORT) standards (<http://www.consort-statement.org/>).

### 2.2. Participants

Sixty women survivors of breast cancer will be randomized to one of the three intervention groups: (i) daily estimated one-repetition maximum (1RM) using individual load-velocity relationship; (ii) initial 1RM estimation via load-velocity relationship, without daily updates; or (iii) initial 1RM estimation via a 10RM test, without daily updates. Inclusion criteria are i) woman aged  $\geq 18$ , ii) to have had a breast cancer diagnosis, iii) to have completed chemotherapy/radiotherapy and/or surgery up to 5 years before the beginning of the study. Exclusion criteria include i) to present with stage IV breast cancer, ii) to have undergone the last surgical procedure less than four months before the enrolment in the study, iii) to be awaiting for a breast reconstruction surgery during the study duration, iv) to present any absolute contraindication to exercise, v) to be unable or unwilling to provide informed consent to participate in the study.

### 2.3. Procedures

Participants will be recruited through advertisements in social media and local associations, and through referral from oncologists from the Torrecárdenas University Hospital in Almería. Interested women fill out an online form providing some basic sociodemographic information and information about their disease and treatments. Potential eligible participants will be scheduled for a medical screening with the study medical doctor (MD) collaborators at public health centers in the city of Almería. The MD will conduct an initial assessment of inclusion criteria and will determine the participant's aptitude to participate in the study. Additionally, the MD will obtain informed consent from all potential participants before enrolment.

Participants will first complete a 2-week strength training familiarization phase, with emphasis on performing each repetition at the maximum intended velocity. Upon completion of this phase, baseline assessments will be conducted at the Exercise Laboratory of the University of Almería, including muscular strength, muscle function, body composition, health-related quality of life, fatigue, anxiety, and

depressive symptoms. Following the baseline assessment, participants will undertake an 8-week intervention phase, after which all study variables will be reassessed (Fig. 1).

### 2.4. Sample size

The sample size was calculated with G\*Power V.3.1 (Düsseldorf University) for a within-factors repeated measures analysis of variance in the primary outcome, muscular strength. Anticipating a small effect size for the between-group comparisons (Cohen's  $f$ : 0.20) and considering a power of 80% and an  $\alpha$  error of 5%, a total of 52 women survivors of breast cancer would be needed. This assumption was based on the fact that the three intervention groups will follow identical prescribed training volume and intensity, differing only in the method used to estimate and adjust training loads. Therefore, although between-group differences are expected due to variations in the actual training intensity achieved across sessions, large effect sizes are not anticipated. Considering a potential 15% drop-out -based on previous studies conducted at this laboratory [27]-, we will recruit around 60 patients (approximately 20 per group).

### 2.5. Data monitoring

All data, including personal information, will be collected and managed exclusively by the principal investigator (AS-M), who is responsible for maintaining confidentiality and data security. The dataset will only be shared with trial investigators included in the funded project. The principal investigators will monitor entries for completeness and accuracy, address missing data promptly, and document any protocol deviations to ensure data integrity and reliability throughout the study.

### 2.6. Randomization and blinding

Prior to participant recruitment, a blinded investigator generated a simple computer-based randomization sequence to assign participants to the three intervention groups. Those participants who pass the medical screening and are willing to participate in the study, will be allocated into one of the three intervention groups. An investigator involved in delivering the intervention will individually open the envelopes and disclose the allocation to the participants. The primary outcome assessors and participants will be blinded to group allocation. However, due to the nature of the intervention, the investigators delivering the intervention will be aware of the participants allocation.

### 2.7. Intervention

The three intervention groups will follow a strength training program targeting major muscle groups, following the ACSM recommendations and employing different intensity prescription methods. The intervention will have a duration of 10 weeks (2-week familiarization



Fig. 1. Design and timeline of the EFICAN 2.0. randomized trial.

phase and 8-week intervention phase), with a frequency of 3 training sessions per week, for a total of 24 group-based (4–6 participants) training sessions. Strength training intensity will progressively increase from 60% to 75% of the 1RM over the course of the intervention, while training volume will consist of 2–3 sets of 6–12 repetitions per exercise. [Table 1](#) provides a detailed overview of the intervention's periodization. To allow replicability and to maximize transparency, this study follows the Consensus on Exercise Reporting Template guidelines (CERT, Supplementary Table 2) [28]. The entire intervention will take place at the Exercise Laboratory of the University of Almería (Spain), and all training sessions will be supervised by two graduates in Physical Activity and Sport Sciences with specific expertise in exercise prescription for this population.

The familiarization phase will be conducted prior to baseline assessments with the objective of minimizing learning bias and promoting better control of exercise technique, thereby maximizing procedural safety. During this phase, the training sessions will follow the same structure as those in the intervention phase; however, special emphasis will be placed on learning the technique and implementing the maximum intended velocity in all exercises. To standardize the process across participants, a progressive sequence will be implemented: first, all exercises will be performed without external load, followed by the introduction of very light loads in subsequent sessions. During the final familiarization sessions, movement velocity will be monitored to provide individualized feedback and reinforce the desired execution pattern.

All training sessions will be divided into three parts. The first part (10–15 min) will include 5 min of aerobic activity at low intensity using a stationary bike, a treadmill, an air rower or an elliptical trainer; and two thoracic mobility, core stability, scapulohumeral joint stability and dynamic stability exercises. During part 1, exercise intensity will be set at 3 out of 10, as assessed using the OMNI Perceived Exertion Scale for Resistance Exercise (OMNI-RES) [29]. The second part (40 min) will consist of strength exercises targeting major muscle groups, incorporating a combination of two out of the four exercises included in the intervention protocol (i.e., box squat, bench press, leg press, and bent-over row exercises). All exercises will be performed using a Smith Machine (Peroga Fitness, Murcia, Spain) and a leg press machine (Peroga Fitness, Murcia, Spain) to ensure linear movement during lifting. At the beginning of the second part of each training session, the 1RM will be estimated and recorded based on the individual's load-velocity relationship, using the velocity associated with the 1RM for each exercise as previously described [21–24] (see Supplementary Fig. 1). Before completing the resistance-training sets, all participants will perform a standardized three-set warm-up. The first set will consist of 10 repetitions without external load. The second set will consist of 4–5 repetitions using a load corresponding to 65% of the estimated 1RM obtained in the preceding session. The third set will consist of 2–3 repetitions using a load corresponding to 85% of the estimated 1RM from the preceding session. Exercise volume and intensity during the second part will progress as reported in [Table 1](#). The third part (5 min) will include dynamic/static stretching exercises for major muscle groups. A detailed description of the training sessions is presented in [Table 2](#) and a graphical representation of the exercises included in the main part of the session is presented in Supplementary Fig. 2.

**Table 1**  
Strength training program periodization.

Week	1	2	3	4	5	6	7	8
Session	1, 2, 3	4, 5, 6	7, 8, 9	10, 11, 12	13, 14, 15	16, 17, 18	19, 20, 21	22, 23, 24
Sets	2	3	3	3	3	3	3	2
Repetitions	12	12	10	10	8	8	6	6
Intensity (% RM)	60	60	65	65	70	70	75	75

Participants included in the study will be randomly assigned to Group A, Group B, or Group C. To determine each participant's training load, percentages of the 1RM will be used. In Group A, the 1RM will be estimated daily using the individual load-velocity relationship, and the training loads will be adjusted accordingly. In Group B, the 1RM will be estimated using the same procedure during the first session and will serve as a reference value for the entire intervention. In Group C, the 1RM will be estimated for each exercise using a 10RM test and used to prescribe the strength training load throughout the intervention.

In the three groups, barbell velocity will be monitored and recorded for every repetition of each strength training exercise using a linear velocity transducer (T-Force System, Ergotech, Murcia, Spain). Each training group session will be supervised by two experts in exercise prescription for oncology populations. Within each group, participants will be divided into two subgroups of up to three individuals. Each subgroup will perform one exercise at a time and then rotate to the next station. This structure ensures that despite the small-group format, load prescription remains tailored and responsive to each participant's performance.

Attendance and adherence to the strength training program will be tracked daily throughout the intervention using a standardized Excel spreadsheet, which will also be used to document any adverse events or deviations from the prescribed training protocol. To promote adherence, participants will receive motivational messages via WhatsApp every two weeks. In the event of missed training sessions, participants will be contacted to clarify the reasons and to reschedule the session on an alternative day.

## 2.8. Outcomes

### 2.8.1. Primary outcome

The primary outcome is muscular strength. A global muscular strength index will be calculated as the average of the standardized scores ( $z\text{-score} = [\text{value} - \text{mean}] / \text{standard deviation}$ ) of the bench press and mid-thigh pull exercises to provide an integrated measure of overall muscular strength. This approach offers a standardized and robust method to combine different outcomes while preserving the relative contribution of each validated test, which have been previously used in exercise science and rehabilitation research [27,30,31].

Muscular strength will be assessed as the peak force during the isometric bench press and mid-thigh pull exercises using a dual-force plate system (Hawkin Dynamics Inc., Westbrook, USA).

For the mid-thigh pull exercise, participants will stand on the platforms with feet hip-width apart and positioned under a fixed bar. The posture will replicate the second pull of the clean, with a straight back, slightly flexed knees, and shoulders retracted. Joint angles will be standardized using a goniometer (knee: 125–145°, hip: 140–150°), and straps will be used to eliminate grip strength as a limiting factor. Following three warm-up pulls (50%, 75%, and 90% of perceived effort), participants will perform two maximal 5-s trials separated by 2 min, applying force against the ground “as fast and as hard as possible” while pulling on the bar. Trials will be considered valid if peak force differs by  $\leq 15\%$  between attempts.

For the isometric bench press, participants will lie supine on a bench with feet supported on stable surfaces and the bar fixed above the mid-chest line. The bar height will be adjusted to allow an isometric contraction with elbows flexed at 90–100°, confirmed by goniometry. Hand spacing and bar height will be recorded for reproducibility. After the same standardized warm-up, two maximal 5-s trials will be performed with 2 min recovery. In both tests, participants will be instructed to develop maximal force throughout the trial, with explicit emphasis on pre-tensioning prior to the onset of contraction. Verbal encouragement will be provided to ensure maximal effort.

### 2.8.2. Secondary outcomes

Mid-thigh pull and bench press isometric peak force, assessed using a

**Table 2**  
Training program description.

		Exercises	Adaptations	
Preparatory part	Cardiovascular activation	Treadmill or elliptical Seated thoracic rotation		
	Thoracic mobility exercises	Seated thoracic extension with fitball Prone thoracic extension on fitball Standing thoracic rotation Seated pelvic tilt (Visual feedback) Seated abdominal bracing with fitball	Perform only with the unaffected arm	
	Core stability exercises	Abdominal bracing with resistance band in the transverse plane	Perform only with the unaffected arm If bracing cannot be performed, maintain position while the trainer/other participant applies tension to the band	
	Sets: 2			
	Repetitions: 8			
	OMNI-RES Intensity: 3 out of 10	Bird-dog	If the participant cannot maintain quadruped position, the exercise is removed	
	CE Intensity: +12			
	Scapulohumeral stability exercises	Seated humeral rotation without abduction 60° scapulohumeral abduction in the scapular plane Pull (isometric scapulohumeral retropulsion) with 0° abduction Resisted internal rotation with band Bipodal to monopodal support in the frontal plane	Abduction is replaced with flexion	
	Dynamic stability exercises	Lateral movement Slow skipping	Perform isometrically Perform with hand safety support	
		Step up and down with pause in single-leg support on top of the step	Perform with hand safety support Reduce time on single-leg support Perform with hand safety support	
Main part: Strength exercises	Weeks 1, 3, 5 and 7	DAY 1	Row on Smith machine Leg press	
		DAY 2	Bench press on Smith machine	
	Weeks 2, 4, 6 and 8	DAY 3	Box squat on Smith machine Leg press Bench press on Smith machine	Close grip. Performed with 0° abduction
			DAY 1	Row on Smith machine Leg press
		DAY 2	Bench press on Smith machine	Close grip. Performed with 0° abduction
	DAY 3	Box squat on Smith machine Row on Smith machine		

**Table 2 (continued)**

		Exercises	Adaptations
Cool down	General session assessment	Box squat on Smith machine	
		Stretching of major muscle groups	

dual-force plate system (Hawkin Dynamics Inc., Westbrook, USA), following the abovementioned protocol.

Handgrip strength, assessed with a digital dynamometer (Model T.K. K.540; Takei Scientific Instruments Co., Ltd). The participants will be instructed to maintain a standing position with their arms extended downward without touching their body. In this position, two attempts will be performed with each hand, and the highest attempts will be used for the analysis.

Muscle function will be evaluated using the 5 sit-to-stand (5STS) test [32], where shorter completion times indicate better muscular function. Additionally, the test will be performed on force plates to measure peak force during each repetition, providing deeper insights into movement kinetics.

Functional capacity, determined through the 6-min walk test (6MWT) [33]. Participants will wear a heart rate monitor, and the watch will be set to “walk” mode. They will be instructed to walk as fast as possible -without running- around a 30-m cone-marked circuit for 6 min; heart rate and time will be monitored during the test. Upon completion, the total distance covered by the participant will be registered, and heart rate and perceived exertion (using a modified Borg scale) will be recorded after a 1-min seated recovery. Higher total distance in the 6MWT indicates higher functional capacity.

Body composition will be evaluated by bioelectrical impedance analysis (InBody 770; InBody Co., Ltd., Seoul, Korea). Participants will be instructed to fast for at least 8 h prior to the assessment and the evaluation will be developed according to the manufacturer's recommended procedures. Body weight, fat mass, fat percentage and skeletal muscle mass will be registered.

Physical activity will be assessed using the International Physical Activity Questionnaire (IPAQ) [34], previously implemented with survivors of breast cancer [35,36]. Total weekly physical activity will be calculated in MET-minutes/week by summing walking, moderate, and vigorous activities. Participants will be classified as having low, moderate, or high activity levels.

Health-related quality of life (HRQoL) will be evaluated through the Spanish version [37] of the Functional Assessment of Cancer Therapy–Breast (FACT-B) questionnaire [38], a validated instrument specifically designed to evaluate quality of life in individuals diagnosed with breast cancer. The FACT-B questionnaire comprises five subscales: Physical Well-Being, Social/Family Well-Being, Emotional Well-Being, Functional Well-Being, and Breast Cancer Subscale, which collectively provide a comprehensive overview of the patient's perceived well-being. Total score ranges from 0 to 148, with higher scores indicating better HRQoL.

Cancer-related fatigue will be assessed with the Spanish version [39] of the Functional Assessment of Chronic Illness Therapy–Fatigue (FACIT-F) questionnaire [40]. The FACIT-F questionnaire is a 40-item instrument that assesses self-reported fatigue and its impact on daily activities and functioning and has been validated in adult cancer patients. The fatigue subscale score ranges from 0 to 52, where a higher score indicates lower fatigue.

Pain will be evaluated with the Spanish version [41] of the Brief Pain Inventory (BPI) questionnaire [42], validated in cancer patients [43]. This questionnaire is divided into two main sections: pain severity and pain interference, both ranging from 0 to 10. Scores can be averaged within each domain to obtain global severity and interference scores. Higher scores indicate more intense pain and greater impact on

functioning.

Anxiety and depressive symptoms will be assessed through the Spanish version [44] of the Hospital Anxiety and Depression Scale (HADS) questionnaire [45], which has been previously used with survivors of breast cancer [46,47]. This questionnaire is composed of two subscales: Anxiety and Depression, which scores range from 0 to 21 with higher scores indicating higher symptom severity.

### 2.8.3. Other intervention-related measures

To estimate the 1RM of the exercises included in the intervention, participants in Group C will undergo a 10RM [48–50] test for the box squat, bench press, leg press and bent-over row exercises. The 10RM test was selected as a submaximal estimator of 1RM because it provides a validated, practical and less fatiguing approach to estimating maximal strength in clinical and rehabilitation settings. Compared with direct 1RM testing, the 10RM reduces maximal exertional demands and psychophysiological stress while maintaining acceptable accuracy for load prescription and monitoring [51]. Thus, including the 10RM arm allows us to compare a commonly used, pragmatic submaximal method with velocity-based approaches, aligning with the trial's aim to evaluate the feasibility and precision of alternative intensity-prescription strategies in breast cancer survivors.

The test will begin with a general warm-up (5–10 min of joint mobility and light muscle activation), followed by two specific warm-up sets using light to moderate loads (40–70% of estimated effort), with 2-min rest intervals. After a 3-min rest, the participant will perform progressive attempts to determine their 10RM. Each set will consist of 10 repetitions with increasing weight until a load is reached that allows exactly 10 repetitions with correct technique and no assistance, ending in voluntary fatigue. In the case that the load is too light, the weight will be increased and the set repeated after a 3-min rest. A maximum of 2–4 attempts is allowed to avoid excessive fatigue. The estimated 1RM will be used to prescribe strength training load during the intervention period.

At the beginning and at the end of each training session, mood will be registered for all participants using a Feeling Scale, which scores range from –5 (very poor) to 5 (very good). Additionally, the session Rating of Perceived Exertion (session RPE) will be recorded using a Borg modified scale (0–10) [52] and perceived fatigue with a visual analogue scale for fatigue (VAS–F) (0–10).

The participants' global impression of change after the intervention will be assessed with a Patient Global Impression of Change scale (PGCI) [53] consisting in one 7-point Likert-type item: “*Since the start of the study, my overall status is:*”, where a higher score means a higher impression of change.

## 2.9. Statistical analysis

The descriptive characteristics of the study participants will be presented using the mean and standard deviation (or median and interquartile range, as appropriate) for continuous variables and the frequency and percentage for categorical variables. The distribution of the variables will be checked using histograms and the Kolmogorov-Smirnov test. Comparability of the groups will be visually checked at baseline. A repeated measures analysis of variance will be used to assess the between-group differences in the changes from baseline to week 10. Post-hoc analyses will be used to identify specific group differences. The Greenhouse-Geisser correction will be used when the Mauchly's sphericity test is violated and pairwise differences will be identified using Bonferroni posthoc corrections. For each comparison, the between-group difference (95% CI) and the level of statistical significance will be presented, together with the standardized effect size (Cohen's *d*). An intention-to-treat approach will be applied as the primary analysis, and missing data will be handled using appropriate imputation methods, such as multiple imputations or last observation carried forward, depending on the nature and extent of missingness. Sensitivity (i.e. per-

protocol) analyses will be performed to explore the robustness of the findings and the efficacy of the interventions. Moderator analyses will be conducted to examine the influence of adherence, baseline fitness, and type of surgery and treatments on the observed outcomes. Statistical significance will be set at  $P < 0.05$  and all statistical analyses will be conducted using Stata v.16.1 (StataCorp LP, College Station, TX).

## 3. Discussion

Although strength training is widely recommended and implemented in survivors of breast cancer [2,3], the optimal intensity prescription method is unknown. The EFICAN 2.0 randomized trial aims to address this issue by comparing traditional approaches with the innovative use of the load-velocity relationship, which offers a more precise and objective alternative for prescribing strength training intensity [54]. This prescription method uses real-time velocity monitoring to adjust training loads according to each participant's daily readiness, which may be particularly valuable in clinical populations with fluctuating physical conditions [55].

In strength training interventions, one of the major challenges lies in determining the actual intensity at which participants train, as prescribed loads do not always reflect the real effort produced during each session [56]. This study will provide a unique opportunity to objectively monitor the actual training intensity, allowing for a more accurate understanding of the relationship between exercise dose and physiological adaptations. By quantifying the effective intensity sustained during training, it will be possible to identify how deviations from these targets influence outcomes. This approach addresses a critical limitation in previous exercise-based trials, where the lack of precise monitoring hindered the interpretation of the dose–response relationship. Consequently, the ability to verify and analyze actual training intensity may contribute to optimizing prescription strategies and improving the understanding of how specific intensity thresholds drive meaningful health- and performance-related benefits.

The study design enhances the clinical relevance and applicability of the findings by comparing different intensity prescription strategies, with the aim of improving the precision, safety, and personalization of strength training interventions for breast cancer survivors. By implementing a method that has been validated in other populations [14,19,20] but has not been explored in this context, the study contributes to methodological innovation in exercise oncology and may offer valuable insights for clinicians and exercise professionals involved in cancer rehabilitation by supporting the integration of velocity-based monitoring into rehabilitation protocols and survivorship care plans, offering clinicians a more responsive approach to tailoring training loads according to day-to-day variations in physical readiness.

Nevertheless, several limitations inherent to exercise intervention studies must be acknowledged. The outcome assessors are blinded, however, due to the nature of the intervention, the intervention team is not blinded, which might potentially introduce potential bias regarding the delivery of the intervention and the interaction with participants; nevertheless, to avoid biases, the intervention team is not informed of the study hypothesis, and all exercise professionals adhered to standardized procedures for instruction, feedback, and coaching style across all intervention arms. Also, although the study includes a broad set of secondary outcomes, the sample size was powered primarily for the main outcome. Consequently, some secondary comparisons may be underpowered, therefore, results for secondary outcomes should be interpreted as exploratory. Challenges related to participant adherence and retention are also anticipated. To address these, strategies such as regular monitoring and motivational support will be implemented. Although the load-velocity relationship has shown promising results in healthy individuals and some clinical populations, its validation in breast cancer survivors is still limited, potentially affecting the generalizability of results. Generalizability may also be influenced by demographic characteristics (e.g., age distribution), treatment history (e.

g., prior exposure to chemotherapy, radiotherapy, or hormonal therapy), and the presence of comorbidities commonly observed in this population, all of which may influence training tolerance and responsiveness. Additionally, recruitment is limited to the province of Almería, due to the fact that participants are required to attend 3 in-person sessions per week, which may potentially introduce selection bias and limit generalizability to the broader population of women with breast cancer. Importantly, this protocol provides a foundation for future studies examining the long-term effects, cost-effectiveness, and broader implementation of velocity-based training across diverse oncological populations. Building on the present design, future studies should examine whether velocity-based prescription enhances long-term adherence, facilitates sustainable improvements in functional capacity and quality of life, or reduces symptom burden across different treatment subgroups. Such investigations will be essential to further refine and expand personalized exercise prescription in cancer rehabilitation.

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.cct.2026.108225>.

### Dissemination plan

The results of the trial will be published in international peer-reviewed journals without restrictions. Each participant will be provided with their individual outcomes as well as a summary of the overall trial findings.

### CRediT authorship contribution statement

**Alba Esteban-Simón:** Writing – review & editing, Writing – original draft, Methodology, Conceptualization. **David M. Díez-Fernández:** Writing – review & editing, Methodology, Conceptualization. **Andrés Baena-Raya:** Writing – review & editing, Methodology, Conceptualization. **Alejandro Pérez-Castilla:** Writing – review & editing, Methodology, Conceptualization. **Andrea Rodríguez-Solana:** Writing – review & editing. **Márium Ramos Teodoro:** Writing – review & editing. **Antonio Pérez-Romero:** Writing – review & editing. **Manuel A. Rodríguez-Pérez:** Writing – review & editing, Methodology, Conceptualization. **Alberto Soriano-Maldonado:** Writing – review & editing, Supervision, Methodology, Conceptualization.

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### Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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### Data availability

Data will be made available on request.

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