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Motor Imagery and Action Observation in Breast Cancer Survivors: A Study Protocol

María Pilar Arnal-Vallés, Nelia Soto-Ruiz, Ana Beatriz BAYS-MONEO, Cristina García-Vivar, Paula Escalada-Hernández

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Motor Imagery and Action Observation in Breast Cancer Survivors: A Study Protocol

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Abstract

Background: Breast cancer is the most common type of cancer in women worldwide, and its incidence is increasing. Although breast cancer survival is slowly increasing, related sequelae can persist after the disease has been treated. The main physical symptoms associated with breast cancer include pain, lymphedema and associated functional limitations.
Although multiple treatments are available for alleviating symptoms in breast cancer survivors, their effectiveness remains limited. Motor imagery (MI) and action observation (AO) therapies, which are based on the theory of motor simulation and are used in multiple fields with satisfactory results, have been proposed as alternatives for treating pain and improving mobility and strength.

Objective: To design, implement and evaluate the effectiveness of a program combining MI therapies and AO to improve functionality, mobility and alleviate pain and lymphedema of the affected upper limb in women who have survived breast cancer

Methods: A randomized controlled clinical study will be conducted in a sample of 108 participants who have experienced breast cancer and, as a result, have pain in the affected extremity, lymphedema or loss of strength and/or mobility. The intervention group will include 54 participants managed with the MIAO program (a combination of motor imagery, action observation and mobility exercises), while the control group will consist of 54 women performing mobility exercises alone. Pain intensity, muscle strength, joint range, limb diameter, fear of movement and imagery capability will be evaluated.

Results: The intervention is expected to yield improvements in pain intensity, joint range, muscle strength and symptoms associated with lymphedema, among other outcomes

Conclusions: The implementation of an intervention based on motor imagery and action observation has the potential to positively impact female breast cancer survivors who face physical and psychological sequelae that interfere with their daily lives. Clinical Trial: has been registered on ClinicalTrials.gov (Number NCT07067710)

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ABSTRACT

Introduction

Breast cancer is the most common type of cancer in women worldwide, and its incidence is increasing. Although breast cancer survival is slowly increasing, related sequelae can persist after the disease has been treated. The main physical symptoms associated with breast cancer include pain, lymphedema and associated functional limitations.

Background and Justification

Although multiple treatments are available for alleviating symptoms in breast cancer survivors, their effectiveness remains limited. Motor imagery (MI) and action observation (AO) therapies, which are based on the theory of motor simulation and are used in multiple fields with satisfactory results, have been proposed as alternatives for treating pain and improving mobility and strength.

Objective

To design, implement and evaluate the effectiveness of a program combining MI therapies and AO to improve functionality, mobility and alleviate pain and lymphedema of the affected upper limb in women who have survived breast cancer.

Methods

A randomized controlled clinical study will be conducted in a sample of 108 participants who have experienced breast cancer and, as a result, have pain in the affected extremity, lymphedema or loss of strength and/or mobility. The intervention group will include 54 participants managed with the MIAO program (a combination of motor imagery, action observation and mobility exercises), while the control group will consist of 54 women performing mobility exercises alone. Pain intensity, muscle strength, joint range, limb diameter, fear of movement and imagery capability will be evaluated.

Expected results

The intervention is expected to yield improvements in pain intensity, joint range, muscle strength and symptoms associated with lymphedema, among other outcomes.

Conclusions

The implementation of an intervention based on motor imagery and action observation has the potential to positively impact female breast cancer survivors who face physical and psychological sequelae that interfere with their daily lives.

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Keywords: action observation; breast cancer; lymphedema; motor imagery; pain; survivorship

INTRODUCTION

Worldwide, breast cancer represents approximately 23.8% of all malignant tumours in women, establishing it as the most prevalent cancer in this population, with incidence rates continuing to rise (World Health Organization, 2022). Data from the International Agency for Research on Cancer of the World Health Organization indicate that, in 2022, 2,296,840 new cases of breast cancer were diagnosed among women worldwide (World Health Organization, 2022)., with the 5-year global prevalence projected to rise to 8,178,393 cases (World Health Organization, 2022).

Although incidence continues to increase, declining mortality rates have contributed substantially to the growing prevalence of the disease (Bray et al., 2024; World Health Organization, 2022). According to Globocan, in 2020, the number of deaths worldwide among women with breast cancer was 684,996, representing 15.5% of all deaths from cancer. Improvements in treatments and prevention strategies have allowed a reduction in mortality, mainly in African countries, but global lifestyle changes have driven an increase in disease prevalence (Sung et al., 2021). As a result, the number of breast cancer survivors worldwide is increasing (Bray et al., 2024), creating significant challenges for long-term follow-up and the management of persistent symptoms (Nardin et al., 2020).

Many breast cancer survivors continue to live with physical and emotional sequelae as a result of the treatments received and the oncological process itself. These late and persistent side effects not only compromise quality of life and functionality but may also prevent survivors from integrating the cancer experience into their dialy lives (Sociedad Española de Oncología Médica, 2012). Among the most common physical sequelae are pain, lymphedema, and postmastectomy syndrome. The latter is characterized by a burning sensation, tightness, stabbing and pain in the chest, armpit, upper medial part of the arm and the surgical scar, characteristics similar to those of phantom limb syndrome. The likelihood of developing lymphedema is greater in women undergoing axillary

lymphadenectomy, sentinel node biopsy, or mastectomy (Nesvold et al., 2008). Lymphedema causes a decrease in the functionality of the affected arm, negatively impacting quality of life. This condition is estimated to affect 35% of patients and is associated with pain and functional limitations in activities of daily living (ADLs) (Dawes et al., 2008).

Although it is one of the most frequent symptoms, pain secondary to breast cancer has not been sufficiently investigated (Stubblefield & Custodio, 2006). It has been ascribed a number of aetiologies, such as cervical radiculopathy, rotator cuff tendinopathy, postmastectomy syndromes or neuropathies, as well as preexisting comorbidities (back pain, arthritis, osteoarthritis, axillary lymphadenectomy accompanied by chemotherapy and/ or radiotherapy), young age (18-39 years), fibromyalgia, and depression or anxiety about the possibility of suffering chronic pain (Schou Bredal et al., 2014). Existing evidence suggests that breast cancer is associated with pain that can become chronic, affecting both patients and survivors.

Various interventions have been developed in an attempt to improve functionality and indirectly reduce pain (D. Chan et al., 2010). Nonpharmacological strategies used in physiotherapy include multicomponent training (aerobic exercise, flexibility and strength), neuromuscular bandaging, manual lymphatic drainage and multimodal therapy. However, in many cases, the pain persists after the strategies have been completed (Forsythe et al., 2013).

In light of this situation, it is necessary to assess the effectiveness of emerging therapies, such as motor imagery (MI) and action observation (AO). Both interventions are based on simulation theory, which suggests that imagined or observed actions activate brain regions, similar to those involved in the actual execution of the movement (Jeannerod, 2001). Specifically, MI is based on the fact that imagining the performance of an action stimulates the same parts of the brain map involved in performing the action itself (Jeannerod, 2001). This therapy has proven useful in various fields, such as sports, psychology, rehabilitation, medicine and education (Schuster et al., 2011). Studies have reported beneficial effects of MI on the range of motion, strength, pain, and functionality of the affected limb (Di Rienzo et al., 2015; Herrador Colmenero et al., 2018; Hoyek et al., 2014; La Touche et al., 2020;

Mateo et al., 2015; Salik Sengul et al., 2021; Suso-Martí et al., 2020). For example, in the case of phantom limb syndrome, patients have reported a significant reduction in pain, which even disappears in some cases (Herrador Colmenero et al., 2018).

AO, meanwhile, is based on the hypothesis that, when observing the performance of an action or movement in the first or third person, the neural and brain circuits that would be involved in the execution of the action are activated (Jeannerod, 2001). That is, seeing how an action is carried out is the same, at the brain level, as performing the action itself (Jeannerod, 2001). Similar to MI, AO has been applied in different disciplines and has shown positive results in the reorganization of action, motor control and functional rehabilitation (Ertelt et al., 2007).

Individually, both MI and AO have demonstrated effectiveness in improving muscle strength, joint range, pain intensity, and functionality (Ertelt et al., 2007; Herrador Colmenero et al., 2018; Salik Sengul et al., 2021). However, current evidence suggests that their combined use produces greater activation of motor brain regions than when applied individually (Eaves et al., 2016). although studies assessing the effectiveness of this combined therapy remain scarce (Choi et al., 2022). A systematic review and meta-analysis published in 2025 has reported that combining both therapies effectively improves motor functionality, gait speed, upper- extremity functionality, pain intensity and fear of movement, especially in the upper extremities (Arnal-Vallés et al., 2025). Despite their promising potential, the application of these techniques within oncology—and especially among breast cancer survivors—has been insufficiently investigated, leaving a significant gap in the evidence base.

Therefore, the aim of this project is to design, implement and evaluate the effectiveness of a program combining MI therapies and AO to improve functionality, mobility and alleviate pain and lymphedema of the affected upper limb in women who have survived breast cancer.

MATERIALS AND METHODS

Design

A randomized controlled trial will be conducted to test the following hypothesis: A combination of MI and AO therapies is effective for improving mobility and alleviating pain and lymphedema of the upper limb in breast cancer survivors.

The protocol follows the definitions of items for clinical trials according to the Standard Protocol Items: Recommendations for Intervention Trials (SPIRIT) (A. Chan et al., 2013) and has been registered on ClinicalTrials.gov (Number NCT07067710). Future publications of the study results will be written in accordance with the Consolidated Standards of Reporting Trials (CONSORT) (Schulz et al., 2010).

Settings

The study will be carried out in Navarra, an autonomous community and province in northern Spain. Information about the study will be disseminated through social networks and newspapers, and collaboration will be requested from the Navarra Breast Cancer Association (SARAY), a nonprofit regional association that promotes comprehensive care for women who have experienced breast cancer and provides biopsychosocial support through different services (psychology, physiotherapy, accompaniment, etc.).

Study participants and eligibility criteria

Female survivors of breast cancer who reside in Navarra will be invited to participate in the study.The inclusion criteria for participants in the study will be: being female, aged over 18 years, having a diagnosis of breast cancer, having completed any active cancer treatments (chemotherapy, radiotherapy and/or immunotherapy) and being disease-free at the time of data collection. Women undergoing hormonal therapy after treatment completion will also be included, as hormonal treatment is not considered an active cancer therapy and is commonly prescribed among breast cancer survivors. In turn, participants will be excluded if they have a diagnosis of cancer other than breast cancer, evidence of recurrence or metastasis requiring new treatment, or are undergoing active cancer therapy (for recurrent or newly diagnosed disease).

Sample size

To determine the sample size, we assumed a type I error of 0.05, a type II error of 0.20 (80% power), with a minimum detectable difference of 1.5 points on the VAS pain scale and an estimated standard deviation of 2.61 (Sheridan et al., 2012). Considering an estimated 10% dropout, the required sample size was108 women, with 54 allocated to the control group (CG) and 54 to the intervention group (IG). The power calculations were performed

with the Granmo online program, version 7.12.

Randomization, allocation and blinding

The participants in the study will be randomly assigned to one of two groups: the IG (MI + AO + mobility exercises) or the CG (mobility exercises alone). All the subjects will perform mobility exercises of the upper limb involving flexion, extension, abduction, adduction, internal rotation and external rotation for approximately 20 minutes, 3 times a day, 3 times a week during the duration of the intervention (6 weeks).

The randomization process will be carried out with the Randomizer® tool and an allocation ratio of 1:1 with the aim of guaranteeing impartiality and validity in the study and ensuring a balanced distribution, simple randomization and a reduction in biases while preserving the integrity and reliability of the results.

This is a single-blind study, as neither participants nor the researchers delivering the intervention can be blinded. Blinding will be maintained for the researchers responsible for collecting outcomes, administering evaluation instruments, and performing the statistical analyses.

Intervention: Description of the IM-OA23 Program

The study intervention is part of the IM-OA23 Program, a structured initiative designed to integrate MI and AO into rehabilitation strategies.Support for the intervention will be presented in video format and will be accompanied by instructions for performing the MI and OA therapies as well as the additional mobility exercises.

The intervention will last six weeks, during which the content of the program will be progressively modified. During the first two weeks, the following anatomical movements will be visualized and imagined, with an approximate duration of 20 seconds per movement: 1) arm flexion from 0 to 180°, 2) arm extension from 0 to -10°, 3) arm abduction from 0 to 180°, 4) arm adduction from 0 to 45°, 5) internal arm rotation from 0 to 45° with the elbow flexed at 90°, 6) external arm rotation from 0 to 45° with the elbow flexed at 90°, and 7) forwards and backwards arm circumductions (Figure 1 and 2).In the third and fourth weeks, the participants will progress to performing the anatomical movements

described above with a small weight, for example, a 1 kilogram dumbbell. The videos will depict a woman dressed in black in the frontal and lateral planes performing the described anatomical movements.In the final two weeks (fifth and sixth), the content will focus on ADLs with the following tasks: 1) reaching for a jar, 2) raising and lowering blinds, 3) drawing a curtain, 4) changing a light bulb, 5) stirring a pot, 6) scratching one's back, 7) stretching, 8) putting on and taking off a coat, 9) hugging someone, 10) cleaning a window pane, 11) turning the steering wheel of a car, and 12) throwing a ball.

For each of the movements and ADLs, AO will be performed first, followed by MI. After the completion of the MI + AO blocks, the participants will also carry out mobility exercises involving repeating the movements they had seen in the videos.

As indicated, all the participants will perform upper extremity mobility exercises involving flexion, extension, abduction, adduction, internal rotation and external rotation for approximately 20 minutes, 3 times a day, 3 times a week during the duration of the intervention (6 weeks).

Each participant will be instructed on how to access the audiovisual resources developed specifically for this study and hosted on a dedicated website. (Figure 3). They will also receive an information sheet describing the exercises and a field diary to record the frequency of intervention practice during the established weeks. At the end of the explanation, the participant will be scheduled for data collection at six weeks (T1) and at three months (T2).

The videos will be structured as follows: first, a black screen will appear, and a female voice will provide the instructions for performing the therapies. Next, the video will show the movement chosen for the action observation therapy. Third, the black screen will appear again, and two acoustic signals will play, indicating the start and end of the motor imagery task. The same process will be subsequently repeated with the next selected movement. The videos will last between 6 and 10 minutes. After viewing the videos and performing the MI + AO therapies, the participants will actively perform the exercises displayed in the previous screens.

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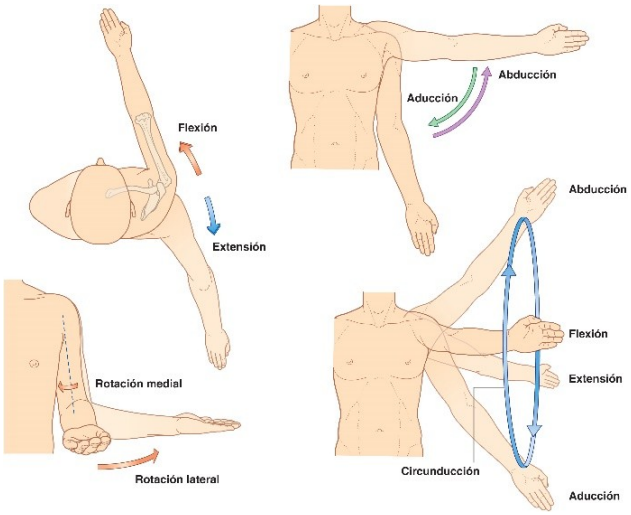


Figure 1: Anatomical movements performed (Drake et al., 2020).

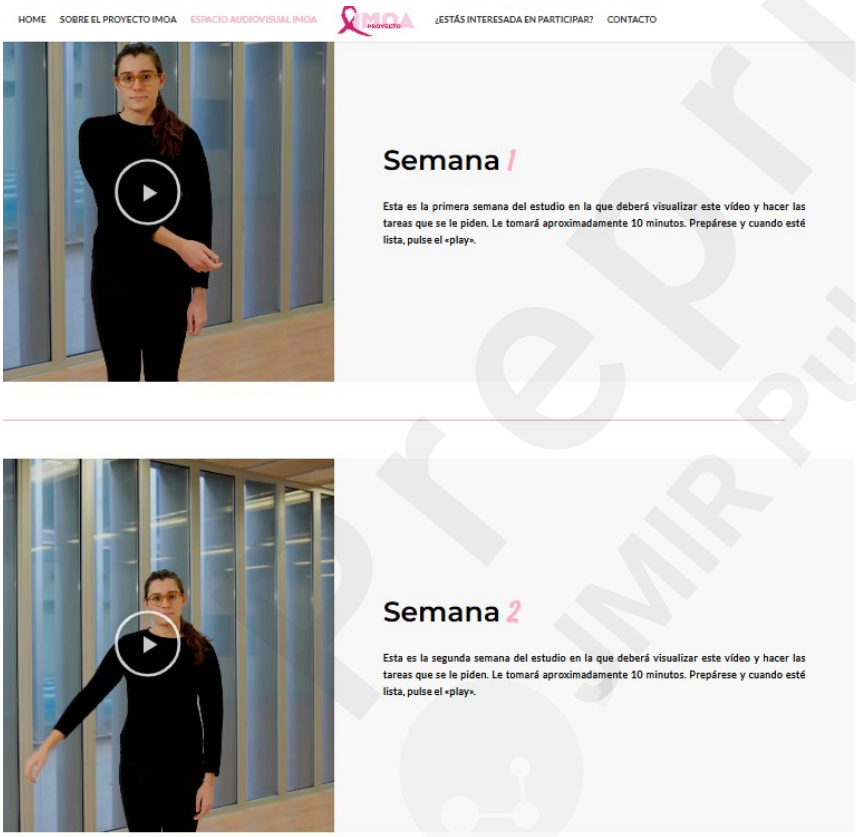


Figure 2: Prepared videos. The images illustrate the exercises assigned for weeks 1, 2, and so on.



Figure 3: Web page created for the IMOA-23 project. The image shows the project name accompanied by the phrase: “Innovating in breast cancer care to improve quality of life. Learn more.”

Control group:

The CG will perform the same movement exercises as the IG but without the addition of MI or AO therapies. All the participants will perform mobility exercises of the upper limb involving flexion, extension, abduction, adduction, internal rotation and external rotation for approximately 20 minutes, 3 times a day, 3 times a week during the duration of the intervention (6 weeks).

Once participants consent and are allocated to the CG, sociodemographic and clinical data will be collected, and the remaining variables will be measured (T0). Finally, participants will receive detailed instructions on the exercises, including the number of series and repetitions per series, along with a diary to record exercise frequency throughout the established 6 weeks. Follow-up assessments will be scheduled at six weeks (T1) and at three months (T2).

Variables and measurement instruments

The independent variable will be the IM-OA23 Program, which will combine MI and AO therapies. The following dependent variables will be evaluated:

. Pain: Evaluated with the Numerical Rating Scale for pain (NRS), an objective scale that quantifies the intensity of pain, similar to the visual analogue scale (VAS). The NRS is an 11-point scale presented as a horizontal line, with 0 indicating "no pain" and 10 indicating

"the worst pain imaginable" or "the worst pain that can exist". Participants will be asked to report their average pain or pain experienced in the last 24 hours (Hawker et al., 2011).

. Joint range: The degree of movement of the shoulder joint will be measured with a goniometer. Flexion, abduction and internal and external rotation will be measured with previously established reference points (Taboadela, 2007).

. Muscular strength: The grip strength of the affected limb will be measured using a dynamometer (Jamar). The measurement will be made with the participant in a sitting position with the elbow in 90° flexion, the shoulder close to the torso and a neutral wrist position. The maximum achievable force will be recorded from the best value of three attempts (Ha et al., 2018; Roberts et al., 2011).

. Fear of movement: The Tampa Scale for Kinesiophobia (TSK) adapted to Spanish (TSK-11) will be used. The scale consists of 11 items rated on a 4-point Likert scale (1–4), yielding a total score from 11 to 44, with higher scores indicating greater fear of movement. (Gómez-Pérez et al., 2011; Hudes, 2011).

. Diameter of the affected limb: Measurements will be obtained with anthropometric tape with a precision of one millimetre. The measurement will be made at the midpoint between the acromion and the olecranon, leaving the tape perpendicular to the extremity without compressing the area. The midpoint will be located with 90° elbow flexion, and subsequently, the measurement will be obtained with the elbow in extension; the result will be recorded in centimetres (Canda, 2012).

. Imagination capability: will be assessed with the Movement Imagery Questionnaire–Revised, Second Edition (MIQ-RS), an 8-item instrument. . The questionnaire requires two tasks: first, forming a drawing or a mental image of a movement, and second, attempting to feel the sensation of performing the movement without physically executing it. The difficulty of each item will be rated on a 7-point scale, ranging from 1 (“very difficult to see/feel”) to 7 (“very easy to see/feel”). The total score is obtained by adding the scores of the questions. Higher scores correspond to greater ease of imagination and perceived vividness (Gregg et al., 2010).

Data collection

As previously described in the recruitment section, participants will be enrolled through the

dissemination of study information via various media, including the press, social networks and SARAY association. The study information will include a Google Forms questionnaire, in which subjects can express their interest in participating and provide their contact information. All respondents to the questionnaire will be invited to an individual meeting with the research team, during which study information will be provided, questions addressed, and written informed consent obtained upon confirmation of participation. In turn, the planning of the intervention and data collection will be explained, and the assigned group will be indicated to each participant.

In both the IG and CG, outcomes will be assessed at three time points. The preintervention time point (T0) will coincide with the initial meeting and study inclusion, during which the sociodemographic and clinical data will be collected, along with the other study variables. Postintervention will take place at 6 weeks (T1). Follow-up (T2) will subsequently be carried out 3 months after the end of the intervention to determine whether the effects have persisted over time.To collect the data, an electronic questionnaire will be designed with the help of the Microsoft Office® Forms tool.

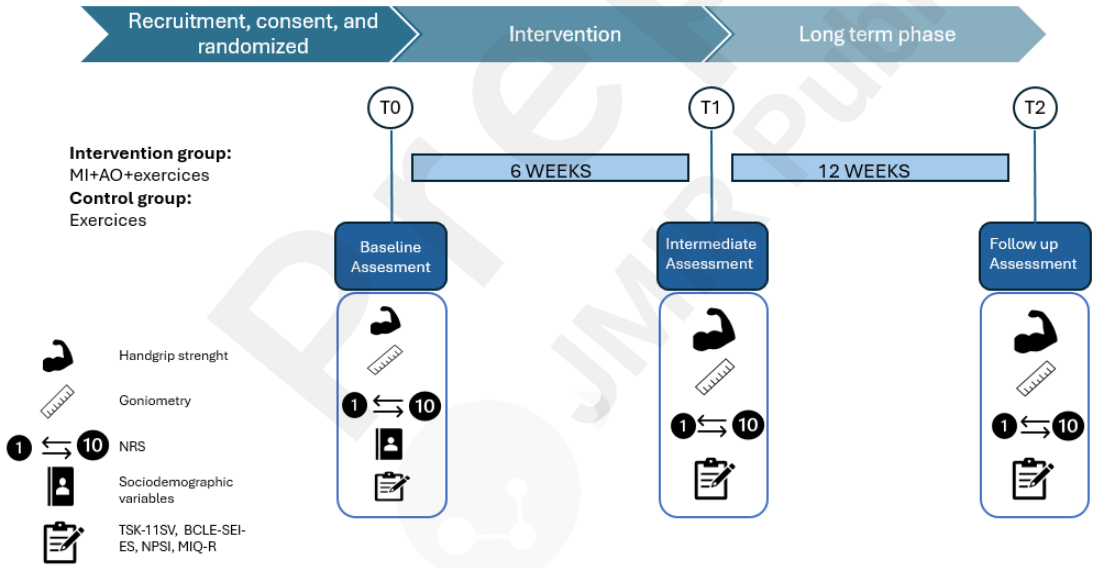


Figure 4: Time course of the study

The intervention group will participate in the IM-OA23 program.

Data analysis

First, a descriptive analysis of the variables will be conducted. The means and standard deviations will be reported for continuous variables, and frequencies and percentages will be reported for categorical variables.

Second, inferential analyses will be carried out. The homogeneity of the groups will be analysed with tools such as Student's t test for quantitative variables and the chi-square test for nominal variables. The differences between the groups over time will be subsequently analysed with multivariate analysis (analysis of variance, ANOVA). In all cases, the significance level will be set at 0.05. The data will be analysed using the Statistical Package for the Social Sciences (SPSS) program.

Ethical considerations

This project has been approved by the Ethics Committee for Drug Research of Navarra (PI_2023/81), and the necessary institutional authorization to carry out the study has been obtained. Participants will receive information about the project, their degree of involvement and the legal requirements observed in an information sheet, as well as an informed consent form to be signed if they agree to voluntarily participate. The study will exhaustively comply with all the ethical–legal requirements in force related to research involving humans. In the event that the IM-OA23 program is shown to be effective in improving pain, mobility and lymphedema in breast cancer survivors, once the research is completed, breast cancer survivors from the CG will be invited to participate in the full program, and the resources used for the IG will be provided. In addition, the feasibility of incorporating the tool into the national health system will be assessed, with the aim of making it accessible to the entire population.

DISCUSSION

This randomized controlled trial will investigate the potential effect of the combination of MI + AO therapies in improving the functionality of the affected upper limb in breast cancer survivors. Although previous studies have demonstrated the effectiveness of combining

these therapies in improving pain, fear of movement, and other outcomes in conditions such as phantom limb syndrome, stroke, or chronic pain, no studies to date have examined their impact in female breast cancer survivors with upper-extremity symptoms. This study seeks to address that gap. Given the similarities of symptoms in breast cancer survivors to those observed in other conditions where MI + AO therapies have proven effective, the potential benefits for quality of life and treatment appear promising.

Implications for Clinical Practice

The results of this study have the potential to generate evidence supporting new therapeutic approaches for addressing functional limitations and mobility problems of the affected limb in women with breast cancer- a population in which these symptoms are common and frequently insufficiently treated.

This project is of particular interest given the growing number of female breast cancer survivors, many of whom face limitations in recovery and reintegration into daily activities due to disease-related consequences.

The implementation of the IM-OA23 Program could directly benefit female breast cancer survivors with upper-limb sequelae. Aligned with current priorities for survivorship care outlined in the Strategic Framework of Primary and Community Care and the Comprehensive Plan of Care for Long-term Cancer Survivors of the Spanish Society of Medical Oncology (Ministerio de Sanidad, 2025) the IMAO23 Program also represents an innovative approach with potential for significant social and economic impact nationally and internationally.

Short-term benefits may include improved pain management, increased mobility and reduced lymphedema. If effective, the program could offer breast cancer survivors additional tools to alleviate pain and lymphedema while improving upper-limb mobility. This could reduce the need for pain medication and improve the ability to perform daily activities, such as dressing, grooming, and reaching for objects, while also helping to prevent complications like lymphedema-related infections.

Evaluating the medium-term impacts of the program would generate valuable knowledge on the translation of research into healthcare practice. Such assessments could clarify the program’s sustainability, its integration into clinical workflows, and its potential to inform evidence-based

guidelines for survivorship care.

In the long term, the results of this study could have a significant impact on alleviating symptoms affecting the lives of breast cancer survivors. At the same time, it may contribute to improving the quality and continuity of survivorship care, while offering a cost-effective tool to improve patient management and expand the resources available to healthcare professionals.

In addition, if effective, the program could be proposed as an open-access resource at the international level—adapted into different languages—to be accessible not only to rehabilitation professionals but also directly to patients. Such an approach would facilitate global reach, allowing its use from anywhere, while enabling the monitoring of symptom evolution, adherence to the intervention, and the timely resolution of emerging issues.

Finally, this study highlights the need to prioritize research on women and the health challenges they face. Beyond its immediate contributions, it has the potential to open new avenues for future research aimed at understanding and addressing symptoms that emerge with the chronification of specific pathologies.

Study limitations

This study has several limitations. First, the short follow-up period of the intervention, restricted to 3 months. At this time point, the long-term effects of the intervention may not yet have fully emerged, potentially underestimating its sustained impact. However, it should be noted that the selected follow-up times are based on previous studies analyzing the combination of MI and AO therapies. It should also be noted that follow-up is constrained by the funding period and by the practical and organizational limitations of participants. Therefore, future research should include long-term evaluations of the intervention’s outcomes.

Second, given the behavioral nature of the program, it will not be possible to blind either participants or the researchers delivering the intervention, which may introduce expectation bias. In addition, some outcomes (such as the number of repetitions and the frequency of exercises) relied on self-reported diaries, increasing the risk of reporting bias and raising potential concerns about

adherence. Therefore, these limitations should be taken into account when interpreting the findings.

CONCLUSIONS

The implementation of an intervention based on motor imagery and action observation has the potential to positively impact female breast cancer survivors who face physical and psychological sequelae that interfere with their daily lives. This study has the potential to contribute important evidence on the effectiveness of combining motor imagery and action observation, while also offering pioneering insights into the implementation of these therapies within oncology. By extending their use to breast cancer survivorship, the findings could open new avenues for innovative, non-pharmacological strategies to improve long-term care and quality of life in this growing patient population.

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Conflicts of interests

None declared

Data availability

All data generated or analysed during this study are included in this published article.

Author Contributions

List of abbreviations

AO Action observation

CG Control group

IG Intervention group

MI Motor Imagery

ADLs Activities of daily living

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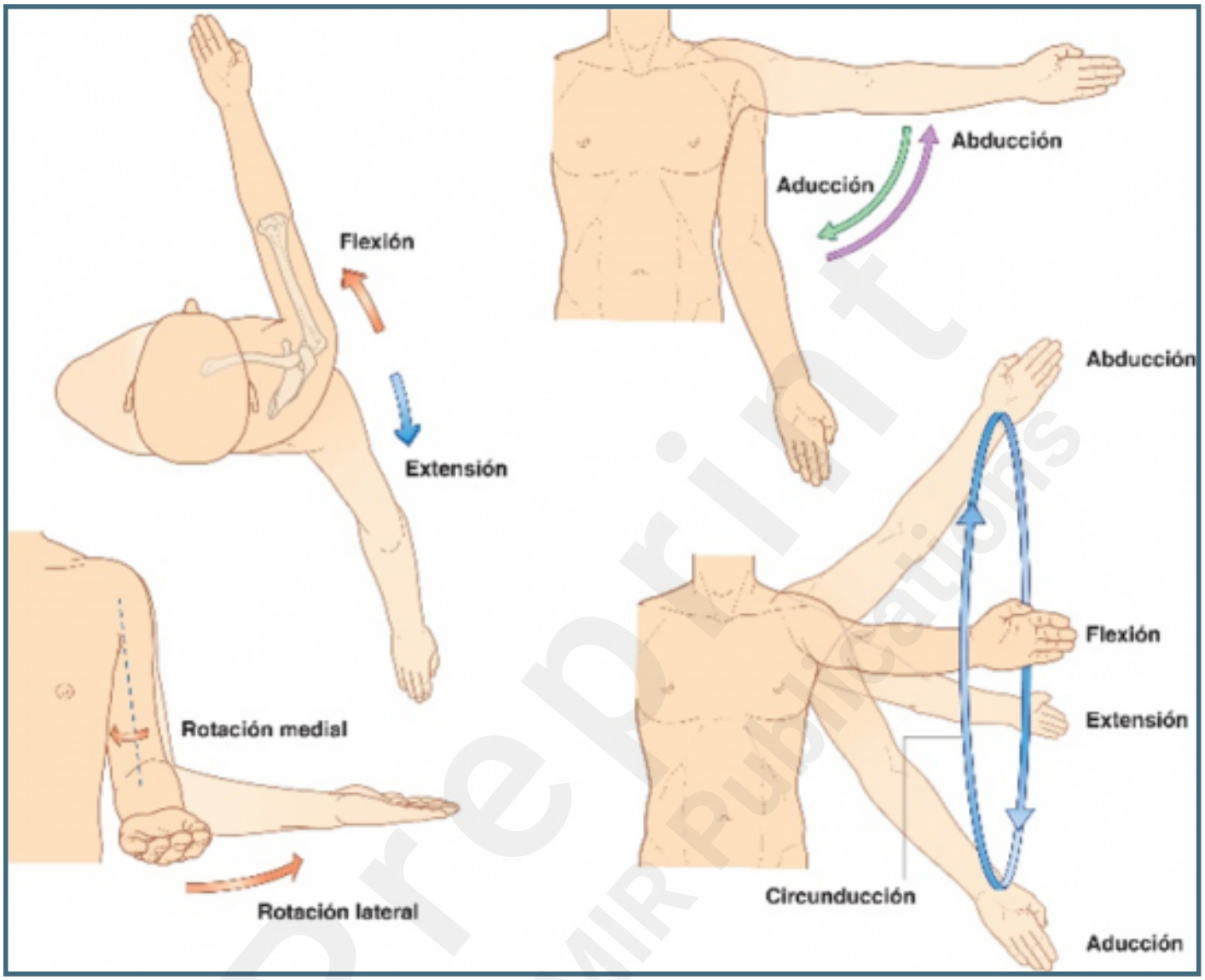
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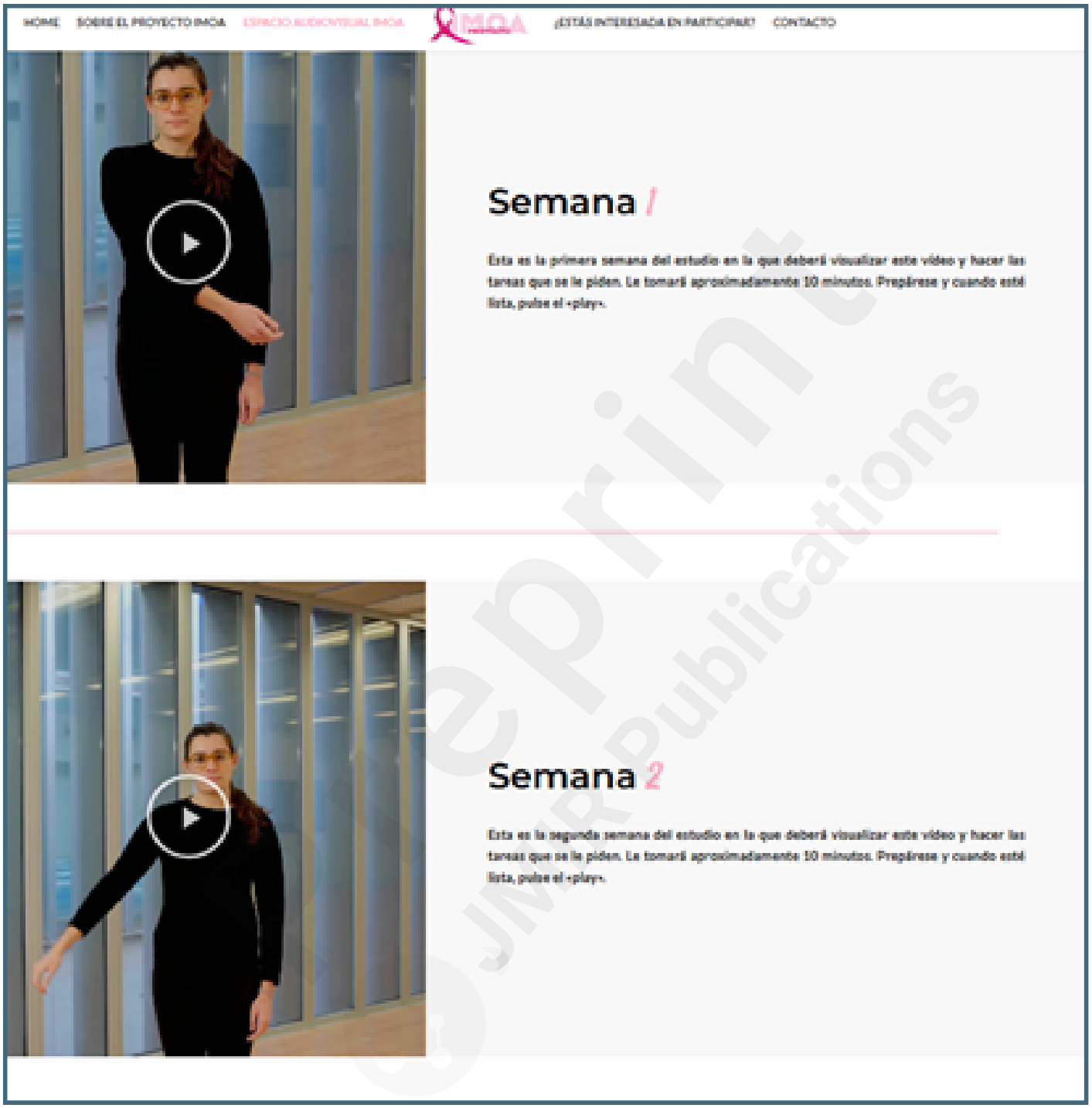
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Anatomical movements performed (Drake et al., 2020).



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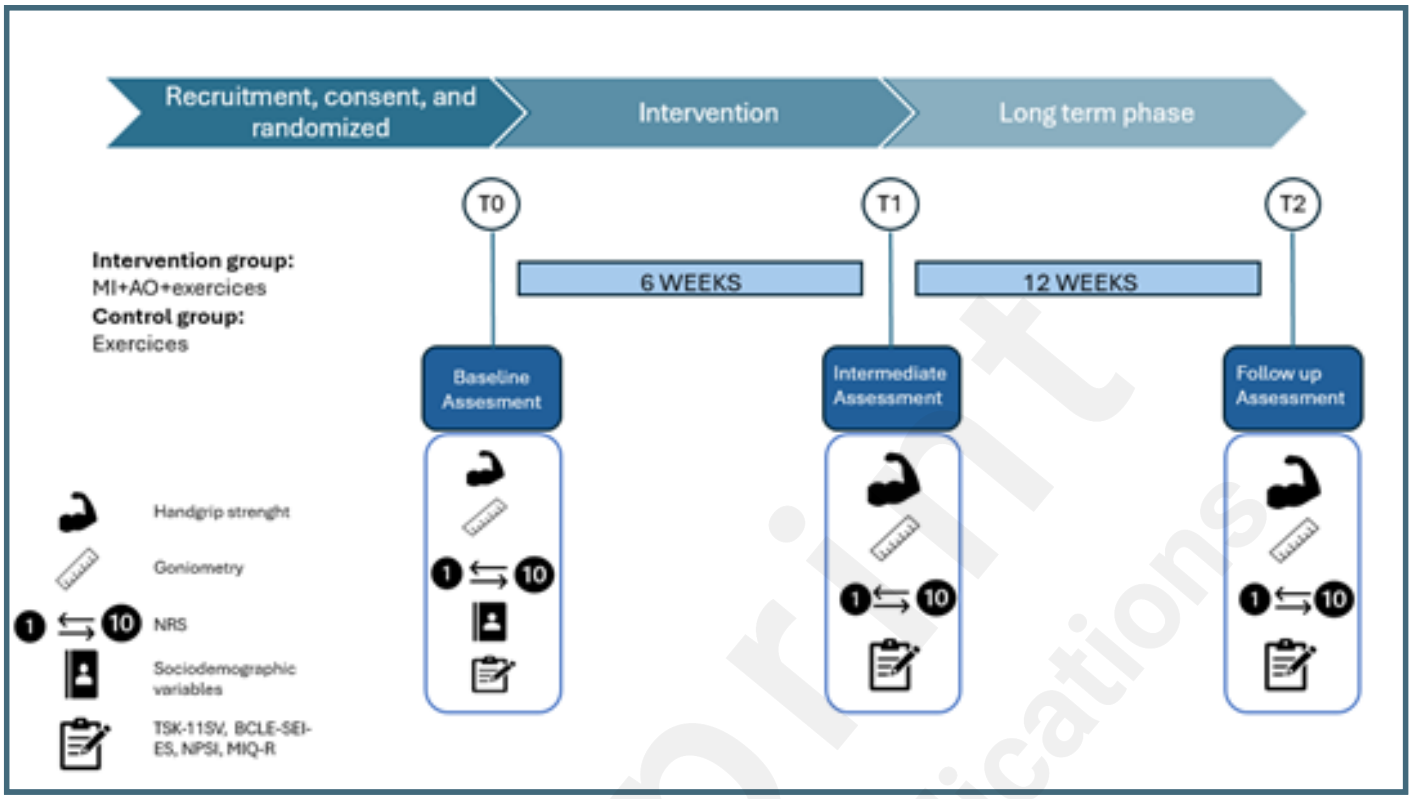
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Web page created for the IMOA-23 project. The image shows the project name accompanied by the phrase: Innovating in breast cancer care to improve quality of life. Learn more.



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