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Review studies

Virtual reality in rehabilitation of Post-mastectomy patients: a systematic review

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Abstract

Background: Virtual reality (VR) interventions have emerged as a promising approach in postmastectomy rehabilitation, aiming to improve physical function, alleviate pain, and enhance overall well-being.

Purpose: This systematic review synthesizes current evidence from studies exploring the effects of VR interventions on post-mastectomy patients.

Materials and Methods: A systematic search of databases yielded 1,938 initial records, with 10 articles meeting inclusion criteria after screening and full-text assessment. Studies included randomized controlled trials (RCTs), clinical trials, and non-randomized controlled trials conducted across various countries.

Results: Seven studies were included in qualitative synthesis, examining diverse VR interventions such as gaming systems and balance boards. Key outcomes measured included upper limb function, pain severity, range of motion, emotional well-being, and activities of daily living. Findings indicated significant improvements in upper limb function, particularly in range of motion and strength metrics. However, variability in pain management outcomes was observed across studies.

Conclusion: Virtual reality interventions represent a promising adjunctive therapy in postmastectomy rehabilitation, offering multifaceted benefits in improving upper limb function and potentially reducing pain. Implementation strategies should focus on tailored protocols, clinician training, and addressing technological accessibility to maximize therapeutic efficacy and patient outcomes.

Keywords: **virtual reality; post-mastectomy; rehabilitation; systematic review; upper limb function; pain management.**

Introduction:

Breast cancer stands as one of the most prevalent and impactful diseases among females worldwide, annually affecting approximately 1.3 million individuals and ranking as the second leading cause of death among women **(1).** Advances in early detection and treatment have contributed to improved survival rates for breast cancer patients over recent decades **(1).** Despite these advancements, the management of breast

cancer poses significant challenges, exacerbated by treatment-related adverse effects that can profoundly affect patients' physical and psychological well-being **(2).**

The spectrum of medical treatments for breast cancer, including surgery, radiotherapy, chemotherapy, and targeted therapies, has been pivotal in reducing mortality rates. However, these treatments are often accompanied by debilitating side effects such as chemotherapy induced neuropathy, hormonal therapy side effects, and psychological distress **(3).** Among the psychological symptoms commonly observed in breast cancer survivors are pain, fatigue, depressive symptoms, and anxiety, which can persist long after treatment completion **(4).**

Cancer-related fatigue, a prevalent issue among cancer patients, is characterized by persistent physical, emotional, or cognitive exhaustion attributed solely to cancer treatments **(5).** Depression and anxiety are also highly prevalent, affecting up to 66.1% and 33% of breast cancer survivors, respectively **(6).** Moreover, pain management remains a critical concern, impacting patients across multiple dimensions of life **(7).**

Breast cancer-related lymphedema, characterized by chronic limb swelling and restricted shoulder mobility, further complicates post-surgical outcomes, affecting approximately 21.4% of patients **(8,9).** Factors contributing to lymphedema include surgical interventions, radiation therapy, and lifestyle factors **(10,11).**

Physical therapy, particularly exercise therapy, has emerged as a cornerstone in managing these treatment-related symptoms. Exercise interventions, including resistance training and manual lymphatic drainage, have demonstrated efficacy in improving physical function and quality of life in breast cancer survivors **(12,13).**

Virtual reality (VR) technology, originally developed for surgical training, has garnered attention for its potential in rehabilitation settings. VR offers immersive environments that can simulate real-life activities, providing tailored rehabilitation programs that enhance patient engagement and adherence **(14,15).** Despite challenges like cybersickness and equipment costs, VR interventions have shown promise in alleviating symptoms such as pain, depression, anxiety, and fatigue, while improving physical function and overall well-being **(4,16).**

However, there remains a need for systematic evaluation of VR's effectiveness in managing specific symptoms like breast cancer post-mastectomy. This review aims to synthesize existing evidence from clinical trials to establish the clinical utility of VR-based rehabilitation programs in improving outcomes for breast cancer survivors post-mastectomy. By exploring the integration of VR with conventional therapeutic approaches, this study seeks to provide insights into optimizing rehabilitation strategies and enhancing long-term patient outcomes.

Materials and Methods:

Literature Search Strategy:

This study was registered with PROSPERO, the International prospective register of systematic reviews (CRD42024502615). We followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines during the conduct and reporting of this review.

Our search strategy encompassed six major online databases: PubMed, Web of Science

(WOS), Scopus, the Physiotherapy Evidence Database (PEDro), Virtual health library (VHL), and Cochrane Central Register of Controlled Trials (CENTRAL), covering the period from inception until February 25, 2024. We employed specific keywords including "Virtual Reality," "virtual rehabilitation system," "virtual reality head-mounted display," "breast cancer," "Breast Neoplasms," "Breast Cancer Lymphedema," "breast tumor," "breast cancer," "breast carcinoma," and "upper limb rehabilitation." These keywords were combined using Boolean operators, and the search strategy was tailored to

each database accordingly. Filters were applied to include only English articles involving human participants. Additionally, we manually scrutinized the reference lists of the included studies to identify any relevant articles missed during the initial search process.

Eligibility criteria: We set the selection criteria using PIOCS (P-population, I-intervention, C-comparison, Ooutcome, S-study design). We included only English randomized clinical trials that; 1) included post-mastectomy patients with several complications as breast cancer-related lymphedema, 2) used virtual reality rehabilitation techniques either alone or as adjuvant therapy, 3) used traditional or conventional physical therapy, placebo, no intervention, or any other type of physical therapy modalities for comparison.4) used any outcome to measure the effect of the intervention. We excluded observational studies, studies published in languages other than English, and published abstracts with no full-text articles.

Study selection: Two reviewers independently screened the titles and abstracts of the retrieved articles using predetermined eligibility criteria. Any disagreements or discrepancies were resolved by a third reviewer until consensus was reached.

Data extraction

The full text of the included articles was further analyzed and the following data were extracted; sample size, participant's age and gender, type, and dose of intervention, virtual reality device, diagnosis, outcome measures, and the main results. Any potential conflicts were resolved by a third reviewer.

Quality appraisal

The methodological quality of the included studies was independently assessed by two reviewers using the modified Downs and Black scale for clinical trials. The scale consists of 27 questions rating four categories; 1) reporting, 2) external validity, 3) internal validity, and 4) power. Studies are considered of an excellent quality when the final score ranges from 26 to 28, good quality if the score ranges from 20 to 25, fair quality if the score ranges from 19 to 15, and poor if the score was 14 or less. Any disagreements or discrepancies were resolved by discussion till consensus was reached.

Data synthesis and analysis

Meta-analysis was conducted if there was at least two studies compare the efficacy of two different programs of VR or study the effect of VR against traditional intervention or nointervention or placebo. Standardized mean difference (SMD), 95% confidence interval (CI), and P value were calculated by the comparing the change in the outcomes between the VR and the control groups using the random-effect model of analysis. Heterogeneity in treatment effect was examined by calculating the I2 index. The level of significance was set at a P-value of up to 0.05. All Meta-analyses were carried out using the comprehensive meta-analysis, version 2.2.064 software package (Biostat, Englewood, New Jersey, USA).

Results:

Study Selection

The study selection process for this systematic review was rigorous and systematic, following the

PRISMA guidelines to ensure the inclusion of relevant studies as shown in Prisma flow diagram **(Figure 1).** Initially, a total of 1,938 records were identified through comprehensive database searches and additional sources. After removing duplicates, 1,659 unique records remained. Each of these records underwent thorough screening based on their titles and abstracts, resulting in the exclusion of 1,649 studies that did not meet the predefined inclusion criteria. These criteria included relevance to the research question, appropriateness of participant characteristics, and suitability of the intervention or comparator studied.

Following this initial screening phase, the full texts of the remaining 10 articles were reviewed in detail to assess their eligibility. Three studies were excluded during this phase due to discrepancies in participant criteria, intervention details, or comparator specifications. Ultimately,

seven studies met all inclusion criteria and were included in the qualitative synthesis **(17–23).** These studies collectively provided a robust foundation for addressing the research question, offering valuable insights into the topic under investigation within the systematic review framework.

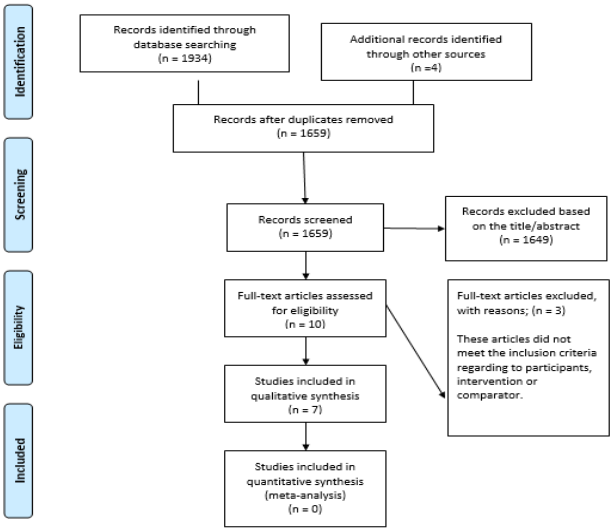


Figure 1. Prisma flow diagram

Study Characteristics

This systematic review encompasses seven studies from various countries, examining the impact of virtual reality (VR) interventions on post-mastectomy patients. The studies vary in design, sample size, participant demographics, and the type of VR technology employed as shown in **Figure 2 and 3** Below is a detailed summary of each included study:

House (2016) conducted a clinical trial in the USA with a single group of six participants averaging 57.8 years old. The study focused on individuals experiencing post-mastectomy chronic pain and depression. The intervention used was the Bright Arm Duo VR system. Participants engaged in nine VR games targeting upper limb (UL) exercises and cognitive functions for 20-50 minutes, twice a week, over three weeks. The outcomes measured included UL function, hand activity and function, range of motion (ROM), shoulder and grasp strength, activities of daily living (ADL), and pain **(17).**

El Sayed (2022) performed a randomized controlled trial (RCT) in Egypt with 60 participants divided into two groups (experimental: 30, control: 30). The participants were approximately 52 years old and diagnosed with unilateral post-mastectomy lymphedema. The experimental group used the Wii Fit balance board program, including exercises like Ski Slalom, Advanced Skiing, and Ski Jumping, for three days a week over four weeks. Balance was measured using the time up and go (TUG) test **(23).**

Atef (2020) conducted a non-randomized controlled trial (NRCT) in Egypt with 36 participants, split into two groups of 18. Participants were around 54 years old and had unilateral postmastectomy lymphedema. The VR intervention included exercises, manual lymphatic drainage, and pneumatic compression, conducted for 70 minutes, twice a week, over four weeks. Outcome measures included affected UL function and circumferential measurements **(18).**

Feyzioğlu (2020) carried out an RCT in Turkey with 36 women who had undergone unilateral mastectomy with axillary lymph node dissection. The participants, averaging around 51 years old, were divided into two groups (experimental: 19, control: 17). The experimental group engaged in VR games like darts, bowling, and boxing for 45 minutes, twice a week, over six weeks. Measured outcomes included pain, shoulder ROM, arm and hand strength, and upper extremity function **(22).**

Gupta (2019) conducted a clinical trial in India with a single group of 30 participants aged between 40 and 70 years old. The study focused on post-mastectomy radiation (MRM) patients using Vision VR TM itek TM for 30 minutes daily over a week. The primary outcome measure was anxiety, assessed using the Hospital Anxiety and Depression Scale (HADS) **(21).**

Feyzioğlu (2021) also conducted a clinical trial in Turkey with 15 women who had undergone unilateral mastectomy and were receiving neo-adjuvant chemotherapy. The

average age was approximately 50 years. The intervention consisted of VR games such as Beach volleyball and Boxing for a single 30-minute session. Outcomes measured included pain severity, shoulder ROM, exercise pleasure, and perceived fatigue level **(19).**

Harfoush (2023) performed an NRCT in Egypt with 100 post-MRM patients divided into two groups (experimental: 50, control: 50), with participants averaging around 58 years old. The experimental group used Vision VR TM itek TM to demonstrate exercises in six 30-minute sessions. Outcome measures included post-mastectomy complications and self-care practices **(20).**

Figure 2.

	Country	Design	Sample size	Age	Diagnosis	VR type
House 2016	USA	CT	One group; 6	57.8 (20.4)	Post-mastectomy chronic pain with depression score of 10 or above	BrightArm Duo
El Sayed 2022	Egypt	RCT	Two groups; 60; E1 (30), CG(30)	E1; 52.5 (7.5), CG; 52 (7)	Unilateral post mastectomy lymphedema	Wii Fit balance board program
Atef 2020	Egypt	NRCT	Two groups; 36 E1 (18), E2 (18)	E1; 54.07 (8.28), E2; 53.07 (7.24)	Unilateral postmastectomy lymphedema	Nintendo Wii video game
Feyzioğlu 2020	Turkey	RCT	Two groups; 36 E1 (19), E2 (17)	E1; 50.84 (8.53), E2; 51.00 (7.06)	Women with breast cancer who had undergone unilateral mastectomy with axillary lymph node dissection	Xbox 360 Kinect-based virtual reality
Gupta 2019	India	CT	One group; 30	40-70 yearsold	Post MRM patients	Vision VR TM itek TM
FEYZIOGLU 2021	Turkey	CT	One group; 15	50.13±8.79	Women had undergone unilateral mastectomy receiving neo-adjuvant chemotherapy	Xbox Kinect 360 video games
Harfoush 2023	Egypt	NRCT	Two groups; 100 E1 (50), E2 (50)	E1; 58.25 (3.736), E2; 59.5 (2.179)	Post MRM patients	Vision VR TM itek TM

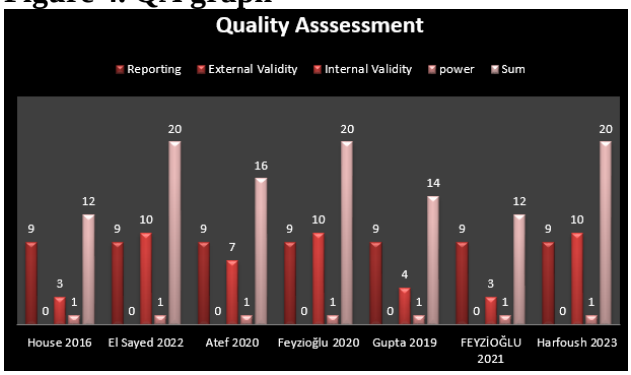
Figure 3. Characteristics of included trials.

Author Id	E1	E2	Control group	Dosage	Outcome measures	Results
House 2016	Nine VR games targeting UL exercises and emotive and cognitive functions	-	-	20-50 min/d, 2 d/wk. for 3 wks.	• UL functions using FMA • Hand activity using CAHAI-9 • Hand functions using JHFT • ROM using mechanical goniometers • Shoulder strength using wrist weights • Grasp strength using Jamar mechanical dynamometer and a Jamar pinchmeter. • ADL • Pain using NRS	The study demonstrated a 20% reduction in pain intensity, significant improvements in cognitive metrics ($p = 0.01$), and an 8.3-point decrease in depression severity ($p = 0.04$). Range of motion metrics notably increased ($p < 0.01$), with some shoulder improvements exceeding the Minimal Clinically Important Difference.
El Sayed 2022	Wii Fit balance board program form of (Ski Slalom, Advanced Skiing, Ski Jumping followed by Header and Jump Rope)	Core stability exercise	-	3 d/wk, for 4 wks.	• **Balance** using time up and go (TUG)	The between-group analysis showed significant differences in TUG after treatment ($p < 0.05$), with non-significant differences observed in Wii fit after treatment ($p > 0.05$).
Atef 2020	VR exercises , manual lymphatic drainage , and pneumatic compression	PNF, manual lymphatic drainage , and pneumatic compression	-	70 min/d, 2 d/wk. for 4 wks.	• Affected UL function using the validated Arabic version of the QuickDASH-9 scale • Circumferential measurements	The functional improvement percentage was statistically significantly different between the two groups. while there was no significant difference between the two groups regarding arm volume
Feyzioğlu 2020	VR games such as darts, bowling, boxing, beach volleyball, table tennis and Fruit Ninja	Standard physiotherapy program such as breathing exercises and strengthening exercises for UL	-	45 min/d, 2 d/wk. for 6 wks.	• Pain using VAS • Shoulder ROM using digital goniometer • Arm strength • Hand grip strength using hand dynamomter • UE function using DASH	Both groups detected significant changes in all outcome measures. However, There were no significant differences between both groups after treatment
Gupta 2019	VR interactive games	-	-	30 min/ day 7d/ wk. for 1 wk.	• Anxiety using HADS	HADS showed statistical significant difference between pre and post treatment
Feyzioğlu 2021	VR games such as Beach volleyball, Bowling, Boxing, and Fruit Ninja	-	-	1 session for 30 min	• Pain Severity using VAS • Shoulder ROM using digital goniometer	Sig improvement was observed in shoulder flexion, abduction, and external rotation. However, no sig difference was observed regarding pain and shoulder abduction strength
Harfoush 2023	Demonstrating of exercises by using VR games.	-	the routine oncology center care provided for all patients with modified radical mastectomy	6 sess., 30min/sess.	• Post mastectomy complications using Early Post Modified Radical Mastectomy Complications Checklist. • Self-care practices of modified radical mastectomy structured interview schedule	The VR group had significantly higher mean scores than the booklet group across all studied dimensions and the total score of self-care practices.

Quality Assessment

The quality assessment evaluates these seven studies using a structured framework to assess various aspects of study reporting, external validity, internal validity, and power as shown **Figure 4.** All studies scored highly in reporting quality (9 out of 9), indicating clear descriptions of objectives, outcomes, patient characteristics, and interventions. However, none of the studies scored in external validity, suggesting limitations in representing broader patient populations and typical treatment settings.

Figure 4. QA graph



Internal validity varied across studies: El Sayed (2022) **(23),** Feyzioğlu (2020) **(22),** and Harfoush (2023) **(20)** scored highest (10 out of 12), reflecting robust methodologies including blinding, statistical adjustments, and accurate outcome measures. Atef (2020) **(18)** scored 7, while House (2016) **(17),** Gupta (2019) **(21),** and Feyzioğlu (2021) **(19)** scored lower (3-4), indicating limited blinding and adjustments for confounding factors.

All studies demonstrated sufficient power (scored 1 out of 1) to detect clinically significant effects with adequate sample sizes. Overall quality scores ranged from 12 to 20, with El Sayed (2022) **(23),** Feyzioğlu (2020) **(22),** and Harfoush (2023) **(20)** achieving higher scores, indicating stronger methodological rigor. House (2016) **(17),** Gupta (2019) **(21),** and Feyzioğlu (2021) **(19)** scored lower, suggesting potential limitations in validity. This systematic review underscores the importance of rigorous methodologies to enhance the reliability and applicability of findings in VR interventions for post-mastectomy rehabilitation.

Findings

This systematic review examined the effects of virtual reality (VR) interventions on various outcomes in post-mastectomy patients across different studies:

Effect of VR on Pain Post-Mastectomy

VR interventions showed mixed results in pain management:

- Feyzioğlu (2020) **(22)** reported a significant decrease in pain intensity post-treatment ($p = 0.001$), indicating positive outcomes.
- Feyzioğlu (2021) **(19)** did not find significant changes in pain intensity following VR interventions ($p > 0.05$).
- House (2016) **(17)** showed a non-significant decrease in pain severity over an 8-week protocol, with individual improvements noted despite varied outcomes ($p = 0.1$).

Effect of VR on Upper Extremity (UE) Range of Motion (ROM) Post-Mastectomy

VR interventions consistently improved shoulder ROM across studies:

- House (2016) demonstrated significant improvements in all 10 ROM metrics for the affected arm post-training ($p < 0.0001$) **(17).**
- Feyzioğlu (2020) and Feyzioğlu (2021) also reported significant gains in shoulder ROM ($p = 0.001$), though variations existed in specific metrics like abduction **(19,22).**

Effect of VR on UE Strength and Functional Assessments Post-Mastectomy VR interventions positively impacted strength and functional assessments:

- House (2016) reported significant improvements in shoulder and grip strength ($p < 0.05$), exceeding Minimal Clinically Important Difference (MCID) values **(17).**
- Atef (2020) and Feyzioğlu (2020) showed significant enhancements in upper limb function assessed by scales like QuickDASH-9 ($p = 0.025$) **(18,22).**

Effect of VR on Cognitive and Emotive Outcomes Post-Mastectomy

- House (2016) indicated significant improvements in depression severity and visuospatial memory ($p < 0.05$), highlighting cognitive benefits **(17).**

Effect of VR on Balance Post-Mastectomy

- El Sayed (2022) demonstrated improved balance post-treatment using the Timed Up and Go (TUG) test ($p < 0.05$), suggesting VR's role in enhancing balance **(23).**

Effect of VR on Circumferential Measurements of UE Post-Mastectomy

- Atef (2020) reported significant reduction in excess arm volume (EAV) post-VR interventions, indicating effective lymphedema management **(18).**

Effect of VR on Anxiety Post-Mastectomy

- Gupta (2019) found significant reductions in anxiety levels post-VR interventions ($p < 0.05$), as measured by the Hospital Anxiety and Depression Scale (HADS) **(21).**

Effect of VR on Presence of Complications Post-Mastectomy

- Harfoush (2023) did not find a significant association between VR interventions and post-mastectomy complications ($p = 0.191$) **(20).**

Effect of VR on Self-Care Practices Post-Mastectomy

- Harfoush (2023) demonstrated significantly higher self-care scores in the VR group compared to the control group ($p = 0.000$), indicating improved self-care practices with VR rehabilitation **(20).**

Discussion:

The systematic review meticulously selected studies to evaluate the impact of virtual reality (VR) interventions on post-mastectomy patients. Initially, 1,938 records were identified, of which 10 articles met the inclusion criteria following full-text assessment. These studies, originating from diverse countries and employing various VR technologies, provided comprehensive insights into VR's effects on pain management, upper extremity (UE) range of motion (ROM), strength, cognitive and emotive outcomes, balance, lymphedema management, anxiety, and self-care practices.

The review process rigorously filtered studies, starting with 1,938 records, then excluding duplicates to leave 1,659 records for relevance screening. Of these, 1,649 were excluded, leading to a final selection of 10 articles for full-text assessment. Ultimately, seven studies were included in the qualitative synthesis.

Feyzioğlu (2020) reported significant pain reduction ($p = 0.001$), consistent with previous VR pain distraction studies **(22,24).** In contrast, Feyzioğlu (2021) and House (2016) did not find significant pain changes post-intervention, reflecting variability in VR's efficacy for pain relief **(17,19).**

Significant improvements in shoulder ROM were consistently observed across studies, with metrics exceeding the Minimal Clinically Important Difference (MCID) **(17,19,22).** Varied outcomes in specific ROM metrics highlight the need for standardized VR protocols **(19,22).**

VR interventions significantly enhanced strength metrics and functional assessments, including grip and shoulder strength **(17).** Significant improvements in upper limb function were noted using the QuickDASH-9 scale **(18,19).** Contrasting results in muscle strength indicate potential protocol refinement **(19).**

VR interventions improved cognitive metrics, reducing depression severity and enhancing visuospatial memory (17). Consistent with broader literature on VR's psychological benefits **(25).**

Improved balance and effective lymphedema management were noted post-VR interventions (**18,23),** aligning with studies in other patient populations **(26).**

Significant reductions in anxiety levels and improved self-care practices underscore VR's potential in psychological support and rehabilitation engagement **(20,21).**

Overall, findings align with existing literature on VR's efficacy in rehabilitation settings,

suggesting VR's versatility in enhancing traditional therapy outcomes **(27).** Mixed results highlight the need for standardized protocols and further investigation into VR's mechanisms and long-term effects **(28).**

Conclusions:

VR interventions offer promising outcomes across multiple domains of post-mastectomy rehabilitation, with significant improvements in ROM, strength, pain management, and psychological well-being. Future research should focus on protocol standardization, long-term effects, and mechanisms underlying VR's therapeutic benefits to optimize rehabilitation outcomes.

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Conflicts of Interest: The authors stated no conflict of interest.

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