Original Article

Effect of physical exercise on postoperative shoulder mobility and upper limb function in patients with breast cancer: a systematic review and meta-analysis

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Background: The shoulder pain and reduced range of motion caused by breast cancer seriously affect the quality of life of women. Such persistent impairments can escalate into chronic pain, diminished muscle strength, lymphedema, and compromised cardiorespiratory health potentially culminating in permanent disability. This systematic review aims to evaluate how physical exercise impacts shoulder mobility and upper limb function in breast cancer patients post-surgery, examining various aspects of exercise such as type, intensity, duration, frequency, and intervention timing to determine the influence on outcomes.

Methods: A comprehensive search was conducted across seven databases up to April 16, 2024. Two reviewers independently assessed randomized controlled trials (RCTs) focusing on the effects of physical exercise on postoperative outcomes in breast cancer patients. Quality was assessed using the Cochrane risk of bias tool, with meta-analyses and publication bias tests performed via RevMan5.4, and evidence quality evaluated using GRADEPro. Effect sizes were calculated using standardized mean differences (SMDs) with 95% confidence intervals (CIs).

Results: Twenty studies (25 RCTs involving 2,171 patients) were included for both the systematic review and the meta-analysis. Meta-analysis confirmed that physical exercise significantly enhanced shoulder flexion (SMD =0.59; 95% CI: 0.32, 0.86; P<0.001) and abduction (SMD =1.01; 95% CI: 0.43, 1.60; P<0.001) in postoperative patients, and improved upper limb function (SMD =0.87; 95% CI: 0.48, 1.26; P<0.001). Subgroup analyses indicated that comprehensive exercise, particularly when performed ≤3 times a week or over 8–12 weeks, was most effective for improving shoulder flexion, while shorter durations (<8 weeks) and similar frequencies were optimal for abduction. Resistance exercises, especially when started early (<2 weeks post-surgery), showed significant benefits for upper limb function.

Conclusions: The included studies were of moderate to high quality, though some lacked detailed reporting on blinding or allocation concealment. Analysis suggests that the timing of intervention initiation, along with exercise type and frequency, may contribute to observed variations in outcomes. Evidence quality assessments did not reveal significant issues with indirectness or imprecision, and no significant publication bias was detected. Given the low heterogeneity and absence of significant downgrade factors, intermediate evidence quality was assigned for upper limb function and shoulder abduction, with high quality for shoulder flexion. Physical exercise is notably effective in enhancing both upper limb function and shoulder mobility in breast cancer patients, with the timing and frequency of exercise interventions influencing these improvements. This provides valuable evidence for clinical rehabilitation strategies.

Keywords: Shoulder mobility; breast cancer; upper extremity function; exercise intervention; systematic review with meta-analysis

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Introduction

Breast cancer, a common condition among women, is the primary cause of cancer deaths in this demographic (1). According to the World Health Organization (WHO), breast cancer is the most common cancer among women worldwide, representing about 12% of all new cancer cases each year (2). The risk of breast cancer increases with age. Although breast cancer can occur at any age, it is most commonly diagnosed in women aged 50 years and older. The year 2020 saw approximately 685,000 women succumbing to breast cancer globally (3). Each year, the global incidence of breast cancer surpasses one million cases (4), underscoring its status as a formidable health challenge worldwide. Research findings suggest that as many as 67% of breast cancer survivors suffer from diminished shoulder mobility and impaired upper limb function (5-7). Shoulder pain and reduced range of motion are common in the immediate postoperative period and can persist long-term. Up to 30% of patients may experience significant shoulder impairment 2 years after surgery. A review indicated that impairments in shoulder movement and muscle strength can be present even beyond the 2-year mark, with varying degrees of severity depending on individual circumstances and treatment received (8). Such persistent impairments can escalate into chronic pain, diminished muscle strength, lymphedema, and compromised cardiorespiratory health (9,10), potentially culminating in permanent disability. The long-term morbidity associated with breast cancer treatments can significantly impact the quality of life (11).

The 2019 edition of the Guidelines and Norms for Diagnosis and Treatment of Breast Cancer, issued by the Chinese Anti-Cancer Association, advocates for targeted physical exercise in breast cancer patients post-surgery (12). Evidence suggests that participation in physical activity is essential for functional limb rehabilitation after breast cancer surgery, common procedures include axillary lymph node dissection and mastectomy (13). A positive relationship has been observed between the extent of postoperative rehabilitation and the level of physical activity among breast cancer patients (14). Given the common issue of upper limb dysfunction following surgery, physical exercise plays a critical role by strengthening muscles, preventing wound adhesions, and activating the deep shoulder and latissimus dorsi muscles to gradually replace the axillary tissue, thus improving shoulder mobility and upper limb function in these patients. Both aerobic and resistance exercises have been shown to enhance upper limb function post-surgery (15). Regular exercise helps reduce lymphedema by promoting protein reabsorption and enhancing the flexibility of soft tissues (16), which is believed to contribute to improved upper limb function. Additionally, exercise has been found to regulate estrogen levels and boost patients' immune responses, thereby aiding in the functional recovery of patients after breast cancer surgery (17).

Systematic reviews conducted in the past suggest that while aerobic exercise enhances shoulder mobility among breast cancer survivors, its impact on upper limb strength is inconclusive (18). There is a need to incorporate more recent studies for a comprehensive analysis. Experimental studies have highlighted the benefits of resistance training (19) and mind-body exercises (20) in improving upper limb function post-surgery in breast cancer patients. However, a systematic evaluation and comparison of these interventions

Highlight box

Key findings

- Physical exercise is notably effective in enhancing both upper limb function and shoulder mobility in breast cancer patients.

What is known and what is new?

- Participation in physical activity is essential for functional limb rehabilitation after breast cancer surgery.
- Timing and frequency of exercise interventions influencing these improvements.

What is the implication, and what should change now?

- This provides valuable evidence for clinical rehabilitation strategies. In the future, more high-quality literature should be added, and the type of surgery and the duration of postoperative intervention should be analysed.

Table 1 Research framework of physical exercise intervention on shoulder mobility and upper limb function of patients after breast cancer surgery (PICOS)

Population	Intervention	Comparison	Outcome	Study
Postoperative breast cancer patient, undergone surgical treatment	Interventionists: therapists	Physical exercise was compared with control group or physical exercise combined with conventional treatment group was compared with conventional treatment group	Upper limb function (CMS, DASH)	RCT
Age ≥18 years No mental abnormality or cardiopulmonary dysfunction	Intervention prescription: include physical exercise or enhanced physical exercise in addition to standard treatments, with at least one experimental group using physical exercise as an intervention on top of the same rehabilitation protocol as the control group	Subgroup analysis: Comparison of form, intensity, duration, intervention cycle and frequency of physical exercise Comparison of different postoperative intervention time	Shoulder range of motion (shoulder forward flexion, shoulder abduction)	

CMS, Constant and Murley Score; DASH, Disability of Arm, Shoulder and Hand; RCT, randomized controlled trial.

are lacking. Additionally, the specific influences of various exercise parameters—including type, intensity, duration, intervention cycle, and frequency—remain unclear. This study, therefore, seeks to systematically analyze randomized controlled trials (RCTs) that investigate the effects of physical exercise on postoperative shoulder mobility and upper limb function in breast cancer patients, using an evidence-based approach. The goal is to provide a foundation for developing effective exercise protocols tailored to post-surgical breast cancer patients. We present this article in accordance with the PRISMA reporting checklist (available at https://gs.amegroups.com/article/view/10.21037/gs-24-255/rc) (21).

Methods

Study framework

This study is registered on the International Platform of Registered Systematic Review and Meta-Analysis Protocols (registration number INPLASY202460058). The detailed structure of the research is outlined in *Table 1*.

Search strategy

Two researchers independently searched seven databases—Web of Science, PubMed, The Cochrane Library, Embase, China National Knowledge Internet (CNKI), WanFang Data, and VIP—from their inception until April 16, 2024. The search strategy combined subject headings with free-text terms, finalized after several preliminary searches, and was enhanced by manual checks, including tracing back to references of included studies when necessary.

Search terms: (breast neoplasms OR breast cancer OR breast tumor OR breast carcinoma) AND (exercise OR aerobic OR resistance OR strength OR physical activity OR qigong OR tai chi OR taiji OR yoga OR baduanjin OR jogging) AND (upper limb function OR upper-extremity function OR upper limb OR limb function OR shoulder range of motion OR shoulder mobility OR range of motion OR shoulder joint OR shoulder) AND (randomized controlled trial OR randomized OR controlled OR trial OR RCT).

Criteria for inclusion and exclusion

Inclusion criteria: (I) subjects are postoperative breast cancer patients, unrestricted by race or nationality, aged 18 years or above, without mental disorders or cardiopulmonary impairments. (II) Interventions include physical exercise or enhanced physical exercise in addition to standard treatments, with at least one experimental group using physical exercise as an intervention on top of the same rehabilitation protocol as the control group; multiple comparisons within a single study are treated as separate studies. (III) The primary outcome measure is upper limb function, assessed by Constant and Murley Score (CMS)—covering pain (15 points), daily activities (20 points), joint mobility (40 points), and muscle strength (25 points), with

Table 2 Includes the definition and composition of physical exercise

Classification of sports in this study	Definition and composition of included programs
Chinese traditional exercises	Chinese traditional exercises, grounded in the rich heritage of Chinese culture, emphasize martial arts techniques and incorporate routines, combat forms, and exercise practices as primary activities. This study encompasses traditional physical activities, including Tai Chi, Baduanjin, and Yangge dance
Resistance exercise	Resistance exercise involves the active engagement of muscles in overcoming external resistance. This study incorporates various forms of resistance training, including equipment-based resistance exercises, progressive resistance training, and isokinetic strength training
Aerobic exercise + resistance exercise	Aerobic exercise is characterized by activities that predominantly rely on aerobic metabolism to meet energy demands. Resistance exercise entails the active engagement of muscles in overcoming external resistance. This study encompasses combined aerobic and resistance exercises, integrating both types of exercise interventions
Ball exercise	Ball games refer to sports or recreational activities that fundamentally involve the use of a ball. This study encompasses ball games, specifically Swiss ball exercises and football
Comprehensive exercise	Comprehensive exercise entails the integration of multiple exercise modalities and training methodologies. This study encompasses various comprehensive exercises, including progressive combined exercises, rehabilitation exercises, inertia training, proprioceptive neuromuscular facilitation, therapeutic exercises, and home-based exercises

higher scores indicating better recovery—and Disability of Arm, Shoulder and Hand (DASH), which evaluates upper limb musculoskeletal conditions and functions through 30 items, with higher scores indicating better outcomes. Secondary outcomes measure shoulder joint mobility, assessed by the maximum angles of forward flexion and abduction using an arthrometer. (IV) The control group receives either standard treatment or no additional treatment. (V) The study design must be a RCT.

Exclusion criteria: patients with recurrent or metastatic breast cancer; studies not published in Chinese or English; animal studies; studies including patients with other cancers; duplicate publications or studies with poor quality assessments.

Screening and extraction of literature

Screening process

Initially screened articles are imported into Endnote X9 for duplicate removal. The screening is independently performed by two researchers based on the inclusion and exclusion criteria. The process begins with a review of titles and abstracts for preliminary selection, followed by a full-text reading and downloading of articles that meet the criteria. After screening, results are compared, and any discrepancies are discussed with a third researcher to finalize inclusion decisions.

Data extraction

A standardized protocol is employed to extract pertinent information from the literature. This task is also independently carried out by two researchers for the included articles. For missing or unclear data, direct contact with the original authors via email is made to acquire and verify the information. In cases of conflicting information inclusion, a consensus is reached through discussion with a third researcher. The extracted data encompasses: (I) basic details (author, year, country, age, sample size, postoperative intervention time); (II) experimental specifics (type, duration, frequency) and outcome measures. The classification of exercise intervention forms in this study is shown in *Table 2*.

Quality assessment of literature

Using the risk of bias tool recommended by the Cochrane Handbook (22), the assessment covers seven areas: random sequence generation, allocation concealment, blinding of participants and researchers, blinding of outcome assessors, incomplete outcome data, selective reporting, and other potential biases. Each criterion is rated as "low bias risk", "unclear bias risk", or "high bias risk".

Statistical analysis

The software used for data analysis was Review Manager

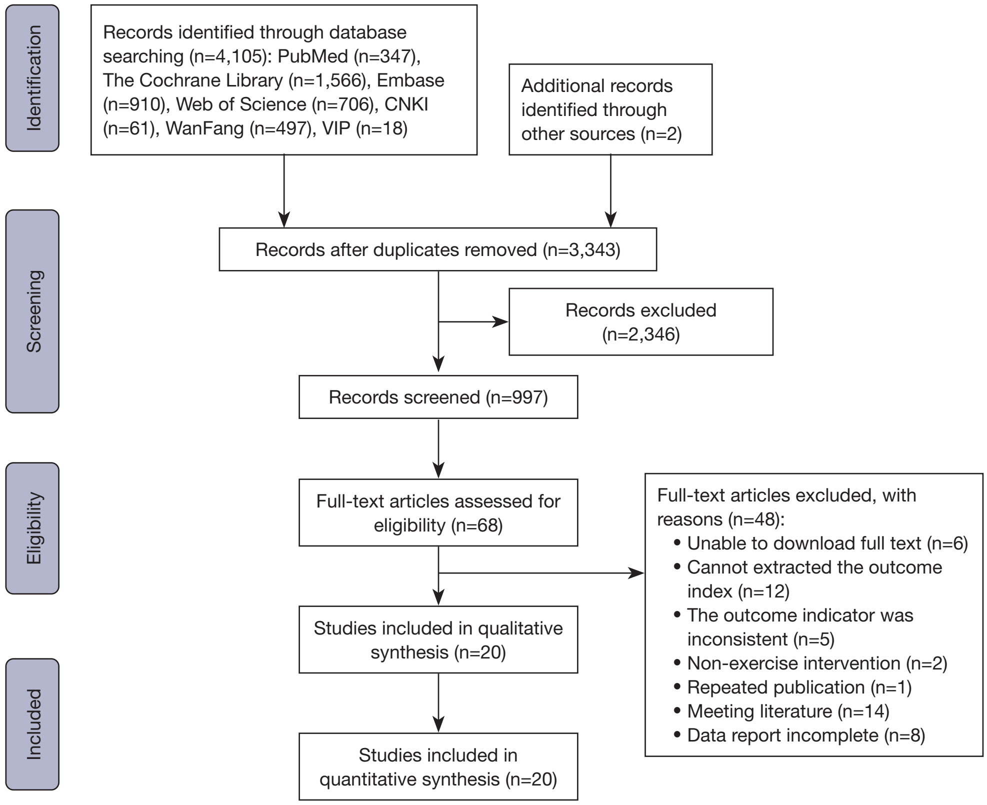

Figure 1 Literature screening flow chart. CNKI, China National Knowledge Internet.

5.4. Heterogeneity was evaluated using the P value and I^2 statistic. If significant heterogeneity was detected ($I^2 \geq 50\%$; $P<0.10$), a random effects model was applied; otherwise, a fixed effects model was used. The standardized mean difference (SMD) was calculated, along with a 95% confidence interval (CI). Sensitivity analysis involved sequentially excluding individual studies. If heterogeneity was substantial, a descriptive analysis was performed. The Egger's test was used to test for publication bias.

Assessment of evidence quality

Evidence quality evaluated using GRADEPro (23). The evaluation of the quality of evidence for outcome indicators encompasses five downgrading factors: publication bias, inconsistency, imprecision, indirectness, and study limitations. The evidence is classified into four levels based on the degree of downgrading: very low, low, moderate, and high. Specifically, a three-level downgrade results in very low evidence, a two-level downgrade results in low evidence, a one-level downgrade results in moderate evidence, and no downgrade results in high evidence. The quality assessment is independently conducted by two researchers. In cases of disagreement, a third researcher is consulted to reach a consensus through discussion.

Results

Outcome of literature search

A systematic online search using computers retrieved 4,105 articles, with an additional 2 articles were found through manual search methods. After removing duplicates, 3,343 articles remained. These were initially screened by examining titles and abstracts, followed by a thorough review of the full texts to exclude those that did not fulfill the inclusion criteria. Consequently, 20 articles were selected for inclusion in the analysis, as illustrated in *Figure 1*.

Basic features of included studies

This review encompasses 20 articles, which represent

25 RCTs and involve a total of 2,171 patients. The youngest patient was only 28 years old (20), the patients in this study (24) were the oldest on average (66.2±10.6 years old). The intervention group was subjected to a variety of exercise regimens, including traditional Chinese exercises (28%), resistance training (24%), combined aerobic and resistance training (12%), ball sports (8%), and integrated exercise routines (28%). In contrast, the control group received standard treatments such as health education, daily activity recommendations, exercise guidance, and conventional rehabilitation. Each study intervention was administered at least once, with durations spanning from a minimum of 6 weeks to a maximum of 52 weeks, and an average intervention period of 17 weeks. The exercise frequency varied from a minimum of once per week to a maximum of 7 times per week, with the predominant frequency being more than 3 times per week. The duration of each exercise session ranged from 40 to 80 minutes, with the most frequently observed duration being 60 minutes per session. The exercise regimen varied from 1 to 7 days per week, eight studies (11 RCTs) set the frequency of exercise to 3 or more times per week, seven studies less than 3 times per week, and five studies did not report. Notably, one study had a 1-month exercise duration, while all others extended for at least 2 months. The timing of interventions post-surgery ranged from 10 days to 6 weeks post-operation, and also included periods post-chemotherapy. The studies were sourced from various countries, with the majority from China (35%) and the United States (25%), followed by contributions from Denmark, Canada, Brazil, the Netherlands, Australia, the United Kingdom, Spain, Poland, and Türkiye, each contributing 5%. Details are shown in *Table 3*.

Evaluation of methodological quality in included studies

The review encompassed 20 articles, all of which were RCTs. Out of these, 17 provided details on the randomization process (11,20,24-38), while eight specified the allocation concealment method (24-28,34,36,39). Single-blinding was used in seven studies (20,25,26,29,30,34,37), and 12 studies blinded the outcome assessors (11,24,25,28,29,32,34-38,40). One study reported missing data (26), but there was no evidence of selective reporting. *Figure 2* illustrates that the included studies exhibited varying degrees of bias, with seven studies deemed to have high methodological quality (11,25,28-30,34,41) and 16 studies rated as having moderate quality.

Results of meta-analysis

Impact of physical exercise on shoulder mobility post-surgery in breast cancer patients

Eleven studies with 741 breast cancer patients were included to compare the differences in shoulder flexion and abduction between the physical exercise group and the control group. *Figure 3* illustrates that for shoulder flexion, the heterogeneity test indicated I^2=65% and P=0.002, suggesting moderate heterogeneity among studies, leading to the application of a random-effects model for analysis. The meta-analysis demonstrated a pooled effect size of SMD =0.59, with a 95% CI of (0.32, 0.86) and P<0.001, suggesting that physical exercise significantly enhances shoulder flexion function post-surgery compared to the control group. *Figure 4* shows that for shoulder abduction, the heterogeneity test revealed I^2=90% and P<0.001, indicating high heterogeneity among studies, and thus a random-effects model was employed. The meta-analysis yielded a pooled effect size of SMD =1.01, with a 95% CI of (0.43, 1.60) and P<0.001, indicating that physical exercise significantly improves shoulder abduction function post-surgery compared to the control group.

Subgroup analyses were performed based on intervention types, frequencies, and durations, as detailed in *Table 4*. For the flexion subgroup, resistance exercise (SMD =0.54; 95% CI: 0.07, 1.02; P=0.02), aerobic + resistance exercise (SMD =0.49; 95% CI: 0.11, 0.87; P=0.01), and comprehensive exercise (SMD =0.88; 95% CI: 0.24, 1.52; P=0.007) showed significant improvements. Frequency subgroup analysis indicated improvements for ≤3 times/week (SMD =0.68; 95% CI: 0.33, 1.03; P<0.001) and >3 times/week (SMD =0.49; 95% CI: 0.11, 0.87; P=0.01). Duration subgroup analysis showed improvements for <8 weeks (SMD =0.66; 95% CI: 0.24, 1.09; P=0.002) and 8–12 weeks (SMD =0.83; 95% CI: 0.45, 1.22; P<0.001), but no significant improvement for >12 weeks (P=0.20). For the abduction subgroup, resistance exercise (SMD =0.93; 95% CI: 0.08, 1.77; P=0.03) and comprehensive exercise (SMD =1.74; 95% CI: 1.10, 2.38; P<0.001) demonstrated significant improvements, whereas aerobic + resistance exercise did not (P=0.20). Frequency subgroup analysis showed improvement for ≤3 times/week (SMD =0.87; 95% CI: 0.18, 1.57; P=0.01), but no significant improvement for >3 times/week (P=0.20). Duration subgroup analysis showed improvements for <8 weeks (SMD =1.78; 95% CI: 1.30, 2.25; P<0.001) and 8–12 weeks (SMD =1.3; 95% CI:

Table 3 Basic features of included studies

Study	Nation	Sample size (E/C)	Age (years) (E/C)	Intervention measure		Intervention duration	Postoperative intervention time	Outcome index
				E	C			
Wang YL, 2012①	China	63/71	47.19	Tai Chi + routine rehabilitation	Routine rehabilitation	7 days/week, 40 minutes/day, 170 days in total	10 days after surgery	CMS↑
Wang YL, 2012②	China	51/71	47.19	Yangko dance + routine rehabilitation	Routine rehabilitation	7 days/week, 40 minutes/day, 170 days in total	10 days after surgery	CMS↑
Sun XY, 2012①	China	35/41	39.18	Tai Chi + routine rehabilitation + muscle strength training	Routine rehabilitation + muscle strength training	7 days/week, 40 minutes/day, 170 days in total	10 days after surgery	CMS↑
Sun XY, 2012②	China	42/41	39.18	Tai Chi + routine rehabilitation + muscle strength training	Routine rehabilitation + muscle strength training	7 days/week, 40 minutes/day, 170 days in total	10 days after surgery	CMS↑
Sun XY, 2020	China	47/38	28–65	Tai Chi + routine rehabilitation	Routine rehabilitation	7 days/week, 40 minutes/day, 90 days in total	10 days after surgery	CMS↑
Lv F, 2015①	China	50/49	48.61	Tai Chi + routine rehabilitation	Routine rehabilitation	≥3 days/week, ≥60 minutes/day, a total of 80 days	Completion of chemotherapy (at least 2 weeks after surgery)	CMS↑
Lv F, 2015②	China	50/49	48.61	Baduanjin + routine rehabilitation	Routine rehabilitation	≥3 days/week, ≥60 minutes/day, a total of 80 days	Completion of chemotherapy (at least 2 weeks after surgery)	CMS↑
Li YP, 2017	China	36/34	57.1±10.3/ 58.2±9.8	Isokinetic strength training + routine rehabilitation	Routine rehabilitation	Total 60 days	4–6 weeks after surgery	CMS↑; shoulder flexion↑; shoulder joint abduction↑
Sweeney FC, 2019	United States	50/50	52.8±10.6/ 53.6±10.1	Progressive joint movement + routine rehabilitation	Routine rehabilitation	3 days/week, 50–80 minutes/day, 16 weeks in total	–	DASH↑
Mariano KOP, 2015	Brazil	6/7	54.5±4.24/ 56.16±3.53	Swiss ball sports + health promotion	Health promotion	30 minutes	–	DASH↑
Ibrahim M, 2017	Canada	29/30	39.2±5	Progressive exercise + standard treatment	Standard treatment	2–3 days/week, 12 weeks in total	–	DASH—
Bloomquist K, 2021	Denmark	46/22	47.4±9.4/ 50±9.3	Soccer	Daily life	2 days/week, 35–41 minutes/day, 52 weeks in total	–	DASH—
Zhou K, 2019	China	51/51	49.94±8.88/ 49.40±9.88	Progressive movement + routine rehabilitation	Routine rehabilitation	7 days/week, ≥30 minutes/day, 24 weeks in total	2 weeks after surgery	CMS↑

Table 3 (*continued*)

Table 3 (*continued*)

Study	Nation	Sample size (E/C)	Age (years) (E/C)	Intervention measure		Intervention duration	Postoperative intervention time	Outcome index
				E	C			
Portela AL, 2008①	United States	12/9	49.8±6.9/ 59.6±16.7	Cardio plus resistance + standard treatment	Standard treatment	5 days/week, 26 weeks in total	–	DASH—; shoulder flexion—; shoulder joint abduction—
Portela AL, 2008②	United States	13/9	51.2±7.3/ 59.6±16.7	Aerobic plus resistance + standard treatment	Standard treatment	5 days/week, 26 weeks in total	–	DASH—; shoulder flexion—; shoulder joint abduction—
Park JH, 2017	Korea	34/34	54.78±3.42/ 54.28±5.57	Aerobic plus resistance + routine rehabilitation	Routine rehabilitation	5 days/week, 60 minutes/day, a total of 4 weeks	–	Shoulder flexion↑; shoulder joint abduction↑
Kilbreath SL, 2012	Australia	81/79	53.5±12.1/ 51.6±11	Aerobic plus resistance + routine rehabilitation	Routine rehabilitation	Once a week for 8 weeks	4–6 weeks after surgery	Shoulder flexion↑; shoulder joint abduction↑
Beurskens CH, 2007	Netherlands	15/15	53.7±13/ 55.4±9.3	Rehabilitation exercise	Routine rehabilitation	3 months in total	2 weeks after surgery	DASH↑; shoulder flexion↑; shoulder joint abduction↑
Bruce J, 2021	United Kingdom	191/191	58.4±12.2/ 57.8±12.0	Rehabilitation exercise	Routine care	Minimum 2/week, 150 minutes/week, 12 months	Within 7–10 days after surgery	DASH↑
Huo M, 2024	China	51/50	51.3±11.2/ 49.5±10.7	Resistance training + routine rehabilitation	Routine rehabilitation	None	1–3 months after surgery	Shoulder flexion↑; shoulder joint abduction↑
Esteban-Simón A, 2024	Spain	30/28	52.6±8.8/ 52.0±9.4	Resistance training + routine rehabilitation	Routine rehabilitation	Twice a week, 12 weeks	–	DASH—
Naczk A, 2022	Poland	12/12	66.2±10.6	Inertial training + routine rehabilitation	Routine rehabilitation	6 weeks	–	Shoulder flexion↑; shoulder joint abduction↑
Guloglu S, 2023①	Türkiye	22/22	46.0±7.7/ 44.2±7.0	Proprioceptive neuromuscular facilitation + routine rehabilitation	Routine rehabilitation	60 min/once, 2 days/week, 8 weeks	–	DASH—; shoulder flexion↑; shoulder joint abduction↑
Guloglu S, 2023②	Türkiye	22/22	48.8±9.8/ 44.2±7.0	Asymptotic resistance training + routine rehabilitation	Routine rehabilitation	60 min/once, 2 days/week, 8 weeks	–	DASH—; shoulder flexion↑, shoulder joint abduction↑
Klein I, 2021	United States	72/85	53.30±12.7/ 51.2±13.10	Therapeutic exercise and family exercise + routine rehabilitation	Routine rehabilitation	3 times/day	The second day after surgery	DASH↑; shoulder flexion↑; shoulder joint abduction↑

"↑" indicates a significant difference between the experimental group and the control group, while "—" denotes no significant difference between the two groups. In the fourth column (age), we preferentially report the age (mean, range, or mean ± SD) of the intervention and control groups, and if not present, we report the age as described in the article. E, experimental group; C, control group; CMS, Constant and Murley Score; DASH, Disability of Arm, Shoulder and Hand; SD, standard deviation.

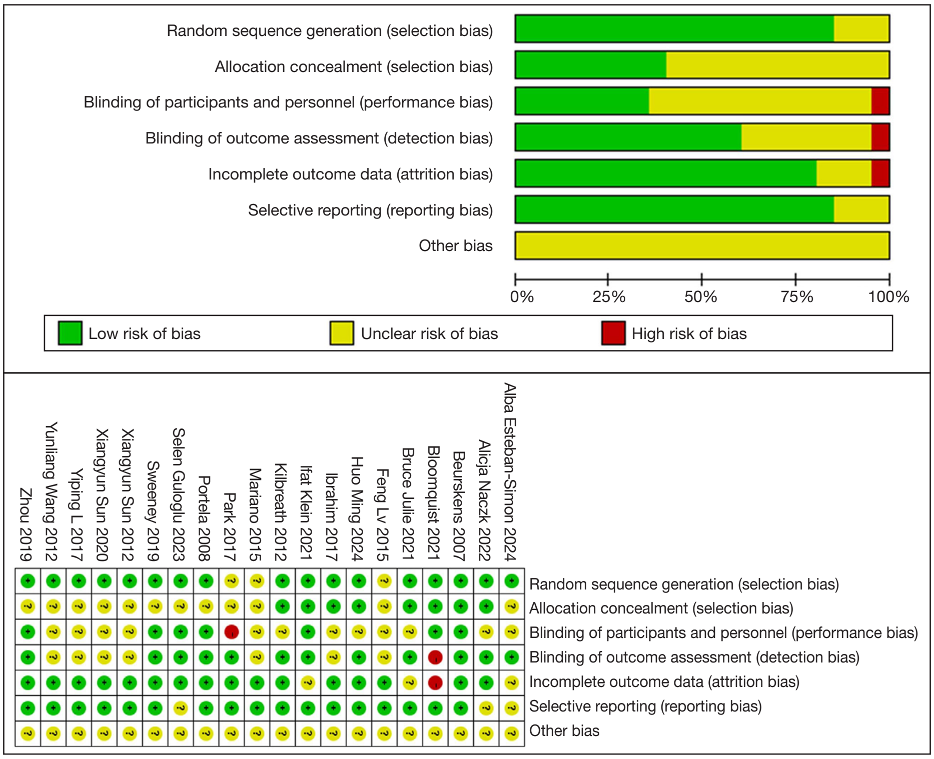

Figure 2 Risk chart of literature bias.

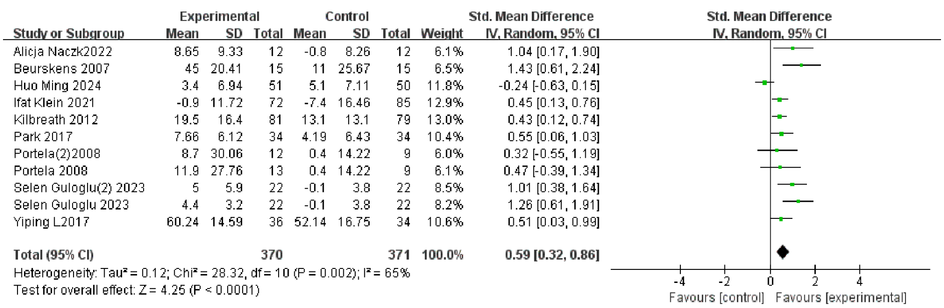

Figure 3 Forest plot of the effect of physical exercise on postoperative shoulder flexion in breast cancer patients. SD, standard deviation; Std., standardized; CI, confidence interval.

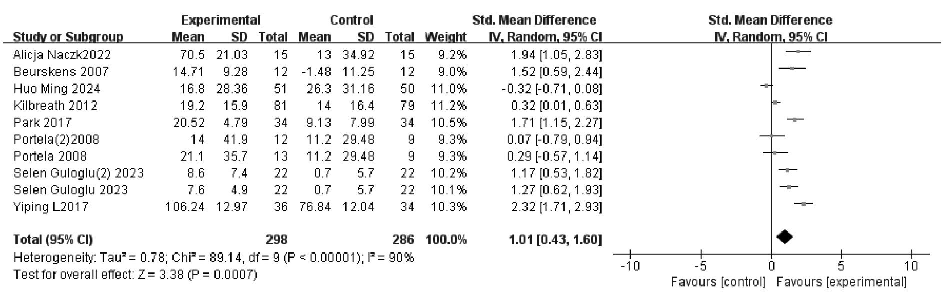

Figure 4 Forest plot of the effect of physical exercise on shoulder abduction in breast cancer patients after surgery. SD, standard deviation; Std., standardized; CI, confidence interval.

Table 4 Results of subgroup analysis of the influence of physical exercise on outcome indicators

Outcome index	Research characteristics	Group	SMD	95% CI	P	I^2 (%)	Heterogeneity
Shoulder flexion	Intervention form	Resistance exercise	0.54	0.07, 1.02	0.02	81	<0.001
		Aerobic + resistance exercise	0.49	0.11, 0.87	0.01	0	0.91
		Comprehensive exercise	0.88	0.24, 1.52	0.007	66	0.05
	Intervention frequency	≤3 times/week	0.68	0.33, 1.03	<0.001	60	0.06
		>3 times/week	0.49	0.11, 0.87	0.01	0	0.91
	Exercise cycle	<8 weeks	0.66	0.24, 1.09	0.002	0	0.33
		8–12 weeks	0.83	0.45, 1.22	<0.001	61	0.04
		>12 weeks	0.4	−0.21, 1.01	0.20	0	0.81
Shoulder joint abduction	Intervention form	Resistance exercise	0.93	0.08, 1.77	0.03	93	<0.001
		Aerobic + resistance exercise	0.73	−0.39, 1.85	0.20	85	0.001
		Comprehensive exercise	1.74	1.10, 2.38	<0.001	0	0.52
	Intervention frequency	≤3 times/week	0.87	0.18, 1.57	0.01	80	0.006
		>3 times/week	0.73	−0.39, 1.85	0.20	85	0.001
	Exercise cycle	<8 weeks	1.78	1.30, 2.25	<0.001	0	0.67
		8–12 weeks	1.3	0.50, 2.09	0.001	89	<0.001
		>12 weeks	0.18	−0.43, 0.79	0.56	0	0.73
Upper limb motor function	Intervention form	Chinese traditional sports	0.68	0.52, 0.85	<0.001	14	0.32
		Resistance exercise	1.43	0.88, 1.98	<0.001	69	0.02
		Aerobic + resistance exercise	1.68	−0.81, 4.17	0.19	96	<0.001
		Ball game	−0.05	−0.51, 0.42	0.85	0	0.58
		Comprehensive exercise	0.52	−0, 38, 1.42	0.26	96	<0.001
	Intervention frequency	≤3 times/week	1.21	0.20, 2.21	0.02	96	<0.001
		>3 times/week	0.58	0.22, 0.95	0.002	88	<0.001
	Exercise cycle	8–12 weeks	0.98	0.43, 1.54	<0.001	87	<0.001
		>12 weeks	0.75	0.14, 1.35	0.02	95	<0.001
	Initiation of postoperative intervention	<2 weeks	0.42	0.01, 0.83	0.04	90	<0.001
		≥2 weeks	0.86	−0.37, 2.08	0.17	97	<0.001

SMD, standardized mean difference; CI, confidence interval.

0.50, 2.09; P=0.001), but no significant improvement for >12 weeks (P=0.56).

Impact of physical exercise on upper limb motor function

Twenty-one studies with 1,868 breast cancer patients were included to compare the effects on upper limb motor function between the physical exercise group and the control group, as depicted in *Figure 5*. The heterogeneity test revealed I^2=93% and P<0.001, indicating high heterogeneity among studies, leading to the use of a random-effects model for analysis. The meta-analysis demonstrated a pooled effect size of SMD =0.87, with a 95% CI of (0.48, 1.26) and P<0.001, suggesting that physical exercise significantly enhances upper limb motor function post-surgery compared to the control group. Subgroup analyses were performed based on intervention types, frequencies, durations, and the timing

Study or Subgroup	Experimental Mean	SD	Total	Control Mean	SD	Total	Weight	Std. Mean Difference IV, Random, 95% CI
Alba Esteban-Simon2024	-0.14	2.34	30	-2.21	2.17	28	4.8%	0.90 [0.36, 1.45]
Beurskens 2007	-11.8	19.73	15	-29.9	16.46	15	4.4%	0.97 [0.21, 1.73]
Bloomquist 2021	-1.3	11.65	46	0	13.29	22	4.9%	-0.11 [-0.61, 0.40]
Bruce Julie 2021	-5.3	19.7	191	2.6	19.7	191	5.2%	-0.40 [-0.60, -0.20]
Feng Lv(2)2015	52.22	11.54	50	44.44	13.5	49	5.0%	0.62 [0.21, 1.02]
Feng Lv2015	55.92	7.27	50	44.44	13.5	49	5.0%	1.05 [0.63, 1.48]
Ifat Klein 2021	17.6	15.48	72	13.4	13.81	85	5.1%	0.29 [-0.03, 0.60]
Ibrahim 2017	-8.15	12.65	29	-2.53	10.45	30	4.9%	-0.48 [-1.00, 0.04]
Mariano 2015	-3.43	9.64	6	-7	16.96	7	3.8%	0.24 [-0.86, 1.33]
Portela(2)2008	2.8	14.24	12	-4.2	21.9	9	4.2%	0.38 [-0.50, 1.25]
Portela 2008	2.8	14.24	13	-6.6	16.87	9	4.2%	0.59 [-0.28, 1.46]
Selen Guloglu(2) 2023	-0.3	0.6	22	-17.3	10.7	22	4.4%	2.20 [1.44, 2.97]
Selen Guloglu 2023	-0.3	0.6	22	-10.9	8.4	22	4.5%	1.75 [1.04, 2.45]
Sweeney 2019	4	15.4	50	-51.8	11.72	50	4.6%	4.05 [3.35, 4.74]
Xiangyun Long(2) 2012	47.04	11.35	35	41.8	12.77	41	5.0%	0.43 [-0.03, 0.88]
Xiangyun Long 2012	51.88	11.45	47	41.9	12.64	38	5.0%	0.82 [0.38, 1.27]
Xiangyun Long 2020	51.83	12.88	42	41.8	12.77	41	5.0%	0.77 [0.33, 1.22]
Yiping L2017	51.23	10.59	36	39.55	10.53	34	4.9%	1.09 [0.59, 1.60]
Yunliang Wang(2) 2012	47.88	10.63	63	39.58	11.91	71	5.1%	0.73 [0.38, 1.08]
Yunliang Wang 2012	44.4	10.97	51	39.58	11.91	71	5.1%	0.42 [0.05, 0.78]
Zhou 2019	47.96	8.54	51	28.53	8.22	51	4.9%	2.30 [1.80, 2.81]
Total (95% CI)			**933**			**935**	**100.0%**	**0.87 [0.48, 1.26]**

Heterogeneity: $Tau^2 = 0.75$; $Chi^2 = 298.90$, df = 20 (P < 0.00001); $I^2 = 93\%$
Test for overall effect: Z = 4.36 (P < 0.0001)

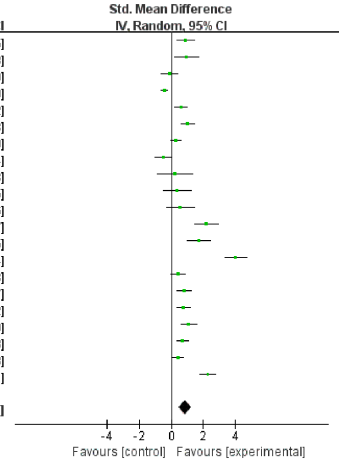

Figure 5 Effect of physical exercise on upper limb motor function. SD, standard deviation; Std., standardized; CI, confidence interval.

of postoperative intervention, as detailed in *Table 4*.

Subgroup analysis demonstrated that among the intervention forms, Chinese traditional exercise (SMD =0.68; 95% CI: 0.52, 0.85; P<0.001) and resistance exercise (SMD =1.43; 95% CI: 0.88, 1.98; P<0.001) significantly improved upper limb motor function. In contrast, aerobic + resistance exercise (P=0.19), ball exercise (P=0.85), and comprehensive exercise (P=0.26) did not exhibit significant improvement effects. Frequency subgroup analysis indicated improvements for ≤3 times/week (SMD =1.21; 95% CI: 0.20, 2.21; P=0.02) and >3 times/week (SMD =0.58; 95% CI: 0.22, 0.95; P=0.002). Duration subgroup analysis showed improvements for 8–12 weeks (SMD =0.98; 95% CI: 0.43, 1.54; P<0.001) and >12 weeks (SMD =0.75; 95% CI: 0.14, 1.35; P=0.02). However, interventions starting less than 2 weeks post-surgery showed some improvement (SMD =0.42; 95% CI: 0.01, 0.83; P=0.04), while those starting ≥2 weeks post-surgery did not show significant improvement (P=0.17).

Sensitivity analysis

This study aimed to investigate whether the observed heterogeneity among studies was due to a single study by performing a sensitivity analysis on the studies with high heterogeneity concerning the impact of physical exercise on shoulder abduction and upper limb motor function post-surgery in breast cancer patients. This was achieved by sequentially excluding each study and reanalyzing the pooled effects, as detailed in *Table 5*. For shoulder abduction, the pooled effect size was SMD =1.01, with a 95% CI of (0.43, 1.60), P<0.001, and I^2=90%. After excluding each study, the range of the pooled effect size varied from 0.86 to 1.20, with all P values ≤0.05, and the range of I^2 was 86–91%. For upper limb motor function, the SMD was 0.87, with a 95% CI of (0.48, 1.26), P<0.001, and I^2=93%. After excluding each study, the range of the pooled effect size was 0.71–0.94, with all P values <0.05, and the range of I^2 was 90–94%.

Publication bias assessment

The Egger's test conducted for the DASH outcome yielded a z-value of 1.35 (continuity corrected) with a corresponding probability Pr > |z| =0.179 (continuity corrected), which is greater than 0.05. This indicates that there is no statistically significant evidence of publication bias. The overall assessment suggests that the study results are free from publication bias and are therefore reliable. See *Figure 6* for details.

Assessment of evidence quality

The GRADEPro software assessment revealed no deductions for publication bias, imprecision, indirectness, or risk of bias. Inconsistency, however, led to a deduction in the evidence quality score. The evidence quality for upper limb motor function is classified as moderate, while the evidence for shoulder flexion is rated as high quality, and for shoulder abduction, it is moderate quality, as depicted in *Table 6*. The potential reasons for these ratings include the absence of allocation concealment in some studies and incomplete blinding, indicating that the research may have certain limitations.

Table 5 Combined effect sizes of shoulder abduction and CMS were excluded from a single study

Outcome index	Study	SMD	95% CI	P (combined effect size)	I^2 (%)
Shoulder abduction	Naczk A, 2022	0.92	0.31, 1.53	0.003	90
	Beurskens CH, 2007	0.97	0.34, 1.59	0.002	91
	Huo M, 2024	1.18	0.62, 1.74	<0.001	86
	Kilbreath SL, 2012	1.20	0.41, 1.80	0.002	90
	Park JH, 2017	0.93	0.32, 1.55	0.003	89
	Portela AL, 2008①	1.11	0.48, 1.74	<0.001	91
	Portela AL, 2008②	1.09	0.46.1, 72	<0.001	91
	Guloglu S, 2023①	0.99	0.35, 1.63	0.003	91
	Guloglu S, 2023②	1.00	0.35, 1.64	0.002	91
	Li YP, 2017	0.86	0.31, 1.40	0.002	87
Upper limb motor function	Esteban-Simón A, 2024	0.87	0.46, 1.28	<0.001	94
	Beurskens CH, 2007	0.87	0.46, 1.27	<0.001	94
	Bloomquist K, 2021	0.92	0.52, 1.33	<0.001	94
	Bruce J, 2021	0.94	0.57, 1.30	<0.001	90
	Lv F, 2015②	0.89	0.47, 1.30	<0.001	94
	Lv F, 2015①	0.86	0.45, 1.27	<0.001	94
	Klein I, 2021	0.90	0.48, 1.33	<0.001	94
	Ibrahim M, 2017	0.94	0.54, 1.34	<0.001	93
	Mariano KOP, 2015	0.90	0.49, 1.30	<0.001	94
	Portela AL, 2008②	0.89	0.49, 1.30	<0.001	94
	Portela AL, 2008①	0.88	0.48, 1.29	<0.001	94
	Guloglu S, 2023②	0.81	0.42, 1.20	<0.001	93
	Guloglu S, 2023①	0.83	0.43, 1.23	<0.001	93
	Sweeney FC, 2019	0.71	0.38, 1.05	<0.001	90
	Sun XY, 2012②	0.90	0.48, 1.31	<0.001	94
	Sun XY, 2012①	0.87	0.46, 1.29	<0.001	94
	Sun XY, 2020	0.88	0.47, 1.29	<0.001	94
	Li YP, 2017	0.86	0.45, 1.27	<0.001	94
	Wang YL, 2012②	0.88	0.46, 1.30	<0.001	94
	Wang YL, 2012①	0.90	0.48, 1.31	<0.001	94
	Zhou K, 2019	0.80	0.42, 1.17	<0.001	91

CMS, Constant and Murley score; SMD, standardized mean difference; CI, confidence interval.

Incidence of adverse events

There were no reported adverse events within the studies that were included in the analysis.

Discussion

Our study utilized a meta-analysis approach to assess the effects of physical exercise on postoperative shoulder abduction, flexion, and upper limb function in breast cancer patients. Subgroup analyses were conducted based on intervention types, duration, frequency, and timing of postoperative initiation. The results demonstrate that physical exercise can enhance postoperative shoulder abduction, flexion, and upper limb function in breast cancer patients, consistent with nearly all prior research findings. Yang *et al.* on the other hand, found that aerobic exercise only improves shoulder joint mobility but does not enhance upper limb strength (18). This discrepancy may arise because our study included various types of exercise, such as aerobic, resistance, and combined exercises, whereas Yang *et al.* focused exclusively on aerobic exercise. Similar findings have been reported in other studies as well. A systematic review by Lin indicates that aerobic exercise is effective in improving shoulder abduction, flexion, and upper limb function in postoperative breast cancer patients, whereas resistance exercise is only effective in improving upper limb function (15). Postoperative complications in breast cancer patients, such as damage to the pectoralis major and minor muscles, their blood supply, and nerves like the medial and dorsal pectoral nerves, along with incision scars, tissue adhesions, and disrupted blood and lymph circulation, can impair upper limb function (42). Physical exercise aids in improving shoulder joint mobility, potentially by facilitating increased blood flow in the surgical area, preventing the accumulation of fluids and blood beneath the skin, and reducing the risk of joint stiffness and muscle atrophy (43). Additionally, research has shown that aerobic exercise can modulate estrogen levels and boost the patient's immune response, contributing to improved functional recovery in breast cancer patients post-surgery (17).

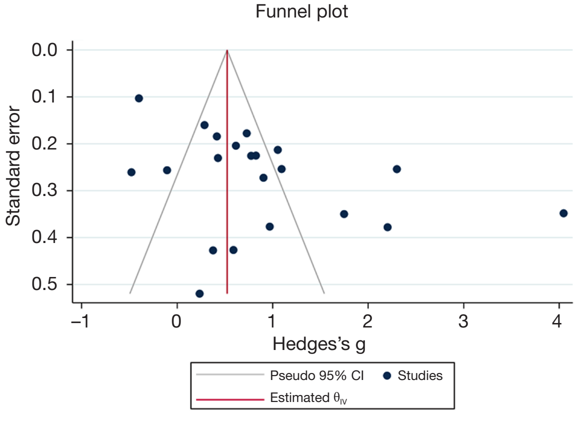

Figure 6 Present a bias graph. CI, confidence interval.

The study encompassed 20 articles, all of which were classified as grade B or higher, with no instances of low-quality literature, reflecting a high overall quality of the included studies. The GRADEPro assessment of the evidence level in this review identified that some studies failed to fully disclose their blinding methods or allocation concealment, potentially influencing the post-test outcomes. A test for publication bias regarding upper limb motor function did not reveal significant bias. No clear reasons for downgrading the evidence quality due to indirectness or imprecision were identified. The meta-analysis indicated an I^2 of 65% for flexion, with heterogeneity attributed to the type, frequency, and duration of interventions, and thus the evidence level remained unchanged; for abduction, an I^2 of 90% was observed, with heterogeneity stemming from the intervention type and duration, leading to a one-level downgrade in evidence quality; for upper limb function, an I^2 of 93% was noted, with heterogeneity due to the intervention type, resulting in a one-level downgrade. Consequently, the evidence quality for the effects of physical exercise on upper limb motor function and shoulder abduction mobility in postoperative breast cancer patients is rated as moderate, while the evidence quality for shoulder flexion mobility is rated as high. Further investigation into the intensity of physical exercise is warranted, and given the substantial heterogeneity among studies, the reliability of the conclusions may be compromised, necessitating careful interpretation.

Our findings indicate that physical exercise lasting less than 8 weeks enhances shoulder abduction and flexion in breast cancer patients post-surgery, whereas exercise lasting 8–12 weeks improves shoulder abduction, flexion, and upper limb function. In contrast, exercise exceeding 12 weeks only benefits upper limb function in these patients. This contrasts with prior research. Wang *et al.* conducted a study where postoperative breast cancer patients were assigned to three groups receiving Yangge dance, Tai Chi, or standard interventions, with shoulder function evaluations at

Table 6 Results of GRADEPro evidence quality assessment for included studies

Outcomes	Risk of bias	Inconsistency	Indirectness	Inaccuracy	Publication bias	Quality of evidence
Upper limb function	1	0	1	1	1	Moderate
Shoulder joint forward	1	1	1	1	1	High
Shoulder joint abduction	1	1	1	1	1	Moderate

10 days, 1 month, 3 months, and 6 months post-surgery. The study revealed that all groups experienced significant improvements in shoulder function as the intervention duration increased, with Tai Chi demonstrating superior outcomes over the other two interventions (33). The discrepancy in results may stem from the varying exercise intervention methods used. Our study encompassed a range of exercise modalities, whereas Wang *et al.* observed that Tai Chi held a distinct advantage in long-term interventions, with aerobic exercise showing limited superiority.

Our research highlights that the choice of exercise modality is pivotal for the rehabilitation of breast cancer patients, with resistance exercise offering the most holistic improvement post-surgery. By regularly engaging in resistance exercises, patients can fortify their upper limb and back muscles, using muscles like the trapezius and latissimus dorsi to compensate for the loss of axillary tissue, thus enhancing shoulder joint functionality. These exercises also facilitate protein reabsorption and enhance the flexibility of soft tissues, thereby mitigating lymphedema (16). Traditional Chinese exercises, such as Tai Chi, which are characterized by their flexibility, stability, slowness, and continuity, can improve upper limb function (33,44,45). Nonetheless, the benefits of other exercise types for breast cancer patients are selective, possibly due to variations in patient compliance. Furthermore, resistance exercise and Tai Chi are particularly effective in integrating upper limb function, thereby fostering the recovery of upper limb function. This effectiveness may also be influenced by the type of surgery the patient has undergone, as different surgical procedures can result in varying degrees of upper limb dysfunction (45). Physical exercise conducted either ≤3 or >3 times/week can enhance shoulder abduction and flexion in breast cancer patients post-surgery. Integrating physical exercise into standard rehabilitation protocols can expedite blood flow in the surgical wound, prevent the accumulation of subcutaneous fluids and blood, deter joint stiffness, muscle atrophy, and adhesion, and foster functional recovery (43).

Our findings also indicate that initiating physical exercise within the first 2 weeks post-surgery enhances the recovery of upper limb function in breast cancer patients. Early postoperative functional exercises boost both systemic and localized blood circulation, aiding in the absorption and removal of pathological byproducts, reducing pain, and facilitating limb function recovery. Conversely, delaying physical exercise may result in disuse-induced limb dysfunction (46,47). However, other research suggests that early rehabilitation exercises may impede wound healing and lead to hematoma formation. Additionally, frequent exercises early in the recovery phase can elevate lymphatic fluid production, potentially causing fluid buildup and complications like infection and pain (48). Thus, the timing of physical exercise should be tailored to the patient's recovery status.

Our study also has several limitations. We did not explore the impact of different surgical types, such as breast-conserving surgery and modified radical mastectomy. While both procedures hold value in early breast cancer treatment, breast-conserving surgery is safer, facilitates faster postoperative recovery, and reduces the incidence of postoperative complications (49,50). Although we investigated the effects of exercise type, duration, and frequency, the number of studies included was limited, and some studies did not provide detailed intervention protocols. Therefore, our categorizations of these factors were broad rather than detailed. Furthermore, exercise prescription also includes intensity and duration, but these parameters were inconsistently reported or not specified in the included studies. We did not conduct subgroup analyses for exercise intensity and duration, which might contribute to the heterogeneity observed in our results.

Conclusions

To conclude, physical exercise improves shoulder flexion, abduction, and upper limb function in breast cancer patients post-surgery. Resistance exercise, performed for 8–12 weeks, either ≤3 or >3 times/week, offers the most comprehensive rehabilitation for upper limbs, and exercising within the first 2 weeks post-surgery yields the most significant improvements in upper limb function. Future studies should focus on conducting more high-quality RCTs to further validate the impact of physical exercise on shoulder joint mobility and upper limb function in breast cancer patients post-surgery, thereby providing robust evidence for clinical practice.

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Footnote

Reporting Checklist: The authors have completed the PRISMA reporting checklist. Available at https://

gs.amegroups.com/article/view/10.21037/gs-24-255/rc

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Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://gs.amegroups.com/article/view/10.21037/gs-24-255/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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