Hao *et al. BMC Musculoskeletal Disorders* (2025) 26:254
https://doi.org/10.1186/s12891-025-08500-7

BMC Musculoskeletal Disorders

RESEARCH

Open Access

Effects of early exercise and immobilization after arthroscopic rotator cuff repair surgery: a systematic review and meta-analysis of randomized controlled trials

Boran Hao[1], Hongqiu Li[1] and A. Liang[1*]

Abstract

Objective Early exercise is a physical adjuvant therapy that begins on day 1 postoperatively. It prevents postoperative stiffness, fatty infiltration, muscle atrophy and loss of range of motion. Usually, use of a brace fixation that immobilizes the shoulder in 30° of abduction during the postoperative rehabilitation period reduces tension on the repaired tendon, which improves tendon-bone healing. To investigate the effect of early exercise and brace fixation on postoperative recovery after arthroscopic rotator cuff repair by systematic review, thereby providing evidence-based evidence for clinical practice.

Methods Chinese and English databases (PubMed, Web of Science, Cochrane Library, CNKI, Wanfang database, and VIP database) were searched by keywords until November 15, 2024. Randomized controlled studies comparing early exercise versus brace fixation after arthroscopic rotator cuff repair surgery were included, along with an evaluation of such studies using the Cochrane Collaboration risk assessment tool. Afterward, the effect of the intervention on the visual analogue scale (VAS) for pain, function, shoulder range of motion (forward flexion, abduction, internal rotation, external rotation), and postoperative complications (stiffness, re-tear) was evaluated based on a fixed or random effects model.

Results Eleven high-quality randomized controlled studies were included. Compared with brace fixation, early exercise improved the range of motion of the subjects' shoulders. Compared with brace fixation, shoulder flexion (WMD of 6 weeks = 10.57, 95% CI: 1.30, 19.84, WMD of 3 months = 12.39, 95% CI: 7.51, 17.27, WMD of 6 months = 2.88, 95% CI: 1.02, 4.73, WMD of 1 year = 2.59, 95% CI: 0.40, 4.77) and shoulder abduction (WMD of 6 weeks = 13.17, 95% CI: 9.80, 16.55, respectively). The improvement degree of WMD = 2.28 in 6 months and internal rotation (WMD = 5.08, 95% CI: 3.16, 7.01, in 6 weeks and WMD = 8.23, 95% CI: 4.23, 12.23, in 3 months) was statistically different. Early exercise also reduced the risk of postoperative stiffness (RR = 0.34; 95%CI:0.19, 0.60). However, compared with brace fixation, there was no statistical difference in pain score (WMD = 0.05, 95% CI:0.09, 0.18) and shoulder joint recovery score (SMD = 0.05, 95% CI: 0.12, 0.03).

*Correspondence:
A. Liang
a6aliang@163.com
Full list of author information is available at the end of the article

Conclusion Early exercise can improve the range of motion of early shoulder joint and reduce the risk of postoperative stiffness, but the effect of pain and function improvement is not obvious, which can play a positive role in postoperative rehabilitation of patients, but it needs more comprehensive research and improvement to guide clinical practice.

Keywords Rotator cuff repair surgery, Arthroscopic, Early exercise, Fixation

Introduction

Previous epidemiological surveys have shown that rotator cuff tendon tears and cuff abnormalities are very common in the adult population, with the incidence increasing with age from 9.7% in those aged ≥ 20 to 62% in those aged ≥ 80 [1]. The rotator cuff is composed of the subscapularis, supraspinatus, infraspinatus, teres minor, and tendons, while rotator cuff lesions are a common cause of shoulder pain and may eventually seriously affect the daily life and activities of patients. Meanwhile, symptomatic disease affects 4-32% of patients with rotator cuff tears [2]. Although the patient's age, activity level, and tear size affect treatment decisions, non-surgical treatment is often preferred as the first treatment option, and surgical treatment can relieve pain and improve shoulder function in over 90% of patients if non-surgical treatment fails [3]. With the development of minimally invasive techniques, arthroscopic repair has been widely used in clinical practice as it is less invasive, can achieve safe fixation, and promotes early exercise [4, 5]. Previous studies have shown that approximately 250,000 rotator cuff repairs are performed annually in the United States [6]. However, with the rising number of repair surgeries, uncertainty about the optimal approach of postoperative rehabilitation remains, which is a key component of patient postoperative rehabilitation [7].

According to an international practice investigation report, there is no consistent understanding of how postoperative rehabilitation affects clinical results, so in the past twenty years, postoperative rehabilitation has made little progress [8]. At present, the standard postoperative rehabilitation still uses some cautious methods, such as sling fixation [9]. At present, new research progress shows that early exercise can prevent joint stiffness caused by tendon adhesion [10]. After arthroscopic repair of rotator cuff tear, patients' shoulder joint is usually in abduction rest position, which is beneficial to reduce the tissue tension at the operation site. Long-term immobilization of shoulder joint will not only affect the recovery of shoulder joint function, but also cause shoulder joint stiffness, shoulder joint adhesion and even muscle atrophy, but some people worry that early exercise may lead to rotator cuff healing, and more people tend to accept stent fixation rather than early exercise after operation [11]. Therefore, the purpose of this meta-analysis is to synthesize the existing literature and evaluate the effects of early exercise and brace fixation following arthroscopic rotator cuff repair, aiming to establish an evidence-based, effective, and timely rehabilitation protocol for patients undergoing this procedure.

Materials and methods

The protocol for this meta-analysis was registered on INPLASY. The registration number is INPLASY2024120051. This study was strictly implemented in accordance with PRISMA2020.

Retrieval strategy

The retrieval strategy referred to the statement of PRISMA2020 [12], three English databases including PubMed, Web of Science, and Cochrane Library, as well as three Chinese databases including China National Knowledge Infrastructure (CNKI), Wanfang database, and VIP database were systematically searched. The retrieval period was from database establishment to November 15, 2024, and the retrieval strategies for English databases were as follows: ("Shoulder" OR "Shoulder Injuries" OR "Shoulder Joint" OR "Shoulder Pain" OR "Rotator Cuff") AND ("Physical and Rehabilitation" OR "Physical Therapy Modalities"OR"Exercise"). The Chinese databases were retrieved using the same search terms. Additionally, target articles were obtained by reviewing references from included studies. Contact experts and researchers in related fields as much as possible by telephone or email to find unpublished literature(We sent emails to the corresponding authors of 11 studies included in the study. Consult them about whether there were currently unpublished related studies).

Inclusion and exclusion criteria

Inclusion Criteria: (1) Articles published in a peer-reviewed journal in English and Chinese; (2) arthroscopic rotator cuff repair surgery in subjects aged ≥ 18; (3) rehabilitation intervention with early exercise had no restrictions on the pattern, length, intensity, and frequency of exercise; (4) control group underwent brace fixation alone or with brace fixation and delayed rehabilitation training; (5) study outcomes were pain, function, range of motion, strength, and repair integrity; (6) randomized controlled trials.

Exclusion Criteria (1) non-population studies; (2) studies such as conference articles, case reports, and systematic reviews; (3) studies in which outcome information was insufficient and the data analysis could not be performed; (4) duplicate reports of literature research; and (5) studies for which complete articles could not be obtained.

Literature screening and data extraction

Literature screening was performed by two researchers separately per the inclusion and exclusion criteria, first by reading the title and abstract of the articles for initial screening, followed by reading the full text of studies that may have met the inclusion criteria. If the two evaluation researchers disagree, a third researcher will be introduced, and after discussion and analysis, a vote will be taken to decide whether to include it. After literature screening, the two researchers extracted data according to the available standard data extraction table, which mainly included literature information (author, year, region, literature source, etc.), research characteristics (sample size, gender, age, disease classification, etc.), rehabilitation options and outcome effect (the main outcome was shoulder function, range of motion and complications, and the secondary outcome was pain) data, and original research methodology (randomization, blindness, loss of follow-up, etc.).

Quality evaluation

The Cochrane Collaboration risk assessment tool [13] was used to evaluate the quality of the literature in terms of randomization method, allocation scheme concealment, blinding, outcome data integrity, selective reporting of study results, and other sources of bias. Two researchers Hao BR and A L review the quality of literature, and when the results of an audit are inconsistent, a third researcher LI HQ is introduced to discuss and vote. The Grade (The Grading of Recommendations Assessment, Development and Evaluation) grading system is used to check the certainty of the evidence and evaluate the evidence grade of each result.

Statistical analysis methods

Statistical analysis was performed using the Stata16.0 software. The effect size of count data was expressed as relative risk (RR), with measurement data expressed as standard mean difference (SMD) or weighted mean difference (WMD), and a 95% confidence interval (CI) was used to estimate the interval range of effect size. Meanwhile, the heterogeneity was determined by heterogeneity tests using statistics and Q tests; $I^2 < 50\%$ or $P > 0.1$ indicated obvious homogeneity among the included studies, so the analysis was conducted with a fixed effect model; $I^2 > 50\%$ or $P \leq 0.1$ indicated a poor homogeneity among the included studies, so a random effect model was used for analysis. For measurements at different follow-up times, subgroup analyses were combined. Unless otherwise specified, the test level was set at 0.05.

Results

Basic characteristics of included studies and results of literature quality evaluation

A total of 3,392 articles were reviewed for this study (PubMed:, Web of Science:, Cochrane Library:, CNKI:, Wanfang database:, VIP database:) with 11 randomized controlled studies finally included [14–24], as shown in Fig. 1. These articles were published from 2011 to 2019, involving 1,216 patients who underwent arthroscopic rotator cuff repair, of whom 626 subjects completed postoperative rehabilitation training with early exercise, compared with 590 controls (an average age of 50.43–65.1 and male subjects accounting for 10.3-68.46%). The study subjects came with minor to major tear characteristics, and the basic characteristics of more included studies are shown in Table 1. The results of the literature quality evaluation revealed a low risk of bias for the included studies in terms of data integrity and selective reporting of results, as shown in Table 2.

Pain

4 studies evaluated pain at 6 weeks, 3 months, 6 months, 1 year, and 2 years post-intervention using the visual analogue scale (VAS) for pain. Heterogeneity evaluation showed obvious homogeneity among the included studies ($I^2 = 0\%$, $P = 0.735$), with the pooled effect size calculated using a fixed effects model. The results of subgroup analysis based on follow-up time showed no statistically significant effect of early exercise versus brace fixation on pain (WMD = 0.05, 95% CI: −0.09,0.18), as shown in Fig. 2.

Function

Outcome measures of shoulder function differed, with 4 studies providing functional evaluations utilizing the American Shoulder and Elbow Surgery score, Constant-Murley score, Simple Shoulder Test, or Western Ontario Rotator Cuff Index. In this study, a meta-analysis of functional improvement results at different follow-up times was performed using SMD, with pooled effect sizes calculated for different scales. Since the heterogeneity evaluation results indicated no heterogeneity among the included studies ($I^2 = 0\%$, $P = 0.987$), a fixed effects model was used to calculate the pooled effect size. Moreover, the meta-analysis showed that early exercise had no statistically significant effect on postoperative shoulder function recovery in subjects (SMD: −0.05; 95% CI: −0.12,0.03), as shown in Fig. 3. Additionally, similar findings were observed when the different shoulder function measurement tools were analyzed separately, with the American Shoulder and Elbow Surgery score of -2.19 (95% CI: -6.10, 1.71) at 6 months of follow-up, the GRADE rating of this result was moderate. See Table 3.

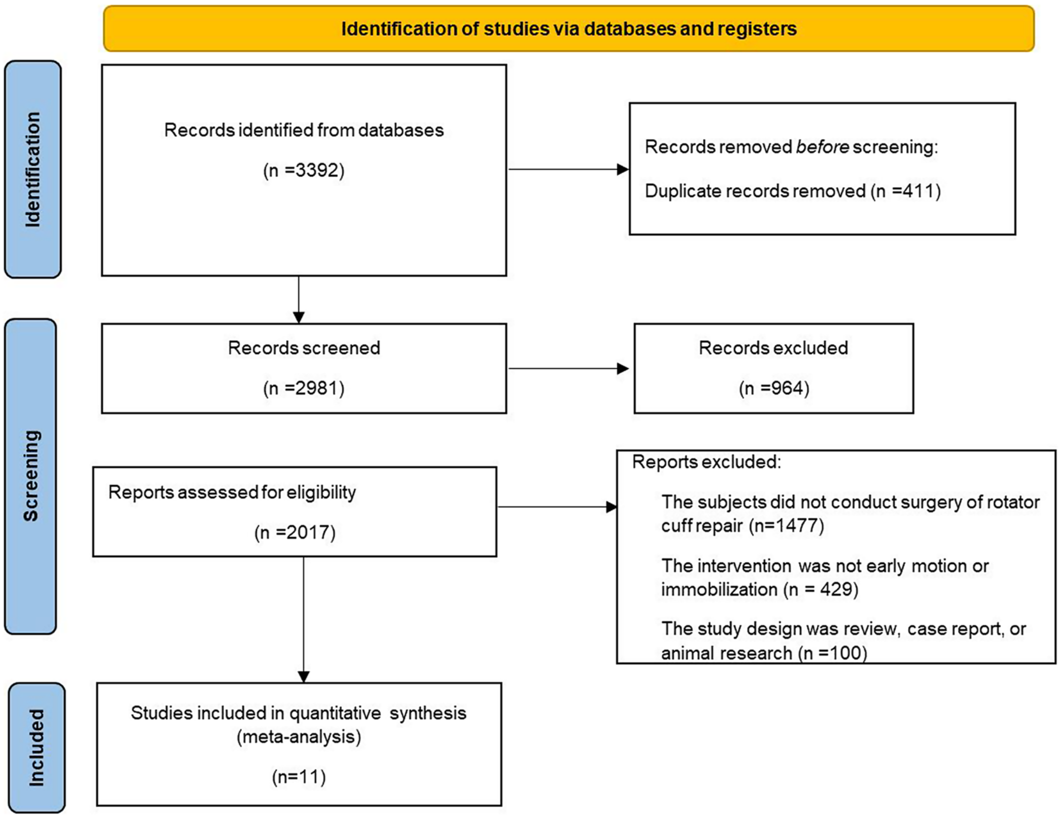

Fig. 1 Flow Chart of Literature Screening

Range of motion

Shoulder flexion

11 studies reported improvement in shoulder flexion after early exercise. The heterogeneity evaluation results suggested heterogeneity among the included studies ($I^2 = 89.4\%$, $P < 0.001$), with the pooled effect size calculated using a random effects model. Compared with brace fixation, the subgroup analysis results at different follow-up times demonstrated that the early exercise improved shoulder flexion in subjects as follows: 6 weeks (WMD: 10.57; 95% CI: 1.30, 19.84), 3 months (WMD: 12.39; 95% CI: 7.51, 17.27), 6 months (WMD: 2.88; 95% CI: 1.02, 4.73), and 1 year (WMD: 2.59; 95% CI: 0.40, 4.77), and the effect of early exercise gradually decreased with the increasing follow-up time. However, the effect was not statistically significant at 2 years (WMD: 2.48; 95% CI: -0.82, 5.77), the GRADE rating of this result was moderate. See Fig. 4.

Shoulder abduction

6 studies reported improved shoulder abduction in subjects following early exercise. The heterogeneity evaluation results suggested heterogeneity among the included studies ($I^2 = 93.7\%$, $P < 0.001$), with the pooled effect size calculated using a random effects model. The subgroup analysis at different follow-up times showed that early exercise could improve shoulder abduction in subjects at 6 weeks (WMD: 13.17; 95% CI: 9.80, 16.55) and 3 months (WMD: 13.90; 95% CI: 0.51, 27.29) post-surgery. However, no statistically significant effect was observed on shoulder abduction at 6 months (WMD: 2.25; 95% CI: -0.11, 4.61), 1 year (WMD: 0.36; 95% CI: -3.47, 4.19), and 2 years (WMD: -1.73; 95% CI: -7.41, 3.94), the GRADE rating of this result was moderate. See Fig. 5.

External rotation

Improved shoulder external rotation in subjects following early exercise were reported in 11 studies. The heterogeneity evaluation results showed heterogeneity among the included studies ($I^2 = 78.8\%$, $P < 0.001$), with the pooled effect size calculated using a random-effects model. Meanwhile, the subgroup analysis at different follow-up times revealed that early exercise improved shoulder external rotation at 3 (WMD: 8.94; 95% CI: 6.37, 11.50) and 6 (WMD: 2.28; 95% CI: 0.88, 3.67) months post-surgery. However, the effect of the intervention was not statistically significant at 6 weeks (WMD: 4.66; 95% CI: -1.56, 10.87), 1 year (WMD: 0.55; 95% CI: -2.70, 3.79), and 2 years (WMD: 0.30; 95% CI: -4.31, 4.92), the GRADE rating of this result was moderate, as shown in Fig. 6.

Table 1 Basic characteristics of included studies

Study	Country	Sample size	Intervention-t	Intervention-c	Tear characteristics	Mean age(E/D)	Male%
Düzgün [14]	Turkey	29	early active movement in combination with preoperative rehabilitation	immobilization and delayed exercise	Medium and large	55.8/56.6	10.3
Sheps[15]	Canada	206	early active motion	sling immobilization	All tear sizes included. Mean length of tear AP: E: 2.1 cm vs. D: 2.1 cm Mean length of tear ML: E: 1.9 cm vs. D: 1.9 cm	55.5/56.2	63.59
Sheps [16]	Canada	189	early mobilisation	sling immobilization	All tear sizes included. full-thickness	55.4/54.9	60.85
Zhang [17]	China	132	early motion	immobilization	tear length: 37.28 ± 2.28 vs. 38.49 ± 3.38 mm	52.32/50.43	52.27
Koh [18]	Korea	100	early motion and immobilization	delayed motion and immobilization	Postero-superior; medium; full-thickness; 2–4 cm	60.1/59.5	50
Lee [19]	Korea	64	immobilization and aggressive early passive rehabilitation and unlimited self–passive stretching exercise	immobilization and limited early passive rehabilitation	Medium: 41, large: 45; full-thickness	54.5/55.2	64.06
Düzgün [20]	Turkey	40	early exercise	immobilization and delayed exercise	Medium and large	57.6/57.2	
Arndt [21]	France	92	Immediate passive motion	immobilization	Non-retracted isolated tears of supraspinatus; partial-thickness: 24%, full-thickness: 76%	55.3	37
Kim [22]	Korea	105	immobilization and early passive motion exercise	immobilization and no passive motion exercise	Small and medium; full-thickness Tear size in anteroposterior dimension: 18.9 ± 12.6 vs. 16.3 ± 6.5 mm	60.06/60.00	41.9
De Roo [23]	Belgium	130	immediate daily passive mobilization	immobilization	Small to large; full-thickness	65.1/64.6	68.46
Keener [24]	USA	129	early motion	immobilization	Supraspinatus and/or infraspinatus; Small and medium; full-thickness	55.8/54.8	53.49

Table 2 Quality evaluation results of included research literature

study	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Blinding of participants and personnel (performance bias)	Blinding of outcome assessment (detection bias)	Incomplete outcome data (attrition bias)	Selective reporting (reporting bias)	Other bias
Düzgün [14]	low	low	low	unclear	low	low	unclear
Sheps [15]	low	low	low	low	low	low	low
Sheps [16]	low	low	low	low	low	low	low
Zhang [17]	low	low	low	low	low	low	low
Koh [18]	low	low	low	low	low	low	low
Lee [19]	unclear	low	high	low	low	low	unclear
Düzgün [20]	low	unclear	high	unclear	low	low	unclear
Arndt [21]	unclear	unclear	unclear	low	low	low	unclear
Kim [22]	low	unclear	low	low	low	low	low
De Roo [23]	low	unclear	unclear	unclear	low	low	unclear
Keener [24]	low	low	unclear	low	low	low	unclear

Internal rotation

8 studies reported improved shoulder internal rotation in subjects following early exercise. The heterogeneity evaluation results indicated heterogeneity among the included studies ($I^2 = 91.6\%$, $P < 0.001$), and a meta-analysis was performed using a random-effects model. Per the subgroup analysis at different follow-up times, early exercise could improve shoulder internal rotation at 6 weeks (WMD: 5.08; 95% CI: 3.16, 7.01) and 3 months (WMD: 8.23; 95% CI: 4.23, 12.23) post-surgery, without statistically significant effect at 6 months, 1 year, and 2 years, the GRADE rating of this result was moderate. See Fig. 7.

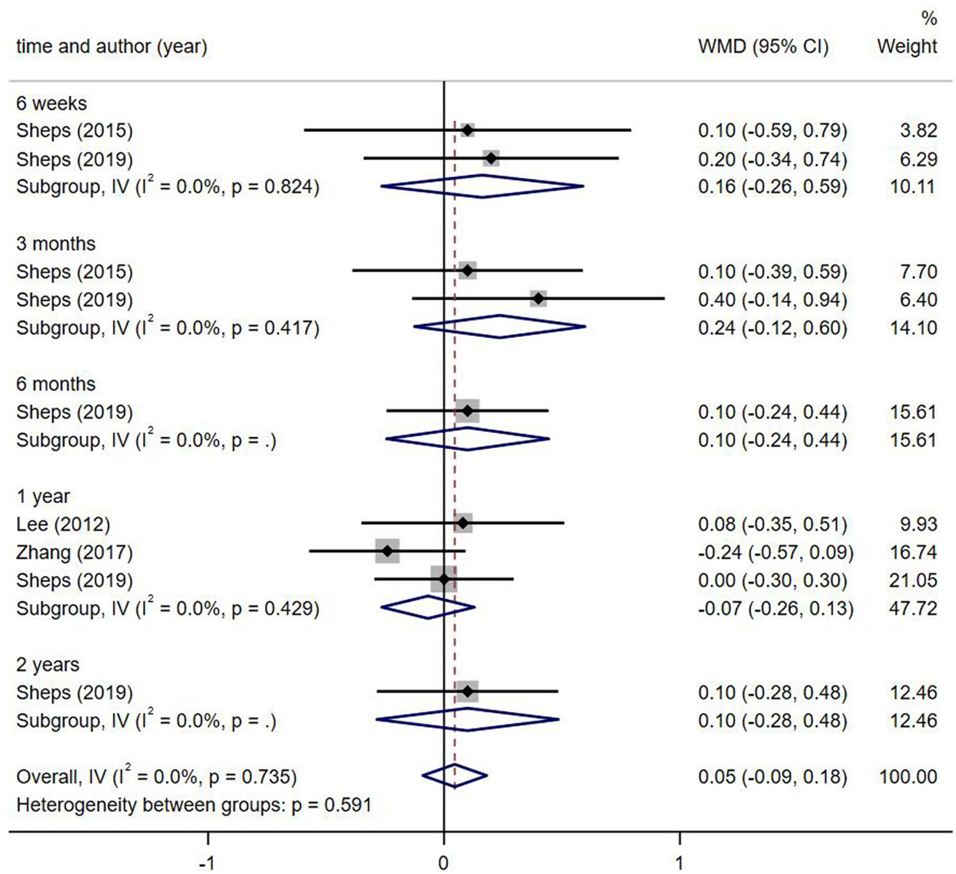

Fig. 2 Effects of Early Exercise and Brace Fixation on Pain (VAS) of Subjects

Complications

Three studies reported the results of postoperative complications (stiffness and re-tear) in subjects, with the pooled effect size calculated using a fixed effects model based on the heterogeneity evaluation results ($I^2 = 0.0\%$, $P = 0.983$). Meta-analysis revealed a lower risk of rigidity (RR: 0.34; 95% CI: 0.19, 0.60) for subjects who underwent early exercise, but the effect on re-tear was not statistically significant (RR: 1.46; 95% CI: 0.78, 2.73), the GRADE rating of this result was low, as shown in Fig. 8.

Discussion

This study is designed to conclude the effects of early exercise and brace fixation on the clinical outcomes and complications of patients after arthroscopic rotator cuff repair. The findings showed that early exercise did not significantly improve pain and shoulder function in patients. Meanwhile, the meta-analysis of shoulder range of motion found that early exercise significantly improved shoulder flexion, abduction, external rotation, and internal rotation, which mainly had a short-term positive effect in terms of the duration of the effect. For postoperative complications, patients who received early exercise had a lower risk of stiffness, without seeing a statistically significant risk of re-tear. Compared with a previous meta-analysis comparing early exercise with conservative rehabilitation, this study found similar results, i.e., no statistically significant effect of early exercise on pain, function, and re-tear risk. However, it has been found that early exercise could improve the shoulder range of motion and risk of postoperative stiffness. Therefore, this study provides a reference for understanding the effects of early exercise and standard postoperative rehabilitation on the postoperative recovery of patients undergoing rotator cuff repair.

Previous studies have demonstrated that early exercise may lead to a higher rate of surgical failure [25], possibly due to a combination of the following factors. In addition

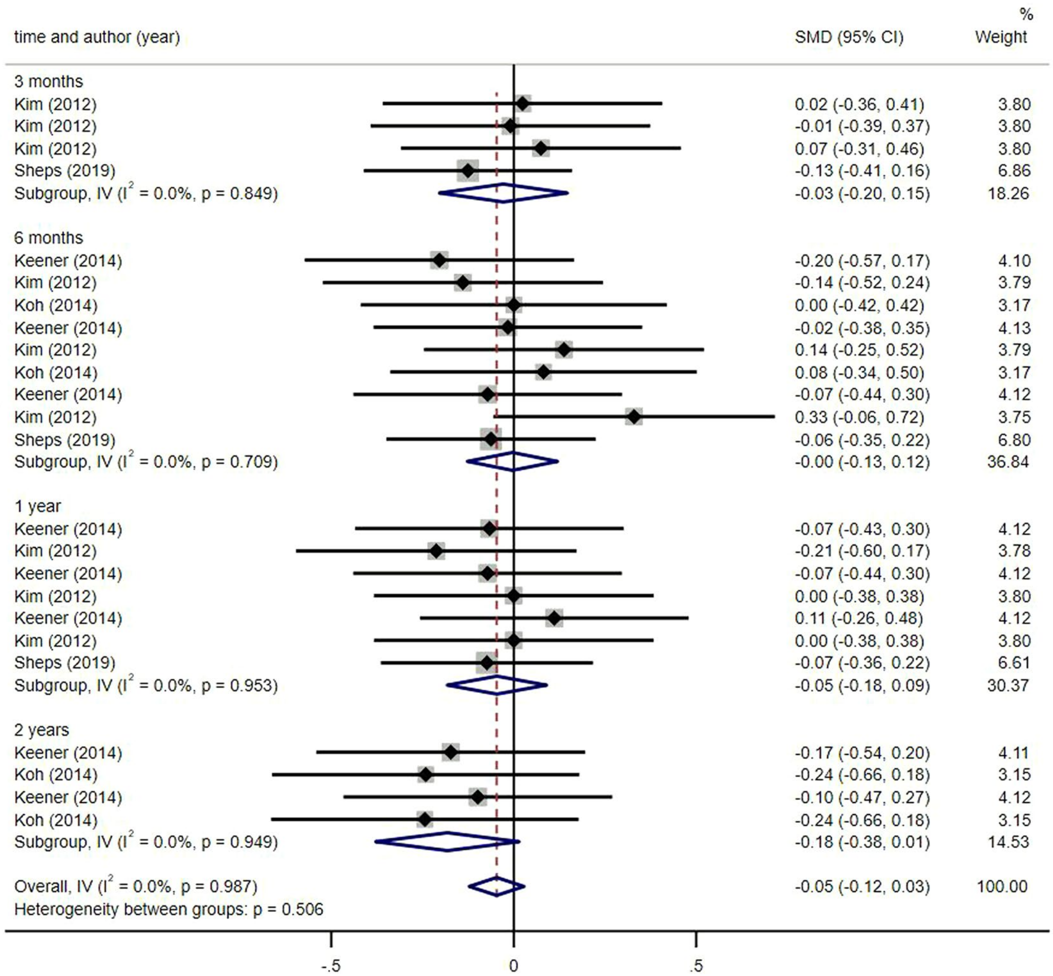

Fig. 3 Effects of Early Exercise and Brace Fixation on Shoulder Function in Subjects

Table 3 Shoulder function improvements by measurement tools

Scale	Follow time	Studies	I^2	SMD/RR/WMD (95%CI)
American Shoulder and Elbow Surgery score	3 months	1	0.0%	0.50(-7.52, 8.52)
	6 months	3	0.0%	-2.19(-6.10, 1.71)
	1 year	2	0.0%	-1.85(-7.06, 3.37)
	2 years	2	0.0%	-2.67(-6.35, 1.02)
Constant-Murley score	3 months	1	0.0%	-0.10(-4.33, 4.13)
	6 months	3	0.0%	0.81(-2.10, 3.73)
	1 year	2	0.0%	-0.41(-3.37, 2.56)
	2 years	2	0.0%	-1.80(-5.10, 1.49)
Simple Shoulder Test	3 months	1	0.0%	0.29(-1.21, 1.79)
	6 months	2	58.1%	0.31(-0.50, 1.12)
	1 year	2	0.0%	0.24(-0.66, 1.14)

to different rehabilitation protocols, the size of the rotator cuff tear and the choice of surgical technique in the study subjects are also important factors affecting the prognosis of patients, with large tears and single-row surgical techniques potentially associated with increased failure rates [26, 27]. Lee et al. [19] suggested that performing surgery on patients with medium to large rotator cuff tears using a single-row technique may increase the risk of surgical failure in patients undergoing active early exercise. Arndt et al. [21] included patients with both full-thickness and partial-thickness tears, and some patients underwent concomitant procedures such as biceps tenotomy, tendon fixation, and acromioplasty, resulting in increased difficulty in comparative analysis. Therefore, in addition to the need for standardized

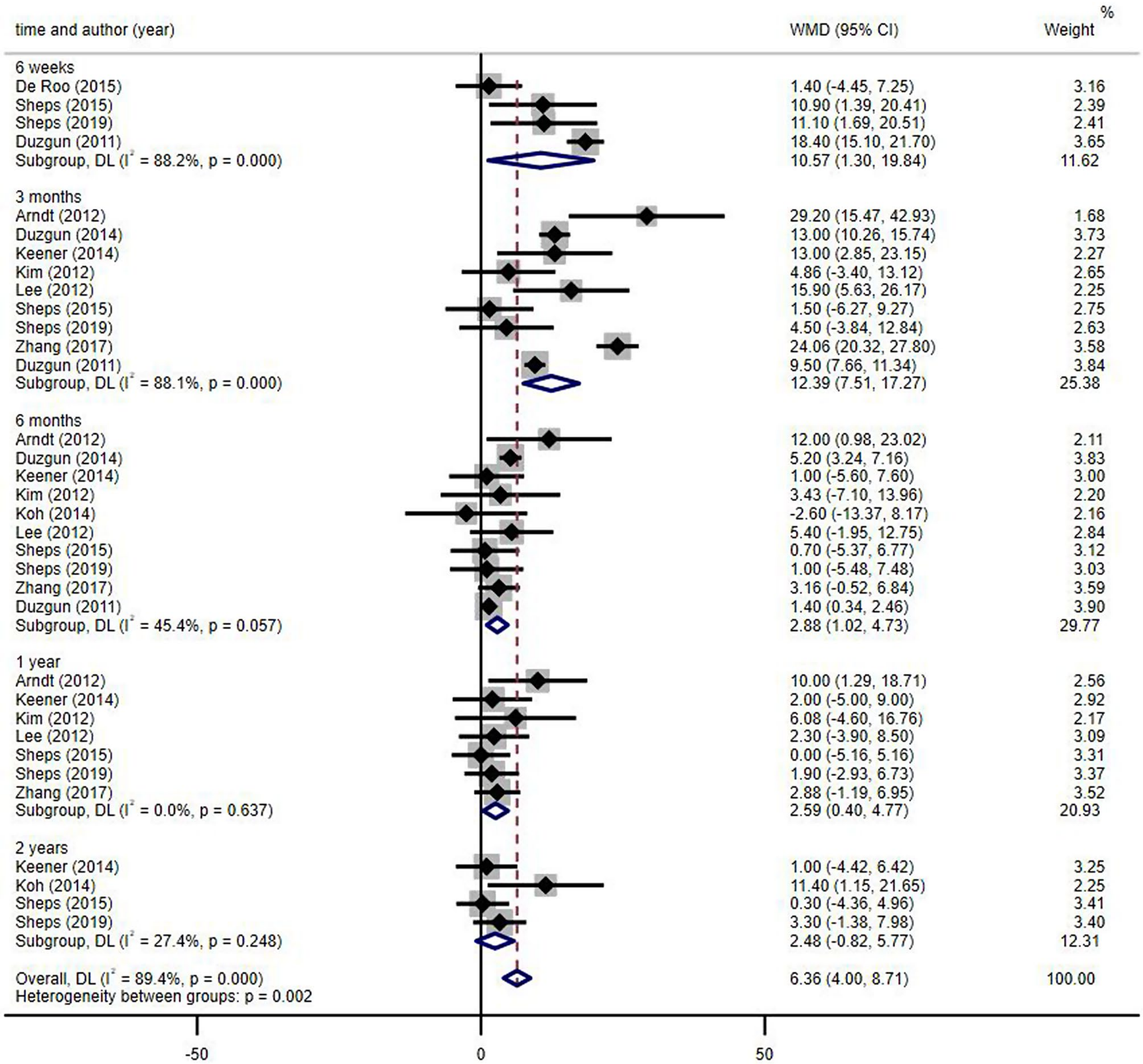

Fig. 4 Effects of Early Exercise and Brace Fixation on Shoulder Flexion of Subjects

rehabilitation protocols, patient-oriented and personalized rehabilitation protocols that take into account the characteristics of the disease may be more beneficial for the postoperative recovery of patients.

Based on the current findings, the limitations in determining superior rehabilitation protocols remain. Advocates of active early exercise argue that it may offer economic advantages as it can speed up short-term improvements, which in turn can help patients return to work earlier [28]. This argument is consistent with the findings of this review. However, patient selection for early exercise remains crucial, and it is best to avoid this option for those with complications (e.g., diabetes) or risk factors (e.g., smoking) known to hinder tendon healing due to the risk of re-tear [29, 30].

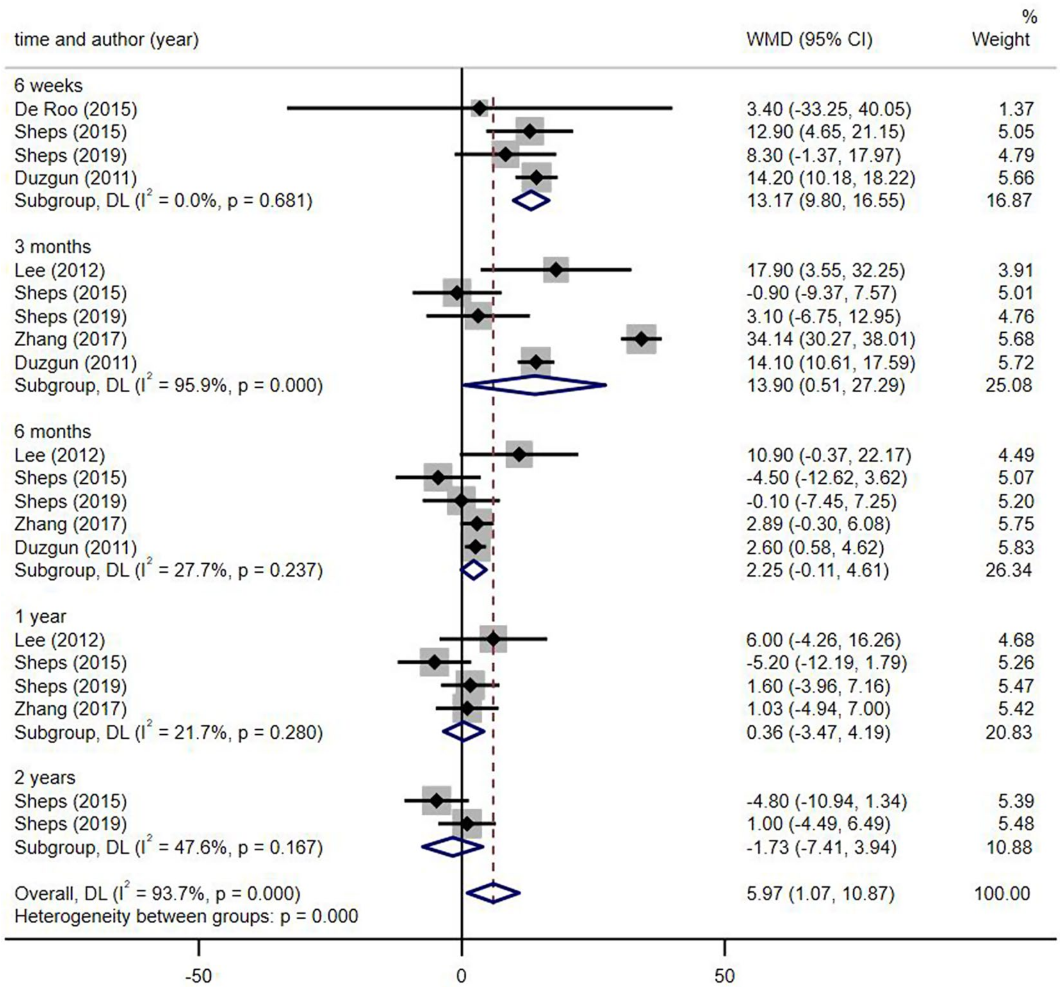

Fig. 5 Effects of Early Exercise and Brace Fixation on Shoulder Abduction of Subjects

This study still has the following limitations. Firstly, the sample size of RCT research included in meta-analysis is small, which may affect the results. In addition, there are differences in the definition of rehabilitation programs among different studies, and the location, size, age, and organizational integrity of cuff tear are not consistently reported, which may contribute to the heterogeneity observed among the included studies. While this heterogeneity could hinder the exploration of the influence of differences in research programs on the outcomes, it is important to note that heterogeneity in meta-analyses is not uncommon and does not necessarily invalidate the findings. In this study, we acknowledge the presence of heterogeneity but consider it acceptable given the clinical relevance and consistency of the overall results. However, due to the limited number of included studies, it was challenging to further reduce heterogeneity through subgroup analysis or sensitivity analysis. Additionally, this study only searched published articles, and the exclusion of unpublished studies may introduce publication bias. These limitations should be considered when interpreting the results, but they do not undermine the robustness

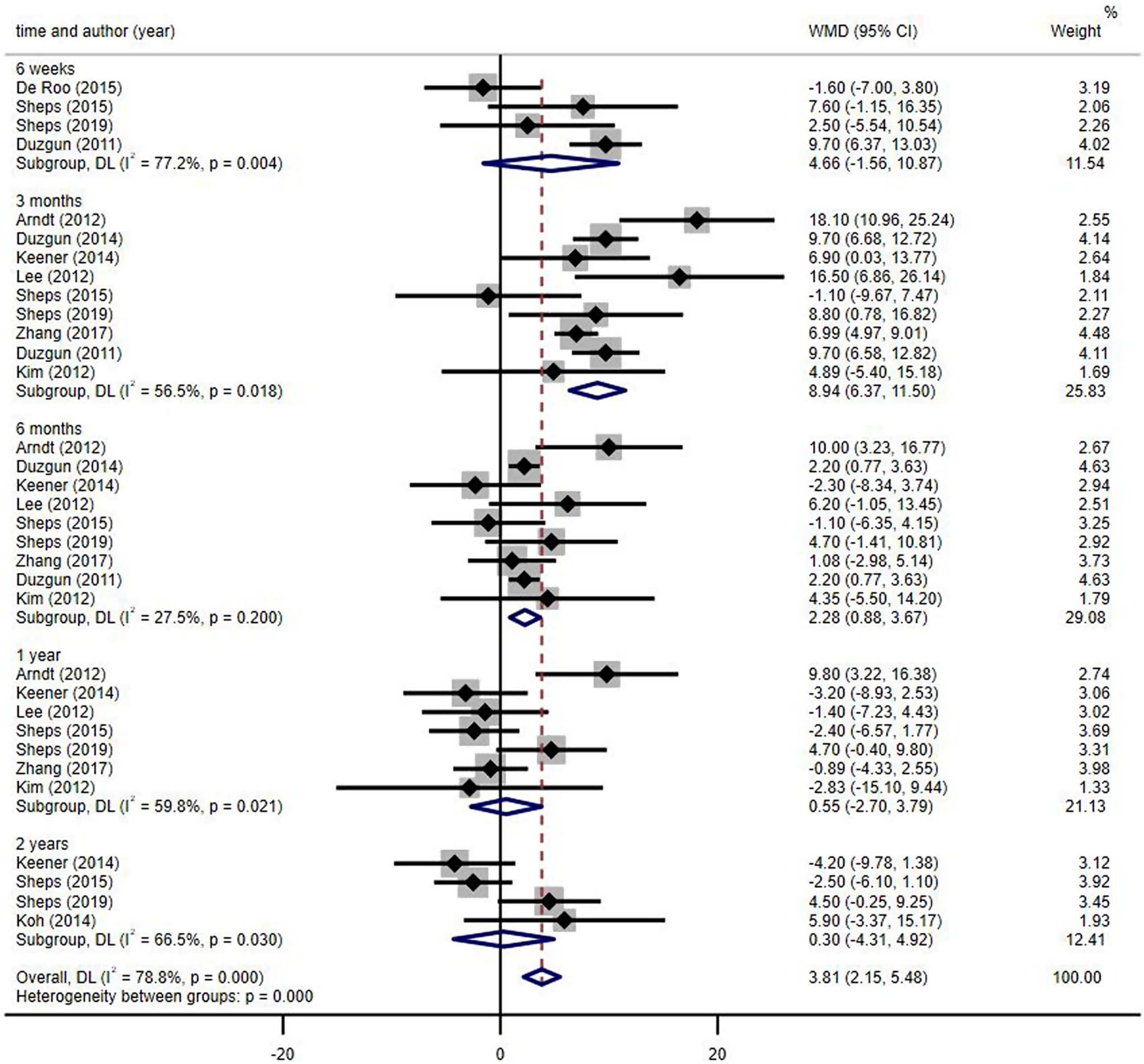

Fig. 6 Effects of Early Exercise and Brace Fixation on Shoulder External Rotation of Subjects

of the meta-analysis, as the findings remain valuable for informing clinical practice and future research.

In a word, summarizing the current research, it is found that early exercise has a better effect on improving early shoulder joint activity than brace fixation, and it may reduce the risk of postoperative stiffness. But no positive effect on pain and functional improvement was found. On the one hand, due to the heterogeneity of various studies, the information about early exercise and brace fixation among patients is very different, and its clinical significance remains to be seen. Large-scale, high-quality multicenter randomized controlled trials are needed, including detailed rotator cuff tear size and standardized rehabilitation interventions, in order to better understand the best rehabilitation program and provide conclusive suggestions.

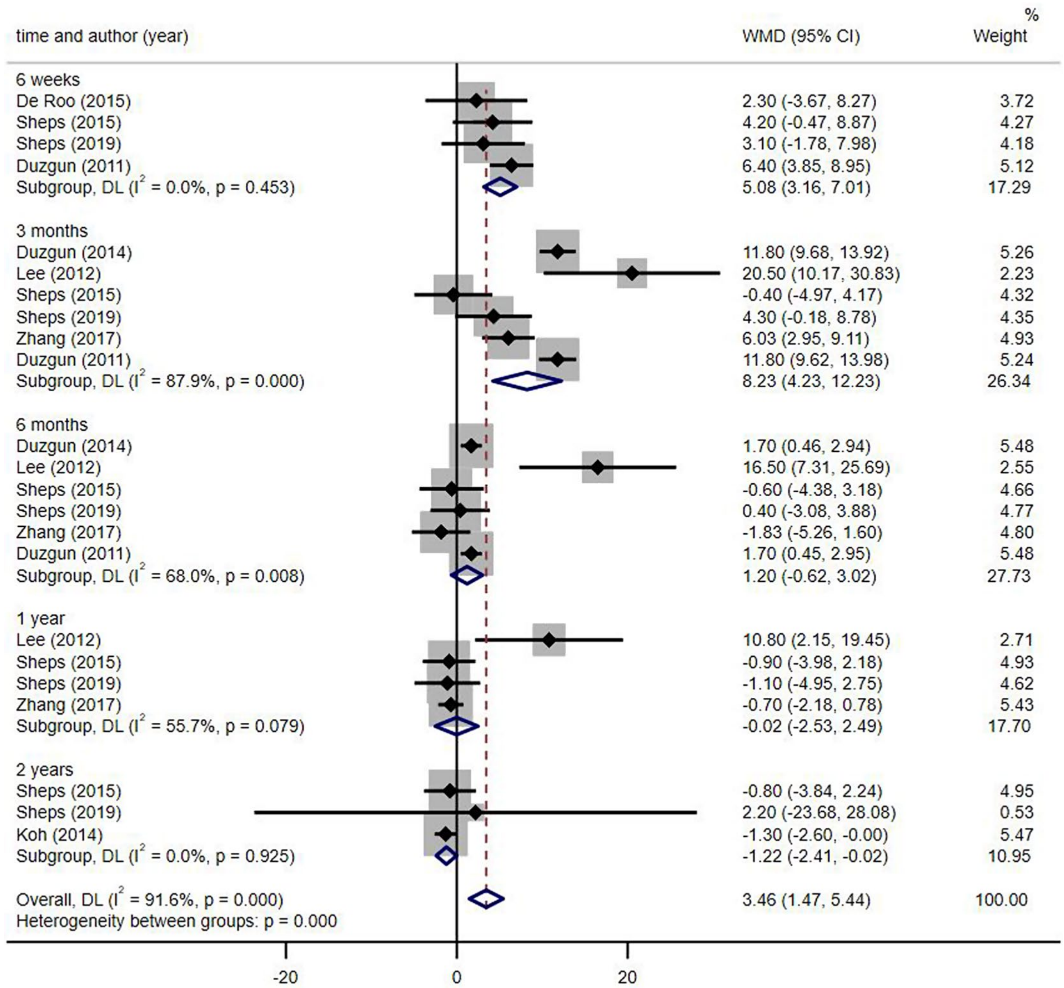

Fig. 7 Effects of Early Exercise and Brace Fixation on Shoulder Internal Rotation of Subjects

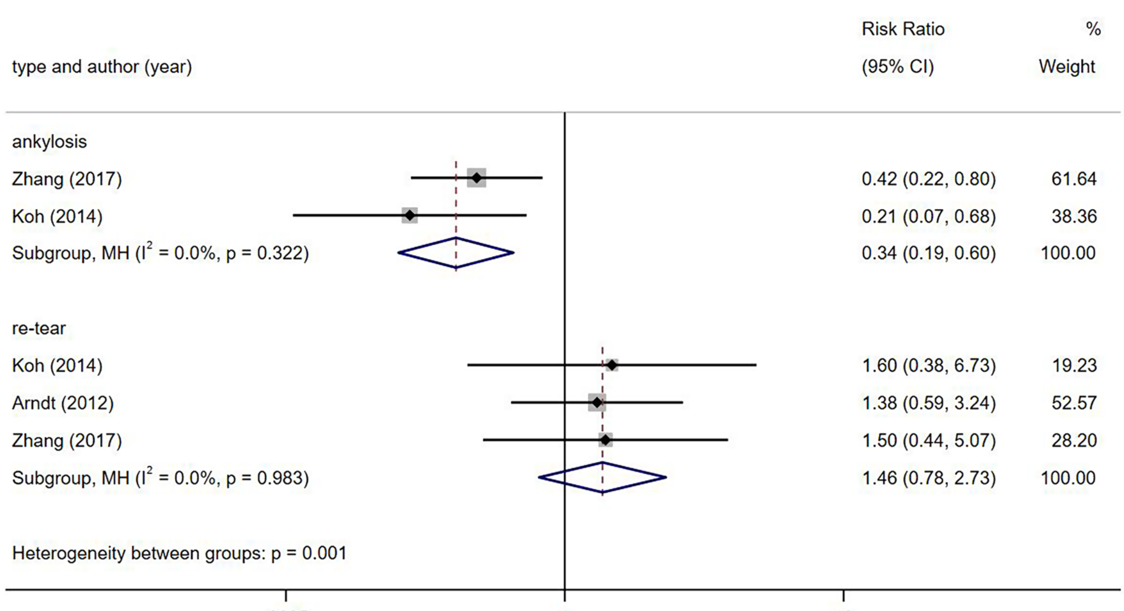

Fig. 8 Effects of Early Exercise and Brace Fixation on Complications in Subjects

Acknowledgements
Not applicable.

Author contributions
Study identification: Hao BR and A L; Data extraction: Hao BR and LI HQ; Critical appraisal: Hao BR, Li HQ and A L; Analysis and Article writing: Hao BR and A L.

Funding
Not applicable.

Data availability
All data generated or analyzed during this study are included in this published article.

Declarations

Ethics approval and consent to participate
This study was conducted in accordance with the Declaration of Helsinki and approved by the ethics committee of Central Hospital Affiliated to Shenyang Medical College.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Author details
[1]Department of Sports Medicine Orthopedics, Central Hospital Affiliated to Shenyang Medical College, No.5 South Seventh West Road, Tiexi District, Shenyang 110024, China

Received: 22 November 2023 / Accepted: 4 March 2025
Published online: 13 March 2025

References

1. Teunis T, Lubberts B, Reilly BT, Ring D. A systematic review and pooled analysis of the prevalence of rotator cuff disease with increasing age. J Shoulder Elb Surg. 2014;23(12):1913–21. https://doi.org/10.1016/j.jse.2014.08.001.
2. Boykin RE, Heuer HJ, Vaishnav S, Millett PJ. Rotator cuff disease: basics of diagnosis and treatment. Rheumatol Rep. 2010;2:el1–12. https://doi.org/10.4081/rr.2010.e1.
3. Lapner P, Li A, Pollock JW, Zhang T, McIlquham K, McRae S, MacDonald P. A multicenter randomized controlled trial comparing Single-Row with Double-Row fixation in arthroscopic rotator cuff repair: Long-Term Follow-up. Am J Sports Med. 2021;49(11):3021–9. https://doi.org/10.1177/03635465211029029.
4. Kelly BC, Constantinescu DS, Pavlis W, Vap AR. Arthroscopic versus open rotator cuff repair: Fellowship-Trained orthopaedic surgeons prefer arthroscopy and Self-Report a lower complication rate. Arthrosc Sports Med Rehabil. 2021;3(6):e1865–71. https://doi.org/10.1016/j.asmr.2021.09.001.
5. MacDermid JC, Bryant D, Holtby R, Razmjou H, Faber K, JOINTS C, Balyk R, Boorman R, Sheps D, McCormack R, Athwal G, Hollinshead R, Lo I, Bicknell R, Mohtadi N, Bouliane M, Glasgow D, Lebel ME, Lalani A, Moola FO, Litchfield R, Moro J, MacDonald P, Bergman JW, Bury J, Drosdowech D. Arthroscopic versus Mini-open rotator cuff repair: A randomized trial and Meta-analysis. Am J Sports Med. 2021;49(12):3184–95. https://doi.org/10.1177/03635465211038233.
6. Mather RC 3rd, Koenig L, Acevedo D, Dall TM, Gallo P, Romeo A, Tongue J, Williams G Jr. The societal and economic value of rotator cuff repair. J Bone Joint Surg Am. 2013;95(22):1993–2000. https://doi.org/10.2106/JBJS.L.01495.
7. Funk L. Arthroscopic shoulder surgery has progressed, has the rehabilitation? Int Musculoskelet Med. 2012;34(4):141–5. https://doi.org/10.1179/1753614612Z.00000000025.
8. Littlewood C, Mazuquin B, Moffatt M, Bateman M. Rehabilitation following rotator cuff repair: A survey of current practice (2020). Musculoskelet Care. 2021;19(2):165–71. https://doi.org/10.1002/msc.1514.
9. Kane LT, Lazarus MD, Namdari S, Seitz AL, Abboud JA. Comparing expert opinion within the care team regarding postoperative rehabilitation protocol following rotator cuff repair. J Shoulder Elb Surg. 2020;29(9):e330–7. https://doi.org/10.1016/j.jse.2020.01.097.
10. Parnes N, DeFranco M, Wells JH, Higgins LD, Warner JJ. Complications after arthroscopic revision rotator cuff repair. Arthroscopy. 2013;29(9):1479–86. https://doi.org/10.1016/j.arthro.2013.06.015.
11. Huang CL, Wu H, Chen G. Comparison of the efficacy of early and delayed rehabilitation intervention after arthroscopic rotator cuff repair. Chin J Rehabilitation Med. 2015;30(03):255–9.
12. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, Shamseer L, Tetzlaff JM, Akl EA, Brennan SE, Chou R, Glanville J, Grimshaw JM, Hróbjartsson A, Lalu MM, Li T, Loder EW, Mayo-Wilson E, McDonald S, McGuinness LA, Stewart LA, Thomas J, Tricco AC, Welch VA, Whiting P, Moher D. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ. 2021;372:n71. https://doi.org/10.1136/bmj.n71.
13. Higgins J, Altman DG. Chapter 8: Assessing risk of biasin included studies. In: Higgins JPT, Green S, editors. Cochrane Handbook for Systematic Reviews of Interventions Version 5.0. (2008). pp. 151–158. https://doi.org/10.1002/9780470712184. [Accessed July 20, 2010].
14. Düzgün I, Baltacı G, Atay OA. Comparison of slow and accelerated rehabilitation protocol after arthroscopic rotator cuff repair: pain and functional activity. Acta Orthop Traumatol Turc. 2011;45(1):23–33. https://doi.org/10.3944/AOTT.2011.2386.
15. Sheps DM, Silveira A, Beaupre L, Styles-Tripp F, Balyk R, Lalani A, Glasgow R, Bergman J, Bouliane M, Shoulder and Upper Extremity Research Group of Edmonton (SURGE). Early active motion versus sling immobilization after arthroscopic rotator cuff repair: A randomized controlled trial. Arthroscopy. 2019;35(3):749–e7602. https://doi.org/10.1016/j.arthro.2018.10.139.
16. Sheps DM, Bouliane M, Styles-Tripp F, Beaupre LA, Saraswat MK, Luciak-Corea C, Silveira A, Glasgow R, Balyk R. Early mobilisation following mini-open rotator cuff repair: a randomised control trial. Bone Joint J. 2015;97–B(9):1257–63. https://doi.org/10.1302/0301-620X.97B9.35250.
17. Zhang JL, Bai DY, Yang JW, Luan YJ, Zhao CJ. Early motion versus immobilization for arthroscopic repair in the treatment of large size rotator cuff tears. Biomed Res. 2017;28(15):6818–22.
18. Koh KH, Lim TK, Shon MS, Park YE, Lee SW, Yoo JC. Effect of immobilization without passive exercise after rotator cuff repair: randomized clinical trial comparing four and eight weeks of immobilization. J Bone Joint Surg Am. 2014;96(6):e44. https://doi.org/10.2106/JBJS.L.01741.
19. Lee BG, Cho NS, Rhee YG. Effect of two rehabilitation protocols on range of motion and healing rates after arthroscopic rotator cuff repair: aggressive versus limited early passive exercises. Arthroscopy. 2012;28(1):34–42. https://doi.org/10.1016/j.arthro.2011.07.012.
20. Düzgün İ, Baltacı G, Turgut E, Atay OA. Effects of slow and accelerated rehabilitation protocols on range of motion after arthroscopic rotator cuff repair. Acta Orthop Traumatol Turc. 2014;48(6):642–8. https://doi.org/10.3944/AOTT.2014.13.0125.
21. Arndt J, Clavert P, Mielcarek P, Bouchaib J, Meyer N, Kempf JF. French society for shoulder & elbow (SOFEC). Immediate passive motion versus immobilization after endoscopic supraspinatus tendon repair: a prospective randomized study. Orthop Traumatol Surg Res. 2012;98(6 Suppl):S131–8. https://doi.org/10.1016/j.otsr.2012.05.003.
22. Kim YS, Chung SW, Kim JY, Ok JH, Park I, Oh JH. Is early passive motion exercise necessary after arthroscopic rotator cuff repair? Am J Sports Med. 2012;40(4):815–21. https://doi.org/10.1177/0363546511434287.
23. De Roo PJ, Muermans S, Maroy M, Linden P, Van den Daelen L. Passive mobilization after arthroscopic rotator cuff repair is not detrimental in the early postoperative period. Acta Orthop Belg. 2015;81(3):485–92.
24. Keener JD, Galatz LM, Stobbs-Cucchi G, Patton R, Yamaguchi K. Rehabilitation following arthroscopic rotator cuff repair: a prospective randomized trial of immobilization compared with early motion. J Bone Joint Surg Am. 2014;96(1):11–9. https://doi.org/10.2106/JBJS.M.00034.
25. Boileau P, Brassart N, Watkinson DJ, Carles M, Hatzidakis AM, Krishnan SG. Arthroscopic repair of full-thickness tears of the supraspinatus: does the tendon really heal? J Bone Joint Surg Am. 2005;87(6):1229–40. https://doi.org/10.2106/JBJS.D.02035.
26. Quan X, Wu J, Liu Z, Li X, Xiao Y, Shu H, Zhou A, Wang T, Nie M. Outcomes after Double-Layer repair versus En masse repair for delaminated rotator cuff injury: A systematic review and Meta-analysis. Orthop J Sports Med. 2023;11(10):23259671231206183. https://doi.org/10.1177/23259671231206183.

27. Ross D, Maerz T, Lynch J, Norris S, Baker K, Anderson K. Rehabilitation following arthroscopic rotator cuff repair: a review of current literature. J Am Acad Orthop Surg. 2014;22(1):1–9. https://doi.org/10.5435/JAAOS-22-01-1.
28. Bandara U, An VVG, Imani S, Nandapalan H, Sivakumar BS. Rehabilitation protocols following rotator cuff repair: a meta-analysis of current evidence. ANZ J Surg. 2021;91(12):2773–9. https://doi.org/10.1111/ans.17213.
29. Podsiadło M, Błasiak A, Borkowski L, Brzóska R. Smoking as an additional risk factor in arthroscopic rotator cuff repair among type 2 diabetics. Ortop Traumatol Rehabil. 2022;24(6):375–84. https://doi.org/10.5604/01.3001.0016.2319.
30. Kashanchi KI, Nazemi AK, Komatsu DE, Wang ED. Smoking as a risk factor for complications following arthroscopic rotator cuff repair. JSES Int. 2020;5(1):83–7. https://doi.org/10.1016/j.jseint.2020.10.002.

Publisher's note