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The clinical effect of rehabilitation following arthroscopic rotator cuff repair

A meta-analysis of early versus delayed passive motion

Shuxiang Li, MD, Han Sun, MD, Xiaomin Luo, MD, Kun Wang, MD, Guofeng Wu, MD, Jian Zhou, MD, Peng Wang, MD, Xiaoliang Sun, MD*

Abstract

Background: The argument on the recommended rehabilitation protocol following arthroscopic rotator cuff repair remains to be resolved. So this meta-analysis was presented to evaluate the differences of clinical effects between the 2 distinct rehabilitation protocols after arthroscopic rotator cuff repair.

Methods: The PubMed, Cochrane Library, Web of Science, and EMBASE were systematically searched. Only randomized controlled trials (RCTs) published up to July 25, 2017, comparing early passive motion (EPM) versus delayed passive motion (DPM) rehabilitation protocols following arthroscopic rotator cuff repair were identified. The primary outcomes included range of motion and healing rate, while the secondary outcomes were Constant score, American Shoulder and Elbow Society (ASES) score, and Simple Shoulder Test (SST) score. The exclusion criteria contained biochemical trials, reviews, case reports, retrospective studies, without mention about passive motion exercise, no assessment of outcomes mentioned above, and no comparison of EPM and DPM rehabilitation protocols.

Results: Eight RCTs with 671 patients were enrolled in this study. The EPM resulted in improved shoulder forward flexion at short term, mid-term, and long-term follow-ups. The EPM group was superior to the DPM group in terms of external rotation (ER) at short-term and mid-term follow-ups. However, the DPM performed better long-term ASES score. These 2 protocols were equivalent in terms of ER at long term, ASES score at mid-term, SST score, Constant score, and healing rate. After excluding 2 RCTs that examined only small- and medium-sized tears, the pooled results of healing rate decreased from 82.4% to 76.6% in the EPM and 86.9% to 85.9% in the DPM.

Conclusion: The meta-analysis suggests that the EPM protocol results in superior ROM recovery after arthroscopic rotator cuff repair but may adversely affect the shoulder function, which should be supported by further research. The healing rate at long-term follow-up is not clearly affected by the type of rehabilitation, but the EPM protocol might result in lower rates of tendon healing in the shoulder with large-sized tendon tears.

Abbreviations: ASES = American Shoulder and Elbow Society, DPM = delayed passive motion, EPM = early passive motion, ER = external rotation, RCTs = randomized controlled trials, SST = Simple Shoulder Test.

Keywords: arthroscopy rotator cuff repair, early passive motion, meta-analysis, rehabilitation

1. Introduction

With constant developments and advances in surgical instruments and technique, open techniques are slowly being replaced by arthroscopic repairs that allow faster recovery and good cosmetic results in rotator cuff repair. A partial or full-thickness tear, which can produce symptoms that interfere with the normal functioning of patients and has no response to conservative treatment, is an indication for arthroscopic repair of a rotator cuff tear.[1] However, the rate of anatomical failure after arthroscopic rotator cuff repair still remains at 20% to 90% despite the significant advances and refinements in the arthroscopic techniques.[2,3] Shoulder stiffness, which is the most common complication of rotator cuff repair, can be a source of pain, functional limitation, and frustration for patients.[4]

In recent years, controversy still exists regarding the influence of early passive motion (EPM) versus delayed passive motion (DPM) on the stiffness and healing rate after rotator cuff repair. Traditionally, the EPM protocol refers to the shoulder range of motion (ROM) that begins on day 1 postoperatively, whereas the DPM regimen requires rigorous sling immobilization within the first 4 to 6 weeks after surgery. In theory, the EPM rehabilitation prevents postoperative stiffness, fatty infiltration, and muscle atrophy, but may also decrease the possibility of tendon healing.[5,6] Most of the animal studies have shown that early

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Articular Orthopaedics, The Third Affiliated Hospital of Soochow University, Changzhou, Jiangsu Province, China.

* *Correspondence: Xiaoliang Sun, Articular Orthopaedics, The Third Affiliated Hospital of Soochow University, No. 185, Juqian Road, Changzhou, Jiangsu Province 213003, China (e-mail: xiaoliangsuncz@163.com).*

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ROM exercise deteriorates tendon healing, but an artificial tendon injury may not have the usual degenerative tear patterns in human rotator cuffs.[7,8] Furthermore, recent studies have shown that most recurrent rotator cuff tears occur within 3 to 6 months after surgery, which further supports the DPM protocol.[9,10] However, delayed motion exercise may increase the risk of shoulder stiffness, and then delay the recovery of shoulder function.

As far as we know, several previous systematic reviews[11–13] and meta-analyses[14–16] have been published comparing the EPM and DPM protocols after arthroscopic rotator cuff repair. However, there was discordance in the conclusions of these published studies, and the argument on the recommended postoperative protocol remains to be resolved. In 2015 and 2017, 3 new randomized controlled trials (RCTs)[17–19] were published. Some important information may be obtained if these 3 studies are analyzed. Thus, it is important to conduct a new meta-analysis on these studies to make a relatively more credible and overall assessment about which rehabilitation protocol after arthroscopic rotator cuff repair is the best choice.

2. Materials and methods

2.1. Search strategy

We followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) reporting guidelines[20] and the recommendations of the Cochrane Collaboration[21] to conduct this meta-analysis. The detailed guidelines can be found at www.prisma-statement.org. Reviewers searched the PubMed, Cochrane Library, Web of Science, and EMBASE online databases using the key phrases "early passive motion exercise," "delayed motion," "rehabilitation," "immobilization," "early physical therapy," "stiffness," and "rotator cuff repair" for all English-language RCTs published up to July 25, 2017. Ethical approval was not necessary because the present meta-analysis was performed on the basis of previous published studies.

2.2. Inclusion and exclusion criteria

The studies on RCT focusing on comparing EPM and DPM rehabilitation exercise following arthroscopic rotator cuff repair were included in our meta-analysis. At least 1 of the following outcomes should have been measured: Constant score, American Shoulder and Elbow Society (ASES) score, Simple Shoulder Test (SST) score, ROM, and healing rate of rotator cuff. EPM required passive shoulder ROM exercises conducted within the first 2 weeks after arthroscopic rotator cuff repair. The exclusion criteria contained biochemical trials, reviews, case reports, retrospective studies, without mention about passive motion exercise, no assessment of outcomes mentioned above, and no comparison of EPM and DPM rehabilitation protocols.

2.3. Study selection

Two independent authors (S.X.L. and H.S.) followed the unified search strategy to screen the titles and abstracts of potentially relevant studies. Any inconsistencies between reviewers were resolved through discussion and consensus. If a consensus could not be reached, a senior author (X.L.S.) was consulted for a final decision.

2.4. Data extraction

Data were extracted from the included studies by 2 independent reviewers (S.X.L. and X.M.L.). Relevant data extracted from the RCTs included patient characteristics, technical categories of arthroscopic repair, details of rehabilitation protocols, duration of follow-up, and outcome measurements (Table 1).[22–27] The primary outcome measures of the study included ROM and healing rate, whereas the secondary outcomes were functional scores, including Constant score, ASES score, and SST score. Short-term follow-up was defined as within 3 months, mid-term was defined as 3 to 6 months, and long-term was defined as more than 6 months. If the data could not be extracted directly, we contacted the authors for more information. Otherwise, we extracted them from figures or calculated them with the guideline of Cochrane Handbook for Systematic Reviews of Interventions 5.1.0.[28]

2.5. Data analysis

The present meta-analysis was performed using the Review Manager Software (RevMan Version 5.3, The Cochrane Collaboration, Copenhagen, Denmark). Risk ratios (RRs) with a 95% confidence interval (CI) or mean difference (MD) with 95% CI were assessed for dichotomous outcomes or continuous outcomes, respectively. $P < .05$ was set as the level of significance. It was also considered as statistically significant if "1" was not included in the 95% CI of RR or "0" was not included in the 95% CI of MD. The heterogeneity was assessed by using the Q test and I^2 statistic. If $P > .1$ and $I^2 < 50\%$, no significant heterogeneity was noted and the fixed effect model was used. On the contrary, if $P \leq .1$ or $I^2 \geq 50\%$, a random effects model was used for the heterogeneity. The source of heterogeneity was investigated using the sensitivity analysis.

2.6. Assessment of methodological quality and evidence synthesis

On the basis of Cochrane Handbook for Systematic Reviews of Interventions 5.1.0,[28] the risk of bias of the included studies was assessed by 2 independent authors (S.X.L. and X.M.L.) with the application of the "Cochrane collaboration's tool for assessing the risk of bias." The publication bias and funnel plots were not reliable due to the limited number of studies. Evidence grade of outcome was evaluated in accordance with the Grading of Recommendations Assessment, Development, and Evaluation (GRADE).[29] Any disagreement was resolved by discussing with a third reviewer (X.L.S.).

3. Results

3.1. Search results

On the basis of the key phrases mentioned above, a total of 338 citations were identified from the following databases: 28 from PubMed, 171 from Web of science, 130 from EMBASE, and 9 from Cochrane library. A screen of the 10 RCTs[17–19,22–27,30] was conducted for eligibility and the full text read after excluding duplicate, irrelevant, and nonrandomized clinical studies. One trial[30] comparing the clinical outcomes of passive self-assisted ROM exercise with those associated with the use of continuous passive motion in patients after arthroscopic rotator cuff repair was excluded. Another RCT,[27] which compared the differences of slow and accelerated rehabilitation protocols

Table 1

Study characteristics.

Studies	Sample size (EPM/DPM)	Age (EPM/DPM)	Follow-up, mo	Tear size, cm	Arthroscopic technique	Protocol in EPM group	Protocol in DPM group	Relevant outcomes
Arndt et al[22]	49/43	55.3 (37–71)	16	Partial and full-thickness tear (NA)	Single row or double row	Pendulums, manual passive ROM, CPM, no limitations	Pendulums, hand/elbow/wrist ROM	ROM, Constant, healing rate
Cuff et al[23]	33/35	63 (19–74)/63.5 (22–76)	12.2	Full-thickness tear (NA)	Transosseous-equivalent suture-bridge	Pendulums, manual passive ROM, FF < 120° and ER < 30° for 3 wk	Pendulums, hand/elbow/wrist ROM	ASES, SST, ROM, healing rate
Kim et al[25]	56/49	60.1 (30–75)/60.0 (27–82)	12	Full-thickness tear (<3)	Single row or double row or suture-bridge fixation	Pendulums, manual passive ROM	Shoulder shrugs, hand/elbow/wrist ROM	ROM, SST, ASES, Constant, healing rate
Lee et al[26]	30/34	54.5 (39–66)/55.2 (40–65)	12	Full-thickness tear (1–5)	Single row	Pendulums, manual passive ROM, ER < 30°	FF to 90° with CPM, no PT	ROM, VAS, strength, UCLA score, healing rate
Keener et al[24]	61/53	54.8 ± 6.3/55.8 ± 6.3	24	Full-thickness tear (<3)	Double row	Pendulums, manual passive ROM, hand/elbow/wrist ROM	Hand/elbow/wrist ROM	ROM, Constant, abduction and ER strength, VAS, SST, ASES, healing rate
Duzgun et al[27]	19/21	57.68 ± 7.8/57.2 ± 10.1	6	Full-thickness tear (1–5)	Side-to-side repair	Passive ROM, hand/elbow/wrist ROM	Similar programs as EPM but with 2-wk delay	ROM
Roo[17]	79/51	64.6 ± 10.0/65.1 ± 9.7	4	Full-thickness tear (<5)	Single row or double row	Pendulums, manual passive ROM, hand/elbow/wrist ROM	Pendulums, hand/elbow/wrist ROM	ROM, strength, Constant, SST, UCLA, SPADI
Mazzocca et al[18]	31/27	55 ± 8/54 ± 7	12	Full-thickness tear (NA)	Transosseous-equivalent suture-bridge	Manual passive ROM, hand/elbow/wrist ROM	Hand/elbow/wrist ROM	ROM, Constant, VAS, SST, ASES, SANE, healing rate

ASES = American Shoulder and Elbow Society, Constant = Constant-Murley, CPM = continuous passive motion, DPM = delay passive motion, EPM = early passive motion, ER = external rotation, FF = forward flexion, NA = not available, PT = physical therapy, ROM = range of motion, SANE = Single Assessment Numeric Evaluation, SPADI = Shoulder Pain And Disability Index, SST = Simple Shoulder Test, UCLA = University of California at Los Angeles, VAS = visual analog pain score, WORC = Western Ontario Rotator Cuff.

after arthroscopic rotator cuff repair, was also excluded because it only documented the Disabilities of the Arm, Shoulder, and Hand score in patients. Finally, of the 338 studies, only 8 RCTs[17–19,22–26] were included in our meta-analysis (Fig. 1).

3.2. Quality assessment of included RCTs

The detailed information of the characteristics of included studies can be seen in Table 1. A standardized assessment of the risk of bias in the 8 RCTs is summarized in Fig. 2A. There was no blinding of the participants and personnel in all 8 studies.[17–19,22,26] In the study of Arndt et al[22] and Duzgun et al,[27] the details of randomization and outcome assessments were not described, and there was no evident allocation concealment. On the contrary, Kim et al[25] demonstrated the use of a randomization technique; however, the study failed to report allocation concealment and provided incomplete outcome data and could not blind outcome assessors to the rehabilitation protocol. All of these 3 studies represented a high risk of bias in terms of methodologic quality.[19,22,25] Lee et al[26] did not describe their randomization method; although allocation concealment was adequate, treating surgeons who performed outcome assessments were not blinded. A reasonable methodology was used in the study of Cuff et al,[23] but this RCT had incomplete data. The study of Roo[17] mentioned appropriate randomization measures and provided complete statistical data; however, the allocations were not concealed. Finally, the studies by Mazzocca et al[18] and Keener et al[24] used appropriate randomization, detailed allocation concealment, and blinded outcome assessments, representing a methodologic quality with a low risk of bias. Each risk of the bias item was expressed in terms of the percentage across all the included studies, which indicated the proportion of risk levels for each item bias (Fig. 2B).

3.3. The primary outcome measurements

3.3.1. Range of motion. ROM data could be extracted from all of the included RCTs.[17–19,22–26] It was evaluated in terms of forward flexion (FF) and external rotation (ER) at short-term, mid-term, and long-term follow-ups.

The FF and ER on short-term follow-up were shown in 6 studies.[18,19,22,24–26] The result of the meta-analysis revealed a significant difference in the FF at short-term follow-up between the EPM and DPM protocols (MD, 10.31; 95% CI, 5.02–15.61; $P = .0001$; $I^2 = 63\%$, a random effect model was used) (Fig. 3A). The sensitivity analysis presented that the study of Arndt et al[22] contributed to the heterogeneity, and a statistically significant difference still existed after excluding it. In addition, data pooled from these studies indicated a significant difference in the ER at short-term follow-up between the 2 groups (MD, 8.28; 95% CI, 3.52–13.04; $P = .0007$; $I^2 = 67\%$) (Fig. 3B). A sensitivity analysis reported that the study of Mazzocca et al[18] was the main source of the heterogeneity, and a statistically significant difference was also found when it was excluded.

All 8 studies[17–19,22–26] reported the outcomes of FF and ER at mid-term follow-up in 671 patients. On analysis of the pooled data from the studies, the EPM group showed a significantly better FF at mid-term follow-up than did the DPM group (MD, 3.01; 95% CI, 0.31–5.72; $P = .03$; $I^2 = 56\%$) (Fig. 4A). The study conducted by Cuff et al[23] caused the heterogeneity, and the EPM group was also superior to the DPM group in terms of FF after excluding this study. Similarly, the summarized results showed

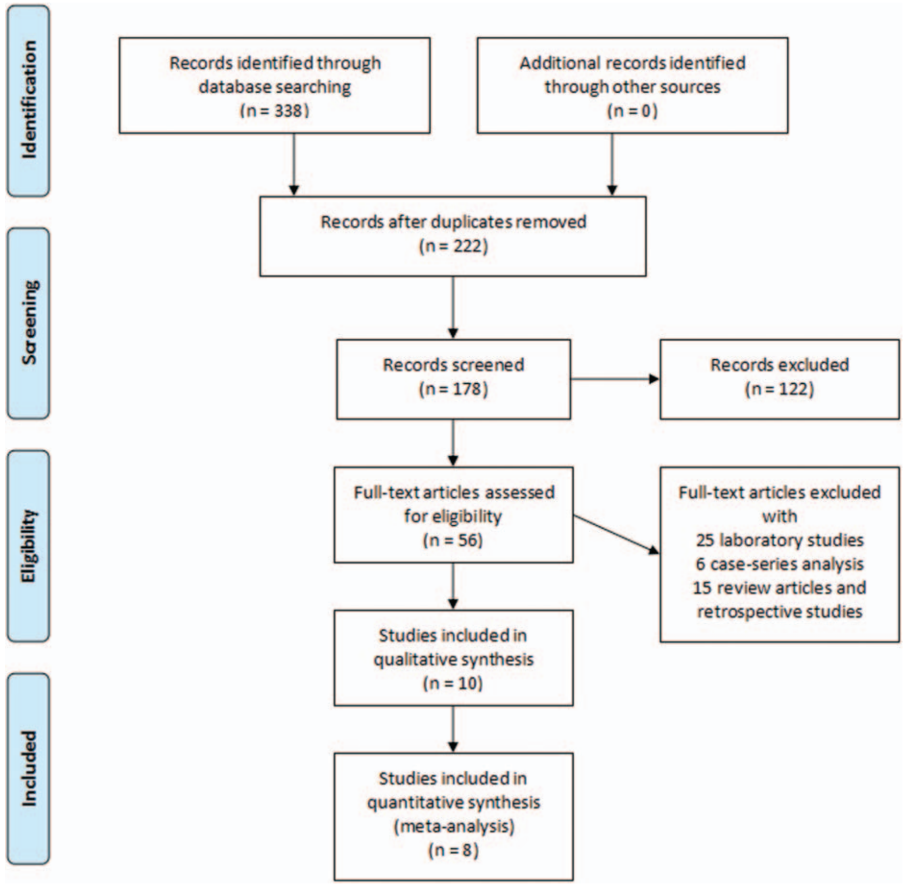


Figure 1. Search results and the selection procedure.

that ER was better in the EPM group at mid-term follow-up (MD, 2.00; 95% CI, 0.94–3.05; $P = .0002$; $I^2 = 48\%$) (Fig. 4B).

Six studies[18,22–26] with 503 patients reported the FF and ER during long-term follow-up. According to our analysis, long-term FF is better with EPM rehabilitation than with DPM rehabilitation (MD, 1.24; 95% CI, 0.25–2.23; $P = .01$; $I^2 = 0$) (Fig. 5A). However, no statistically significant was noted in the differences in the long-term ER between the 2 groups (MD, 2.24; 95% CI, −2.72 to 7.19; $P = .38$; $I^2 = 57\%$) (Fig. 5B). The sensitivity analysis revealed no statistically significant difference between the 2 groups on eliminating study of Arndt et al.[22]

3.3.2. Tendon healing. Tendon healing was compared in 6 studies[18,22–26] at long-term postoperative follow-up, including a total of 493 patients (EPM, n=256; DPM, n=237). Keener et al[24] and Cuff et al[23] assessed the anatomic outcome using the ultrasound; CT arthrography was used by Arndt et al[22] and Kim et al[25]; magnetic resonance imaging (MRI) was used in the remaining 2 studies.[18,26] The summarized results showed that tendon healing was observed in 211 out of 256 patients (82.4%) in the EPM group and 206 out of 237 patients (86.9%) in the DPM group, which revealed that the 2 rehabilitation groups were comparable in tendon healing (RR, 0.95; 95% CI, 0.88–1.02; $P = .16$) (Fig. 6). Then, we excluded the study of Keener et al[24] and Kim et al[25] that examined only small and medium-sized rotator cuff tears to perform a sensitivity analysis. The pooled results changed to 105 out of 137 (76.6%) in the EPM group and 116 out of 135 (85.9%) in the DPM group, which demonstrated that the DPM rehabilitation protocol performed better in tendon healing. However, there was no statistically significant difference in healing rate of rotator cuff between the 2 groups (RR, 0.90; 95% CI, 0.80–1.01; $P = .06$).

3.4. The secondary outcome measurements

3.4.1. Medium functional scores. The Constant score at mid-term follow-up was measured in 4 studies[17,18,24,25] consisting of 407 patients. One study[25] did not present standard deviation, so we imputed it depending on the *P* value. Data pooled from these studies showed no significant difference between both groups (MD, 0.87; 95% CI, −1.97 to 3.71; $P = .55$; $I^2 = 0$) (Fig. 7A). Similarly, the EPM and DPM groups revealed little difference in the ASES scores at mid-term follow-up in 3 studies (MD, 0.19; 95% CI, −6.66 to 7.03; $P = .96$; $I^2 = 55\%$) (Fig. 7B).[18,24,25] The study by Mazzocca et al[18] contributed to the heterogeneity, and no difference was found when it was rejected. Four studies[17,18,24,25] reported the mid-term SST score. The pooled result revealed that the 2 groups were comparable in terms of the SST score (MD, 0.47; 95% CI, -0.08 to 1.02; $P = .09$; $I^2 = 17\%$) (Fig. 7C).

3.4.2. Long-term functional scores. The long-term Constant score was reported in 4 studies[18,22,24,25] with 371 patients. Meta-analysis presented a similar long-term Constant score between the 2 groups (MD, 1.90; 95% CI, −1.62 to 5.41;

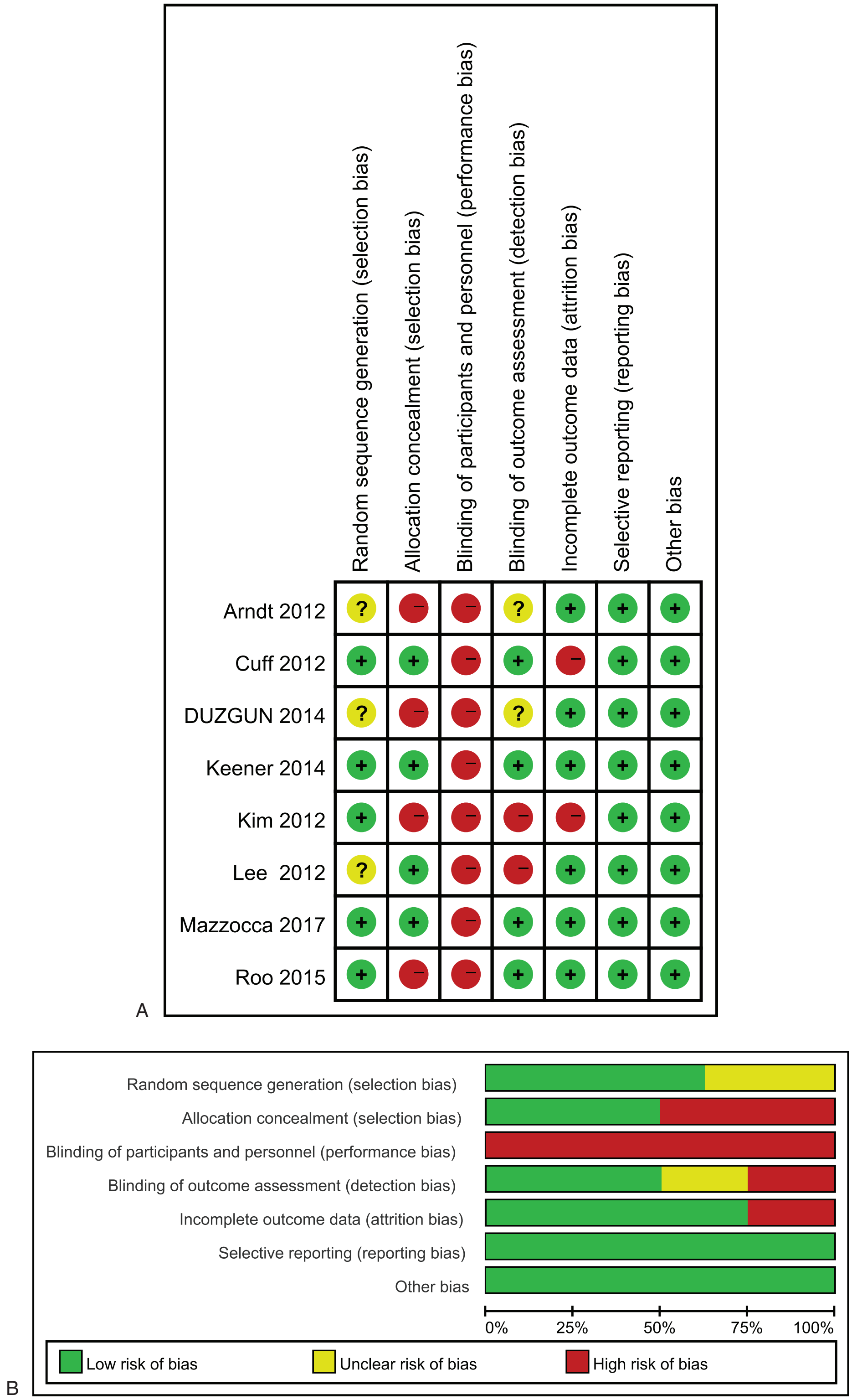


Figure 2. (A) Risk of bias summary. (B) Risk of bias graph.

P=.29; I^2=65%) (Fig. 8A). The sensitivity analysis showed that the study of Arndt et al[22] was the main reason for the heterogeneity; no significant difference was found after excluding it. However, the meta-analysis result for the long-term ASES score indicated that the DPM group had a significantly higher score than the EPM group (MD, −1.66; 95% CI, −2.76 to −0.55; P=.003; I^2=25%) (Fig. 8B). The difference in long-term SST score was not statistically significant according to our analysis (MD, 0.07; 95% CI, −0.26 to 0.40; P=.68; I^2=0) (Fig. 8C).

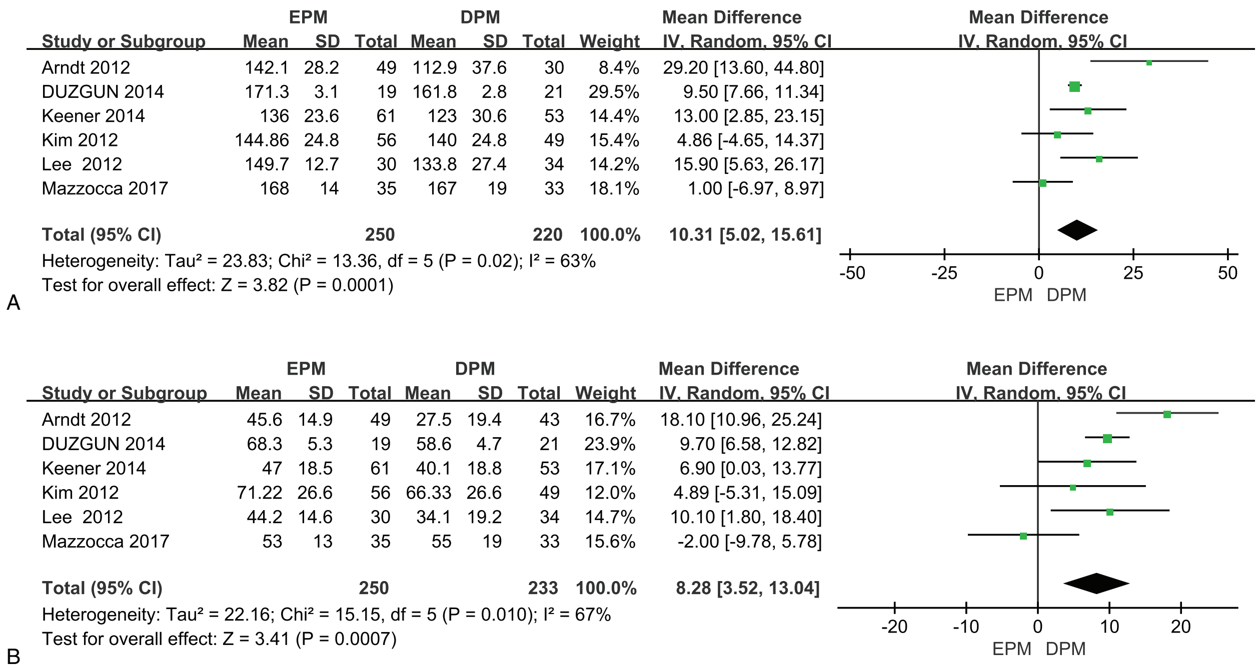


Figure 3. (A) A forest plot diagram showing forward flexion at short term after surgery. (B) A forest plot diagram showing external rotation at short term after surgery.

3.5. Quality of evidence

The GRADE system was used to assess the quality of evidence across the various outcomes in our study. In our final assessments, none of the outcomes showed high quality of evidence, while short-term ER, long-term FF, and long-term ASES score revealed moderate quality. The evidence for short-term or mid-term FF, mid-term ER, mid-term Constant score, mid-term or long-term SST score, and healing rate was low. Evaluation of the results of long-term ER, long-term Constant score, and mid-term ASES score revealed that the evidence was very low. The details of the results are summarized in Table 2.

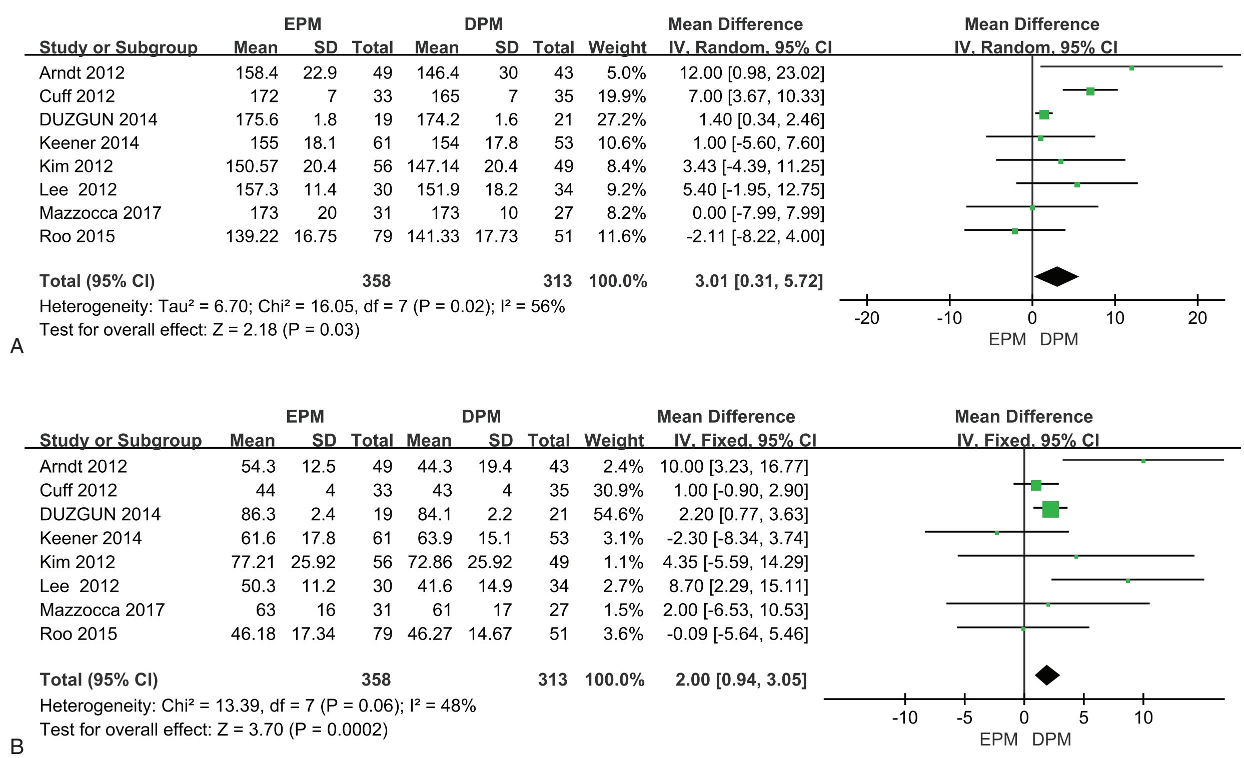
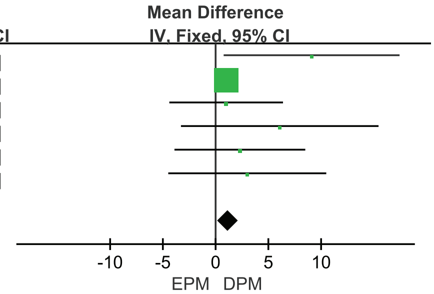


Figure 4. (A) A forest plot diagram showing forward flexion at medium after surgery. (B) A forest plot diagram showing external rotation at medium after surgery.

Study or Subgroup	EPM Mean	EPM SD	EPM Total	DPM Mean	DPM SD	DPM Total	Weight	Mean Difference IV, Fixed, 95% CI
Arndt 2012	172.4	13	49	163.3	25.1	43	1.4%	9.10 [0.76, 17.44]
Cuff 2012	174	2.2	33	173	2.2	35	89.8%	1.00 [-0.05, 2.05]
Keener 2014	164	13.4	63	163	15.8	53	3.4%	1.00 [-4.39, 6.39]
Kim 2012	159.75	24.43	56	153.67	24.43	49	1.1%	6.08 [-3.29, 15.45]
Lee 2012	155.3	13	30	153	12.2	34	2.6%	2.30 [-3.90, 8.50]
Mazzocca 2017	176	11	31	173	17	27	1.8%	3.00 [-4.49, 10.49]
Total (95% CI)			**262**			**241**	**100.0%**	**1.24 [0.25, 2.23]**

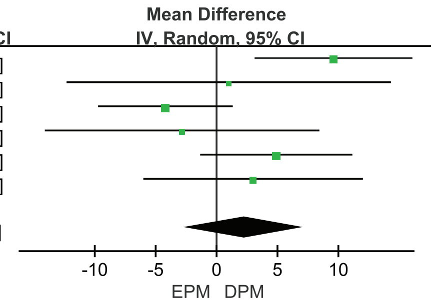
Heterogeneity: Chi² = 4.97, df = 5 (P = 0.42); I² = 0%
Test for overall effect: Z = 2.45 (P = 0.01)



A

Study or Subgroup	EPM Mean	EPM SD	EPM Total	DPM Mean	DPM SD	DPM Total	Weight	Mean Difference IV, Random, 95% CI
Arndt 2012	58.7	12.9	49	49.1	18	43	20.2%	9.60 [3.12, 16.08]
Cuff 2012	46	28	33	45	28	35	9.6%	1.00 [-12.32, 14.32]
Keener 2014	62	16.4	63	66.2	14	53	22.3%	-4.20 [-9.73, 1.33]
Kim 2012	78.5	29.4	56	81.33	29.4	49	11.9%	-2.83 [-14.10, 8.44]
Lee 2012	53	11.6	30	48.1	13.9	34	20.7%	4.90 [-1.35, 11.15]
Mazzocca 2017	61	18	31	58	17	27	15.3%	3.00 [-6.01, 12.01]
Total (95% CI)			**262**			**241**	**100.0%**	**2.24 [-2.72, 7.19]**

Heterogeneity: Tau² = 20.64; Chi² = 11.69, df = 5 (P = 0.04); I² = 57%
Test for overall effect: Z = 0.89 (P = 0.38)



B

Figure 5. (A) A forest plot diagram showing forward flexion at long term after surgery. (B) A forest plot diagram showing external rotation at long term after surgery.

4. Discussion

Currently, arthroscopic repair has been increasingly used in the treatment of rotator cuff tears. However, there has been debate on the timing of shoulder passive ROM postoperatively, with proponents of the DPM rehabilitation protocol submitting the potential for increased rate of tendon healing by minimizing micromotion and improved shoulder functional outcomes.[31] Advocates of the EPM rehabilitation protocol suggest that it may increase shoulder ROM, which could ultimately decrease shoulder stiffness and muscle atrophy. To our knowledge, several systematic reviews[11] and meta-analyses[14] have been published to compare the effect of the EPM and DPM rehabilitation protocols after arthroscopic rotator cuff repair. However, the number of included RCTs among the studies was small and discordance existed in the conclusions of these studies. With this, the argument on the recommended postoperative protocol remains to be resolved. Therefore, we performed a meta-analysis of RCTs to compare the EPM and DPM rehabilitation protocol in terms of ROM, healing rate, and shoulder function scores and to provide an evidence-based recommendation of the best rehabilitation after arthroscopic rotator cuff repair.

The present meta-analysis indicated that these 2 rehabilitation protocols were equivalent in terms of long-term ER, mid-term ASES score, SST score, Constant score, and healing rate. However, there was a significant difference between the 2 protocols for FF, short-term or mid-term ER, and long-term ASES score according to an accurate analysis. The sensitivity analysis indicated that the patients with large-sized tears preoperatively who underwent the EPM rehabilitation had slow tendon healing, although there was no significant difference compared with DPM rehabilitation (RR 0.90; 95% CI, 0.80–1.01; $P=.06$).

EPM rehabilitation was often opposed by many biochemical trials. Peltz et al[32] suggested that an EPM performed postoperatively could increase scar formation and extracellular tissue in the subacromial space in a rat model and lead to

Study or Subgroup	EPM Events	EPM Total	DPM Events	DPM Total	Weight	Risk Ratio M-H, Fixed, 95% CI
Arndt 2012	33	43	33	39	16.2%	0.91 [0.73, 1.12]
Cuff 2012	28	33	32	35	14.6%	0.93 [0.78, 1.11]
Keener 2014	57	63	50	53	25.5%	0.96 [0.86, 1.06]
Kim 2012	49	56	40	49	20.0%	1.07 [0.91, 1.26]
Lee 2012	23	30	31	34	13.6%	0.84 [0.67, 1.05]
Mazzocca 2017	21	31	20	27	10.0%	0.91 [0.66, 1.27]
Total (95% CI)		**256**		**237**	**100.0%**	**0.95 [0.88, 1.02]**
Total events	211		206			

Heterogeneity: Chi² = 3.53, df = 5 (P = 0.62); I² = 0%
Test for overall effect: Z = 1.40 (P = 0.16)

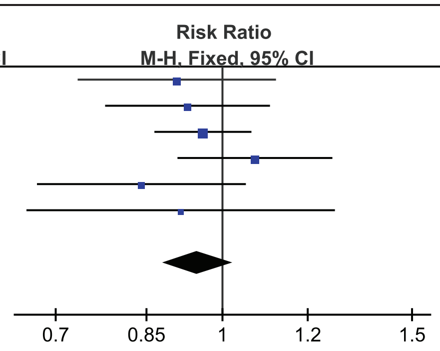


Figure 6. A forest plot diagram showing tendon healing at long-term follow-up.

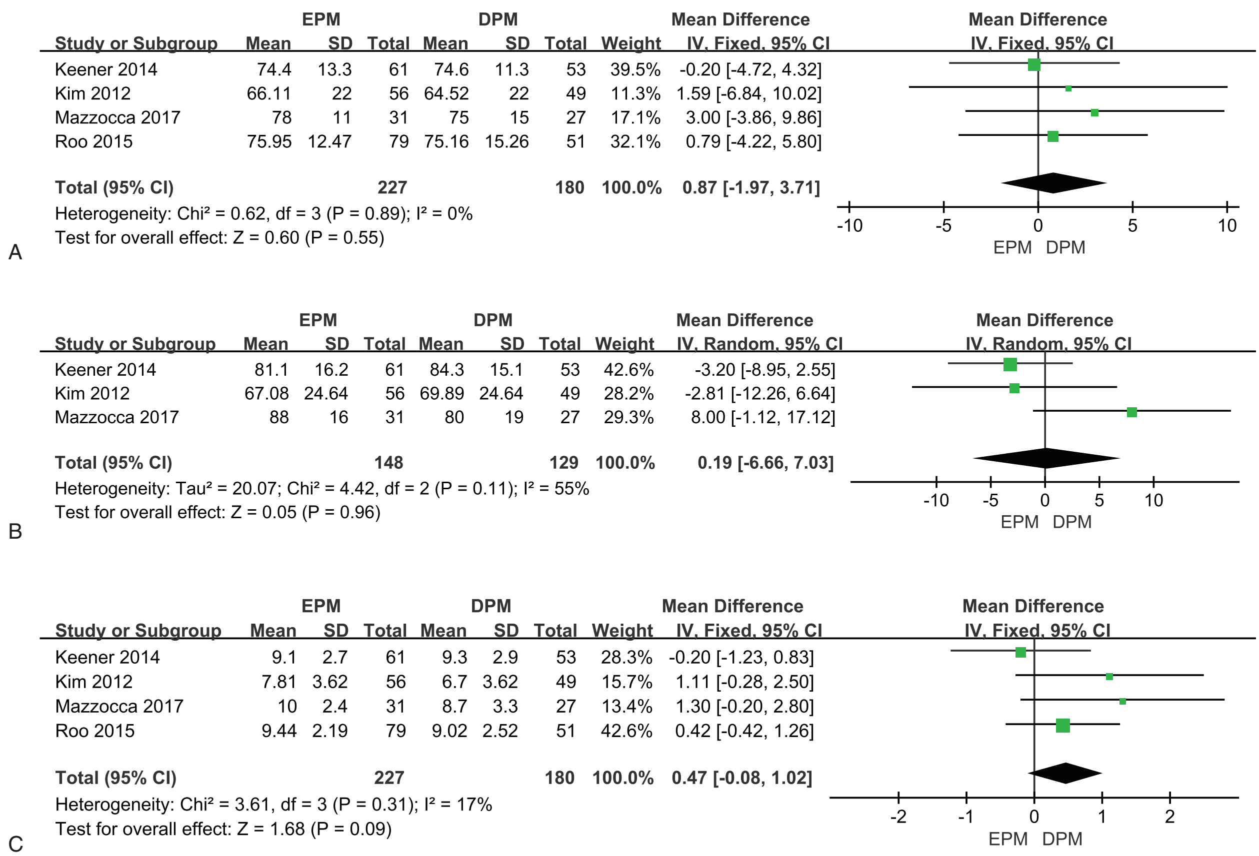


Figure 7. (A) A forest plot diagram showing Constant score at medium after surgery. (B) A forest plot diagram showing ASES score at medium after surgery. (C) A forest plot diagram showing SST score at medium after surgery.

decreased ROM and increased joint stiffness. On the basis of largest number of available RCTs, our pooled analysis provided the most stable and reasonable evidence that the EPM protocol is beneficial in terms of FF and ER. However, unlike that for FF, the advantage of ER could not be extended to long-term follow-up. It was speculated that the inconsistent results between FF and ER were generated by the initial ROM limit given by the shoulder motion planes. To avoid excessive loading on the sutured supraspinatus tendons, the ER angle was restricted to 30° and the FF angle was allowed to be more than 90° in the EPM protocol of the most trials. The ROM difference between the 2 protocols in 3 difference periods showed a downward trend at 1 year postoperatively regardless of the FF and ER. In addition, a previous retrospective cohort study suggested that the DPM protocol would not lead to long-term stiffness.[33] Evaluation of the permanent ROM defects in the DPM protocol was not performed because majority of the data in the long-term follow-up were extracted at 1 year postoperatively. Thus, further RCTs need to assess and compare the outcomes of the 2 rehabilitation protocols at longer-term follow-up.

As far as we know, the possibility that EPM reduced the probability of tendon healing has been the principal focus of the debate. On the basis of the currently available evidence, the present meta-analysis showed that the EPM and DPM rehabilitation protocols led to statistically equivalent tendon healing at long-term follow-up ($P=0.16$). Consequent sensitivity analysis also revealed no statistically significant difference in tendon healing of the rotator cuff between the 2 protocols ($P=.06$) after excluding 2 studies[24,25] that only enrolled patients with small and medium-sized rotator cuff tears. However, the factors associated with rotator cuff healing include tear size, surgical techniques, patient's age, tendon quality and number, and fatty muscle degeneration and atrophy. The diversity of factors in our included trials tended to mitigate the statistical significance of the tendon healing. Therefore, after excluding the study of Keener et al[24] and Kim et al,[25] which examined only small- and medium-sized tears, the pooled results of healing rate decreased from 82.4% to 76.6% in the EPM group and 86.9% to 85.9% in the DPM group. Our discovery might indicate that the large-sized tears (3–5 cm) might benefit from delayed motion. Thus, it was warranted that the comparison of outcomes in the 2 protocols be focused on larger tear size in future research.

A previous study[24] indicated that most functional scores were at the plateau after 6 to 12 months postoperatively. Our analysis revealed that there was no statistically significant difference in shoulder function outcomes between the 2 protocols, with the exception of the long-term ASES score, which was higher in the DPM protocol. The ASES score includes pain assessment, instability scales, and daily-life questionnaires.[34] It has been validated and widely used for the evaluation of shoulder function after arthroscopic rotator cuff repair. According to our comprehensive and detailed analysis, the quality of evidence of the long-term ASES score was moderate, which represented a relatively credible level. In contrast, the quality of evidence for the

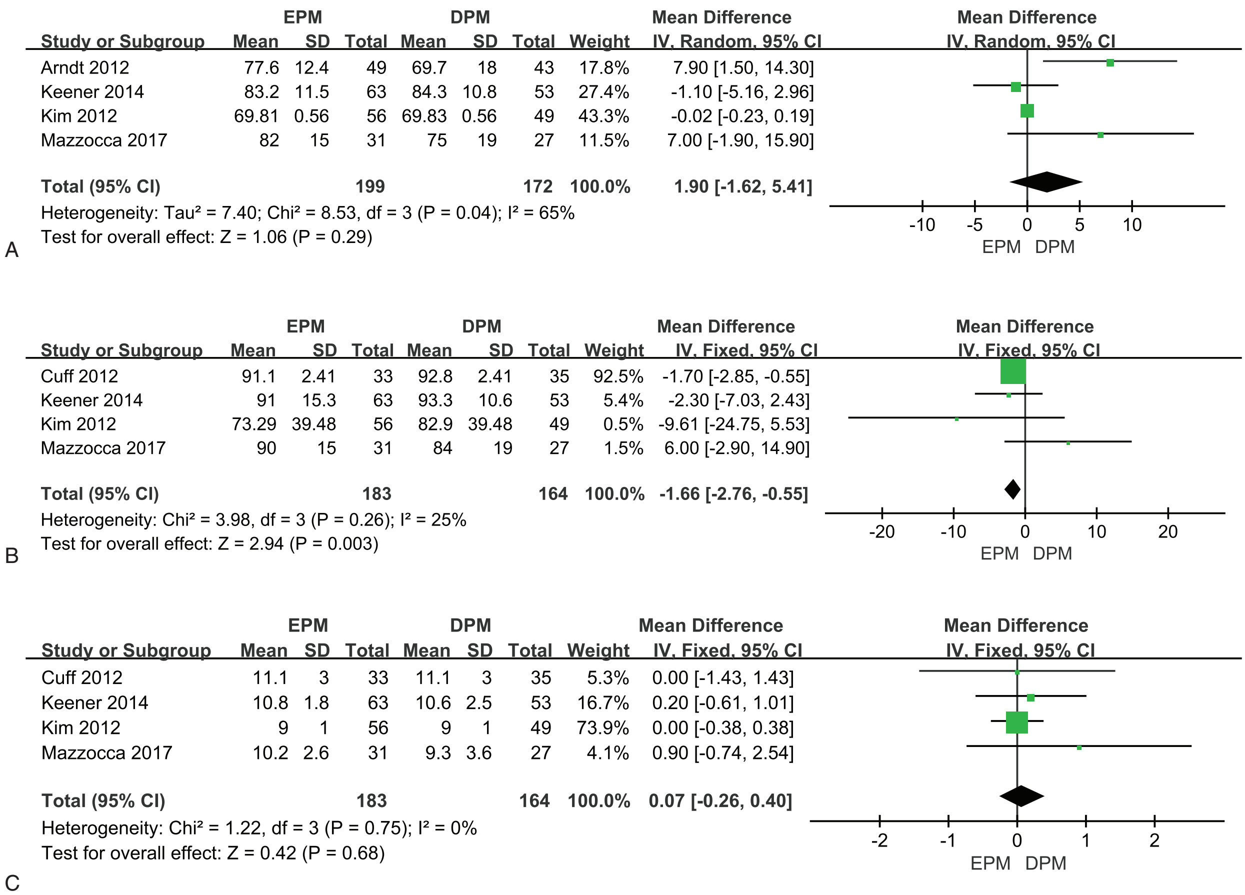


Figure 8. (A) A forest plot diagram showing Constant score at long term after surgery. (B) A forest plot diagram showing ASES score at long term after surgery. (C) A forest plot diagram showing SST score at long term after surgery.

Table 2

Quality of the evidence.

Outcomes	No. of participants (studies) follow-up	Quality of the evidence (GRADE)	Anticipated absolute effects
Short-term FF	470 (6 studies) 3 mo	LOW [*,†,‡,§,||] due to risk of bias, large effect, inconsistency, imprecision	MD 10.31 higher (5.02–15.61 higher)
Mid-term FF	671 (8 studies) 4–6 mo	LOW [*,†,‡,§,||,¶] due to risk of bias, large effect, inconsistency, imprecision	MD 3.01 higher (0.31–5.72 higher)
Long-term FF	503 (6 studies) 12–24 mo	MODERATE[*,†,‡,||,¶] due to risk of bias, large effect, imprecision	MD 1.24 higher (0.25–2.23 higher)
Short-term ER	415 (5 studies) 3 mo	MODERATE[*,†,‡,||] due to risk of bias, large effect, imprecision	MD 10.22 higher (6.46–13.98 higher)
Mid-term ER	671 (8 studies) 4–6 mo	LOW [*,†,‡,§,||,¶] due to risk of bias, large effect, inconsistency, imprecision	MD 2.00 higher (0.94–3.05 higher)
Long-term ER	503 (6 studies) 12–24 mo	VERY LOW[*,†,§,||,¶] due to risk of bias, inconsistency, imprecision	MD 2.24 higher (2.72 lower to 7.19 higher)
Mid-term Constant score	407 (4 studies) 4–6 mo	LOW[†,||,¶] due to risk of bias, imprecision	MD 0.87 higher (1.97 lower to 3.71 higher)
Long-term Constant score	371 (4 studies) 12–24 mo	VERY LOW[*,†,§,||,¶] due to risk of bias, inconsistency, imprecision	MD 1.90 higher (1.62 lower to 5.41 higher)
Mid-term ASES score	277 (3 studies) 6 mo	VERY LOW [†,§,||,#] due to risk of bias, inconsistency, imprecision	MD 0.19 higher (6.66 lower to 7.03 higher)
Long-term ASES score	347 (4 studies) 12–24 mo	MODERATE[†,‡,||,¶] due to risk of bias, large effect, imprecision	MD 1.66 lower (2.76 to 0.55 lower)
Mid-term SST score	407 (4 studies) 4–6 mo	LOW [†,||,¶] due to risk of bias, imprecision	MD 0.47 higher (0.08 lower to 1.02 higher)
Long-term SST score	347 (4 studies) 12–24 mo	LOW [†,||,¶] due to risk of bias, imprecision	MD 0.07 higher (0.26 lower to 0.40 higher)
Healing rate	493 (6 studies) 6–24 mo	LOW[*,†,¶] due to risk of bias, imprecision	RR 0.95 (0.88–1.02)

ER = external rotation, FF = forward flexion, MD = mean difference, RR = risk ratio.

[*] No details of randomization.

[†] No concealment.

[‡] Effect is really stable.

[§] Result is inconsistent.

[||] Indirect data.

[¶] Inconsistent follow-up time point.

[#] Limited sample size.

Constant and SST scores was low or very low. Therefore, our findings implied that the EPM protocol might adversely affect the shoulder function compared with the delay protocol.

There are some limitations in the current systematic review and meta-analysis: First, although the present study included the largest number of RCTs, the number of trials was still relatively small, and more large-scale prospective studies were needed to produce more convincing conclusions. Second, there was no high quality of evidence in all outcomes of our study. Most of the included studies provided only Level II data due to incomplete or inaccurate protocol reports or due to small sample size. The most common defect in these studies was that outcome assessors were not blinded to rehabilitation protocol. Inconsistencies in the observation time for some of the outcomes could have a negative influence on the reliability of results. Third, the standard deviation is not provided in some included studies, so we had to calculate them with the guideline of the Cochrane Handbook for Systematic Reviews of Interventions 5.1.0.[22] Fourth, publication bias is unavoidable because only English trials were included.

5. Conclusion

On the basis of the largest number of available RCTs, the meta-analysis suggests that the EPM protocol results in superior ROM recovery after arthroscopic rotator cuff repair but may adversely affect the shoulder function, which should be supported by further research. The healing rate at long-term follow-up is not clearly affected by the type of rehabilitation, but the EPM protocol might result in lower rates of tendon healing in the shoulder with large-sized tendon tears.

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