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CLINICAL FEATURE
REVIEW

Early versus delayed rehabilitation following arthroscopic rotator cuff repair: A systematic review

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Abstract

Background. Early passive range of motion (ROM) following arthroscopic cuff repair is thought to decrease postoperative stiffness and improve functionality. However, early aggressive rehabilitation may compromise repair integrity. Our purpose was to perform a systematic review to determine if there are differences between early and delayed rehabilitation after arthroscopic rotator cuff repair in terms of clinical outcomes and healing. *Methods*. We performed a literature search with the terms 'arthroscopic rotator cuff', 'immobilization', 'early', 'delayed', 'late', and 'rehabilitation' using PubMed, Cochrane Central Register of Controlled Trials, and EMBASE. Selection criteria included: level I/II evidence ≤ 6 months in duration, comparing early versus delayed rehabilitation following arthroscopic repair. Data regarding demographics, sample sizes, duration, cuff pathology, surgery, rehabilitation, functional outcomes, pain, ROM and anatomic assessment of healing were analyzed. PRIMSA criteria were followed. *Results*. We identified six articles matching our criteria. Three reported significantly increased functional scores within the first 3–6 months with early rehabilitation compared to the delayed group, only one of which continued to observe a difference at a final follow-up of 15 months. Four articles showed improved ROM in the first 3–6 months post-operatively with early rehabilitation. One noted transient differences in pain scores. Only one study noted significant differences in ROM at final follow-up. No study reported any significant difference in rates of rotator cuff re-tear. However, two studies noted a trend towards increased re-tear with early rehabilitation that did not reach significance. This was more pronounced in studies including medium-large tears. *Conclusions*. Early rehabilitation after arthroscopic cuff repair is associated with some initial improvements in ROM and function. Ultimately, similar clinical and anatomical outcomes between groups existed at 1 year. While there was no significant difference between groups in anatomic failure of the repaired cuff, there may be a trend towards increased re-tear with larger tears.

Keywords

Rehabilitation, rotator cuff, shoulder, surgery

History

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Introduction

Surgery for rotator cuff tears are among the most widely performed orthopedic surgeries [1]. Procedures have evolved from an open approach to a primarily arthroscopic repair. Due to its minimally invasive nature and increased patient satisfaction, arthroscopic repair has become the preferred method among most surgeons [2]. It has been associated with decreased frequencies of complications, including deltoid injury, scarring, adhesions, pain and stiffness [3]. Despite its successes, arthroscopic repair still suffers from a historic average re-tear rate of between 20 and 90%, depending on tear severity and repair technique. However, more recent studies have shown improvement [4-8]. Due to this high rate, significant research has examined various factors influencing failure of the repair, including fixation strength compared to open techniques and differences between using a single- or double-row approach [3].

Recently, increased emphasis has been placed on post-operative influences of rehabilitation techniques on healing [4,5]. Of particular interest has been the timing of patients' rehabilitation programs, including the initiation of early motion and strengthening [9]. The traditional consensus of early passive range of motion (ROM) has been predicated on a decreased risk of stiffness and earlier functional return to activity [10]. This notion has been challenged by some who argue that this may place excessive stress on an insufficiently healed repair, potentially predisposing it to a greater risk of anatomic failure [11]. Delayed rehabilitation with a protracted course of immobilization may allow for increased healing,

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which has been shown to take up to 4 months in animal models [12-14]. Since most re-tears occur within 3 and 6 months of surgery, the rationale behind delayed rehabilitation is to protect the patient during a period of increased vulnerability [5,15,16]. The major risk associated with delaying rehabilitation is the potential for the extended early period of immobilization to lead to greater shoulder stiffness [10,17]. However, since arthroscopic repair may have a lower predisposition towards stiffness, early ROM protocols may be less important for ultimate outcome following repair.

There has been considerable debate whether early or delayed rehabilitation provides the greatest outcomes for patients undergoing arthroscopic rotator cuff repair [4,9,18]. We believe that it is important to identify a program that will most effectively promote tendon healing while providing the patient with the greatest level of functionality and decreased stiffness. We performed a systematic review of the literature of levels I and II evidence directly comparing early versus delayed rehabilitation following arthroscopic rotator cuff repair. We specifically sought to compare functional outcomes, pain, ROM, and re-tear rates for early rehabilitation versus delayed rehabilitation following arthroscopic rotator cuff repair.

Methods

Identification of studies

Our aim was to identify all prospective studies investigating the difference in clinical outcomes between early rehabilitation with passive ROM (PROM) versus delayed rehabilitation with immobilization after arthroscopic rotator cuff repair. We performed a literature search of English language articles using PubMed, Cochrane Central Registrar of Controlled Trials and EMEDBASE from their respective inceptions through January 2014. Our search was conducted using the terms 'arthroscopic rotator cuff', 'immobilization', 'early', 'delayed', 'late', and 'rehabilitation'. All references from selected studies were reviewed to identify any additional papers that may have been overlooked or were not indexed in the electronic databases.

Selection criteria included: studies of level I and II evidence, with at least 6 months of clinical follow-up, directly comparing early versus delayed rehabilitation, using clinical and radiographic measures to quantify healing.

Excluded studies included level III and lower evidence, review articles, studies less than 6 months duration, biomechanical studies and studies that did not directly compare early and delayed rehabilitation.

Outcome measures

Functional outcome measures included the Constant shoulder score, Simple shoulder test (SST), American Shoulder and Elbow Surgeons (ASES) score and Disabilities of the Arm Shoulder and Hand (DASH) questionnaire. Anatomic outcomes were assessed by evaluating rotator cuff healing and rates of failure between groups using computed tomography (CT), magnetic resonance imaging (MRI) or ultrasound (US). A full re-tear was defined broadly as a lack of maintenance of rotator cuff insertion into the footprint, discontinuity or tendon rupture [4,5,19-22].

Data extraction

Data was collected according to a predetermined form. Information collected for each study included: demographic characteristics, sample sizes, length of follow-up, extent of injury prior to surgery, repair technique, size of tear, rehabilitation protocols, pain scores, functional outcome measures used (ASES, Constant, SST, University of California Los Angeles [UCLA], DASH), ROM scores, and radiographic assessment of healing (MRI, US, CT). Mean, standard deviation and 95% confidence interval data were extracted.

Analysis of bias

Bias was assessed within studies by evaluating the presence of several methodological sources, including adequate sequence generation, allocation concealment, blinding, presence of incomplete outcome data reporting and presence of selective reporting. Additionally, we noted any other potential sources of bias not directly addressed by the above criteria, including differences between surgical procedure and tear pathology, statistical power and number of surgeons without compensatory randomization.

Data synthesis

Data was ordered by early versus delayed rehabilitation and organized in order to make comparisons and draw conclusions of protocol efficacy when possible. To draw positive conclusions we looked for clear, consistent and replicated evidence from high quality studies of an association between a treatment and a change in either primary or secondary outcome measures. Due to differences among surgery, rehabilitation protocols and outcome variables measured, the data was not pooled in the form of a meta-analysis, but was summarized in systematic review format. Preferred reporting items for systematic reviews and Meta-Analyses guidelines were followed throughout the composition of this systematic review [23].

Results

Article selection

Initial literature searches yielded 1535 references. Nine were selected based on title for further investigation. From those, we identified six articles that fulfilled our criteria for inclusion (Figure 1). Reasons for exclusion included a review article, a biomechanical study and a study not directly comparing early versus delayed rehabilitation.

Characteristics are summarized in Table 1. All studies were prospective in nature. Average follow-up among studies was 16.8 months and included on average 80 patients. Rehabilitation protocols are summarized in Table 2. The early rehabilitation protocols in general called for the use of a sling and PROM exercises during the first 6 weeks before

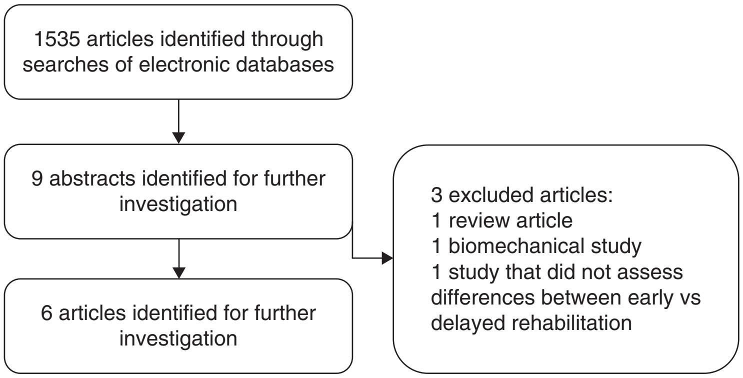

Figure 1. Flowchart diagramming inclusion and exclusion of identified studies.

progressing to active ROM exercises and discontinuation of the shoulder sling. Delayed rehabilitation protocols were characterized by the use of a sling for 6 weeks and either no PROM or very limited exercises such as pendulum circumduction. Two studies, Kim et al. [4] and Keener et al. [5] included only small (< 1 cm) to medium (1–3 cm) full-thickness tears. Of the remaining studies, Lee et al. [20], and Duzgun et al. [19] included medium and large (+3 cm) tears. Arndt et al. included partial and full-thickness tears. Cuff and Pupello [21] included only full-thickness tears without defining the size of the tear.

Functional outcome measures

Five outcome metrics were reported, including the Constant shoulder score, ASES, SST, UCLA and DASH score. Results are summarized in Table 3.

Three studies, Kim et al. [4], Arndt et al. [22] and Keener et al. [5] assessed changes in performance using the Constant shoulder score. Only Arndt et al. [22] noted a difference between protocols at any time point. They noted significantly increased Constant scores in the early rehabilitation group, 77.6 (12.4) versus 69.7 (18), at final follow-up at 16 months, $p < 0.05$ (Table 3) [22].

Kim et al. [4], Cuff and Pupello. [21] and Keener et al. [5] assessed functional changes using the ASES and SST scores. None reported a difference at any time point. Duzgan et al. [19], using the DASH score, found significantly better scores in the early rehabilitation group compared to the delayed rehabilitation group at 8, 12 and 16 weeks (Table 3). However, this difference resolved by 24 weeks ($p > 0.05$) [19]. Lee et al. [20] observed a significantly different UCLA score at 3 months, 29.4 in the early rehabilitation group versus 26.5 in the delayed rehabilitation group ($p = 0.009$). This difference equalized by the 6th month, becoming insignificant ($p = 0.158$). At final follow-up, there was no significant difference ($p = 0.341$) [20].

Pain measures

Four studies, Kim et al., [4], Lee et al. [20], Keener et al. [5] and Duzgan et al. [19] reported pain scores experienced throughout rehabilitation using the Visual Analog Scale (VAS). Only Duzgan et al. [19] reported any difference in pain between the two protocols. At week 5, VAS scores during activity in the early rehabilitation group were 2.32 (2.04) versus 4.67 (2.2) in the delayed rehabilitation group ($p > 0.05$). At rest, the early rehabilitation group reported a score of 0.98 (1.57) compared to 2.83 (2.56) in the delayed rehabilitation group ($p < 0.05$). There was a significant difference in pain scores with activity again in week 16. Those in the early rehabilitation group scored 0.32 (0.86) compared to 2.86 (2.65) in the delayed rehabilitation group ($p < 0.05$) [19]. The remaining three studies only reported a single VAS score for each time point, none of which were significant for differences between protocols. All other time points in the Duzgan et al. [19] trial and in the other three studies that evaluated pain demonstrated no difference between rehabilitation protocols ($p > 0.05$).

ROM measures

ROM measurements at varying points of recovery were recorded by five studies and are documented in Table 4. All study populations showed similar ROM between protocols pre-operatively when reported. All studies with the exception of Kim et al. observed at least one dimension of increased ROM in the early rehabilitation group compared to the delayed rehabilitation group within the first 3–6 months. Only one, Arndt et al. reported any significant difference in any ROM measure between protocols beyond 12 months [22]. The remaining three studies by Keener et al. [5], Cuff and Pupello [21] and Lee et al. [20] only reported differences within the first 3–6 months that eventually normalized before final follow-up (Table 4). Kim et al. reported no significant differences in any parameter of ROM at any time points (Table 4) [4].

Anatomic outcomes

None of the five studies reporting anatomic outcomes observed any significant differences between early rehabilitation and delayed rehabilitation protocols (Table 5). Tear size, surgical procedure, follow-up, radiological assessment measures and outcomes are summarized in Table 5. Studies assessed for the incidence of a full re-tear using CT, US or MRI (Table 5). Two studies, Lee et al. [20], who included medium and large full-thickness tears, and Arndt et al. [22], who included partial and

Table 1. Characteristics of the included studies.

Study	Study design	Level of evidence	Patients	Males/ females	Average age	Follow-up (months)	Tear size	Repair	Number of surgeons	Pain outcome	Functional outcome
Kim et al. [4]	Prospective	I	105	44/61	55.27	12	Small (< 1 cm) to medium (1–3 cm) Full thickness	Single or double row	2	VAS	Constant, SST, ASES
Lee et al. [20]	Prospective	II	64	41/23	54.5	25	Medium (1–3 cm) to large (3–5 cm) Full thickness	Single row	1	VAS	UCLA
Duzgan et al. [19]	Prospective	II	29	NR	56.28	6	Medium (1–3 cm) to large (3–5 cm) Full thickness	Single row	NR	VAS	DASH
Arndt et al. [22]	Prospective	I	100	34/58	55.3	16	Partial and full thickness	Single and double row	5	NR	Constant
Cuff and Pupello [21]	Prospective	I	68	38/30	63.2	12	Full thickness	Suture bridge	NR	NR	ASES, SST
Keener et al. [5]	Prospective	I	114	NR	60.6	30	Small (< 1 cm) to medium (1–3 cm) Full thickness	Modified double row	NR	VAS	Constant, SST, ASES

Abbreviations: ASES = American shoulder and elbow surgeons; DASH = Disabilities of the arm and shoulder; NR = Not reported; SST = Simple shoulder test; VAS = Visual analog scale.

full-thickness tears, did note a trend towards greater risk of re-tear in the early rehabilitation group compared to the delayed group, $p = 0.106$ and $p = 0.269$, respectively. No other study reported any significant difference or trend towards increased re-tear between either protocol group [4,18,20].

Bias assessment

Results of our bias assessment are summarized in Table 6. All studies were limited primarily by an inability to adequately blind individuals and healthcare professionals. Kim et al. [4], Arndt et al. [22], Duzgan et al. [19] and Lee et al. [20] were unclear in demonstrating proper randomization. Cuff and Pupello [21] and Duzgan et al. [19] did not adequately address incomplete outcome data. Kim et al. [4] and Arndt et al. [22] were restricted by the use of multiple surgeons, two and five respectively, without addressing if adequate randomization compensated for any potential discrepancies between surgeons. Furthermore, surgeries performed in the Arndt et al. study included individuals with partial tears and those simultaneously undergoing biceps tenotomy, tenodesis and acromioplasty. Cuff and Pupello [21], Duzgan et al. [19], Keener et al. [5] and Lee et al. [20] suffered from small sample sizes and insufficient power to detect differences in anatomic failure between groups. Additionally, Lee et al. was limited by the use of a non-parametric analysis [20].

Discussion

Delayed rehabilitation following arthroscopic rotator cuff repair has been favored recently due to the potential for increased healing rates and decreased incidence of re-tear. However, it has been proposed that delaying ROM exercises may ultimately lead to greater joint stiffness and decreased functional outcomes [10]. Currently, there are only a few prospective studies comparing patient outcomes. This systematic review compares the outcomes of early versus delayed rehabilitation in arthroscopic rotator cuff repair. In this study, we have concluded that there is no difference in rates of re-tear between early and delayed rehabilitation. Additionally, we noted a trend towards improved functional and ROM measures, with early rehabilitation focusing primarily on PROM. These differences, however, appear to be only transient and most differences normalize between protocols within the first year following surgery.

Three studies reported a difference in functional score at any point during follow-up. In two of those studies, Lee et al. [20] and Duzgan et al. [19], the difference was only significant within the first 6 months, after which point functional scores between groups became insignificant. Only Ardnt et al. observed a difference in functional score at final follow-up (16 months) [22]. Pain measures were not significantly different between rehabilitation groups. Only one study, Duzgan et al., observed any difference in pain between protocols, which can only be described as a small, transient difference in favor of an early rehabilitation program [19]. We concluded that this represents, at best, a trend towards

Table 2. Summary of rehabilitation protocols for the early rehabilitation and delayed rehabilitation groups among studies.

Study	Early rehabilitation	Delayed rehabilitation
Kim et al. [4]	Early PROM exercises 3–4 times/day for 4–5 weeks during bracing, Active assisted ROM after brace period, Strengthening exercises beginning at 9 weeks	No passive ROM for 4–5 weeks of brace period
Lee et al. [20]	Manual PROM exercises 2 times/day × 6 weeks during brace period, Unlimited stretching × 6 weeks during brace period, Active ROM after 6 week brace period	Limited early passive ROM × 6 weeks during bracing period, Increase to active ROM at 6 weeks
Duzgan et al. [19]	Early PROM exercises 4 times/day for first 2 weeks, Begin strengthening exercises at 3rd week, Removal of brace at 6 weeks, Active ROM and strengthening at 4–6 weeks finished at 8 weeks	Passive ROM at 1 week, Active ROM at 6 weeks, Removal of brace at 6 weeks, Completion at 22 weeks
Arndt et al. [22]	Immediate passive ROM exercises 3–5 times/week-× 6 weeks, Removal of brace at 6 weeks, Active ROM after 6 weeks, strengthening after 4 months	Only pendulum exercises allowed during brace period of 6 weeks Active ROM after 6 weeks, strengthening after 4 months
Cuff and Pupello [21]	Immediate passive ROM 3 times/week for 6 weeks, Removal of brace after 6 weeks and active ROM, Full active ROM at 10 weeks, strengthening at 12 weeks	Bracing and pendulum exercises for 6 weeks, Limited passive ROM and active assisted ROM at 7 weeks, Full active ROM at 10 weeks, strengthening at 12 weeks
Keener et al. [5]	Immediate pendulum and PROM exercises during 6 week bracing, Active ROM during weeks 6–12, strengthening at month 3–4, Resume full activity by 4–6 months	Immobilization for first 6 weeks, Supervised PROM from weeks 6–12, AROM beginning at 3–4 months, strengthening at 3–4 months

Abbreviations: AROM = Active range of motion; PROM = Passive range of motion.

better functional outcomes with early rehabilitation that may or may not be clinically significant.

Not surprisingly, allocation to the early rehabilitation group was associated with improved initial ROM measures compared to a delayed program. Four of the five studies investigating ROM measures reported at least one significantly improved parameter of improved motion in the early rehabilitation group compared to the delayed group [4,5,20-22]. Importantly, once the delayed rehabilitation group had a chance to advance ROM through a course of physical therapy, these differences equilibrated in all studies except for external rotation at final follow-up in Arndt et al. [22]. We concluded that early rehabilitation focusing on PROM is correlated with increased initial ROM compared to delayed rehabilitation. Ultimately, these differences seem to resolve with further follow-up. Since almost all studies showed an equivalent ROM between protocols, we determined that there is minimal, if any, increased stiffness associated with delayed rehabilitation.

Overall, the rates of re-tear 6–23% reported in this study are lower than historical rates present in the literature of 20–90% [6-8]. This may be in part due to the inclusion of only small-to-medium tears in two studies and partial tears in Arndt et al. [4,5,22]. Additionally, average final follow-up was 12 months. It is possible that the reported rate of re-tear may not represent the ultimate incidence of re-tear after arthroscopic repair.

We concluded that there was no significant difference in rotator cuff healing between the early and delayed rehabilitation protocols. Prior studies have indicated that there may be a trend towards higher failure rates with an accelerated program [24]. Lee et al. [20] and Arndt et al. [22],in particular, reported results that approached, but did not reach significance. Differences may be, in part, due to several factors. Both tear size and surgical procedure may affect failure rates in addition to rehabilitation protocol. Larger tears and a single-row technique have been linked with potentially increased failure rates [2,3]. Lee et al. [20] operated on medium and large tears with a single-row technique, possibly predisposing those allocated to the early rehabilitation group to increased failure rates. Arndt et al. [22] also noted a trend towards incomplete healing in the early rehabilitation group. However, they included partial in addition to full-thickness tears in their analysis, making comparisons between studies more difficult. Additionally, surgery was performed by five different surgeons with unclear randomization between groups while additional procedures, including biceps tenotomy, tenodesis and acromioplasty, were carried out simultaneously in some cases [22]. Kim et al. [4], Keener et al. [5] and Cuff and Pupello [21] reported no anatomic differences between groups. However, Keener et al. [5] and Cuff and Pupello [21] did not possess sufficient power to detect differences between protocols, possibly predisposing it to finding a lack of significance. Surgeries in the Kim et al. [4] study were performed by two surgeons and randomization was not sufficient to correct for any potential variation in surgeons between groups. Due to confounding factors among studies, we found it difficult to conclusively determine if early rehabilitation is linked to increased rates of failure.

When studies are further stratified by tear severity, the trend towards re-tear becomes slightly more prominent. Of the two studies that included large full-thickness tears, one reported a trend towards increased failure, while the other did

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Table 3. Functional outcomes reported throughout rehabilitation.

Study	Final Follow-Up (months)	Pre-operative		3 months		6 months		12 months		Final Follow-Up after 12 Months	
		Early rehab (SD)	Delayed rehab (SD)	Early rehab (SD)	Delayed rehab (SD)	Early rehab (SD)	Delayed rehab (SD)	Early rehab (SD)	Delayed rehab (SD)	Early rehab (SD)	Delayed rehab (SD)
Constant Shoulder Score											
Kim et al. [4]	12	53.7 (15.1)	49.9 (14.5)	63.2 (11.4)	63.3 (13.0)	66.1 (10.9)	64.5 (13.0)	69.8 (7.6)	69.8 (13.8)	NR	NR
Arndt et al. [22]	16	46.1 (12.0)	46.1 (12.0)	NR	NR	NR	NR	NR	NR	77.6 (12.4)[a]	69.7 (18)[a]
Keener et al. [5]	30	NR	NR	NR	NR	74.4 (13.3)	74.6 (11.3)	79.1 (10.0)	79.9 (12.3)	83.2 (11.5)	84.3 (10.8)
ASES Score											
Kim et al. [4]	12	48.4 (20.6)	46.3 (18.3)	65.2 (20.0)	64.7 (21.7)	67.1 (20.5)	69.9 (20.6)	73.3 (57.42)	82.9 (28.3)	NR	NR
Cuff and Pupello [21]	12	43.9	41	NR	NR	NR	NR	91.1	92.8	NR	NR
Keener et al. [5]	30	NR	NR	NR	NR	81.1 (16.2)	84.3 (15.1)	88.1 (15.8)	84.3 (15.1)	NR	NR
SST Score											
Kim et al. [4]	12	4.1 (3.9)	3.5 (3.4)	6.34 (3.8)	6.05 (4.0)	7.81 (3.2)	6.70 (3.6)	9.0 (5.7)	9.0 (4.8)	NR	NR
Cuff and Pupello [21]	12	5.5	5.1	NR	NR	NR	NR	11.1	11.1	NR	NR
Keener et al. [5]	30	NR	NR	NR	NR	9.1 (2.7)	9.3 (2.9)	10.3 (2.3)	10.0 (3.1)	10.8 (1.8)	10.6 (2.5)
UCLA Score											
Lee et al. [20]	25	15.7	16	29.4[a]	26.5[a]	NS	NS	NS	NS	32.3	31.8
		8 weeks		12 weeks		16 weeks		24 weeks			
DASH Score											
Duzgan et al. [19]	6	31.6 (21.7)[a]	53.8 (13.3) [a]	22.7 (17.8) [a]	35.4 (17.8)[a]	15.9 (15.3)[a]	31.4 (20.5)[a]	NS	NS		

Measures included the Constant Shoulder Score, ASES, SST, UCLA and DASH score.

[a]Indicates a statistically significant difference, $p < 0.05$.

Abbreviations: ASES = American Shoulder and Elbow Surgeon; DASH = Disabilities of the Arm Shoulder and Hand; NR = Not reported, NS = Not significant, numbers not reported; SD = Standard deviation; SST = Simple shoulder test.

Table 4. Range of motion recorded throughout rehabilitation between protocols.

		Pre-operative		3 Months		6 Months		12 Months		Final follow-up after 1 Year	
Study	Final Follow-up (months)	Early rehab (SD) [degrees]	Delayed (SD) [degrees]	Early rehab (SD) [degrees]	Delayed (SD) [degrees]	Early rehab (SD) [degrees]	Delayed (SD) [degrees]	Early rehab (SD) [degrees]	Delayed (SD) [degrees]	Early rehab (SD) [degrees]	Delayed (SD) [degrees]
Flexion											
Kim et al. [4]	12	144.7 (34.0)	144.8 (31.8)	144.9 (18.3)	140.0 (24.1)	150.6 (34.0)	147.1 (21.7)	159.8 (31.7)	153.7 (24.1)	NR	NR
Lee et al. [20]	25	149.0 (16.6)	151.9 (12.6)	149.7 (12.7)[a]	133.8 (27.4)[a]	157.3 (11.4)	151.9 (18.2)	155.3 (13.0)	153.0 (12.2)	NR	NR
Arndt et al. [22]	16	174.9 (9.4)	170.5 (12.9)	142.1 (28.2)[a]	112.9 (37.6)[a]	158.4 (22.9)[a]	146.4 (30.0)[a]	171.9 (13.6)	161.9 (26.2)	172.4 (13)	163 (25.1)
Cuff and Pupello [21]	12	158	160	NR	NR	NR	NR	NR	NR	NR	NR
Keener et al. [5]	30	NR	NR	136 (23.6)[a]	123 (30.6)[a]	155 (18.1)	154 (17.8)	161 (13.4)	159 (22.8)	164 (13.4)	163 (15.8)
External Rotation											
Kim et al. [4]	12	67.3 (26.7)	69.8 (26.2)	71.2 (29.6)	66.3 (25.5)	77.2 (20.6)	72.9 (30.5)	78.5 (26.4)	81.3 (37.5)	NR	NR
Lee et al. [20]	25	49.8 (14.5)	52.8 (13.6)	44.2 (14.6)[a]	34.1 (19.2)[a]	50.3 (11.2)[a]	41.6 (14.9)[a]	53.0 (11.6)	48.1 (13.9)	NR	NR
Arndt et al. [22]	16	58.4 (12.5)	57.2 (13.9)	45.6 (14.9)[a]	27.5 (19.4)[a]	54.3 (12.5)[a]	44.3 (19.4)[a]	58.1 (13.2)[a]	48.3 (18.2)[a]	58.7 (12.9)[a]	49.1 (18)[a]
Cuff and Pupello [21]	12	44	42	NR	NR	44	43	46	45	NR	NR
Keener et al. [5]	30	NR	NR	47.0 (18.5)[a]	40.1 (18.8)[a]	61.6 (17.8)	63.9 (15.1)	64.1 (15.2)	67.3 (15.9)	62.0 (16.4)	66.2 (14.0)
External rotation at 90° abduction											
Lee et al. [20]	25	74.2 (9.10)	78.1 (12.5)	70.5 (14.0)*	54.0 (24.5)*	74.0 (11.0)	67.8 (18.1)	76.3 (12.1)	77.7 (11.6)	NR	NR
Keener et al. [5]	30	NR	NR	NR	NR	80.0 (14.1)	81.3 (13.0)	84.7 (13.9)	88.6 (11.9)	90.0 (10.3)	87.7 (11.9)
Internal rotation											
Kim et al. [4]	12	9.7 (4.2)	9.2 (3.9)	7.6 (4.6)	8.4 (3.9)	9.0 (3.1)	10.1 (3.9)	10.0 (3.4)	9.9 (5.4)	NR	NR
Keener et al. [5]	30	NR	NR	NR	NR	80.0 (14.1)	81.3 (13.0)	84.7 (13.9)	88.6 (11.9)	90.0 (10.3)	87.7 (11.9)
Internal rotation at 90° abduction											
Lee et al. [20]	25	57.8 (16.4)	51.3 (26.3)	59.0 (17.9)[a]	38.5 (24.1)[a]	63.8 (14.3)[a]	47.3 (22.7)[a]	65.7 (13.3)	54.9 (21.5)	NR	NR
Cuff and Pupello [21]	12	NR	NR	NR	NR	79	60	94	91	NR	NR
Abduction											
Lee et al. [20]	25	158.8 (20.4)	162.1 (24.3)	161.5 (22.0)[a]	143.6 (35.7)[a]	165.3 (13.9)	154.4 (30.1)	167.8 (12.8)	161.8 (27.3)	NR	NR

[a]Indicates a statistically significant difference, $p < 0.05$.
Abbreviation: SD = Standard deviation.

Table 5. Comparison of anatomic outcomes between protocols among studies.

Study	Tear size	Repair technique	Number of surgeons	Radiological assessment	Radiological follow-up (months)	No re-tear early rehabilitation	No re-tear delayed rehabilitation	*p*-Value
Kim et al. [4]	Small (0–1 cm) and Medium (1–3 cm) Full thickness	Single or Double Row	2	CT or MRI	12 (minimum)	88%	82%	0.429
Lee et al. [20]	Medium (1–3 cm) and Large (3–5 cm) Full thickness	Single Row	1	MRI	7.6 (mean)	77%	91%	0.106
Arndt et al. [22]	Partial and full thickness	Single or Double Row	5	CT	14 (mean)	77%	85%	0.269
Cuff and Pupello [21]	Full thickness	Suture Bridge	NR	US	12.2 (mean)	85%	91%	0.470
Keener et al. [5]	Small (0–1 cm) and Medium (1–3 cm) Full thickness	Modified Double Row	NR	US	12 (minimum)	90%	94%	0.460

Abbreviations: CT = Computed tomography; MRI = Magnetic resonance imaging; NR = Not reported; US = Ultrasound.

Table 6. Bias analysis of the included studies.

Study	Adequate sequence generation	Allocation concealment	Adequate blinding	Addressed incomplete outcome data	Free of selective reporting	Other potential sources of bias
Kim et al. [4]	Unclear	No	No	Yes	Yes	Two different surgeons, inadequate randomization
Arndt et al. [22]	Unclear	No	No	No	Yes	Five surgeons who also performed additional procedures
Cuff and Pupello [21]	Yes	No	No	Unclear	Yes	Small sample size, insufficient power to detect differences
Duzgun et al. [19]	Unclear	No	No	Unclear	Yes	Small sample size, insufficient power to detect differences
Keener et al. [5]	Yes	No	No	Yes	Yes	Insufficient power
Lee et al. [20]	Unclear	No	No	Yes	Yes	Small sample size, non-parametric analysis

not possess significant power to conclude a difference [20-22]. Ultimately, the best course of rehabilitation for a particular patient may require risk stratification. The results from this study indicate that individuals with a small-to-medium tear are just as likely to experience a re-tear with either early or delayed rehabilitation. Those who have large, full-thickness tears may benefit from delayed rehabilitation to ensure healing, given the potential trend towards increased failure, which has been shown to confer no additional risk of shoulder stiffness.

Currently in our practice, we employ two different rehabilitation protocols following arthroscopic rotator cuff repair, depending on several factors. Patients with partial-thickness or small-to-medium full-thickness tears undergo an early ROM protocol. This protocol allows immediate PROM in formal physical therapy beginning the first week after surgery. We feel that the risk of anatomic failure is low, and the potential benefits of early ROM outweigh any risks. However, for patients with large or massive tears undergoing surgery, particularly those too large to be amenable to double-row fixation, we utilize a delayed rehabilitation protocol. This protocol provides immobilization for the first 4 weeks in a sling. Patients with large tears with double row fixation are allowed pendulum exercises only from post-operative week 2–4. Following this initial immobilization, a PROM protocol in physical therapy is utilized. In both protocols, a sling is used for the first 6 weeks for protection when not performing the ROM protocol above. A small abduction pillow is used for the first week in both protocols, and discontinued at the first post-operative visit at 7–10 days.

This study has several strengths. It included only level I and II studies and evaluated several major objective outcomes, including functional outcome, ROM, pain, and anatomic failures following repair. By conducting a systematic review, we were also able to stratify risks based on differing tear size.

Just recently a similar review was published addressing the question of early versus delayed rehabilitation. Riboh and Garrigues, using a pooled statistical analysis, concluded that early passive motion is associated with 15 degrees of additional flexion within the first 3 months and 5 degrees within 6–12 months [9]. They also noted that external rotation is improved within the first 3 months only by 10 degrees. Finally, they determined that re-tear rates are comparable between rehabilitation protocols at 1 year. While we observed similar trends, our review also discusses the differing impacts on functional scores and pain between protocols in an attempt to elucidate the clinical significance of improved early ROM. Additionally, by using a pooled statistical analysis, their results become skewed in favor of those studies with greater number of patients. In this case, it would tend to bias results towards studies including only small-to-medium tears (Kim et al. and Keener et al.) and a study that included partial tears and individuals undergoing additional procedures (Arndt et al.). Due to the small number of studies and methodological heterogeneity leading to a potential bias towards less severe pathology, we decided that the topic was better served by a systematic review rather than meta-analysis. This allows the reader to examine the best available data without the potential bias of a pooled analysis. While we agree that individuals with small tears are at a decreased risk for re-tear, we concluded that there may be a population of people with more extensive tears that may be at an increased risk for re-tear and may require a more conservative rehabilitation program.

This study was primarily limited by a lack of uniform, prospective trials comparing similar rehabilitation protocols. Variability in protocols, surgery, tear size and outcome measures made drawing definitive conclusions difficult and more susceptible to bias among studies. For these reasons, we elected to not provide any pooled statistical analysis. Bias within studies was also a major limitation. All studies suffered from an intrinsic inability to properly blind individuals and several suffered from inadequate randomization or insufficient incomplete outcome reporting. ROM measurements are an additional source of bias between studies. Kim et al. [4], Keener et al. [5], and Arndt et al. [22] assessed ROM using a goniometer but did not address if or how the measurement was standardized. Lee et al. [20] made no mention of measurement methodology. Cuff and Pupello [21] did attempt to standardize measurements using a video camera and three consistent independent observers. Finally, we did not assess the differing levels of patient satisfaction and return to work or sport that may or may not accompany an earlier return to functional activity. Ultimately, more uniform studies, sufficiently powered to detect differences in anatomic outcomes are required to draw more definitive conclusions. These should include individuals with small, medium and large full-thickness tears and stratify risks and outcomes based on tear severity.

In summary, we noted a trend towards better outcome scores and ROM in the early rehabilitation protocols compared to the delayed rehabilitation programs in the first 3–6 months after surgery, which equalized by final follow-up. Ultimately, there was not a higher rate of stiffness associated with delayed rehabilitation. We could not identify a significant difference in pain or rates of re-tear experienced between groups. However, differences among studies made drawing definitive conclusions difficult. We did, note a minor trend towards greater risk of re-tear in those studies that evaluated patients with larger full-thickness tears. Therefore, we recommend that a particular rehabilitation program should be tailored to the patient, particularly those with large to massive tears. Physicians should consider aggressive rehabilitation programs in individuals when there is a low risk of re-tear and potential for increased satisfaction and quality of life from increased early functionality and ROM. Individuals with larger tears or who are otherwise at greater risk for re-tear may benefit from a delayed rehabilitation protocol due to a potentially decreased risk of re-tear without an increase in ultimate stiffness.

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Declaration of interest

The authors have no relevant affiliations or financial involvement with any organization or entity with a financial interest in or financial conflict with the subject matter or materials discussed in the manuscript. This includes employment, consultancies, honoraria, stock ownership or options, expert testimony, grants or patents received or pending, or royalties.

References

[1] Tempelhof S, Rupp S, Seil R. Age-related prevalence of rotator cuff tears in asymptomatic shoulders. J Shoulder Elbow Surg 1999;8:296–9.

[2] 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;22:1–9.

[3] DeHaan AM, Axelrad TW, Kaye E, Silvestri L, Puskas B, Foster TE. Does double-row rotator cuff repair improve functional outcome of patients compared with single-row technique? A systematic review. Am J Sports Med 2012;40:1176–85.

[4] 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;40:815–21.

[5] 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;96:11–19.

[6] Tashjian RZ, Hollins AM, Kim HM, Teefey SA, Middleton WD, Steger-May K, et al. Factors affecting healing rates after arthroscopic double-row rotator cuff repair. Am J Sports Med 2010;38:2435–42.

[7] Slabaugh MA, Nho SJ, Grumet RC, Wilson JB, Seroyer ST, Frank RM, et al. Does the literature confirm superior clinical results in radiographically healed rotator cuffs after rotator cuff repair? Arthroscopy 2010;26:393–403.

[8] Galatz LM, Ball CM, Teefey SA, Middleton WD, Yamaguchi K. The outcome and repair integrity of completely arthroscopically repaired large and massive rotator cuff tears. J Bone Joint Surg Am 2004;86-A:219–24.

[9] Riboh JC, Garrigues GE. Early passive motion versus immobilization after arthroscopic rotator cuff repair. Arthroscopy 2014;30:997–1005.

[10] Debeyre J, Patie D, Elmelik E. Repair of Ruptures of the Rotator Cuff of the Shoulder. J Bone Joint Surg Br 1965;47:36–42.

[11] Thomopoulos S, Williams GR, Soslowsky LJ. Tendon to bone healing: differences in biomechanical, structural, and compositional properties due to a range of activity levels. J Biomech Eng 2003; 125:106–13.

[12] Sonnabend DH, Howlett CR, Young AA. Histological evaluation of repair of the rotator cuff in a primate model. J Bone Joint Surg Br 2010;92:586–94.

[13] Gerber C, Schneeberger AG, Perren SM, Nyffeler RW. Experimental rotator cuff repair. A preliminary study. J Bone Joint Surg Am 1999;81:1281–90.

[14] Peltz CD, Sarver JJ, Dourte LM, Wurgler-Hauri CC, Williams GR, Soslowsky LJ. Exercise following a short immobilization period is detrimental to tendon properties and joint mechanics in a rat rotator cuff injury model. J Orthop Res 2010;28:841–5.

[15] Kluger R, Bock P, Mittlbock M, Krampla W, Engel A. Long-term survivorship of rotator cuff repairs using ultrasound and magnetic resonance imaging analysis. Am J Sports Med 2011;39:2071–81.

[16] Miller BS, Downie BK, Kohen RB, Kijek T, Lesniak B, Jacobson JA, et al. When do rotator cuff repairs fail? Serial ultrasound examination after arthroscopic repair of large and massive rotator cuff tears. Am J Sports Med 2011;39:2064–70.

[17] McLaughlin HL. Lesions of the musculotendinous cuff of the shoulder. The exposure and treatment of tears with retraction. 1944. Clin Orthop Relat Res 1994:3–9.

[18] Keener JD, Wei AS, Kim HM, Paxton ES, Teefey SA, Galatz LM, Yamaguchi K. Revision arthroscopic rotator cuff repair: repair integrity and clinical outcome. J Bone Joint Surg Am 2010; 92:590–8.

[19] Duzgun I, Baltaci G, Atay OA. Comparison of slow and accelerated rehabilitation protocol after arthroscopic rotator cuff repair: pain and functional activity. Acta Orthop Traumatol Turc 2011;45:23–33.

[20] 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;28:34–42.
[21] Cuff DJ, Pupello DR. Prospective randomized study of arthroscopic rotator cuff repair using an early versus delayed postoperative physical therapy protocol. J Shoulder Elbow Surg 2012;21:1450–5.
[22] 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:S131–8.
[23] Swartz MK. The PRISMA statement: a guideline for systematic reviews and meta-analyses. J Pediatr Health Care 2011;25: 1–2.
[24] 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;87:1229–40.