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Title	What is the impact of early rehabilitation following rotator cuff repairs on clinical and biomechanical outcomes? A randomised controlled trial
Type	Article
URL	<a href="https://clock.uclan.ac.uk/37863/">https://clock.uclan.ac.uk/37863/</a>
DOI	<a href="https://doi.org/10.3233/PPR-200489">https://doi.org/10.3233/PPR-200489</a>
Date	2021
Citation	Mazuquin, Bruno Fles, Monga, Punnet, Basu, Subhasis, Selfe, James and Richards, James (2021) What is the impact of early rehabilitation following rotator cuff repairs on clinical and biomechanical outcomes? A randomised controlled trial. <i>Physiotherapy Practice and Research</i> , 42 (2). pp. 127-135. ISSN 2213-0683
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It is advisable to refer to the publisher's version if you intend to cite from the work.  
<https://doi.org/10.3233/PPR-200489>

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1 **What is the impact of early rehabilitation following rotator cuff repairs on**  
2 **clinical and biomechanical outcomes? A randomised controlled trial**

3 **ABSTRACT**

4 **Background:** The number of rotator cuff repairs performed worldwide is increasing  
5 every year. However, there are still controversies regarding when rehabilitation after  
6 surgery should start.

7 **Objectives:** To assess and to compare clinical and biomechanical outcomes of  
8 patients who were randomised and allocated to early or conservative rehabilitation  
9 after rotator cuff repairs.

10 **Methods:** Twenty patients were randomised to two treatment groups. The  
11 biomechanical assessments were performed before surgery and at three and six  
12 months, consisting of 3D kinematics and muscle activity from 5 muscles (upper  
13 trapezius, anterior deltoid, middle deltoid, posterior deltoid and biceps brachii) from  
14 six movement tasks. In addition, the Oxford Shoulder Score and EQ-5D-5L were  
15 also recorded. At 12 months an ultrasound scan was performed to check the repair  
16 integrity.

17 **Results:** Overall, both groups had similar results for function and health-related  
18 quality of life. However, at six months patients in the early group had better range of  
19 motion (ROM) than those in the conservative group, especially for shoulder flexion  
20 (Early: median=152.1° vs Conservative: median=140.0°). The number of re-tear  
21 events was higher in the early group (5 vs 1), and of these only two patients reported  
22 symptoms at 12 months.

23 **Conclusion:** Early rehabilitation may improve ROM but it does not seem to be  
24 superior to a conservative management in improving function and quality of life. In

25 addition, more re-tear events were observed in the early group. However, the results  
26 should be interpreted with caution due to the small sample size.

27

## 28 **INTRODUCTION**

29 Rotator cuff tear is a common disorder affecting approximately 30% of people older  
30 than 60 years (1) and it is responsible for almost 450,000 operations per year in the  
31 US (2). Rotator cuff tear can be debilitating and impair patients' quality of life and  
32 function; if initial non-operative treatments fail, surgical repair is often recommended  
33 (3). However, for optimal results, the postoperative rehabilitation must be adequately  
34 planned to help patients with their recover and return to daily activities (4).

35 Following a rotator cuff repair, a period of movement restriction is advised (5). Using  
36 a sling for six weeks is encouraged to protect the tendon and allow adequate soft-  
37 tissue healing and possibly avoid a re-tear (6). In contrast, delaying mobilisation may  
38 increase the risk of shoulder stiffness and potentially postpones improvements in  
39 function and return to work (7). Based on the available evidence, it is difficult to make  
40 an informed clinical decision on the most favourable postoperative time to start  
41 physiotherapy and reduce the use of sling. An overview of systematic reviews with  
42 updated meta-analyses demonstrated that, currently, there is almost the same  
43 number of systematic reviews compared with randomised controlled trials (RCTs)  
44 published on the topic, with reviews and primary studies showing conflicting  
45 conclusions (8).

46 In a clinical setting, it is common to use questionnaires to screen patients'  
47 impairments in activities of daily living (ADL) and goniometers to quantify range of  
48 motion (ROM). These tools have the advantage of being easy to use and are

49 relatively inexpensive; however, their simplistic capacity for measurement may not  
50 objectively define how patients are affected and how they are recovering. For  
51 instance, the deltoid and upper trapezius muscles are activated for longer periods in  
52 patients having surgery for rotator cuff related problems but there is a lack of studies  
53 investigating if an early postoperative structured exercise program could be more  
54 effective than a conservative in readjusting the activity of the shoulder muscles (9,  
55 10). Considering the uncertainties related to the application of early rehabilitation  
56 following rotator cuff repairs, and the lack of information on how different timing of  
57 starting physiotherapy affect muscle activation and quality of movement during ADLs  
58 after surgery; this study aimed to investigate the effectiveness of a therapist-led early  
59 rehabilitation regime compared with a conservative management on clinical and  
60 biomechanical outcomes.

61

## 62 **METHODS**

63 This study was an RCT which followed the CONSORT statement (11). Ethical  
64 approval was gained (16/NW/0143) and it was registered in the clinicaltrials.gov  
65 database (NCT02631486). The patients' recruitment and screening for eligibility  
66 were made on the same day that patients attended their scheduled appointments  
67 with the consultant regarding their shoulder symptoms and need for surgery.

68 Potential patients were approached and informed about the study, this included what  
69 would happen if they agreed to take part and how their rehabilitation would progress.

70 All participants signed an informed consent form after the study details were  
71 explained and any questions from the patient were addressed.

72

73

74 **Eligibility criteria**

75 The inclusion criteria consisted of 1) males and females aged between 40 and 70  
76 years old (most common age range for rotator cuff tears) (1), 2) on the waiting list for  
77 a rotator cuff repair for a chronic tear (symptoms for >3 months), 3) with no other  
78 previous shoulder surgery on the same side, and 4) no other musculoskeletal  
79 impairment on the assessed limb or in the cervical and thoracic spine. Patients were  
80 excluded if 1) during the surgery a repair was deemed not needed or the tear was  
81 too extensive to allow early rehabilitation, 2) they had previous shoulder surgery  
82 and/or other musculoskeletal impairment on the assessed limb or in the cervical and  
83 thoracic spine, and 3) were unable to follow instructions.

84

85 **Intervention**

86 Rehabilitation consisted of two groups who received physiotherapy post-surgery with  
87 a planned frequency of once every two weeks, lasting for approximately 3-4 months.  
88 In the first stage (discharge to 4 weeks), patients in the Early group used the sling for  
89 comfort only, which could be discarded when the patient felt comfortable and  
90 confident in doing so; whereas the Conservative group was asked to remain in the  
91 sling until the 6<sup>th</sup> week and remove it only to perform the prescribed exercises. The  
92 full protocols are available in the Supplementary file A. Treatment compliance and  
93 adherence were checked at the follow-up assessment sessions and were based on  
94 patients self-report on sling usage and attendance to physiotherapy.

95

96 **Randomization and allocation concealment**

97 A sequence of random numbers ([www.randomization.com](http://www.randomization.com)) was generated by an  
98 independent research team member (JR) who was also responsible for the allocation

99 concealment. The opaque sealed envelopes were opened after surgery by one of  
100 the treating physiotherapists who was not involved with the study design or data  
101 analysis.

102

### 103 **Procedures**

104 Four assessment sessions were undertaken in the outpatient setting at baseline  
105 (before surgery), three, six and 12 months follow-up. The first three assessment  
106 sessions consisted of completing the Oxford Shoulder Score (OSS) for function, the  
107 EQ-5D-5L for health-related quality of life and a biomechanical assessment. The  
108 OSS is a 12 item questionnaire about pain and function commonly used in  
109 randomised controlled trials. It is valid, reliable and showed good responsiveness  
110 (12, 13). The EQ-5D is a generic questionnaire about quality of life which has been  
111 extensively used and researched and validated (14, 15). The assessments were led  
112 by an assessor (BM) who was blinded to patients' allocation until the final data  
113 analysis. The last assessment session at 12 months consisted of an ultrasound scan  
114 only. The scans were performed by a single Fellowship-trained Musculoskeletal  
115 Radiologist (SB), blinded to patient's group allocation, using a GE Logiq S8  
116 ultrasound scanner (General Electric Healthcare; Chicago, United States of  
117 America).

118

### 119 **Biomechanical assessment**

120 The biomechanical assessment used two different systems that were synchronized;  
121 the Xsens MVN system (Xsens Tech®, Enschede, Netherlands) motion capture  
122 system which recorded upper body kinematics at 120 Hz, and the Trigno (Delsys®,  
123 Boston, USA) wireless EMG system which recorded muscle activity at 2000 Hz.

124 Every participant performed six shoulder movements and repeated each of them five  
125 times at a comfortable self-selected speed. The decision about using the tasks  
126 described in Table 1 was based on what is generally used during routine clinical  
127 assessments and common tasks used in everyday life that were assessed in similar  
128 studies (16-18). After determining the ROM (humerus in relation to the thorax) in  
129 degrees for each repetition, an average was calculated. For the EMG analysis, the  
130 muscles chosen were the anterior (AD), middle (MD) and posterior (PD) deltoids,  
131 upper trapezius (UT) and biceps brachii (BC). These muscles are easy to access  
132 and are sensitive to changes to the rotator cuff muscles activation (19). The integral  
133 was calculated and expressed as a percentage of the peak value (20). All sensors  
134 were placed on each participant by the same assessor at every assessment session.

135

136

### ***Table 1***

137

#### **Sample size calculation**

139 The primary outcome was shoulder ROM during flexion at 6 months. Based on a  
140 similar study (4), 14 patients would be needed in each group to detect a minimal  
141 clinically important difference (MCID) of 25° of flexion ROM, with a standard  
142 deviation of 23.6° at the 5% significance level, with 80% power. Adding 20% for  
143 eventual follow-up loss, the final total sample needed was 34 participants.

144

#### **Statistical Analysis**

146 Considering the number of patients recruited in each group and the number of  
147 patients that were reassessed at the follow-up points, descriptive statistics were  
148 preferred (21). We followed the intention-to-treat principle to report all outcomes.

149 **RESULTS**

150 Ninety-nine patients were assessed for eligibility between May 2016 and January  
151 2017; 57 were excluded as they did not agree to take part in the study. From the  
152 remaining 42, a further 22 were excluded: 17 did not need a rotator cuff repair and 5  
153 had a massive tear, which were considered inappropriate for the early mobilisation  
154 protocol. Therefore, 20 patients were randomised, 10 per group (Figure 1).

155

156 *Figure 1*

157 **Demographics**

158 Table 2 shows the demographic details at baseline. Most of the variables were  
159 similar between groups; there was a substantial difference in the length of time from  
160 first symptoms until the date of surgery and the Early group had more smokers than  
161 the Conservative group. Based on the surgeons' reports for the repairs, the most  
162 common lesions were found in the supraspinatus combined with the infraspinatus  
163 (Table 3).

164 *Table 2*

165 *Table 3*

166 **Physiotherapy compliance**

167 Seventy percent of patients in the Early group used the sling for less than 4 weeks  
168 and 88% of patients in the Conservative group used for at least 6 weeks (Table 4).  
169 Patients in the Early group reported a usage of 8.7 (SD=10.6) hours per day (h/d) in  
170 comparison to 22.1 h/d (SD=3.5) in the Conservative group. The Early group had an  
171 average of 6.5 (SD= 2.9) sessions with a physiotherapist and the Conservative group  
172 had an average of 8.7 (SD= 4.3).



173

**Table 4**

174 **Clinical scores**

175 A large improvement from baseline was observed for both groups on both follow-ups  
176 for the OSS. Both groups had better scores for the EQ-5D-5L compared to baseline  
177 with equivalent values at 6 months (Table 5).

178

179 **Biomechanics**

180 ***Combing***

181 At three months, the Conservative group showed slightly better ROM and higher  
182 muscle activity for the PD. At six months, the Early group had better ROM (6.7°  
183 between groups difference) and similar muscle activity apart from the BC, which  
184 showed 18% higher activity in the Conservative group (Supplementary file B).

185 ***Abduction***

186 Similar to the results of the Combing task, the Conservative group had better ROM  
187 at three months (7.6° between groups difference) and the Early group at six months,  
188 (14° between groups difference). At three months, the Conservative group showed  
189 higher muscle activity for all muscles. At six months, the Early group showed higher  
190 activity of the AD, MD and BC, with between groups differences of 15%, 9.6% and  
191 25.8%, respectively.

192 ***Carrying***

193 For the Carrying task, the Conservative group showed higher ROM and EMG activity  
194 at three and six months, although the between groups differences for ROM were  
195 small; 0.2° and 1.9°, respectively. The largest difference between groups for muscle  
196 activity was 18.8% for the MD at six months in favour of the Conservative group.

197 **Reaching**

198 The Early group had better ROM and muscle activity for the PD at three months  
199 (4.9° and 11.7% between groups difference) and the Conservative at six months (2°  
200 and 9.3% between groups difference).

201 **Flexion**

202 Comparing the follow-up values with baseline, the Early group improved 25° at three  
203 months and over 45° at six months. In contrast, the Conservative group had a  
204 reduction of approximately 6° at three months and an improvement of 9° at six  
205 months. The main between groups differences for muscle activity was for the MD  
206 (13.9% in favour of the Conservative group) at three months and for the AD (20.1 %  
207 in favour of the Early group) and the PD (13.4% in favour of the Conservative group)  
208 at six months.

209 **Lifting**

210 Comparing follow-up values with baseline, the Early group improved 40.7° at three  
211 months and 68.9° at six months, while the Conservative group got worse at three  
212 months by 9.5° and improved by 9.6° at six months. The main between groups  
213 differences for muscle activity was observed for MD (19.8%) in favour of the  
214 Conservative group, and PD (12.1%) in favour of the Early group at 3 months. At six  
215 months, the Early group showed greater activity for AD, MD and BC (28.4%, 14.2%  
216 and 20.4%, respectively).

217

218 **Repair Integrity**

219 Sixteen patients (Early n=9; Conservative n=7) had an ultrasound scan and six re-  
220 tears were found (Early n=5, Conservative n=1). Based on patients self-report, only 2

221 patients, both from the Early group, reported any symptoms; all the others confirmed  
222 that they were satisfied and had no pain or difficulties with activities involving the  
223 shoulder.

#### 224 ***Table 5***

### 225 **DISCUSSION**

226 The study aimed to assess and to compare outcomes of patients who had a rotator  
227 cuff repair and were randomised to either early or conservative rehabilitation. We  
228 found that the majority of patients reported adhering to the use of the sling as per  
229 instructions, which corroborates with the study of Mazzocca, Arciero (22). In their  
230 study, the authors reported that the majority of patients in the trial comparing early  
231 with conservative rehabilitation following rotator cuff repairs also used the sling as  
232 requested. Although the information on sling usage from our study is important, it  
233 relies on patients' self-reported information, which may be prone to inaccuracies.

234 Overall, both groups improved self-reported function at both follow-ups with similar  
235 results at six months. However, it could be observed that the Early group continued  
236 to improve over time, while the Conservative group did not improve further at six  
237 months. Both groups improved above the OSS MCID of six points from baseline to  
238 six months (23, 24). Previous studies that have evaluated the effectiveness of rotator  
239 cuff repairs only have shown that the surgery is effective in improving function and  
240 quality of life of patients (25-27). Other RCTs on the topic have used different  
241 questionnaires, which limit direct comparisons. However, based on the MCID of each  
242 scale some estimations are possible. For example, the MCID for the Constant-  
243 Murley Score (0-100), is 11 and for the Simple Shoulder Test (0-12) is 2.2 points (23,  
244 24). Using this approach, it is possible to observe the same trend on the RCTs

245 reported by Kim, Chung (28) and Koh, Lim (29). These authors did not find  
246 statistically significant differences between groups at follow-ups, but both groups in  
247 both studies improved more than the MCID after 6 months.

248         Trying to compare the biomechanics results of the ADLs from this RCT to  
249 other studies is challenging due to the lack of similar design and hypotheses tested.  
250 Most studies with a similar method of assessment compared differences between  
251 healthy groups with patients who had the injury but were still untreated or compared  
252 patients after surgery versus healthy groups. For example, Vidt, Santago (30)  
253 assessed 7 functional activities comparing patients with rotator cuff tears to a healthy  
254 control group, which included two similar tasks (combing and upward reach) to those  
255 used in our study. Their results showed that for upward reaching, which was similar  
256 to the Flexion and Lifting tasks, patients with rotator cuff tears had approximately a  
257 60° range of motion in the sagittal plane. Another study, from Fritz, Inawat (31),  
258 measured 3D kinematics and EMG at 9-12 weeks post-surgery for 10 patients who  
259 had rotator cuff repairs compared to 10 healthy subjects. The authors assessed 10  
260 activities which included Combing and Reaching, with patients showing a lower ROM  
261 for Combing, Reaching and for all the other tasks included in their study. From the  
262 six tasks proposed in our study, a clear pattern was observed where the Early group  
263 continually improved their ROM at every follow-up time point for all tasks excepting  
264 for Reaching. Whereas the Conservative group showed a slight deterioration at 3  
265 months for the tasks Carrying, Flexion and Lifting, and at 6 months for Combing;  
266 Abduction was the only task to improve in the Conservative group at both follow-up  
267 time points.

268         At three months, the differences in ROM between groups were generally  
269 small. Nevertheless, at six months, substantial differences of 14° for Abduction,

270 12.1° for Flexion and 13.8° for Lifting were observed. The MCID for shoulder flexion  
271 reported by Muir, Corea (32) is 14° when measured with a goniometer. Considering  
272 that the glenohumeral relative angle was defined as the humerus in relation to the  
273 thorax, it could be possible that the difference between groups for ROM are clinically  
274 important; however, such analysis is beyond the scope of our study and the  
275 instrument used to measure ROM was not a goniometer. Despite the difference in  
276 ROM for some of the tasks favouring the Early group, the narrow margin for other  
277 tasks may explain why the OSS score was similar. Patients may not see a  
278 substantial increase in range of motion being the same as an indicator of a better  
279 outcome; as long as they reach a functional range that permits the return to some of  
280 their basic activities. Therefore, even though the Early group had greater  
281 improvements in ROM, both groups were functionally equivalent and consequently,  
282 one rehabilitation regime does not seem to be superior to the other on meeting  
283 patients' expectations. Moreover, at this stage, patients may consider that a better  
284 improvement in pain intensity and quality of sleep is more relevant than having a  
285 greater ROM of their shoulders (33, 34).

286 In our study, muscle recruitment was assessed with EMG. Overall, the integral of the  
287 5 muscles showed some changes between groups but with high variability, which  
288 indicates that the amount of work done by each muscle was similar between groups  
289 and time points. However, as mentioned previously, the Conservative group  
290 generally showed a reduction in ROM over the tasks. Therefore, although groups  
291 may have equivalent muscle recruitment, Early rehabilitation may facilitate an earlier  
292 return to activities. The similar amount of work done and EMG amplitude, but with  
293 better ROM for the Early group, indicates that their shoulder muscles may be more  
294 efficient than the Conservative group, i.e. patients in the Early group needed

295 equivalent muscle activity to perform greater joint excursions (35). This rationale is  
296 supported by other studies showing that the amount of power generated by muscles  
297 is not associated with an increase in EMG activity (36).

298 We found that the Early group had a higher number of re-tear events. However,  
299 three patients from the Conservative group did not attend their scan appointment  
300 compared to one from the Early group, thus, additional events in the Conservative  
301 group may have been missed. Moreover, the Early group had a greater number of  
302 smokers; smoking has been linked to worse outcomes and is considered a risk factor  
303 for rotator cuff tears (37). Although a higher number of re-tear events was found for  
304 the Early group only two patients were symptomatic. This finding corroborates with  
305 other studies reporting that even if a re-tear occurs patients may present significant  
306 improvement of their pain and strength (38-40).

307

### 308 **Limitations**

309 The sample size planned was not achieved and considerable lost to follow-up was  
310 observed, therefore, descriptive statistics was preferred as the study would have  
311 limited power to determine whether possible non-significant statistical differences  
312 between groups were not truly different (41). These limitations may limit the  
313 applicability of our findings, it is possible that due to missing values the treatment  
314 effects have been underestimated or overestimated (42, 43).

315

### 316 **CONCLUSION**

317 This study suggests that early rehabilitation is not superior to conservative  
318 rehabilitation in improving function and quality of life. There is some indication that

319 an early regime may be beneficial to improve ROM and muscle efficiency; however,  
320 the number of re-tears, although mostly asymptomatic (no pain or difficulties with  
321 daily activities), were higher for this group.

322

### 323 **CONFLICT OF INTEREST**

324 The authors have no conflict of interest to report.

325

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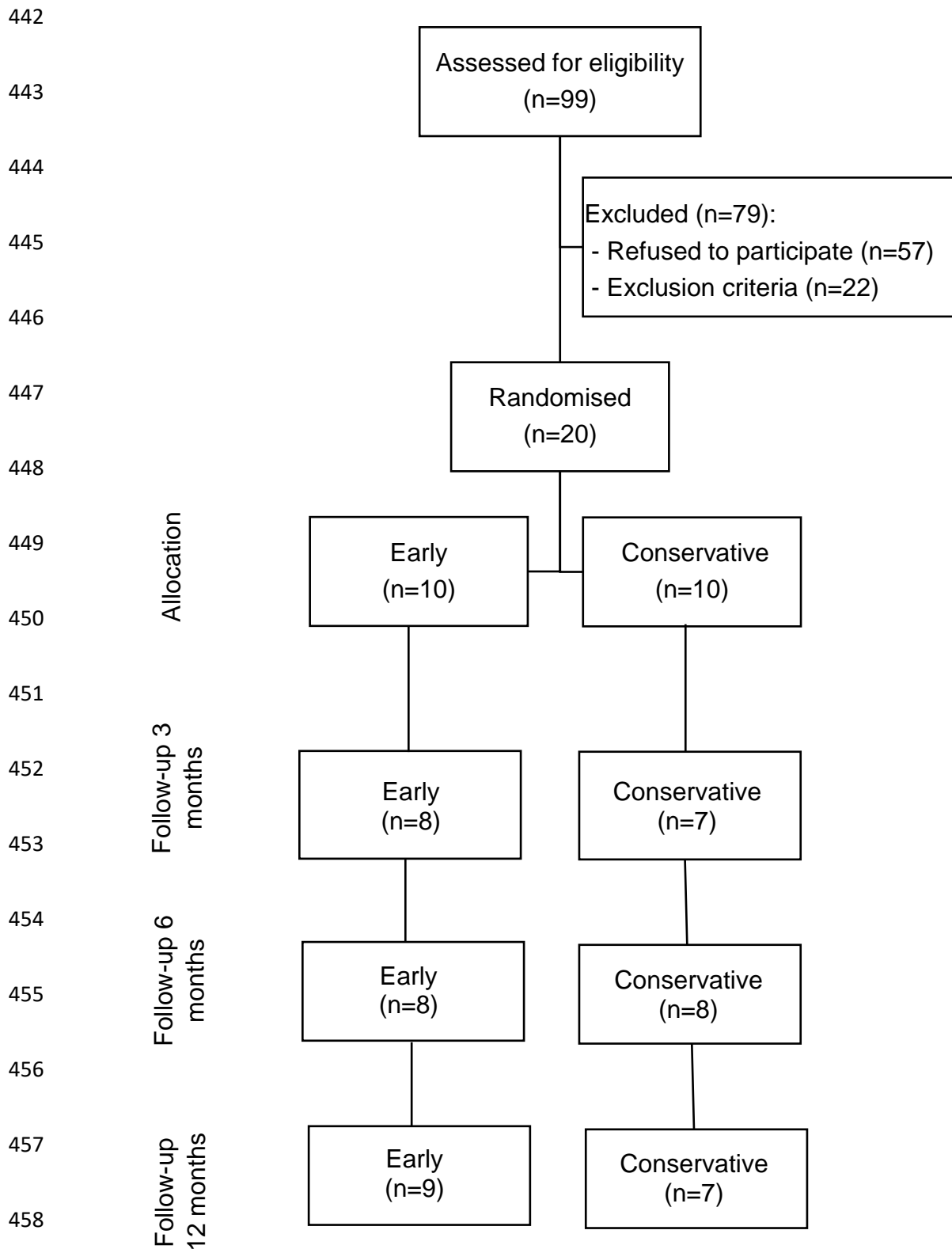
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459 **Figure 1.** Flow diagram of patient recruitment, allocation and analyses.

**TABLE 1.** Range of motion tasks.

<b>Task</b>	<b>Description</b>	<b>Movement involved</b>
1) Combing	Simulated combing movement taking the hand to the back of the head.	Shoulder abduction (coronal plane) combined with external rotation (transverse plane).
2) Abduction	Maximal abduction in the coronal plane.	Abduction only (coronal plane).
3) Carrying	With the arms resting besides the body, the participant took a dumbbell to the furthest point in a horizontal shoulder abduction and adduction movement with the elbow in complete extension.	Horizontal shoulder adduction and abduction (transverse plane).
4) Reaching	The participants tried to reach their opposite back pocket.	Shoulder extension (sagittal plane) combined with internal rotation (transverse plane)
5) Flexion	Maximal forward flexion and extension in the sagittal plane.	Flexion only (sagittal plane)
6) Lifting	With the arm resting beside the body, the participant raised a dumbbell (1 kg) to the highest point above the head.	Flexion only (sagittal plane)

**TABLE 2.** Baseline characteristics.

	<b>Group</b>	
	<b>Early <math>\bar{x}</math> (SD)</b>	<b>Conservative <math>\bar{x}</math> (SD)</b>
<b>Demographics</b>		
Age (years)	55.2 (8.1)	58.3 (11.7)
Weight (kg)	85.2 (13.7)	95.0 (14.2)
Height (m)	1.71 (0.08)	1.75 (0.08)
<b>Sex</b>		
Female (%)	3 (30)	3 (30)
Male (%)	7 (70)	7 (70)
<b>Smoker</b>		
Yes (%)	3 (30)	0
No (%)	7 (70)	10 (100)
<b>Diabetes</b>		
Yes (%)	0	0
No (%)	10 (100)	10 (100)
<b>Side of surgery</b>		
Right (%)	5 (50)	7 (30)
Left (%)	5 (50)	3 (30)
<b>Dominance</b>		
Right (%)	6 (60)	8 (80)
Left (%)	4 (40)	2 (20)
<b>Time from first symptoms to surgery (months)</b>	20.0 (13.0)	9.80 (4.2)

SD: standard deviation

**TABLE 3.** Surgery characteristics.

	<b>Early (n)</b>	<b>Conservative (n)</b>	<b>Total (n)</b>
<b>Muscle Affected</b>			
Supraspinatus	4	3	7
Supra+Infra	4	6	10
Multiple	2	1	3
<b>Total</b>	<b>10</b>	<b>10</b>	<b>20</b>
<b>Tear Size</b>			
Small (< 1 cm)	2	2	4
Medium (1-3 cm)	5	6	11
Large (3-5 cm)	3	2	5
<b>Total</b>	<b>10</b>	<b>10</b>	<b>20</b>
<b>Thickness</b>			
Full	10	9	19
Partial	0	1	1
<b>Total</b>	<b>10</b>	<b>10</b>	<b>20</b>
<b>Fixation method</b>			
Single-row	7	7	14
Double-row	3	3	6
<b>Total</b>	<b>10</b>	<b>10</b>	<b>20</b>
<b>Additional procedure</b>			
SAD	4	4	8
Multiple	6	6	12
<b>Total</b>	<b>10</b>	<b>10</b>	<b>20</b>
<b>Previous contralateral repair</b>			
Yes	3	1	4
No	7	9	16
<b>Total</b>	<b>10</b>	<b>10</b>	<b>20</b>

SAD: subacromial decompression.

**TABLE 4.** Self-reported sling usage.

Number of weeks w/ sling	Group		Total
	Early (n)	Conservative (n)	
<1	4	0	4
2	1	0	1
3	2	1	3
4	1	0	1
5	1	0	1
6	1	6	7
>6	0	1	1
<b>Total</b>	10	8	18

**TABLE 5.** Questionnaires and ROM results.

<b>Clinical score</b>	<b>Early</b>		<b>Conservative</b>	
	<b>Median</b>	<b>IQR (25-75%)</b>	<b>Median</b>	<b>IQR (25-75%)</b>
<b>OSS</b>				
Baseline	27.5	15-35.2	34.5	27.7-40.5
3 months	34.5	27.5-43.5	43	40-44
6 months	46	42.5-48	42	34.5-47
<b>EQ-5D</b>				
Baseline	10	7.7-12.5	7.5	6-9.7
3 months	8.5	6-13.7	6	5-14
6 months	6	5.5-11	6	5-12
<b>ROM (°)</b>				
<b>Combing</b>				
Baseline	79.2	65.5-113.2	87.6	72.9-96.4
3 months	93.3	89.4-101.7	96.4	85.8-107.6
6 months	102.0	96.6-118.7	95.3	66.2-103.8
<b>Abduction</b>				
Baseline	63.2	29.4-86.4	91.9	50.2-113.3
3 months	92.5	81.4-103.5	100.1	77.7-110.5
6 months	115.8	94.9-117.3	101.8	64.2-115.5
<b>Carrying</b>				
Baseline	43.5	19.8-64.6	64.7	43.2-71.6
3 months	56.8	41.4-85.7	57.0	42.9-68.3
6 months	78.6	71.0-87.9	80.5	43.3-90.2
<b>Reaching</b>				
Baseline	13.6	3.14-20.8	15.4	11.9-20.6
3 months	20.3	10.0-25.8	15.4	9.9-21.1
6 months	19.5	-2.2-29.5	21.5	4.6-22.9
<b>Flexion</b>				
Baseline	105.9	66.7-138.9	131.0	103.4-152.5
3 months	130.0	125.2-144.9	125.1	104.1-140.1
6 months	152.1	147.7-165.9	140.0	104.3-157.9
<b>Lifting</b>				
Baseline	83.9	60.3-107.7	129.4	87.4-150.4
3 months	124.6	97.8-141.2	119.9	82.9-142.4
6 months	152.8	141.4-154.1	139.0	83.9-157.1

IQR: interquartile range, OSS: Oxford Shoulder Score.

**SUPPLEMENTARY FILE A. Early and Conservative protocols.**

<b>Early Rehabilitation</b>		<b>Conservative Rehabilitation</b>	
<b>Stage 1</b> On Discharge – 4 weeks	<ul style="list-style-type: none"> <li>• Sling for comfort only</li> <li>• Advice on sling management</li> <li>• Neck, elbow, wrist &amp; hand exercises</li> <li>• Postural awareness and scapula control</li> <li>• Active assisted closed chain ROM in safe zone</li> <li>• Kinetic chain rehabilitation</li> <li>• Thoracic spine ROM'</li> <li>• Avoid combined abduction and external rotation and HBB</li> </ul>	<b>Stage 1</b> On Discharge – 4 weeks	<ul style="list-style-type: none"> <li>• Sling 6 weeks, if abduction wedge then reduce to standard sling at 2-3 weeks</li> <li>• Advice on sling management</li> <li>• Neck, elbow, wrist &amp; hand exercises</li> <li>• Postural awareness and scapula control</li> <li>• Active assisted closed chain ROM in safe zone</li> <li>• Kinetic chain rehabilitation</li> <li>• Thoracic spine ROM</li> <li>• Avoid combined abduction and external rotation and HBB</li> </ul>
<b>Stage 2</b> 4-6 weeks	<ul style="list-style-type: none"> <li>• Progress from active-assisted to active ROM beyond safe zone (short to long lever).</li> <li>• HBB within limits of pain</li> <li>• Begin cuff control exercises and submaximal (approx. 30%) isometric strengthening in neutral through available range</li> </ul>	<b>Stage 2</b> 4-6 weeks	<ul style="list-style-type: none"> <li>• Continue with stage 1</li> <li>• Light proprioceptive exercises</li> <li>• Remain in sling</li> </ul>
<b>Stage 3</b> 6-8 weeks	<ul style="list-style-type: none"> <li>• Commence open chain rotator cuff strengthening (short to long lever)</li> <li>• Active short lever kinetic chain rehabilitation of the affected arm progressing to long lever function movement</li> <li>• Begin stretching into combined movement ranges</li> </ul>	<b>Stage 3</b> 6-8 weeks	<ul style="list-style-type: none"> <li>• Wean from sling</li> <li>• Progress active-assisted ROM beyond safe zone (short to long lever).</li> <li>• HBB with limits of pain</li> <li>• Begin cuff control exercises and submaximal (approx. 30%) isometric strengthening in neutral through available range</li> </ul>

**Continue**



**SUPPLEMENTARY FILE A (CONTINUE).** Early and Conservative protocols.

<b>Early Rehabilitation</b>		<b>Conservative Rehabilitation</b>	
<b>Stage 4</b> 8-12 weeks	<ul style="list-style-type: none"> <li>• Progression of full kinetic chain rehabilitation</li> <li>• Progression of stretching</li> <li>• Patient-specific functional/sports training</li> <li>• Begin combined abduction and external rotation</li> </ul>	<b>Stage 4</b> 8-12 weeks	<ul style="list-style-type: none"> <li>• Commence open chain rotator cuff strengthening (short to long lever)</li> <li>• Active short lever kinetic chain rehabilitation of the affected arm progressing to long lever function movement</li> <li>• Begin stretching into combined movement ranges</li> </ul>
<b>Stage 5</b> 12 weeks +	<ul style="list-style-type: none"> <li>• Continue and progress with stage 4</li> <li>• Manual therapy to address ROM deficits</li> </ul>	<b>Stage 5</b> 12 weeks +	<ul style="list-style-type: none"> <li>• Begin combined abduction and external rotation</li> <li>• Full kinetic chain rehabilitation</li> <li>• Patient-specific functional/sports training</li> <li>• Manual therapy to address ROM deficits</li> </ul>
<b>Milestones</b>		<b>Milestones</b>	
Week 4	<ul style="list-style-type: none"> <li>• ROM 75%-80% of normal, sling discarded, return to driving as able, return to sedentary work</li> </ul>	Week 8	<ul style="list-style-type: none"> <li>• ROM 75%-80% of normal, sling discarded, return to driving as able, return to sedentary work</li> </ul>
3-6 months	<ul style="list-style-type: none"> <li>• Full active ROM, can consider return to non-contact sport.</li> <li>• Return to manual work as guided by surgeon/physiotherapist</li> </ul>	3-6 months	<ul style="list-style-type: none"> <li>• Full active ROM, can consider return to non-contact sport.</li> <li>• Return to manual work as guided by surgeon/physiotherapist</li> </ul>
6 months	Unrestricted activity	6 months	<ul style="list-style-type: none"> <li>• Unrestricted activity</li> </ul>

HBB: hand behind back.

**SUPPLEMENTARY FILE B.** Muscle activity for the various tasks at baseline, three and six months follow-ups.

EMG (%)	Early Median (IQR 25-75%)					Conservative Median (IQR 25-75%)				
	UT	AD	MD	PD	BC	UT	AD	MD	PD	BC
<b>Combing</b>										
Baseline	38.1 (17.6- 51.6)	32.6 (21.1- 47.1)	38.8 (20.6- 54.5)	30.8 (17.1- 40.3)	37.5 (27.3- 51.5)	31.3 (22.3- 40.5)	22.3 (10.3- 39.2)	25.5 (16.8- 42.6)	17.8 (10.4- 26.1)	35.8 (20.7- 48.2)
3 months	39.0 (28.12- 50.9)	43.6 (35.7- 54.1)	31.0 (25.0- 37.5)	13.1 (9.1- 28.7)	35.7 (25.0- 50.0)	31.4 (21.8- 45.6)	36.8 (23.8- 45.7)	35.9 (32.0- 41.5)	23.5 (21.4- 32.5)	36.6 (27.3- 65.6)
6 months	33.6 (20.0- 45.6)	41.1 (33.7- 54.8)	33.5 (28.4- 41.7)	23.4 (14.4- 34.7)	30.0 (17.5- 49.6)	33.0 (23.6- 41.6)	43.9 (35.0- 52.5)	30.5 (18.0- 38.1)	22.8 (16.2- 32.3)	48.4 (35.6- 59.4)
<b>Abduction</b>										
Baseline	45.7 (24.0- 61.7)	30.1 (16.2- 47.0)	49.8 (32.5- 75.7)	54.5 (41.2- 66.0)	20.0 (15.3- 27.5)	52.0 (39.0- 72.3)	46.5 (39.1- 63.8)	65.6 (56.0- 77.9)	49.6 (31.5- 73.5)	30.6 (15.7- 55.6)
3 months	50.0 (39.6- 73.9)	48.8 (32.5-64)	51.0 (44.0- 68.1)	52.9 (31.2- 64.1)	16.7 (8.4- 35.7)	61.8 (45.0- 77.3)	58.6 (37.3- 71.5)	69.2 (49.2- 79.2)	53.6 (34.3- 71.7)	28.2 (23.5- 35.7)
6 months	51.8 (42.4- 56.0)	63.4 (47.0- 69.6)	64.1 (52.2- 68.6)	53.5 (44.2- 69.0)	43.5 (20.1- 51.0)	58.9 (44.7- 64.5)	48.4 (42.2- 64.0)	54.5 (37.9- 68.3)	57.2 (45.3- 67.0)	17.7 (15.0- 40.9)

*Continue*

**SUPPLEMENTARY FILE B (CONTINUED).** Muscle activity for the various tasks at baseline, three and six months follow-ups.

EMG (%)	Early Median (IQR 25-75%)					Conservative Median (IQR 25-75%)				
	UT	AD	MD	PD	BC	UT	AD	MD	PD	BC
<b>Carrying</b>										
Baseline	68.6 (36.5-78.9)	73.7 (42.4-85.6)	40.0 (21.4-74.5)	30.0 (20.1-65.0)	60.0 (38.6-78.8)	71.4 (59.3-78.2)	74.1 (55.5-87.7)	52.0 (40.6-77.6)	52.5 (48.0-69.7)	80.0 (50.5-92.8)
3 months	66.2 (47.2-81.1)	61.4 (48.4-84.0)	78.0 (22.9-88.4)	60.0 (28.2-81.5)	73.3 (71.4-77.1)	73.1 (55.3-80.9)	79.5 (61.1-90.6)	80.1 (58.9-90.0)	77.1 (55.8-83.6)	76.9 (64.9-83.4)
6 months	67.7 (44.9-86.3)	80.1 (63.0-84.8)	66.9 (50.6-78.7)	65.8 (55.1-71.0)	69.8 (62.8-73.7)	80.7 (63.2-86.9)	83.6 (57.9-91.3)	85.7 (57.3-90.2)	77.1 (69.0-86.6)	76.1 (51.8-88.4)
<b>Reaching</b>										
Baseline	11.2 (5.3-19.0)	4.9 (1.6-11.0)	10.2 (6.7-16.8)	31.5 (17.7-42.5)	5.9 (0-12.2)	3.6 (2.6-15.2)	2.6 (1.2-9.4)	6.8 (2.5-15.3)	27.7 (10.9-50.5)	4.2 (1.5-14.3)
3 months	8.3 (4.5-21.5)	14.5 (5.4-18.0)	8.9 (3.1-13.6)	34.8 (20-48)	16.7 (14.2-33.3)	12.5 (1.8-17.8)	5.3 (2.2-6.7)	7.7 (3.9-18.0)	23.1 (13.7-60)	15.4 (7.3-30.0)
6 months	7.0 (3.0-13.5)	3.5 (1.9-5.3)	5.7 (3.2-8.9)	27.8 (23.7-52.7)	18.4 (6.2-48.9)	4.6 (2.9-5.4)	3.7 (2.6-5.8)	7.1 (3.7-13.9)	37.1 (17.0-55.6)	15.5 (8.0-23.9)

*Continue*

**SUPPLEMENTARY FILE B (CONTINUED).** Muscle activity for the various tasks at baseline, three and six months follow-ups.

EMG (%)	Early Median (IQR 25-75%)					Conservative Median (IQR 25-75%)				
	UT	AD	MD	PD	BC	UT	AD	MD	PD	BC
<b>Flexion</b>										
Baseline	40.4 (32.7-45.8)	45.7 (30.7-54.9)	44.6 (23.8-52.9)	45.3 (29.4-53.6)	32.2 (25.7-52)	48.4 (37.3-52.6)	46.7 (36.3-60.2)	50.8 (40.86-67.5)	43.6 (30.7-54.9)	38.2 (30.1-48.3)
3 months	44.4 (40.4-60)	49.0 (47.2-61.2)	42.5 (33.3-50.8)	51.3 (39.4-72.7)	33.3 (36.6-45.7)	51.9 (33.5-64.2)	46.7 (38.5-66.4)	56.4 (39.0-64.6)	49.5 (40.6-52.4)	40.0 (30.7-56.0)
6 months	49.5 (37.6-78.2)	65.7 (55.1-67.4)	56.5 (48.1-74.8)	51.1 (38.2-78.2)	55.6 (26.3-76.8)	57.1 (49.0-63.4)	45.6 (37.6-73.2)	59.7 (43.6-73.6)	64.5 (56.7-74.0)	48.9 (35.2-59.2)
<b>Lifting</b>										
Baseline	36.1 (31.6-47.1)	48.6 (37.3-66.6)	41.3 (25.3-51.7)	43.3 (27.3-72.0)	57.5 (35.2-72.5)	49.5 (42.2-69.1)	55.7 (48.4-72.7)	56.6 (39.8-76.2)	70.0 (39.7-86.6)	55.0 (47.9-86.6)
3 months	52.4 (38.9-70.8)	64.2 (42.1-81.2)	47.5 (29.7-72.1)	74.0 (25.0-90.1)	53.3 (39.2-67.6)	59.4 (54.8-67.2)	67.3 (49.4-81.3)	63.5 (58.3-84.4)	61.9 (57.5-67.4)	60.0 (55.9-88.1)
6 months	61.9 (53.6-72.3)	77.2 (67.0-89.9)	67.4 (58.9-75.5)	62.3 (54.2-85.8)	80.4 (69.7-90.1)	55.0 (50.1-72.8)	48.8 (44.1-66.3)	53.2 (47.2-78.4)	72.2 (60.3-81.2)	60.0 (54.8-72.9)

AD: anterior deltoid, MD: middle deltoid, PD: posterior deltoid, BC: biceps brachii, IQR: interquartile range.