

Faculté des sciences de la motricité

Telerehabilitation post arthroscopic rotator cuff repair

A production thesis

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Abbreviations

TR: Telerehabilitation

RC: Rotator cuff

ROM: Range of motion

RCR: Rotator cuff repair

ARCR: Arthroscopic rotator cuff repair

PROM: Passive range of motion

AROM: Active range of motion

AAROM: Active assisted range of motion

ADLs: Activities of daily living

ASES: American Shoulder and Elbow Surgeon

ASSET: American Society of Shoulder and Elbow Therapists

WORC: Western Ontario Rotator Cuff Index

EMG: Electromyography

RCT: Randomized control trials

Introduction

Rotator cuff (RC) disease is marked as a primary cause of shoulder pain, which is responsible for up to 70% of all medical consultations related to shoulder problems and its incidence is rising higher after the fourth decade of life (Yamaguchi et al., 2006). Among these various pathologies of the RC, RC tears are leading to various clinical conditions including muscle weakness and shoulder dysfunction (Karasuyama et al., 2023). The prevalence of RC tear increases with age impacting almost 30% of the population aged 60 years and above and doubling to 60% in the population above 80 years (Shim et al., 2023). The treatment of RC tear differs according to the size, severity and location of the tear; and according to the patient: age; comorbidities; activity level; degree of impairment and his expectations. The purpose of the treatment, whether it is operative or non-operative, is to relieve the pain and restore the range of motion (ROM) of the shoulder after the RC tear (Coda et al., 2020; Gutiérrez-Espinoza et al., 2020).

In general, most cases undergo initially conservative treatment that includes non – steroidal anti-inflammatory drug administration, steroid injection, hyaluronic acid injection, physical therapy and exercise therapy (Karasuyama et al., 2023). Nevertheless, 40% of the patients will still have symptoms such as enduring pain and when conservative treatment was unsuccessful, therefore surgical repair might be used in these cases (Correia et al., 2022). Noting that, the prevalence of full-thickness RC tears is higher in symptomatic patients compared to partial-thickness tears (Reilly et al., 2006). RC repair (RCR), and especially for the older population, stands out as one of the most common surgical procedures. In the United States of America alone, more than 300,000 RCR are conducted per year (Correia et al., 2022).

The prevalence of arthroscopic repair is rising rapidly in North America, Australia, Asia and Europe (Paloneva et al., 2015). According to Tirefort et al. (2019), better long-term results have been associated with RC healing after repair. However, like any other procedure, it has a number of complications that can still occur in association with its benefits (Gutiérrez-Espinoza et al., 2020). Following arthroscopy, physical rehabilitation is a must (Longo, Risi Ambrogioni, et al., 2021). The key

objectives of the rehabilitation include the protection of the healing process and prevention of joint stiffness and muscle atrophy. Due to the diversity of the patient's demographics and tear characteristics, both physicians and physical therapists face difficulties and challenges in developing a postoperative rehabilitation program after arthroscopic RCR (ARCR) (Mollison et al., 2017). Immobilization duration, progression of ROM and resistance exercises depend on the surgical procedure performed and the patient's prognostic factors of retear such as age, tear size, preoperative fatty infiltration, and muscle atrophy, smoking, diabetes mellitus, obesity and bone mineral density (Kokmeyer et al., 2016).

Healthcare systems, insurance companies and employers consider RC tear to be like a massive “responsibility”, knowing that in the United States, the annual financial burden of RC disorders management was estimated at 3 billion US \$ (Correia et al., 2022). Also, one-fourth of the population indicates that they have postponed or foregone their physical therapy sessions due to cost-related challenges. The cost of physical therapy varies depending on factors such as insurance type, the number of sessions needed, facility charges, and transportation expenses (Arshi et al., 2015).

Telehealth provides the improvement of efficiency and streamline care, likewise its capacity to develop care access in hard-to-reach populations (Kane et al., 2020). Telerehabilitation (TR) is one of the branches of telehealth, which involves distant managing rehabilitation using new telecommunication-based practice. Patients with neurological, cardiorespiratory and musculoskeletal problems are being treated via TR which may facilitate their access to rehabilitation services regardless of their geographic location (van Egmond et al., 2018). Therefore, this approach can grant them the pursuit of their rehabilitation in their own social and vocational environment and can be a solution when in-person sessions are challenging (Susó-Martí et al., 2021). It has shown plenty of benefits such as improving access and convenience and reducing cost (Grona et al., 2018; Miller et al., 2021). The literature suggests that videotaped exercises, which patients can review as needed, may be an effective instructional method. This approach could be a suitable model for rehabilitation, especially given the ongoing pressures on the healthcare system (Roddey et al., 2002). Additionally, Muñoz-Tomás et al. (2023) concluded that prescribed TR exercises are equally

effective as face-to-face exercises, laying the groundwork for potential TR practices in a post-pandemic era. The practice of TR in orthopedics has shown efficacy across multiple applications as well as remote consultations, outpatient care and rehabilitation (Kane et al., 2020).

More studies have been developed and confirmed that there are no significant differences between supervised physiotherapy programs and home-based exercise programs regarding the Constant and pain scores after ARCR. These results suggest that home-based exercise programs can deliver the same quality of care after an ARCR (Karasuyama et al., 2023). In the systematic review of van Egmond et al. (2018), physiotherapy combined with TR is possible for surgical patients and is, at least, as effective as standard care. Moreover, this review with meta-analysis revealed an improvement in the quality of life among surgical populations with TR.

Patients' adherence may influence the effectiveness of the program in both conventional rehabilitation programs and telemedicine interventions (Hooas et al., 2016; Lundell et al., 2015). Previous studies have indicated that patients who undergo surgery tend to exhibit stronger adherence to exercise programs and encounter fewer difficulties (Chang et al., 2022). Specifically, it has been highlighted patients' high levels of satisfaction and adherence with TR, which were comparable to those seen in traditional rehabilitation settings (Muñoz-Tomás et al., 2023).

To effectively utilize TR, it's crucial to have a treatment protocol guide that considers the patients characteristics and the variability of RC tears. To the current knowledge there is not a TR video-based program developed for rehabilitation post ARCR, the results of research conducted in the beginning of this study are shown in Appendix 1. Thus, the importance of developing such a program could help reduce care costs and facilitate accessibility to care.

How can an evidence-based exercise program post ARCR including TR be developed and applied as a complementary tool in rehabilitation?

The purpose of this study is to review the current literature about rehabilitation post ARCR for full thickness RC tears and develop a home exercise program including TR with video-based exercises to resume activities of daily living (ADLs). This tool

will provide a flexible and clear program that can be personalized by physical therapists for each patient. It will also improve accessibility to physical therapy for patients during critical postoperative period and encourage them to actively engage in their treatment. The program does not address the return to activity (work/sport), as each activity requires specific considerations and rehabilitation approaches tailored to its unique demands, rather it focuses return to activities of daily living since most patients after arthroscopic RCR only need to complete the first 3 phases of rehabilitation (Thigpen et al., 2016).

Methods

Chapter 1: Rehabilitation post ARCR

Search strategy

A first search was performed in order to identify relevant studies about rehabilitation post ARCR in the databases PubMed, EMBASE and Cochrane from November 2023 to March 2024. The following key words were combined:

“rotator cuff injuries”, “rotator cuff injury”, “rotator cuff tear”, “rotator cuff tears”, “arthroscopy”, “rotator cuff repair”, “shoulder arthroscopy”, “rehabilitation”, “physical therapy”, “modalities, physical therapy”, “shoulder rehabilitation”, “physical therapy program”, “post-operative”, “post-operative program”, “post-operative rehabilitation”, “rehabilitation protocol”.

The search was applied with a 5 year of publication filter to reduce the number of articles screened. Study types searched included systematic reviews, meta-analyses and randomized control trials (RCT). In addition, reference lists and citations of all included papers were also screened.

Table 1. PubMed search strategy

Steps	Search items
1	(rotator cuff injuries/surgery [MeSH Terms] OR "rotator cuff repair"[Title/Abstract] OR "shoulder arthroscop*" [Title/Abstract] OR "rotator cuff surgery"[Title/Abstract] OR "rotator cuff arthroscop*" [Title/Abstract])
2	(rehabilitation[MeSH Terms] OR "physical therapy modalities"[MeSH Terms] OR "shoulder rehabilitation"[Title/Abstract] OR "physical therapy program"[Title/Abstract] OR "post operative program"[Title/Abstract] OR "post operative rehabilitation"[Title/Abstract] OR "rehabilitation protocol"[Title/Abstract] OR "rehabilitation program"[Title/Abstract])
3	(1) AND (2)

Study selection

Studies were included if they: (1) described a shoulder rehabilitation exercise program post ARCR, (2) investigated the effectiveness of a specific exercise for patients post ARCR, (3) allowed comparisons between different rehabilitation programs, (4) investigated the time and type of immobilization or the frequency of exercises or the time to start active mobilization and resistance, (5) were published in English or French.

The exclusion criteria for this study include (1) articles only detailing the return to activity phase, (2) articles specifically addressing RC patch repair, (3) and those exclusively focusing on conservative treatments.

All studies were independently screened and evaluated on Zotero and Rayyan by two investigators (CF and LN), initially based on the title and abstract, in accordance with the inclusion and exclusion criteria. Subsequently, articles that were not excluded by either reviewer were examined in full-text, and any disagreement regarding inclusion was resolved through consensus.

Data extraction

Data extraction involved gathering information on various aspects of the rehabilitation protocol, including the timeline of the protocol, duration of immobilization, types of exercises prescribed, distinctions between early and delayed rehabilitation phases, and the frequency of visits to physical therapists.

Chapter 2: TR program's development

A program will be developed with segmented phases, outlining the immobilization period, exercise types and frequencies based on the postoperative phase, and specifying when to commence passive range of motion (PROM), active assisted range of motion (AAROM), active range of motion (AROM), resistive exercises, and return to activity all guided by the literature.

Subsequently, videos demonstrating the exercises will be recorded to be incorporated into a mobile application designed for both patients and therapists. The exercises can be adjusted by the physical therapist who can customize the program depending on the patient's progress.

Chapter 3: Experts input

Aiming to gather a diverse range of opinions and practical experiences, interviews were conducted with experts on shoulder treatment and rehabilitation until saturation of information was reached. Every effort was made to engage physical therapists and surgeons from various regions in Belgium and other countries. Surgeons with expertise were identified through their 2-year experience in ARCR. For physical therapists, regardless of their level of experience, this anticipation was made in consideration of the program's future use by physical therapists who are new to this domain. A series of questions was presented to these experts following an interview guide (appendix 2), centering on areas where consensus was lacking. The developed program was shown to the experts to gain a more practical understanding of the rehabilitation post ARCR.

Results

Chapter 1: Rehabilitation post ARCR: Literature review

For the first research conducted on rehabilitation post ARCR, a total of 358 studies were identified from 3 different databases (Pubmed, Embase and Cochrane Library), 41 duplicated articles were removed. Then, 289 studies were excluded after screening the title and abstract. A full-text review assessment was applied, and 11 more studies were excluded. Three additional articles, each older than 5 years, were included based on citations within the articles, because they were considered relevant and essential for enhancing the exercise program development. A total of 16 studies were included in this literature review “Fig. 1”.

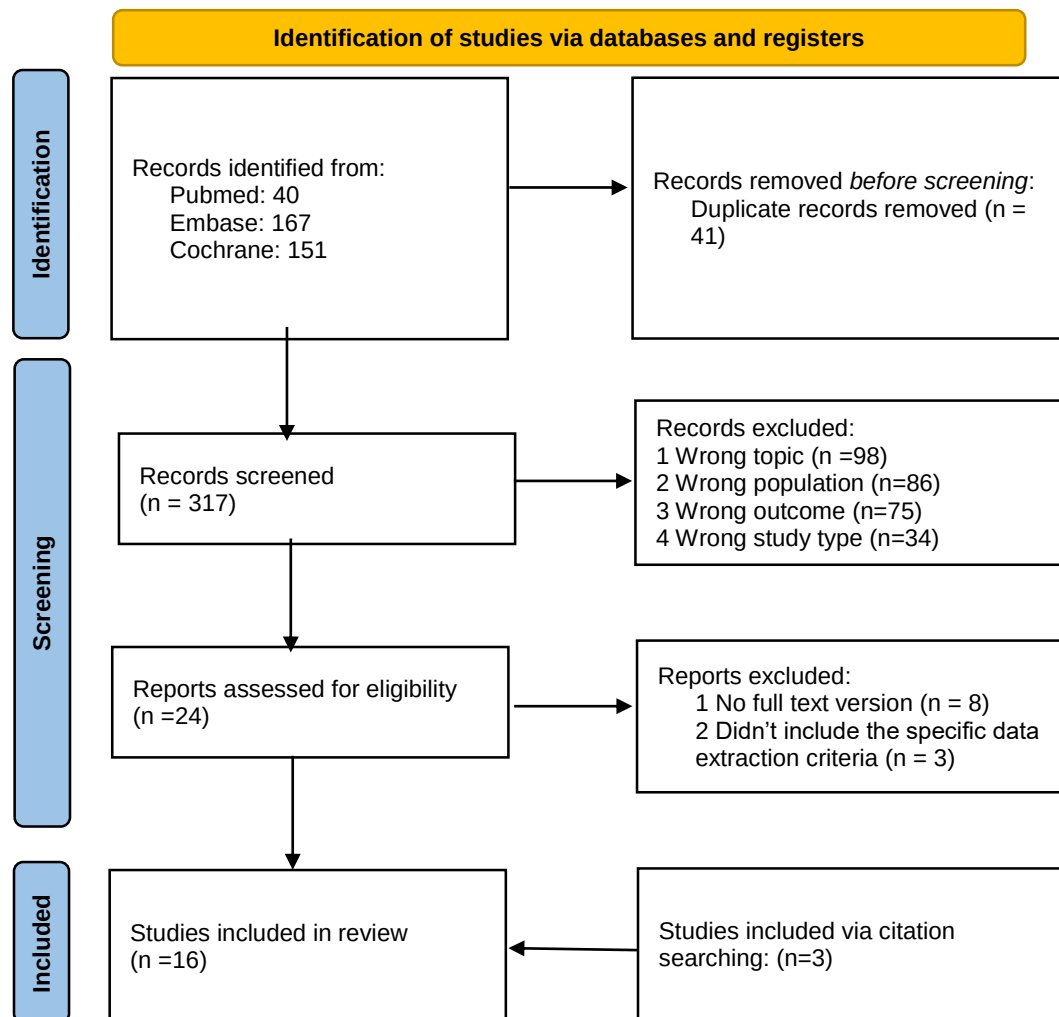


Fig. 1. Flow chart of the research process on rehabilitation post ARCR.

Most of the articles focus on the timing of exercise progression. Out of these 16 articles, 8 examined the comparison between early and delayed physiotherapy (2 RCTs, 5 systematic reviews and meta-analysis and an umbrella review) (Bandara et al., 2021; Bouché et al., 2022; Guity et al., 2023; Longo, Risi Ambrogioni, et al., 2021; Mazuquin et al., 2021; Paolucci et al., 2023; Sheps et al., 2019; Silveira et al., 2021). Among these, most articles discussed the introduction of PROM during the initial weeks to initiate physiotherapy early, while an RCT and a systematic review discussed the introduction of active ROM within the first weeks. A meta-analysis included all RCTs comparing at least two of the three postoperative protocols: strict immobilization for at least 4 weeks, early passive motion and early active motion. And another article discussed the timing for initiation of strengthening exercises. These articles evaluated the impact of these protocols on retear rates, pain levels, ROM, and patient-reported outcomes.

Regarding tear size differentiation, some of the articles categorized tears into small to medium and large to massive categories, while others did not specify tear sizes. One meta-analysis examined the rehabilitation protocol following massive tears treated with superior capsular reconstruction. Additionally, two other articles compared high-frequency visits to the physical therapist with low-frequency visits (Kjær et al., 2021; Longo et al., 2020). And two other articles investigated the impact of scapula training within the rehabilitation program (Rezaie et al., 2023; Zhang et al., 2020).

From the three additional articles included, one being evidence-based guidelines about rehabilitation following ARCR, another one therapists' consensus statement on rehabilitation and the third one a systematic review demonstrating RC activation using electromyography (EMG) to identify exercises with varying levels of RC activation.

Immobilization

The umbrella study by Paolucci et al. (2023), which compared different rehabilitation protocols, found that for large to massive tears, the recommended duration of sling or immobilizer use ranged from 4 to 10 weeks, with the majority of protocols recommending 6 weeks of postoperative use. Regarding medium-sized RTC tears, most articles recommended 6 weeks of sling or immobilizer use postoperatively, while others recommended 4 weeks of use. For small-sized RTC tears, recommendations varied from 2 to 6 weeks, with the highest frequency being 6 protocols recommending 6 weeks of use. Overall, the most common recommendation for the duration of sling or immobilizer use was 6 weeks, regarding the size of the RTC tear.

Another study conducted by Bandara et al. (2021) mentioned that limited shoulder immobilization with sling support for a period of 4–6 weeks could be more beneficial. Thigpen et al. (2016) recommends a 2-week period of strict immobilization followed by PROM.

In the early postoperative phase, PROM exercises are usually performed within the patient's tolerance. During this phase, patients are encouraged to perform AROM exercises for the elbow, hand, wrists and cervical region 1- 2 times per day for 10 to 15 minutes to avoid complications such as muscle atrophy and synarthrosis (joint fusion) and to maintain accessory joint mobility (Lavin et al., 2021; Zhang et al., 2020).

Early versus delayed rehabilitation program

Despite ARCR being such a common surgery, significant differences were observed in the rehabilitation protocols regarding when patients were permitted to begin moving their shoulder and specific timelines for exercise progression.

Lavin et al. (2021) found that there was a divergence in the timing of initiating PROM exercises, with some advocating for immediate implementation postoperatively while others emphasized waiting for 2 to 8 weeks.

According to the articles found, delayed rehabilitation requires strict immobilization for 4 to 6 weeks, whereas early rehabilitation involves reducing the immobilization period and initiating PROM or AROM within the first few weeks.

The articles analyzed which protocol proves to be more effective. Based on the RCTs found by Mazuquin et al. (2021), early rehabilitation groups that allowed PROM in the first few weeks post arthroscopy showed that patients may achieve earlier recovery of ROM without an increased risk of compromising the integrity of the repair. It is expected that patients assigned to early rehabilitation showed better initial ROM compared to those in delayed programs or longer sling immobilization periods. The findings by Sheps et al. (2019) suggest that early movement may improve ROM at 6 weeks postoperatively compared to the use of strict immobilization, although comparable outcomes within 24 months of surgery are achieved in both groups, including RC integrity. According to the RCT by Guity et al. (2023), early rehabilitation is associated with decreased pain, improved function and ROM during the first six months.

According to Thigpen et al. (2016), there is no clear evidence to support strict immobilization versus early protected ROM within the first 6 weeks for small to medium tears. Therefore, they proposed a 2-week period of strict immobilization and a staged introduction of protected PROM starting at 2 weeks postoperatively.

As reported by Silveira et al. (2021), strong evidence suggests that early active movement yields superior results compared to delayed active movement, particularly in terms of improved active forward flexion and abduction at 6 weeks, and greater external rotation at 6 weeks, 3 and 6 months. However, there were no significant differences observed at 12 and 24 months for forward flexion, external rotation, or internal rotation.

Moreover, the meta-analysis by Longo, Risi Ambrogioni, et al. (2021) revealed significant advantages of early rehabilitation over delayed rehabilitation, particularly in terms of external rotation at three months of follow-up, and abduction, forward elevation, and external rotation at six months follow-up. But no differences at 24 month

follow up and no statistically significant differences in retear rates were observed between the two groups.

The network meta-analysis conducted by Bouché et al. (2022) revealed no distinctions among the three postoperative protocols: strict immobilization, early active, or passive motion; except for a notable finding, strict immobilization was associated with decreased flexion after one year.

The study by Sheps et al. (2019) concluded that initiating early active shoulder ROM did not provide notable variances in patient outcomes, including ROM, pain, strength, and health-related quality of life (HRQOL), or in the integrity of the repair compared to the standard postoperative sling immobilization. Although individuals in the early movement group demonstrated significantly better forward flexion and abduction at 6 weeks postoperative, both groups experienced considerable and similar improvements across all measures during the 24-month postoperative period.

During the early postoperative phases, PROM is typically performed according to the patient's tolerance. This involves avoiding pushing for increased ROM at end ranges, but rather using gentle oscillations to reduce muscular tightness, guarding, and pain (Paolucci et al., 2023). (Thigpen et al., 2016) found no clear human evidence to support strict immobilization over protected ROM during the first 6 weeks. Similarly, to Van der Meijden et al. (2012), it highlighted that protected ROM allows for appropriate healing of the repaired rotator cuff, reduces the chances of postoperative stiffness, and communicates to patients that they are active participants in their own recovery. But Achieving PROM too rapidly, particularly in repairs with poor tissue quality, is believed to place undue stress on the suture-tendon interface.

The timing for transitioning to AROM was found to be directly correlated with the size of the RC tear, with smaller tears allowing for an earlier transition. Recommendations for this transition ranged from 6 to 16 weeks, but most protocols suggested returning to full range of motion by 12 weeks (Paolucci et al., 2023). Yet, according to (Lavin et al., 2021) most studies initiated AROM sooner postoperatively, typically at 4 to 5 weeks.

Strengthening

The umbrella study conducted by (Paolucci et al., 2023), established that postoperative strengthening is recommended, and its initiation depends on the size of the tear. They also found that recommendations for the return to strengthening after small ARCR varies from 6 to 12 weeks, the most frequent recommendation was returning at 6 weeks. For medium ARCR protocols, recommendations for initiating postoperative resistance strengthening also ranged from 6 to 12 weeks, the most common recommendation was returning to strengthening at 12 weeks, while other protocols suggest a return at 8 weeks. For large to massive RC tears, most protocols advise to begin the strengthening between 12 and 16 weeks postoperatively.

Whereas, in the articles found by Lavin et al. (2021) about massive RC tear, a more aggressive approach was employed, calling for strengthening to begin as early as 6 to 12 weeks postoperatively.

Exercise selection

As outlined in the systematic review by (Edwards et al., 2017), EMG studies are used to assess the RC activation level in each exercise to guide the progression of postoperative rehabilitation post ARCR. Thereby, exercises are classified into categories of low (0%-20% MVIC), moderate (21%-40% MVIC), high (41%-60% MVIC), and very high (greater than 60% MVIC) based on their level of muscle activation. In this study, many passive exercises are observed to generate minimal muscle activation, making them suitable for the initial phases of rehabilitation. For instance, pendulum exercises are found to elicit low levels of supraspinatus and infraspinatus activation, supporting their early post-surgery use.

Scapular training

Rezaie et al. (2023) showed that focusing on the scapulothoracic joint in addition to the glenohumeral joint in rehabilitation post ARCR, can reduce pain, disability, improve function and ROM in post-test evaluation and at 3 month follow up.

Likewise, starting scapular training at 2 weeks post ARCR, such as strength training of muscles around the scapula and closed-chain stability training, improves

shoulder joint pain, daily activity, and strength test. After 12 weeks, these initial enhancements persisted, with additional improvements observed in abduction, extension, and shoulder strength (Zhang et al., 2020).

Frequency of visits

Kjær et al. (2021) compared two groups: the progressive rehabilitation group, which underwent progressive active exercises combined with home exercises and received physical therapy sessions three times per week for the initial two to five weeks followed by home exercises for the subsequent four days, and the usual care group, which received conventional care consisting of one passive physical therapy session followed by six days of home exercises during the same initial period. The study did not find patients benefiting more in shoulder function, pain, and quality of life after 12 weeks of progressive rehabilitation compared to those receiving usual care, either in the short or long term.

A survey of usual practice among American Society of Shoulder and Elbow Therapists (ASSET) members revealed that they adjust the frequency of follow-up visits based on patient progress, considering factors such as pain, impairments in other regions, and risk factors related to healing or stiffness, patient health status, surgery specifics, resources, patient goals, and clinician preferences. The majority (70%) of ASSET respondents schedule 1-2 visits per week in phase 1 and then 2 visits per week for phases 2-4, as needed (Thigpen et al., 2016).

Chapter 2: TR program's development

Patients begin home exercises tailored by their physical therapists through a mobile application. The exercises, presented via videos and detailed instructions, include exercise frequency, repetition count, and precautionary measures (Appendix 3) and can be performed with simple equipment, such as a cane, an elastic band and a ball.

Video exercises for this TR program were selected from validated exercise platform by INAMI (*Une Rééducation via Application Mobile INAMI*) and Physitrack. Examples of videos filmed are shown in Appendix 4. These exercises are outlined for patients to perform independently at home. However, it is recommended that patients engage in live sessions with their physical therapists for PROM exercises in the early postoperative stages.

Another objective of this TR program is to enhance accessibility for patients to seek advice and ask questions to their physical therapists regarding the difficulty of the exercises, or any additional comments through an online conversation. Patients can share pictures of their progress, their shoulder ROM, or videos of themselves performing their exercises, ensuring correct execution, especially in the first attempt. Thus, they must be informed that the use of videos and pictures sent is confidential and will not be utilized for any other purposes. Subsequently, they are prompted to complete the visual analog scale questionnaire after each session to determine the pain level during and after the exercises, and the American Shoulder and Elbow Surgeon (ASES) or Western Ontario Rotator Cuff Index (WORC) every 4 weeks. This feedback enables the physical therapist to adjust the TR program to better suit the patient's needs. Patients receive daily notifications on their mobile phones reminding them to do their exercises, this could ensure compliance with treatment.

This TR program consists of 3 phases: protection of the operated shoulder, active mobilization of the shoulder, strengthening and return to activity. Furthermore, the timeline varies whether the tear size is small to medium or large to massive (Appendix 5). The exercise program is detailed in Appendix 6.

Phase 1: Protection of the operated shoulder

During the initial phase, that lasts approximately 4 to 6 weeks, the primary objectives are to maintain the integrity of the repair through pain and inflammation management and reaching gradually ROM targets. During the initial two weeks for small to medium tears and the first 4 weeks for large to massive tears, the patient's shoulder is strictly immobilized, while AROM exercises for the neck, elbow and wrist and normal scapular positioning and mobility are performed. Following the initial period of strict immobilization, PROM exercises are started with the physical therapist during face-to-face sessions. Meanwhile patients can gradually discontinue the sling to perform home exercises with low activation of the RC muscles. These exercises should be gentle and controlled to avoid putting too much stress on the healing shoulder (Table 1 and fig. 2 to fig. 5).

To minimize the pain, the patient is recommended to use cryotherapy and adhere to the medications as prescribed by their doctor. It's crucial to avoid AROM exercises for the shoulder, lifting heavy objects, engaging in excessive training or sudden movements, bearing weight on the hands and performing aggressive PROM exercise. And internal rotation exercises aren't recommended at the beginning but are delayed until week 6 with the start of AAROM exercises.

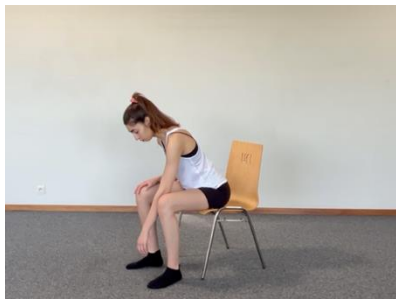


Fig. 2. Sitting forward pendulum.



Fig. 3. Sitting side pendulum.

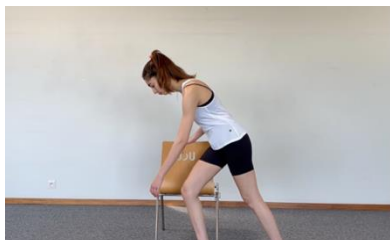


Fig. 4 Standing pendulum

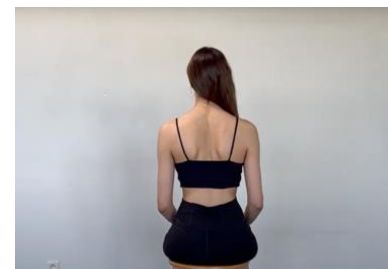


Fig. 5 Scapular retraction

Table 2: Example of exercises for phase 1, protection of the operated shoulder.

Exercises	Starting position	Instructions	Tips	Frequency
Sitting forward pendulum	Sit with your knees slightly apart and feet flat on the floor. Lean forward and support your non-affected arm on your thigh. Bend at the hip, keeping your back straight. Your head and spine should stay aligned. Your affected arm should be fully relaxed and hanging between both legs.	1.Repeatedly shift your weight forward, leaning further forward than the start position, then return to the original position. 2.Let the momentum of your body guide your arm, swinging forward and back.	Keep your affected arm relaxed during the exercise. Initiate the movement from your whole body, not your arm.	5 minutes
Sitting side pendulum	Sit with your knees slightly apart and feet flat on the floor. Side bend to the direction of your affected arm. Your affected arm should be fully relaxed and hanging at your side.	1.Repeatedly shift your weight to the side, leaning further side bent than the start position, then return to the original position. 2.Let the momentum of your body guide your arm swinging.	Keep your affected arm relaxed during the exercise. Initiate the movement from your whole body, not your arm.	5 minutes
Standing pendulum	In a standing position, lean over with your good arm supported on a table or chair. Relax the arm on the painful side, letting it hang straight down.	1. Slowly start to swing your relaxed arm by moving your body back and forth. 2. Then, make circles in a clockwise and counterclockwise direction. 3. Do not actively move it using your shoulder muscles	Let your body promote the “momentum” for the movement.	5 minutes
Scapular retraction	Sit on a chair with your feet flat on the floor.	1. Bring your shoulder blades together by extending your torso. 2. Repeat this movement several times.		3 sets of 10 repetitions

Phase 2: Active mobilization of the shoulder

The goal of this phase is to improve shoulder ROM. The initiation of AAROM depends on the size of the tear. Typically, the duration of this phase ranges from 7 to 12 weeks for small to medium RC tears, and from 7 to 15 weeks for large to massive RC tears. It's important to note that AAROM may be delayed until 10 weeks to ensure tendon healing in the case of massive to large tears.

The patient is encouraged to remove the sling to prevent complications associated with prolonged immobilization and begin using the operated shoulder in ADLs. The patient will progress from AAROM to AROM (Table 2 and fig. 6 and 7). In this stage, while pain may persist, there should be a gradual decrease in medication usage. Thus, it is advised to incorporate cryotherapy, ensure proper utilization of the upper extremity in ADLs, avoid heavy lifting or quick/sudden movements and introduce therapeutic exercises at an appropriate intensity level.

To progress to the strengthening phase, the patient should have approximately full AROM comparable to the non-operated shoulder with minimal to no pain while performing the exercises. Additionally, the patient should have appropriate scapular posture both statically and dynamically during ROM exercises and functional activities.



Fig. 6. Supine shoulder external rotation with a cane

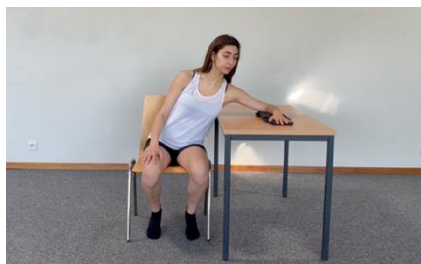


Fig. 7. Sitting shoulder table slides into abduction -flexed elbow.

Table 2: Example of exercises for phase 2, active mobilization of the shoulder.

Exercises	Starting position	Instructions	Tips	Frequency
Supine shoulder external rotation with a cane	Lie on your back with your knees bent and feet flat on the surface. With a cane, broomstick, or similar shaped object. Place the palm of your affected arm on the end of the stick. Your unaffected arm will grab onto the middle of the stick. Keep the elbow of your affected arm on the ground and in contact with the side of your body.	1.Using your unaffected arm on the cane, guide your affected arm away from the starting position. 2.This means your hand will move away from your body and closer to the floor. 3.Return your arm slowly to the starting position.		3 sets of 15 repetition
Sitting shoulder table slides into abduction- elbow flexed	Sit up straight with your feet flat on the floor and to the side of a table or countertop. Your arm should be placed directly to the side of your body, with your fingers pointing forward. The forearm of your affected arm will be supported on the surface of the table or countertop. Your elbow will remain bent for the duration of this motion.	1.Slowly lean sideways towards your arm. 2.Leaning sideways will guide your arm out to the side, sliding on the surface. 3.Return to the starting position, sitting up straight and sliding your arm back towards your body.	Use a towel or something similar placed under your forearm to help with easier sliding.	3 sets of 15 repetitions

Phase 3: Strengthening phase

This phase lasts between 13 to 24 weeks for small to medium RC tears and 16 to 26 weeks for large to massive tears. However, resistive exercises for small to medium tear can start as early as week 8 depending on the patient's progress. The primary aim is to normalize AROM while progressively enhancing shoulder strength and endurance through a variety of exercises, including isometric and strengthening exercises (Table 3 and fig.8 to fig.11). Additionally, the focus shifts towards improving neuromuscular control through targeted exercises. In parallel, another goal is to minimize or eliminate joint stiffness during end-range glenohumeral movements, as well as correcting deficiencies in core and scapular performance.

As the rehabilitation progresses, these efforts help improve shoulder function and stability, making it easier to return to normal activities. As patients return to their ADLs, it's essential for them to recognize the importance of gradually increasing stress on the operated shoulder. Regarding pain management in this phase, cryotherapy post-activity can be continued if necessary. The start time of return to activity may vary depending on the patient's progression and on the specific sport.

Table 3: Example of exercises for phase 3: Strengthening.

Exercises	Starting position	Instructions	Tips	Frequency
Standing shoulder wall lift offs with elastic band- high position	Stand up straight in front of a wall or doorway. Hold an elastic band in both hands and place both palms on the wall. The unaffected hand will be at the level of the shoulder. The affected hand will be below the level of the shoulder.	1. Your unaffected arm's hand will remain on the wall and maintain the position of the elastic band. 2. Lift your affected arm's palm off the wall against the resistance of the elastic band. Your hand and elbow should remain parallel to the wall. 3. Return your palm to the starting position.		3 sets of 10 repetitions
Standing shoulder row exercises single arm & double arm - one stable arm	Anchor an elastic band either around a sturdy structure or closed in a door with a knot. Stand with an upright posture facing the structure/door and adjust the band to the height of your hand when your elbow is bent to 90 degrees. The band should be parallel to the floor. Grab onto the elastic band with both hands. There should be some tension in the band prior to the start of the exercise. Start your arms down by your side,	1. Maintaining a grip on the band, pull the band towards you with both arms, squeezing your shoulder blades together as you pull your arms back. 2. Return to the starting position slowly.	Keep your shoulders relaxed and elbows close to your sides during this exercise. Keep your abdominals tight and maintain a neutral posture at all times, keeping your shoulders over your hips and knees.	3 sets of 10 repetitions

	elbows bend to 90 degrees, and palms facing each other.			
Standing shoulder active stabilization - circles	Stand in front of a wall with your arm straight out in front of you, holding a small ball against the wall. Your arm should be at shoulder height, with your elbow straight.	1.Roll the ball in small circles (clockwise and counterclockwise), in a slow and controlled manner. 2.Repeat this motion.	The motion should be small – try to keep your arm aligned with your shoulder. Keep your spine aligned and your chin tucked throughout this exercise. Keep your elbow straight.	hold 1 minute and repeat 5 times
Standing push up- wall height	Stand up straight, facing the wall, and arm's length away. Place your hands flat on the wall at shoulder height, elbows straight.	1.Keeping your shoulders down and back, gradually bend your elbows to bring your face towards the wall to perform a push-up. 2.To return to the starting position, push through your hands, straighten your elbows, and move your face away from the wall.	Make sure to keep your chin tucked, back straight, and abdominals tight while you perform this movement.	3 sets of 10 repetitions

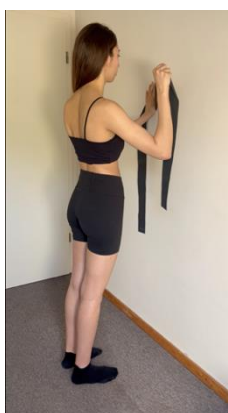


Fig. 8. Standing shoulder wall lift offs with elastic band- high position

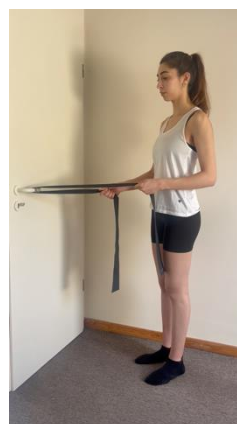


Fig. 9. Standing shoulder row exercises single arm & double arm - one stable arm

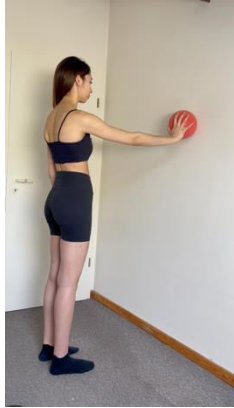


Fig. 10. Standing shoulder active stabilization - circles

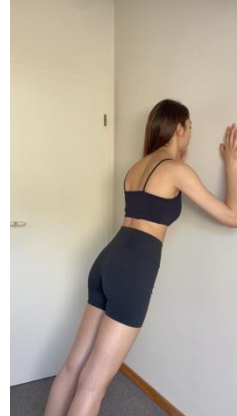


Fig. 11 Standing push up- wall height

Chapter 3: Experts input

Doctors:

- Dr. Mathias Colman: Orthopedic surgeon specialized in upper limb surgery in Belgium: shoulder prosthesis, rotator cuff tear, shoulder instability, shoulder trauma, shoulder arthroscopy et infiltrations.
- Dr. Christel Conso: Orthopedic surgeon and traumatology in France, specialized in upper limb pathologies especially for athletes.
- Dr. Antoon Van Raebroeckx: Orthopedic surgeon specialized in shoulder surgery in Belgium. He is a board member in the Flesss (Flemish Elbow and Shoulder Surgeon's Society) and in the (Bless) Belgian Elbow and Shoulder Society.
- Dr. Justin Smith: Orthopedic surgeon in the United States of America specialized in: minimally invasive arthroscopic repair and reconstructive surgery of sports-related injuries to the shoulder, elbow, hip, knee and ankle; cartilage repair and restoration; orthobiologic therapy; joint preservation and complex shoulder replacement.

Physical therapists:

- Gaeten Hanecour: Physical therapist specialized in orthopedic manual therapy in Belgium.
- Tim Marteleur: Physical therapist specialized in shoulder injuries by testing and research of problematic shoulder injuries and starting a training program for conservative shoulder treatments and works in collaboration with Dr. Van Raebroekx in Belgium.
- Julien Gerard: Orthopedic physical therapist and experienced in TR in Belgium.
- Philippe Declève: Physical therapist, Doctor in Health Sciences (PhD), sports physical therapist specialized in the rehabilitation of shoulder pathologies in Belgium.
- Thomas Hansoulle: Orthopedic physical therapist specialized in manual therapy in Belgium.

➤ Doctors' opinion:**Immobilization**

In recent years, post ARCR rehabilitation has evolved towards earlier shoulder mobilization. An agreement among the surgeons indicates a 6-week shoulder immobilization period for tissue healing. During the first weeks post-surgery, active exercises of neck, elbow and wrist as well as scapular movements and posture correction should be performed. A surgeon advises wearing an Ultrasling (sling with an abduction pillow) for the first three weeks post-surgery, transitioning to a regular sling afterward to maintain shoulder immobilization for 6 weeks in total. Another approach recommends continuous regular sling wear for 2 weeks and starting PROM with a physical therapist after this period. An alternative approach allows patients to remove the sling while at rest but advises wearing it at night and in situations posing a risk of injury such as public transportation. However, sling removal timing varies based on the patient's comfort level, with some preferring to wait until 1 week after surgery due to fear or pain.

Active mobilization of the shoulder

According to one surgeon, for small to medium tears, AROM begins after 6 weeks post-op, while for large to massive tears, it starts after 8 weeks. They also mentioned that recovery of internal rotation may take up to 6 months.

Another surgeon suggests that progression to the active phase depends on the assessment of the patient's healing progress, aiming for a 10% to 20% improvement in shoulder mobility from PROM exercises by 6 weeks post-surgery. Active movements commence at 6 weeks with the removal of the sling.

Additional surgeons advise that the transition to active exercise typically occurs between 4 and 6 weeks after surgery. One specified that patients can begin active internal rotation without applying force but does not recommend PROM exercises for this movement.

Strengthening exercises

Two of the surgeons advise beginning strengthening exercises at 12 weeks. One of them highlights the importance of shoulder flexibility three months post-surgery to advance to the strengthening phase. And the other surgeon suggests that full ROM is not necessary to start the strengthening phase.

A third surgeon recommends a specific timeline for initiating strengthening exercises based on tear size; week 10 for small to medium tears and week 12 for large to massive tears. However, an opposing point of view is presented by another surgeon, who cautioned against engaging in strengthening exercises before 6 months post-surgery, citing potential risks.

Complications post ARCR

Shoulder stiffness emerges as the most common complication post-surgery, according to insights from all interviewed surgeons. Conversely, retear of the RC is not notably prevalent, based on the experiences shared.

One surgeon indicated a risk of developing shoulder stiffness post-surgery, requiring adaptation of the rehabilitation process. Diagnosis typically occurs between 6 to 12 weeks post-surgery, or even at 16 weeks. Another surgeon doesn't consider shoulder stiffness a complication but rather a normal occurrence in post-operative

phases. If it appears three months post-surgery, they advise administering steroids and suspending physical therapy sessions for a few weeks before reassessing the patient's condition.

Regarding retear of the RC, one surgeon suggests that identifying its presence before 6 months post-surgery is challenging. If the patient's progress is unsatisfactory, it is recommended to wait at least 6 months before conducting imaging studies. A second surgical intervention is considered based on the patient's characteristics. If surgery is warranted, the shoulder must have sufficient flexibility before the procedure. Another surgeon adds that patients who smoke, regardless of their age, are at the highest risk of experiencing a retear after arthroscopic surgery.

Concerning the biceps tenotomy and tenodesis

All surgeons emphasize the frequent use of biceps tenotomy for ARCR to reduce pain. Reducing stress on the elbow in the first weeks is important to prevent complications such as the "Poppey sign". PROM should be performed in the first weeks to avoid elbow stiffness and AROM exercises are delayed for 4 to 6 weeks. Another approach suggests continuing the rehabilitation program normally, with no restriction to elbow motion or strength.

Concerning biceps tenodesis, surgeons recommend limiting AROM during the initial weeks. Alternatively, another approach permits AROM immediately after surgery but restricts elbow strengthening until after 6 weeks.

Integration of TR post ARCR

All the surgeons interviewed emphasize the potential benefits of TR, noting its usefulness as a tool for physical therapists during rehabilitation. They also highlight its role in generating clear reports on patients' progress, indicating its potential to enhance communication and monitoring in the rehabilitation process. A surgeon emphasized the advantages of TR after ARCR, particularly in the initial post-surgery weeks when driving is restricted and access to specialized shoulder rehabilitation therapists may be limited. They have recently begun collaborating with physical therapists utilizing a TR platform to monitor their patients after ARCR.

However, TR may pose challenges for patients following ARCR, particularly considering that the patient population tends to be around 60 years old. Physical therapists should be capable of monitoring patients to ensure correct execution of exercises.

➤ **Physical therapists' opinions**

Immobilization

According to physical therapists, the immobilization period typically lasts around 3-6 weeks, although this duration may vary depending on the surgeon's decision. Factors influencing this decision include the specifics of the surgery, tendon quality, type of rupture, medical history, and the patient's overall condition. They all start mobilizing the neck, elbow and wrist during the immobilization period. The initial six weeks, exercises recommended to patients should minimally stimulate the RC. Additionally, they emphasize the significance of core strength and endurance exercises, especially if the activity poses no risk to the shoulder.

Active mobilization of the shoulder

All physical therapists emphasized the importance of a flexible program that allows for faster progression in exercises based on the patient's improvement. Most physical therapists do not adhere to a specific protocol for transitioning from PROM to AROM movements and from AROM to strengthening exercises. Instead, they follow the surgeon's instructions while considering the patients' pain levels and limitations. By week 6, most of the PROM should be regained, and AROM is initiated without exerting pressure on the shoulder. However, this depends on whether the rehabilitation protocol began immediately after surgery or was delayed. If delayed rehabilitation started after a three-week period of strict immobilization, AROM cannot be initiated at the six-week mark. Additionally, they encourage patients to engage in cardiovascular activities such as indoor cycling or walking, if possible and safe, to promote overall fitness.

Strengthening exercises

At the three-month mark, one physical therapist continues with AROM exercises and gradually introduces strengthening exercises, progressing to more challenging exercises once the patient can perform them easily and correctly. They emphasize that exercise progression should respect the healing process, particularly between 3- and 6-months post-surgery when the risk of retear is high. Factors influencing exercise progression include the type of surgery, number of tendon repairs, patient's age and tendon quality, comorbidities, and medication use.

For exercise selection, two physical therapists use the study published in the Journal of Orthopedic Trauma as a reference demonstrating RC activation using EMG to identify exercises with varying levels of RC activation. They emphasize the importance of selecting exercises that match the patient's specific needs and abilities.

Two physical therapists believe that the initiation of the strengthening phase depends on the patient. They prioritize RC activation and implement stability programs with resistance for patients in professions involving heavy lifting, small repairs, and no complications. Full AROM is not always necessary to progress to the strengthening phase, as some patients benefit from starting resistive exercises to improve ROM and reduce stiffness.

Complications post ARCR

Most physical therapists agree that exercise-induced retear is rare, typically occurring due to external factors such as falls or stumbles. One physical therapist highlights important signs to detect complications early, such as constant or increasing pain and lack of ROM progression.

Concerning the biceps tenotomy and tenodesis

Regarding the biceps tenotomy, most physical therapists share their personal experience, stating that they wait until 4-6 weeks to initiate elbow movements. Instead, one physical therapist begins immediately with active movements before 4-6 weeks without resistance to prevent the Poppey sign, explaining that delayed mobilization of

the elbow could result in elbow stiffness, so AROM exercises of the elbow may begin in the first week of post-surgery. For biceps tenodesis, patients may experience increased tenderness around the site, leading them to avoid AROM of the elbow.

Integration of TR post ARCR:

The physical therapists focused on several key aspects of TR, such as its effectiveness in monitoring patient progress, enhancing motivation, and promoting treatment adherence. It's crucial to incorporate diverse exercises to keep patients engaged and prevent monotony, thus promoting higher levels of physical activity. One therapist considers the value of providing timely feedback and clear instructions to be very essential, particularly through physical interaction during the initial stages of rehabilitation.

Another physical therapist marked the importance of tailoring the program and exercise instructions to the age range of the patients, particularly noting that the patients are typically around 60 years old. He emphasized that not all these patients will readily adhere to the program, especially if they are not used to using mobile phone applications. Therefore, it would be interesting to assess patients' familiarity with technology before integrating the program to determine their potential adherence to the digital platform. Additionally, he pointed out the importance of ensuring that patients have adequate space and materials to perform the exercises. He emphasized the therapist's presence to provide reassurance and patient education as important factors. It's crucial to evaluate the patient's pain during exercises and to instruct them on how to assess their own pain during and after the exercises as symptoms can appear after 24h of the session.

➤ **Communication between surgeons and physical therapists**

All experts talked about the importance of establishing solid communication between surgeons and therapists. This implies that the therapists receive a report of the surgical procedure, and surgeons being provided with the rehabilitation protocol used by the physical therapist. Communication should be fluid and efficient, facilitating the exchange of important information about the patient's progression from one phase to another and identifying signs of complication.

Discussion:

The objective of this study is to explore the current evidence about rehabilitation post ARCR and create a suitable and practical digital tool for physical therapists. Heterogeneity in rehabilitation was found in literature and among experts. The studies available in the literature have shown diversity in follow-up duration, outcome measures and types of physical exercises (Longo et al., 2020). The lack of consensus in the timeline and for some progression criteria makes it challenging to guide or personalize a post ARCR rehabilitation program. Consequently, definitive conclusions regarding the most effective form of physical therapy for post ARCR remain elusive.

This TR program serves as a tool for home exercises, offering both physical therapists and patients a structured and accessible platform for post ARCR rehabilitation.

Immobilization

The immobilization period in this program is between 4 to 6-weeks, ensuring safe tendon healing delaying the recovery in the long term. The surgeon decides this immobilization period depending on the prognostic factors of the patient.

In the first two weeks for small to medium tears and in the first 4 weeks for large to massive tears, the shoulder is strictly immobilized, and the patient can do AROM exercises of the cervical, elbow and wrist. This strictly immobilized period helps extracellular matrix representing similar characteristics of uninjured tissue. It results in increased type I collagen organization and less scar formation compared to early mobilization, concluding that the quality of tissue improves with decreased loads that may provide a proper tendon-to-bone integration (Sgroi & Cilenti, 2018). After repair, small RC full-thickness tears typically heal naturally, following a three-stage process; initial inflammation, fibroblastic activity and remodeling (Huegel et al., 2015) (Thomopoulos et al., 2015). While larger tears, with fewer fibroblasts and limited cell proliferation, delay their potential for physiological healing (Matthews et al., 2006).

According to Mazuquin et al. (2021), prolonged sling use may lead to issues such as restricted ROM and further weakening of already compromised RC muscles. Therefore, it is advised to limit sling usage to a maximum of 6 weeks to reduce these potential complications. The surgeons' perspective suggests that whether the patient wears a sling with or without an abducted pillow does not significantly impact outcomes. A study conducted by Pandey et al. (2020) found that maintaining an abducted shoulder position with an abduction brace during the first 6 weeks postoperatively does not provide any advantages in terms of reduced pain levels, improved clinical scores, or enhanced RC healing.

Early versus delayed rehabilitation

Based on the insights from the experts interviewed, surgeons find the timing of initiation of mobilization appropriate as they prioritize protecting the operated shoulder. While physical therapists aim to initiate mobilization sooner in the rehabilitation process. However, they agree that the established timeline is suitable for a TR program, which necessitates a more cautious approach. Most rotator cuff tears occur due to gradual tendon degeneration rather than an acute injury. Considering the degenerative nature of rotator cuff tissue, rehabilitation programs following RCR should be approached with caution (Thigpen et al., 2016).

Numerous studies were reviewed comparing early and delayed rehabilitation following ARCR. The findings suggest that an early rehabilitation program, whether involving PROM or AROM exercises in the early post-operative stages, offers several advantages such as reduced pain and improved function (e.g., forward flexion or external rotation). However, short-term results are observed with early rehabilitation, but no difference persists in the long term, so both early and delayed protocols can lead to a good recovery.

The size of the RC tear determines the time to begin AROM: the smaller the tear, the earlier the transition. Precautions should also be taken during early rehabilitation for large to massive tears to prevent recurrence, and an appropriate timeline should be selected based on the patient's prognostic factors (Paolucci et al., 2023).

Simultaneously, early mobilization aims to prevent shoulder stiffness by reducing the risk of adhesion formation. Controversy, delayed rehab protocol seeks to preserve the tendon to bone integrity, avoiding retear. Such findings suggest that the risk of shoulder stiffness might be avoided by executing balanced and limited ROM in the first weeks after surgery (Longo, Risi Ambrogioni, et al., 2021).

Exercise selection

In this program, exercises are chosen for each phase based on their intensity and activation level of the RC. The exercise selection in most programs, as observed in articles, and interviews with physical therapists, is based on EMG studies.

According to Van der Meijden et al. (2012), exercises in the early stages following ARCR should not exceed 15% of maximal voluntary isometric contraction (MVIC) to ensure safe loading. Edwards et al. (2017) found that AAROM exercises with a cane tended to exceed the 15% MVIC threshold, suggesting that their use for early postoperative phases may be inappropriate. However, a series of progressive, active elevation exercises below 15% MVIC, such as supine and incline press-ups, may still be appropriate.

In early postoperative phases, the focus in PROM exercises is to avoid increasing ROM at the end of range but using gentle movements to reduce muscular tightness and pain. Pendulum exercises, commonly used throughout the first phase, are examples of PROM exercises that demonstrated low levels of supraspinatus and infraspinatus activation (Edwards et al., 2017). Nonetheless, if performed incorrectly, it will lead to a moderate activity of the supraspinatus, making it ideal to avoid during early postoperative (Long et al., 2010). Thus, patient education and monitoring should be implemented to avoid unwanted activation of the RC.

Stretching exercises such as external rotation in increasing angles of abduction, internal rotation in abduction, horizontal adduction, and functional internal rotation are introduced later in phase 2, around week 9 (Thigpen et al., 2016). This precaution is vital to ensure the proper healing and integrity of the repaired tissue as internal rotation

exercises after ARCR in the first weeks may add a risk of significant strain increase (Hatakeyama et al., 2001).

The timing of the strengthening phase is variable and dependent on the prognostic factors (Van der Meijden et al., 2012). Progression to this phase requires the presence of sufficient PROM and uncompensated scapular AROM (Millett et al., 2006).

Most experts agree to begin strengthening exercises according to the timeline proposed by this TR program. However, contradictory opinion from one surgeon suggests that strengthening should not begin before 6 months post-surgery, but no literature was found demonstrating any risks associated with introducing resistance exercises at this stage.

Moreover, Kokmeyer et al. (2016) mentioned the value to consider the surrounding RC muscles that weren't repaired. The support provided by muscles like the subscapularis, infraspinatus, and teres minor influences the static and dynamic positioning of the humeral head within the glenoid. By enhancing support from these surrounding muscles, the direct stress and strain on a repaired supraspinatus can be reduced, potentially improving both short- and long-term outcomes for the soft tissue.

Uhl et al. (2010) recommend that rehabilitation programs advance from short-lever to longer-lever arm activities. They also suggest initiating activities from supine positions and progressing to incline and then upright postures to modify the effect of gravity and subsequently the load on the glenohumeral joint.

Scapular training

In this program, scapula exercises begin in early post-operative phases and are continued until the strengthening phase. According to the articles reviewed, integrating scapular training into rehabilitation post ARCR is crucial to assure the maximum efficacy of rehabilitation and treatment.

Achieving correct posture post ARCR and establishing sufficient muscle balance between scapular upward and downward rotators are necessary. Scapular retraction and downward rotation can increase the subacromial space and facilitate

tendon healing (Sgroi & Cilenti, 2018). Scapular kinesis can be trained in the early rehabilitation, isometric scapular retraction exercises can begin while standing or sitting, and can later advance to the prone position, as detailed in the developed program (Schory et al., 2016; Zhang et al., 2020). The goal is to help normalize the synchronized ROM between the glenohumeral and scapulothoracic joint, by restoring the typical upward rotation mobility and stability of the scapula while simultaneously elevation the humerus (Lawrence et al., 2014).

TR particularities/challenges

Despite the growing integration of telehealth services across healthcare domains, the limited amount of literature on TR initiatives demonstrates the gap in research concerning the efficacy, implementation and results in rehabilitation settings (Chang et al., 2022).

In this research, no articles were found describing video-based TR exercise programs following ARCR. Instead, most articles focused on home-based exercises and digital rehabilitation programs such as utilizing a home-based machine or virtual reality programs. This highlights the wide scope of TR and emphasizes the necessity of developing a video-based therapeutic exercise program for post-ARCR recovery.

For example, Song et al. (2018) compared home-based rehabilitation to a supervised group following ARCR. They found no significant difference between the two groups in terms of ROM, pain levels and single assessment numeric evaluation at 6 months post-surgery. The patients in the home-based group received consistent training, enabling them to perform most exercises easily.

Shim et al. (2023) demonstrated that augmented reality was effective in improving the shoulder function after ARCR and that there were no significant negative outcomes, suggesting that digital therapy through augmented reality is clinically safe.

All interviewed surgeons agree that TR can be implemented during the first 6 weeks after RCR, incorporating AROM exercises for the wrist, elbow, and cervical region. Beyond this period, TR represents a valuable and supplement tool to enhance

patient adherence, although sometimes the guidance of a physical therapist remains essential to provide to the patient's reassurance and adequate education concerning their condition.

As suggested by an expert, it is interesting to assess patients before using this TR program to determine their familiarity with mobile applications, as these tools should be user-friendly rather than complex. Additionally, testing the implementation of TR post ARCR is important to identify the key points that should be improved, such as the frequency of face-to-face visits with the physical therapist. Kjær et al. (2021) found no difference between low frequency and high frequency visit protocols, but more profound studies are needed to determine the optimal frequency of face-to-face visits for each phase of treatment, especially during the initial phase where only PROM exercises are performed.

Personalization of the program

The optimal rehabilitation program after ARCR is debatable; so, it must be personalized by the physical therapist for each patient. According to the umbrella study of Paolucci et al. (2023), the tear size is the only patient-related factor currently considered in determining whether to select an early or delayed rehabilitation protocol. Kokmeyer et al. (2016) proposed using a spectrum of prognostic factors to guide the rehabilitation program and ensure structural and functional success quickly and safely. These factors can be intrinsic to the RC such as: age, tear size, pre-operative fatty infiltration and muscle atrophy; or extrinsic to the RC such as: bone mineral density, smoking, diabetes mellitus, obesity, surgical procedure and fixation technique.

Furthermore, while diabetes mellitus may not directly impact the quality of healing, its presence heightens the risk of post-operative stiffness and contributes to inferior functional outcomes (Chung et al., 2011; Le et al., 2014). Consequently, early ROM may be more suitable for patients with diabetes mellitus.

Kokmeyer et al. (2016) mentioned that to avoid complications and ensure appropriate tendon healing, a conservative approach is advisable for patients exhibiting risk factors, whereas a more accelerated progression can be implemented for those with

factors indicating better healing potential. The authors proposed a model guiding rehabilitation, where patients with low, moderate and high-risk factors follow respectively a moderate, intermediate or conservative rehabilitation.

Patients' follow up

Many tools have been developed to assess patient-specific outcomes. Therefore, the selection of the tool used in this program for patient follow-up depends on whether the questionnaire is administered during a TR program.

A systematic review found that the use of the ASES questionnaire post ARCR has the highest responsive rate compared to other tools and requires only subjective patient input (Unger et al., 2019). According to Bejer et al. (2023), the WORC questionnaire can also be recommended for patients post ARCR as it enables a reliable evaluation of patients' functional abilities and their changes across different life domains, while not requiring direct assessment by a clinician. According to Thigpen et al., (2016), patient related outcomes should be measured every 2 to 4 weeks to evaluate the progression of the patient symptoms and function.

The use of telehealth for follow-up is as efficient as in person-visits for making patients satisfied and managing pain Kane et al. (2020). In the RCT by Descamps et al. (2023), postoperative web-based surveys prove to insure significantly higher response rate at 6 and 12 weeks and higher patient satisfaction compared to traditional paper questionnaires in patients who underwent ARCR. Web-based questionnaires are easier to use because of the automated score calculation, they also improve the quality of postoperative monitoring and are an efficient tool to follow-up regularly the patient postoperatively to detect complications earlier.

In addition, online conversation with the physical therapist can help save time for both parties, as patients can receive follow-up care from their physical therapists without needing to visit the clinic.

Complications post ARCR

The primary complication following ARCR is stiffness, which can be an unfavorable consequence and often result from extended immobilization (Van der Meijden et al., 2012). It's important for rehabilitation protocols to acknowledge the slow process of tendon-to-bone healing (Nikolaidou et al., 2017).

Regarding an additional complication, numerous studies have discussed the risk of retear following ARCR. According to the systematic review by Longo, Carnevale, et al. (2021), the incidence of retear post ARCR is: 15% at 3 months follow-up, 21% between 3- and 6-months follow-up, 16% between 6- and 12-months follow-up, 21% between 12- and 24-months follow-up, and 16% at follow-up beyond 24 months. This is why initiating resistive exercises at week 12 is recommended to patients with lower risk of retear, while additional precautions are advisable for patients with high risk of RC retear. Yet, the likelihood of a retear that is caused by starting an early controlled and progressive mobilization of the shoulder is low and no higher than delayed/standard rehabilitation (Guity et al., 2023; Mazuquin et al., 2021). While initiating early AAROM before 5 weeks post ARCR presents higher risk of retear (Longo, Carnevale, et al., 2021).

Patient adherence

Patients may encounter challenges adhering to exercise programs because of various factors, including not having enough time, work schedules, diminished self-efficacy, doubting the effectiveness of the treatment, or premature cessation when early improvements are observed leading them to perceive the treatment as unnecessary (Argent et al., 2018).

According to Schäfer et al. (2018), there is not enough evidence to prove whether digital interventions promote exercise adherence in patients undergoing physiotherapy. Although, a systematic review by Lang et al. (2022) concluded that digital intervention increases adherence to prescribed exercise rehabilitation in the short-term although their impact in the longer term remains uncertain.

ATEMPT (Adherence To Exercise for Musculoskeletal Pain Tool), a recent questionnaire, has been developed based on the six domains of exercise adherence. It demonstrates adequate content and structural validity, internal consistency, test-retest reliability, and measurement error in patients with musculoskeletal pain (Bailey et al., 2024). Integrating this questionnaire into this TR program could provide valuable insights into patients' adherence to the prescribed exercises.

Patient education

Patient education is important to ensure a successful recovery. TR can be a useful tool to provide crucial information about the surgical procedure, anatomy and physiology of the shoulder, medication use, activity restrictions, rehabilitation phases, exercises, signs of complications and lifestyle modifications. This information can be written or illustrated in pictures or videos allowing patients to communicate with the therapist via chat for additional information or clarification (Pugliese & Wolff, 2020). Patients can better understand their condition while actively participating in their recovery and reaching optimal outcomes following ARCR by receiving comprehensive education and support from their health providers.

Communication

Both physical therapists and surgeons acknowledge the absence of consensus on post ARCR rehabilitation and emphasize the importance of effective communication between them to personalize a treatment protocol for each patient. Effective communication between the health providers is crucial for customizing rehabilitation protocols and ensuring successful patient outcomes (Van der Meijden et al., 2012).

The importance of the surgical and rehabilitation reports sent between the surgeons and the physical therapists was highlighted among experts' interviews. (Schultzel et al., 2021) mentioned that operated reports are rarely transferred to therapists due to the lack of communication, however, enhancing communication about surgical findings, establishing open lines of communication, and adjusting the protocol may improve patient outcomes.

Next step

It's interesting in later studies to test the patients' adherence to this TR program comparing it to traditional home exercises. This will involve interviewing patients to understand their previous experiences with TR or conventional therapy, identifying any challenges or limitations they encountered, and learning about factors that contributed to successful rehabilitation. To complete this rehabilitation program, it is essential to include patient education sheets about educational content, pain management, goal of each phases, adapting ADLs and progress tracking.

Moreover, more studies are needed to identify the factors that determine the adapted frequency of visits for each patient. This will contribute to refining rehabilitation protocols and optimizing patient outcomes.

Limitations and strength

The strength of this study lies in its comprehensive approach to developing a practical TR video-based exercise program. By regrouping expert opinions and recent literature, the study ensured a comprehensive and evidence-based approach. Moreover, the diversity of perspectives was a notable strength, with experts representing regions such as Flanders, Brussels, France, and the United States. Similarly, the inclusion of physical therapists specializing in shoulder or musculoskeletal rehabilitation and TR added valuable insights to the program development process. In addition, their enthusiasm underscored the necessity of developing such a program.

This study presents some limitations. The quality of the articles was not assessed. Moreover, being a production thesis, all the relevant literature wasn't covered concerning post ARCR. For example, shoulder assessment, questionnaires for patients' satisfaction, education and adherence weren't developed. The included studies vary widely in terms of methodology, population, and outcomes, making it challenging to synthesize findings or draw definitive conclusions. No quantitative analysis is involved which limits the ability to summarize study findings. Finally, the developed program is for a specific population and may not be applicable for everyone or may not adequately capture variability within the population.

Conclusion

This study integrated findings from literature reviews and expert opinions to develop a TR video-based exercise program post ARCR for full thickness tears. This 24-week TR program is structured into three distinct phases, beginning with immobilization and transitioning through active mobilization before progressing to the strengthening phase. Patients begin home exercises personalized by their therapists using a mobile application, which can be adjusted according to their individual progress.

This protocol has the potential to facilitate access to high-quality care, ensuring that patients receive effective treatment regardless of their geographical location or financial constraints. It's important to note that this program is not intended for independent patient use; rather, it should be implemented and adapted by their physical therapists.

Interviewing patients in the future to gather their insights about rehabilitation will be valuable for enhancing the program. Additionally, employing validated questionnaires to assess patient adherence to the program presents a promising approach. Further research in this area is warranted to explore the potential benefits, challenges, and effectiveness of TR programs in improving patient outcomes, enhancing accessibility to rehabilitation services, and optimizing healthcare delivery.

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Appendix 1:

Telerehabilitation post ARCR

Methods:

➤ Search strategy:

A second search was performed to identify relevant studies about telerehabilitation post ARCR in the databases PubMed, EMBASE and Cochrane from November 2023 to March 2024. The following key words were combined:

“rotator cuff injuries”, “rotator cuff injury”, “rotator cuff tear”, “rotator cuff tears”, “arthroscopy”, “rotator cuff repair”, “shoulder arthroscopy”, “telerehabilitation”, “remote rehabilitation”, “home exercise”, “telerehab”, “telemedicine”, “post operative telerehabilitation”.

The search was applied with a 10 year of publication filter and reference lists and citations of all included papers were also screened.

➤ Study selection:

Studies were included if they: (1) described a shoulder telerehabilitation exercise program post ARCR, (2) included traumatic or degenerative injuries, (5) were published in English or French.

Studies were excluded if they: (1) described a VR program or another program with material needed.

All studies were independently screened and evaluated on Zotero and Rayyan by two investigators (CF and LN), initially based on the title and abstract, in accordance with the inclusion and exclusion criteria. Subsequently, articles that were not excluded by either reviewer were examined in full-text, and any disagreement regarding inclusion was resolved through consensus.

Results:

For the first research conducted on TR post ARCR, a total of 90 studies were identified from 3 different databases (Pubmed, Embase and Cochrane Library), 15 duplicated articles were removed. Then, 68 studies were excluded after screening the title and

abstract. A total of 8 studies were included in this literature review but none described a TR exercises program.

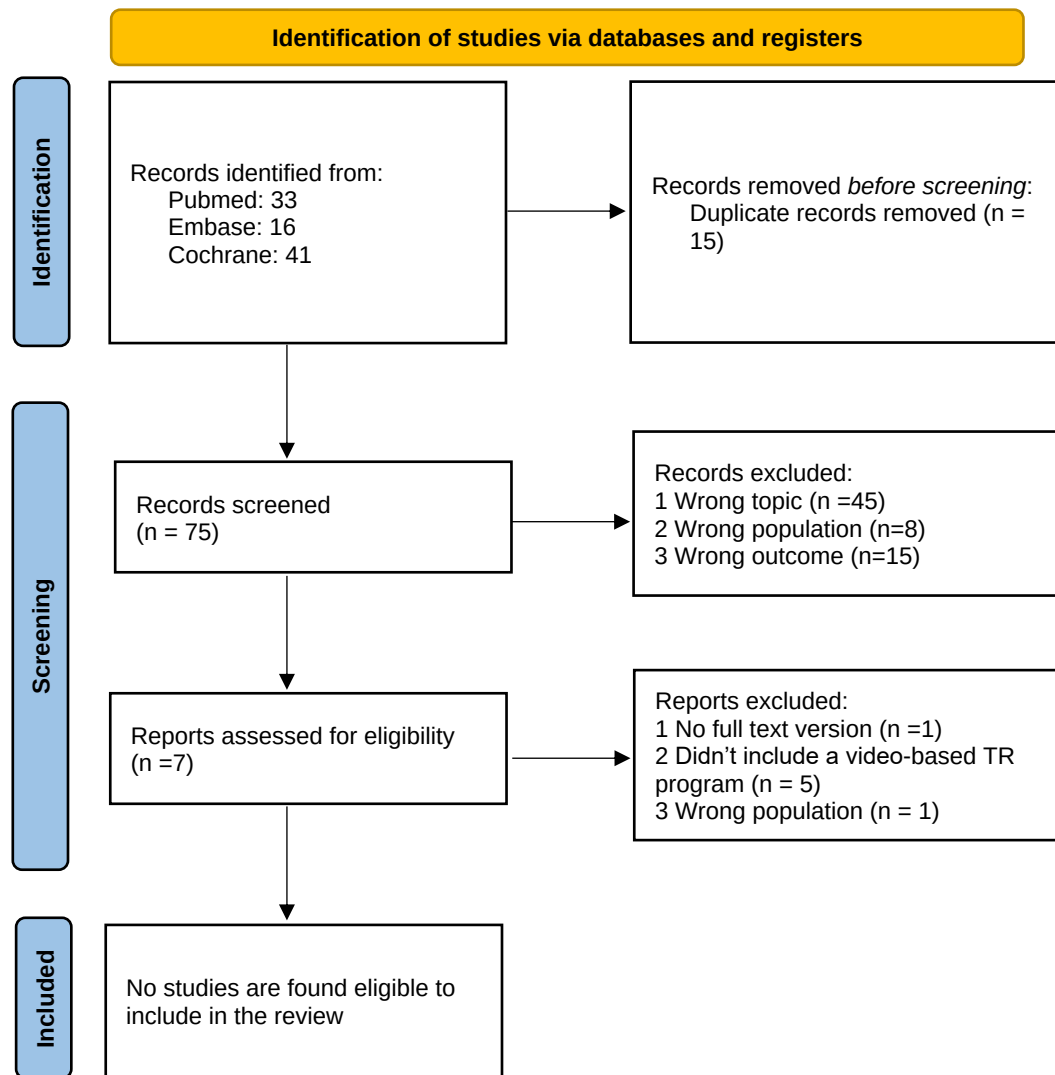


Figure 1: Flow chart of the research process on TR post ARCR

Appendix 2: Interview Guide

Thank you for participating in this interview.

Your expertise as a surgeon or physical therapist is invaluable as we develop a telerehabilitation program post arthroscopic rotator cuff repair for our thesis. We aim to gather insights and perspectives from experts like you to ensure the success and effectiveness of our program. Your input will help us tailor the program to meet the needs of both healthcare professionals and patients.

This is a tele-rehabilitation program that we are conducting as part of our master's studies in physiotherapy. The data will be analyzed by the two of us and could potentially be used for research purposes afterward.

During this interview, which will last about three-quarters of an hour, we will ask you some questions. The goal is for you to speak about your opinion and your experiences.

At any time, you can choose to cancel or stop this interview.

Are you willing to participate? Everything you say will be treated strictly anonymously. However, to facilitate the interview process without having to take extensive notes, would you be comfortable being recorded?

Before we begin the interview, do you have any questions?

Surgeon's Interview

Objectives for the interviewer and themes	Questions
Immobilization period	What is the typical duration of immobilization period that you recommend following arthroscopic rotator cuff repair, and what criteria do you use to determine when to discontinue immobilization?
Active mobilization of the shoulder	What criteria do you use to determine when to initiate active range of motion exercises following arthroscopic rotator cuff repair?
Strengthening and resistive exercises	When do you recommend initiating resistance and strengthening exercises following arthroscopic rotator cuff repair, and what criteria do you use to determine when to begin these exercises?
Complications post arthroscopic rotator cuff repair	Based on your experience, what are the most recent complications you have seen following arthroscopic rotator cuff repair?
Biceps tenotomy and tenodesis	When performing a biceps tenotomy or tenodesis alongside rotator cuff repair, how do you adjust the rehabilitation protocol compared to cases without biceps intervention?
Communication between health providers	What are your thoughts on the current level of communication between you and physical therapists regarding the rehabilitation program for patients post-rotator cuff repair?

Physical therapist's Interview

Objectives for the interviewer and themes	Questions
Immobilization period	What is the typical duration of the immobilization period following arthroscopic rotator cuff repair? What guidance do you typically provide to patients during this period?
Active mobilization of the shoulder	What criteria do you use to determine when to initiate active range of motion exercises following arthroscopic rotator cuff repair? What criteria do you use to select these exercises?
Strengthening and resistive exercises	When do you initiate resistance and strengthening exercises following arthroscopic rotator cuff repair, and what are the criteria to begin these exercises?
Complications post arthroscopic rotator cuff repair	Based on your experience, what are the most recent complications you have seen following arthroscopic rotator cuff repair?
Biceps tenotomy and tenodesis	How do you adjust your rehabilitation protocol in case of biceps tenotomy or tenodesis?
Communication between health providers	What are your thoughts on the current level of communication between you and the surgeons regarding the rehabilitation program for patients post-rotator cuff repair?

Appendix 3: Exercise Instructions

Phase 1: Protection of the operated shoulder

Exercises	Starting position	Instructions	Tips	Frequency
Cervical flexion and extension	Sit on a chair with your feet flat on the floor or stand with your back straight.	1. Look down while bending your head. 2. Slowly tilt your head backward as if you're trying to look at the ceiling or the sky.	Don't remove the sling while doing this exercise.	3 sets of 10 repetitions
Cervical rotation	Sit on a chair with your feet flat on the floor or stand with your back straight.	1. Gently turn your head to one side as if you're trying to look over your shoulder. 2. Slowly return your head to the center, facing forward. 3. Repeat the movement to the other side.	Don't remove the sling while doing this exercise.	3 sets of 10 repetitions
Cervical latero-flexion	Sit on a chair with your feet flat on the floor or stand with your back straight.	1. Gently tilt your head towards one shoulder, as if you're trying to touch your shoulder with your shoulder. 2. Hold the position when you feel a stretch. 3. Return your head to the center, facing forward. 4. Repeat the movement to the other side.	Don't remove the sling while doing this exercise. Avoid elevating the shoulder.	3 sets of 10 repetitions
Elbow flexion and extension	Sit on a chair with your feet flat on the floor or stand with your back straight.	1. Gently bend your elbow while bringing your hand to your shoulder. 2. Then, slowly straighten your elbow while moving your hand away of your shoulder.	Don't remove the sling while doing this exercise.	3 sets of 10 repetitions
Wrist flexion	Sit on a chair with your feet flat on the floor or stand with your back straight. Use the unaffected hand and hold the wrist of the affected hand.	1. Hold your arm out in front of you with your palm facing down. 2. Slowly bend your wrist downward, bringing your palm closer to your forearm. 3. Hold this position for a moment and then relax.	Don't remove the sling while doing this exercise.	3 sets of 10 repetitions
Wrist extension	Sit on a chair with your feet flat on the floor or stand with your back straight. Use the unaffected hand and hold the wrist of the affected hand.	1. Hold your arm out in front of you with your palm facing down. 2. Slowly bend your wrist upward, away from your forearm. 3. Hold this position for a moment and then relax.	Don't remove the sling while doing this exercise.	3 sets of 10 repetitions

Wrist rotation	Sit on a chair with your feet flat on the floor or stand with your back straight. Use the unaffected hand and hold the wrist of the affected hand.	1.Slowly rotate your wrist at one side like you are pouring water in a carafe. 2. Slowly rotate your hand and wrist back to the starting position. 3. Repeat the movement to the other side	Don't remove the sling while doing this exercise.	3 sets of 10 repetitions
Shoulder roll	Stand with your back straight. Arms along your body.	1. Using only your shoulders, make slowly circles forwards. 2. Then repeat backwards.	Start with small circles, then work your way up to larger movements.	3 sets of 10 repetitions
Sitting forward pendulum	Sit with your knees slightly apart and feet flat on the floor. Lean forward and support your non-affected arm on your thigh. Bend at the hip, keeping your back straight. Your head and spine should stay aligned. Your affected arm should be fully relaxed and hanging between both legs.	1.Repeatedly shift your weight forward, leaning further forward than the start position, then return to the original position. 2.Let the momentum of your body guide your arm, swinging forward and back.	Keep your affected arm relaxed during the exercise. Initiate the movement from your whole body, not your arm.	5 minutes
Sitting side pendulum	Sit with your knees slightly apart and feet flat on the floor. Side bend to the direction of your affected arm. Your affected arm should be fully relaxed and hanging at your side.	1.Repeatedly shift your weight to the side, leaning further side bent than the start position, then return to the original position. 2.Let the momentum of your body guide your arm swinging.	Keep your affected arm relaxed during the exercise. Initiate the movement from your whole body, not your arm.	5 minutes
Standing pendulum	In a standing position, lean over with your good arm supported on a table or chair. Relax the arm on the painful side, letting it hang straight down.	1. Slowly start to swing your relaxed arm by moving your body back and forth. 2. Then, make circles in a clockwise and counterclockwise direction. 3. Do not actively move it using your shoulder muscles.	Let your body promote the “momentum” for the movement.	5 minutes
Scapular retraction	Sit on a chair with your feet flat on the floor.	1. Bring your shoulder blades together by extending your torso.	If you have a mirror in front	3 sets of 10 repetitions

		2. Repeat this movement several times.	of you, you will be able to observe your mobility a bit better.	
Forward bow	In a standing position, rest the hand of the affected arm on a table.	1.Relax the shoulder and neck muscles. 2.Slowly step backwards while keeping your affected arm on the table. 3.Pause and hold when you feel a mild stretch.		Hold 5 seconds repeat 5 times
Supine assisted forward elevation with opposite hand	Sit up straight with your feet flat on the floor and to the side of a table or countertop. The forearm of your affected arm will be supported on the surface of the table or countertop. The elbow can be slightly bent. Your forearm and hand should be placed at a 45-degree angle relative to your body.	1.Slowly lean towards your arm, following this 45-degree diagonal. 2.Leaning your body will guide your arm out on the diagonal, sliding on the surface. Your elbow should begin to straighten. 3.Return to the starting position, sitting up straight and sliding your arm back towards your body.		3 sets of 15 repetitions

Phase 2: Active mobilization of the shoulder

Exercises	Starting position	Instructions	Tips	Frequency
Sitting shoulder gear shift into scaption	Sit up straight with your feet flat on the floor, knees slightly apart. Grab a cane, broomstick, or similar-shaped object, holding one end with your affected arm and the other end of the stick contacting the floor. Your elbow will start bent. The stick will be placed at the side of your body.	1. At a 45-degree angle, tilt the stick forward by extending your elbow. You will be moving the stick further away from your body. 2. Then return the stick back to the starting position by bending your elbow, bringing the stick closer to your body.		3 sets of 15 repetitions
Sitting shoulder gear shift into flexion 1	Sit up straight with your feet flat on the floor, knees slightly apart. Grab a cane, broomstick, or similar shaped object, holding one end with your affected arm and the other end of the stick contacting the floor. Your elbow will start bent. The stick will be placed between your legs.	1. Tilt the stick forward by extending your elbow. You will be moving the stick further away from your body. 2. Then return the stick back to the starting position by bending your elbow, bringing the stick closer to your body.		3 sets of 15 repetitions
Sitting shoulder gear shift into flexion 2	Sit up straight with your feet flat on the floor, knees slightly apart. Grab a cane, broomstick, or similar shaped object, holding one end with your affected arm and the other end of the stick contacting the floor. Your elbow will start bent. The stick will be placed at the side of your body.	1. Tilt the stick forward by extending your elbow. You will be moving the stick further away from your body. 2. Then return the stick back to the starting position by bending your elbow, bringing the stick closer to your body.		3 sets of 15 repetitions
Sitting shoulder gear shift into external rotation 1	Sit up straight with your feet flat on the floor, knees slightly apart. Grab a cane, broomstick, or similar shaped object, holding one end with your affected arm and the other end of the stick contacting the floor. Your elbow will stay bent the whole time	1. Tilt the stick outwards towards your leg. 2. Your hand and forearm will create a 45-degree angle with your body. 3. Return to the starting position by tilting the stick backs towards the middle.		3 sets of 15 repetitions

	while also contacting the side of your body near your ribs. The stick will be placed between your legs.			
Sitting shoulder gear shift into external rotation 2	Sit up straight with your feet flat on the floor, knees slightly apart. Grab a cane, broomstick, or similar shaped object, holding one end with your affected arm and the other end of the stick contacting the floor. Your elbow will stay bent the whole time while also contacting the side of your body near your ribs. The stick will be placed at the side of the body.	1.Tilt the stick outwards, away from your leg. Your hand and forearm will create a 45-degree angle with your body. 2.Return to the starting position by tilting the stick back towards your leg.		3 sets of 15 repetitions
Sitting shoulder gear shift into internal rotation	Sit up straight with your feet flat on the floor, knees slightly apart. Grab a cane, broomstick, or similar-shaped object, holding one end with your affected arm and the other end of the stick contacting the floor. Your elbow will stay bent the whole time while also contacting the side of your body near your ribs. The stick will be placed between your legs.	1.Tilt the stick inwards towards your opposite leg. Your hand and forearm will create a 45-degree angle with your body. 2.Return to the starting position by tilting the stick back towards the middle.		3 sets of 15 repetitions
Sitting assisted scaption	Sit up straight with your feet flat on the floor and to the side of a table or countertop. The forearm of your affected arm will be supported on the surface of the table or countertop. The elbow can be slightly bent. Your forearm and hand should be placed at a 45-degree angle relative to your body.	1.Slowly lean towards your arm, following this 45-degree diagonal. 2.Leaning your body will guide your arm out on the diagonal, sliding on the surface. Your elbow should begin to straighten. 3.Return to the starting position, sitting up straight	Use a towel or something similar placed under your forearm to help with easier sliding.	3 sets of 15 repetitions

		and sliding your arm back towards your body.		
Sitting shoulder high speed table slides into scaption	Sit up straight with your feet flat on the floor next to a table or countertop. Place a towel underneath your forearm and palm. Your forearm and hand should be placed at a 45-degree angle relative to your body. The forearm of your affected arm will be supported on the surface. The elbow can begin slightly bent.	Perform quick out-and-in motion with your arm, moving your arm towards and away from your body on a 45-degree diagonal.	The elbow does not need to straighten completely during the movement.	Hold 1 minute and repeat 5 times
Sitting assisted forward elevation with opposite hand	Sit up straight with your feet flat on the floor. Join your hands together.	1.Raise your hands slowly above your head. 2.Pause and hold when you feel a mild stretch. 3.Return slowly to the starting position.		3 sets of 15 repetitions
Sitting assisted external rotation without a cane	Sit up straight with your feet flat on the floor and to the side of a table or countertop. The forearm of your affected arm will be supported on the surface of the table or countertop. Your elbow will remain bent for the duration of this motion.	1.Slowly rotate your torso away from the affected arm. 2.Return to the starting position. 3.Slowly rotate your torso towards the affected arm. 4.Return to the starting position.		3 sets of 15 repetitions
Supine assisted external rotation with a cane	Lie on your back with your knees bent and feet flat on the surface. With a cane, broomstick, or similar shaped object. Place the palm of your affected arm on the end of the stick. Your unaffected arm will grab onto the middle of the stick. Keep the elbow of your affected arm on the ground and in contact with the side of your body.	1.Using your unaffected arm on the cane, guide your affected arm away from the starting position. This means your hand will move away from your body and closer to the floor. 2.Return your arm slowly to the starting position.		3 sets of 15 repetitions
Supine cane-assisted external rotation at	Lie down on the back on a flat surface (bed or sofa) with a cushion / rolled up towel under the knee. Hold a cane with both hands, elbows bent at 90 degrees.	1. Have the cane parallel to your body. Gradually assist your arm out to the side while maintaining your elbow at 90 degrees. 2. Keep the position for 15	Start with a small range of motion and gradually increase it as your shoulder mobility improves.	Hold 15 seconds and repeat 5 times

90 degrees abduction	Place the elbow of your affected side a few centimeters away from your body, making an angle of 90 degrees.	seconds. 3. Come back to the starting position. 4. Repeat trying to go further and further.	Do not force your shoulder into an uncomfortable position; only rotate to your comfortable range	
Supine cane-assisted external rotation at 45 degrees abduction	Lie down on the back on a flat surface (bed or sofa) with a cushion / rolled up towel under the knee. Hold a cane with both hands, elbows bent at 90 degrees. Place the elbow of your affected side a few centimeters away from your body, making an angle of 45 degrees.	1. Have the cane parallel to your body. Gradually assist your arm out to the side while maintaining your elbow at 90 degrees. 2. Keep the position for 15 seconds. 3. Come back to the starting position. 4. Repeat trying to go further and further.	Start with a small range of motion and gradually increase it as your shoulder mobility improves. Do not force your shoulder into an uncomfortable position; only rotate to your comfortable range	Hold 15 seconds and repeat 5 times
Supine cane-assisted external rotation at 20 degrees abduction	Lie down on the back on a flat surface (bed or sofa) with a cushion / rolled up towel under the knee. Hold a cane with both hands, elbows bent at 90 degrees. Place the elbow of your affected side a few centimeters away from your body, making an angle of 20 degrees.	1. Have the cane parallel to your body. Gradually assist your arm out to the side while maintaining your elbow at 90 degrees. 2. Keep the position for 15 seconds. 3. Come back to the starting position. 4. Repeat trying to go further and further.	Start with a small range of motion and gradually increase it as your shoulder mobility improves. Do not force your shoulder into an uncomfortable position; only rotate to your comfortable range	Hold 15 seconds and repeat 5 times
Sitting shoulder table slides into abduction-elbow flexed	Sit up straight with your feet flat on the floor and to the side of a table or countertop. Your arm should be placed directly to the side of your body, with your fingers pointing forward. The forearm of your affected arm will be supported on the surface of the table or countertop. Your elbow will remain bent for the duration of this motion.	1. Slowly lean sideways towards your arm. 2. Leaning sideways will guide your arm out to the side, sliding on the surface. 3. Return to the starting position, sitting up straight and sliding your arm back towards your body.	Use a towel or something similar placed under your forearm to help with easier sliding.	3 sets of 15 repetitions

Sitting shoulder table slides into abduction	Sit up straight with your feet flat on the floor and to the side of a table or countertop. Your arm should be placed directly to the side of your body, fingers pointing to the side. The forearm of your affected arm will be supported on the surface of the table or countertop, the elbow can be slightly bent.	1.Slowly lean sideways towards your arm. 2.Leaning sideways will guide your arm out to the side, sliding on the surface. Your elbow should begin to straighten. 3.Return to the starting position, sitting up straight and sliding your arm back towards your body.	Use a towel or something similar placed under your forearm to help with easier sliding.	3 sets of 15 repetitions
Sitting shoulder table slides into flexion	Sit up straight with your feet flat on the floor and in front of a table or countertop. The forearm of your affected arm will be supported on the surface of the table or countertop. Your elbow can be slightly bent.	1.Slowly lean forward, making sure your head and back are aligned. 2.Leaning forward will guide your arm forward to slide on the surface. 3.With this forward sliding, your elbow should begin to straighten. 4.Return to the starting position, sitting up straight and sliding your arm backward.	Maintain a straight back throughout by bending at the hips when you lean forward. Use a towel or something similar placed under your forearm to help with easier sliding.	3 sets of 15 repetitions
Supine shoulder flexion with cane	Lie on your back with your knees bent and feet flat on the surface. With a cane, broomstick, or similar shaped object. Place the palms of both arms in the middle of the stick.	1.Use your unaffected arm to slowly guide your arm upwards over your head as far as possible. 2.Return your arm slowly to the starting position.	To increase the range of your arm raise, place your unaffected arm lower on the stick.	5 sets of 15 repetitions
Supine shoulder abduction with a cane	Lie on your back with your knees bent and feet flat on the surface. With a cane, broomstick, or similar shaped object. Place the palms of both arms on the edge of the stick.	1.Use your unaffected arm to slowly guide your arm on the side. 2.Return your arm slowly to the starting position.		3 sets of 15 repetitions

Supine shoulder external rotation with a cane	Lie on your back with your knees bent and feet flat on the surface. With a cane, broomstick, or similar shaped object. Place the palm of your affected arm on the end of the stick. Your unaffected arm will grab onto the middle of the stick. Keep the elbow of your affected arm on the ground and in contact with the side of your body.	1.Using your unaffected arm on the cane, guide your affected arm away from the starting position. 2.This means your hand will move away from your body and closer to the floor. 3.Return your arm slowly to the starting position.		3 sets of 15 repetitions
Supine shoulder internal rotation with a cane	Lie on your back with your knees bent and feet flat on the surface. With a cane, broomstick, or similar shaped object. Place the palm of your affected arm on the end of the stick. Your unaffected arm will grab onto the middle of the stick. Keep the elbow of your affected arm on the ground and in contact with the side of your body.	1.Using your unaffected arm on the cane, guide your affected arm towards your body and away from the floor. 2.Return your arm slowly to the starting position.		3 sets of 15 repetitions
Standing wall scrubs flexion-low speed	Stand in front of a wall, about 6 inches away, so that your elbow is bent, and your palm is flat on the wall. Place a small towel under your palm. Your hand should begin at about shoulder height.	1.Move your arm slowly above your head. Your elbow should begin to extend. 2.Do not let the towel fall from under your palm. 3.Slowly lower your arm to return to the starting position.	Keep your spine aligned and your chin tucked throughout this exercise. Avoid hiking your shoulders, activating your upper trapezius	Hold 1 minute repeat 5 times
Standing wall scrubs - abduction	Stand next to a wall, about a foot away, so that your elbow is bent, and your palm is flat on the wall. Place a small towel under your palm. Your hand should begin at about shoulder height.	1.Move your arm slowly above your head and out to the side of your body. Your elbow should begin to extend. 2.Do not let the towel fall from under your palm. 3.Slowly lower your arm to	Keep your spine aligned and your chin tucked throughout this exercise.	Hold 1 minute repeat 5 times

		return to the starting position.		
Standing wall scrubs-scaption	Stand next to a wall, about a foot away, so that your elbow is bent and your palm is flat on the wall. Turn your body to position your arm at a 45-degree angle to your body. Place a small towel under your palm. Your hand should begin at about shoulder height.	1.Move your arm slowly above your head on a 45-degree diagonal. Your elbow should begin to extend. 2.Do not let the towel fall from under your palm. 3.Slowly lower your arm to return to the starting position.	Keep your spine aligned and your chin tucked throughout this exercise.	Hold 1 minute repeat 5 times
Standing Wall scrubs - circles	Stand in front of a wall, about 6 inches away, so that your elbow is bent, and your palm is flat on the wall. Place a small towel under your palm. Your hand should begin at about shoulder height.	1.Move your arm slowly in circles (clockwise and counterclockwise). Your elbow should stay bent. 2.Do not let the towel fall from under your palm.	Keep your spine aligned and your chin tucked throughout this exercise.	Hold 1 minute repeat 5 times
Rolling a ball against the wall in standing position	Face a wall and stand with your feet flat on the ground. Hold a ball in your hands.	1. Position the ball on the wall and roll it with your forearm. Roll up and down. 2. Position the ball a little higher on the wall. 3. Position the ball so that your arm is straight. Move your hand up and down.		3 sets of 15 repetitions
Rolling a ball against the wall-left to right	Face a wall and stand with your feet flat on the floor. Hold a ball in your hands.	1. Position the ball on the wall and move your hand from left to right with your elbow bent. 2. Perform the same left-to-right movement with your elbow extended.		3 sets of 15 repetitions
Rolling ball against the wall-circles	Face a wall and stand with your feet flat on the floor. Hold a ball in your hands.	1.Position the ball on the wall and make circular movements with your elbow bent. 2. Make the same circular movement while moving the		3 sets of 15 repetitions

		ball away from you with your elbow extended.		
Side lying shoulder isotonic abduction - long lever	Lie on your side opposite of the target arm. Place a towel roll, small pillow, or your opposite arm under your head to support it and to keep your neck in line with the rest of your spine. Position your target arm along the side of your torso with your palm facing the floor.	1.Raise your arm up towards the ceiling, keeping your elbow straight. 2.Slowly return your arm to the start position	If appropriate, a dumbbell weight can be used during this exercise to provide resistance. The amount of range of motion you move your arm through will depend on multiple factors. These include your available pain-free range of motion, your strength, and the overall health of the muscles in your shoulder Avoid: Allowing the top of your shoulder to move in the direction of your ear. This is referred to as hiking your shoulder up and should be avoided. Bending or straightening your	3 sets of 15 repetitions

			elbow. Your elbow should stay bent to a 90-degree angle throughout the exercise.	
Side lying shoulder isotonic abduction - short lever	Lie on your side opposite of the target arm. Place a towel roll, small pillow, or your opposite arm under your head to support it and to keep your neck in line with the rest of your spine. Position your target arm along the side of your torso and bend your elbow to 90 degrees.	1.Raise your arm up towards the ceiling, keeping your elbow bent to 90 degrees. 2.Slowly return your arm to the starting position	If appropriate, a dumbbell weight can be used during this exercise to provide resistance. The amount of range of motion you move your arm through will depend on multiple factors. These include your available pain-free range of motion, your strength, and the overall health of the muscles in your shoulder. Avoid: Allowing the top of your shoulder to move in the direction of your ear. This is referred to as hiking your shoulder up and should be avoided.	3 sets of 15 repetitions
Supine assisted	Sit up straight with your feet flat on the floor and to the side of a	1.Slowly lean towards your arm, following this 45-		3 sets of 15 repetitions

forward elevation with opposite hand	table or countertop. The forearm of your affected arm will be supported on the surface of the table or countertop. The elbow can be slightly bent. Your forearm and hand should be placed at a 45-degree angle relative to your body.	degree diagonal. 2. Leaning your body will guide your arm out on the diagonal, sliding on the surface. Your elbow should begin to straighten. 3. Return to the starting position, sitting up straight and sliding your arm back towards your body.		
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Phase 3: Strengthening Phase

Exercises	Starting position	Instructions	Tips	Frequency
Supine scapular protraction-single arm	Lie on your back with your knees bent so that your feet are flat on the ground, about shoulder-width apart. Lift your arm until it is perpendicular to your body.	1.While keeping your elbow straight, reach your hand towards the ceiling to bring your shoulder blade off the floor. 2.Lower your shoulder slowly back down to the floor. This movement will then be repeated.	Keep your feet, pelvis, back, and head in contact with the ground always.	3 sets of 10 repetitions
Supine scapular protraction-single arm Standing shoulder isometric external rotation	Stand up straight with the wall at your side. The exercise will be performed with the arm closest to the wall. With your arm at your side, bend your elbow to 90 degrees. Place the back of your hand against the wall.	1+A4.Slowly push the back of your hand into the wall. 2.Maintain this push for the prescribed amount.		Hold 5 seconds and repeat 5 times
Standing shoulder isometric internal rotation	Stand up straight in a door frame or at the corner of a wall. With your arm at your side, bend your elbow to 90 degrees. Place the palm of your hand against the edge of the wall or door frame.	1.Slowly push the palm of your hand into the wall. 2.Maintain this push for the prescribed amount.		Hold 5 seconds and repeat 5 times
Side lying shoulder	Lie on the opposite side of the affected arm. Place a towel roll,	1.Externally rotate your shoulder by bringing your	If appropriate, a dumbbell weight	Hold 5 seconds and

external rotation isotonic	small pillow, or your opposite arm under your head to support it and to keep your neck in line with the rest of your spine. Position your target arm along the side of your torso and place a small towel roll under your elbow. Bend your elbow to 90 degrees. Start with your shoulder rotated inward, bringing your forearm and hand closer to your stomach while keeping your elbow in contact with the towel roll.	forearm away from your body. Your forearm should move up toward the ceiling while your elbow remains in contact with the towel roll. Your hand should stay in line with your forearm throughout the movement. 2.Slowly return your arm to the start position.	can be used during this exercise to provide resistance. Avoid: Allowing your elbow to come away from your body. Straightening your elbow rather than rotating your shoulder. Your elbow should stay at a 90-degree angle throughout the exercise. Bending your wrist in either direction during the movement. Your hand should align with your forearm to ensure you use your shoulder muscles to generate the motion. Twisting your body backward.	repeat 5 times
Standing shoulder internal rotation stretch behind the back	Stand with your affected arm behind your low back. With your unaffected arm, grab one end of a strap, belt, or towel. Bring your arm above your head with a bent elbow so that the strap is hanging vertically down the middle of your back, in line with your spine. Grab the lower end of the strap behind your back with your affected arm.	1.Pull the strap upwards with your unaffected arm to lift the affected arm as high as you can behind your back. 2.Hold this position for 1 minute. 3.Slowly lower the arm back to the start position.	Keep your spine aligned and your chin tucked throughout this exercise. The affected arm should not be doing any of the movement – keep it relaxed.	Hold 1 minute and repeat 5 times
Standing shoulder	Stand up straight with feet shoulder width apart.	1.Reach your affected arm across your body at the		Hold 1 minute and

posterior rotator cuff stretch	Both arms will be relaxed by the side of your body.	height of your shoulders. 2.Place your unaffected hand on your right elbow to help pull your arm further across your body and increase the stretch. 3.Hold this position for 1 minute.		repeat 5 times
Standing shoulder pectoralis major doorway stretch - upper fiber	Stand up straight in a door frame or at the corner of a wall. Place the palm of your hand and the inside of your elbow against the edge of the wall or door frame. Your elbow should be below the height of your shoulder for a more specific stretch.	1.To begin the stretch, rotate your torso away from the arm that is up on the wall. 2.If you need to increase the stretch, you can move your arm lower on the door/wall or rotate your torso further away. 3.Hold this position for 1 minute.		Hold 1 minute and repeat 5 times
Standing shoulder pectoralis major doorway stretch- middle fiber	Stand up straight in a door frame or at the corner of a wall. Place the palm of your hand and the inside of your elbow against the edge of the wall or door frame. Your elbow should align with your shoulder for a more specific stretch.	1.To begin the stretch, rotate your torso away from the arm that is up on the wall. 2.If you need to increase the stretch, you can rotate your torso further away. 3.Hold this position for 1 minute.		Hold 1 minute and repeat 5 times
Standing shoulder pectoralis major doorway stretch- low fiber	Stand up straight in a door frame or at the corner of a wall. Place the palm of your hand and the inside of your elbow against the edge of the wall or door frame. Your elbow should be above the height of your shoulder for a more specific stretch.	1.To begin the stretch, rotate your torso away from the arm that is up on the wall. 2.If you need to increase the stretch, you can move your arm higher on the door/wall or rotate your torso further away. 3.Hold this position for 1 minute.		Hold 1 minute and repeat 5 times
Side-lying shoulder external	Lie on your side opposite of the target arm. Place a towel roll, small pillow, or your opposite arm under your head to support it	1.Externally rotate your shoulder by bringing your forearm away from your body. Your forearm	If appropriate, a dumbbell weight can be used during this	3 sets of 10 repetitions

rotation isotonic	and to keep your neck in line with the rest of your spine. Position your target arm along the side of your torso and place a small towel roll under your elbow. Bend your elbow to 90 degrees. Start with your shoulder rotated inward, bringing your forearm and hand closer to your stomach while keeping your elbow in contact with the towel roll.	should move up toward the ceiling while your elbow remains in contact with the towel roll. Your hand should stay in line with your forearm throughout the movement. 2.Slowly return your arm to the start position.	exercise to provide resistance. Avoid: Allowing your elbow to come away from your body. Straightening your elbow rather than rotating your shoulder. Your elbow should stay at a 90-degree angle throughout the exercise. Bending your wrist in either direction during the movement. Your hand should align with your forearm to ensure you use your shoulder muscles to generate the motion. Twisting your body backward.	
Standing shoulder row exercises single arm	Anchor an elastic band either around a sturdy structure or closed in a door with a knot. Stand with an upright posture facing the structure/door and	1.Maintaining a grip on the band, pull the band towards you with one arm, squeezing your shoulder blades together as you pull	Keep your shoulders relaxed and elbows close to your sides during this	3 sets of 10 repetitions

& double arm - one stable arm	adjust the band to the height of your hand when your elbow is bent to 90 degrees. The band should be parallel to the floor. Grab onto the elastic band with both hands. There should be some tension in the band prior to the start of the exercise. Start your arms down by your side, elbows bent to 90 degrees, and palms facing each other	your arm back. 2.Return to the starting position slowly.	exercise. Keep your abdominals tight and maintain a neutral posture at all times, keeping your shoulders over your hips and knees.	
Standing shoulder row exercises single arm & double arm - both moving arms	Anchor an elastic band either around a sturdy structure or closed in a door with a knot. Stand with an upright posture facing the structure/door and adjust the band to the height of your hand when your elbow is bent to 90 degrees. The band should be parallel to the floor. Grab onto the elastic band with both hands. There should be some tension in the band prior to the start of the exercise. Start your arms down by your side, elbows bent to 90 degrees, and palms facing each other.	1.Maintaining a grip on the band, pull the band towards you with both arms, squeezing your shoulder blades together as you pull your arms back. 2.Return to the starting position slowly.	Keep your shoulders relaxed and elbows close to your sides during this exercise. Keep your abdominals tight and maintain a neutral posture at all times, keeping your shoulders over your hips and knees.	3 sets of 10 repetitions
Standing forward bent shoulder row exercises single arm & double arm -	Stand up straight with feet shoulder-width apart. Place weights/dumbbells in both hands. Bend forward by hinging at the hips and keeping your back straight. Your head, neck, and the rest of your back should be in a line. Start with your arms by your side, elbows bent to 90 degrees, and palms facing each other.	1.Pull your elbows backward towards your body, squeezing your shoulder blades together as you pull back. 2.Return to the starting position slowly.	Keep your shoulders relaxed and elbows close to your sides during this exercise.	3 sets of 10 repetitions
Standing scapular protraction and retraction wall height	Stand up straight, facing the wall, and arm's length away. Place your hands flat on the wall at shoulder height, elbows straight.	1.While keeping your elbows straight and your hands in the same position on the wall, move your torso forward. Make sure you maintain a straight back during this.	Make sure to keep your back straight and abdominals tight while you perform this movement.	3 sets of 10 repetitions

		2. Your shoulder blades should feel like they are move closer together in the upper back. 3. To return to the start position, push into your hands to move your torso backward. 4. Your shoulder blades should feel like they are moving away from each other slightly.		
Shoulder wall lift offs - high position	Stand up straight in front of a wall or doorway. Place your palm against the wall with your elbow above the level of your shoulder.	1. Lift your palm off the wall so it is no longer making contact. Your hand and elbow should remain parallel to the wall. 2. Return your palm to the starting position.		3 sets of 10 repetitions
Shoulder wall lift offs - intermediate	Stand up straight in front of a wall or doorway. Place your palm against the wall with your elbow in line with the level of your shoulder.	1. Lift your palm off the wall so it is no longer making contact. Your hand and elbow should remain parallel to the wall. 2. Return your palm to the starting position.		3 sets of 10 repetitions
Shoulder wall lift offs - low position	Stand up straight in front of a wall or doorway. Place your palm against the wall with your elbow below the level of your shoulder.	1. Lift your palm off the wall so it is no longer making contact. Your hand and elbow should remain parallel to the wall. 2. Return your palm to the starting position.		3 sets of 10 repetitions
Shoulder wall lift offs elastic band - high position	Stand up straight in front of a wall or doorway. Hold an elastic band in both hands and place both palms on the wall. The unaffected hand will be at the level of the shoulder. The affected hand will be below the level of the shoulder.	1. Your unaffected arm's hand will remain on the wall and maintain the position of the elastic band. 2. Lift your affected arm's palm off the wall against the resistance of the elastic band. Your hand		3 sets of 10 repetitions

		and elbow should remain parallel to the wall. 3.Return your palm to the starting position.		
Shoulder wall lift offs elastic band - intermediate position	Stand up straight in front of a wall or door. Hold a rubber band with both hands and place both palms on the wall. The unaffected hand will be at shoulder level. The affected hand will also be at shoulder level.	1.Your unaffected hand stays on the wall and maintains the position of the thermal band. 2.Lift your affected palm off the wall against the resistance of the thermal band. Your hand and elbow should remain parallel to the wall. 3.Return your palm to the starting position.		3 sets of 10 repetitions
Shoulder wall lift offs elastic band- low position	Stand up straight in front of a wall or doorway. Hold an elastic band in both hands and place both palms on the wall. The unaffected hand will be at the level of the shoulder. The affected hand will be below the level of the shoulder.	1.Your unaffected arm will remain on the wall and maintain the position of the elastic band. 2.Lift your affected palm off the wall against the resistance of the elastic band. Your hand and elbow should remain parallel to the wall. 3.Return your palm to the starting position.		3 sets of 10 repetitions
Standing Push-up - wall height	Stand up straight, facing the wall, and arm's length away. Place your hands flat on the wall at shoulder height, elbows straight.	1.Keeping your shoulders down and back, gradually bend your elbows to bring your face towards the wall to perform a push-up. 2.To return to the starting position, push through your hands, straighten your elbows, and move	Make sure to keep your chin tucked, back straight, and abdominals tight while you perform this movement.	3 sets of 10 repetitions

		your face away from the wall.		
Standing Push-up - countertop height	Stand up straight, facing the countertop or table, and arm's length away. Place your hands flat on the wall at shoulder height, elbows straight. Walk your feet backward a few steps until your body is on an incline.	1.Keeping your shoulders down and back, gradually bend your elbows to bring your face towards the countertop or table to perform a push-up. 2.To return to the starting position, push through your hands, straighten your elbows, and move your face away from the countertop or table.	Make sure to keep your chin tucked, back straight, and abdominals tight while you perform this movement.	3 sets of 10 repetitions
Push-up - kneeling close grip	Start by kneeling on the floor. Walk your hands out to a point where your knees can contact the ground, and your hands are directly under your shoulders with elbows straight. Your knees may be bent so that your feet are off the ground.	1.Keeping your shoulders down and back, gradually bend your elbows to bring your face towards the ground to perform a push-up. 2.To return to the starting position, push through your hands, straighten your elbows, and move your face away from the floor.	Make sure to keep your chin tucked, back straight, and abdominals tight while you perform this movement. Maintain a straight line with your body through your knees, hips, and shoulders.	3 sets of 10 repetitions
Push-up - kneeling wide grip	Start by kneeling on the floor. Walk your hands out to a point where your knees can contact the ground, and your hands are directly under your shoulders with elbows straight. Walk your hands out so that your arms are slightly further than shoulder-width apart. Your fingers should point slightly inwards towards each other.	1.Keeping your shoulders down and back, gradually bend your elbows to bring your face towards the ground to perform a push-up. 2.To return to the starting position, push through your hands, straighten your elbows, and move your face away from the floor	Make sure to keep your chin tucked, back straight, and abdominals tight while you perform this movement. Maintain a straight line with your body through your knees, hips, and shoulders.	3 sets of 10 repetitions

	Your knees may be bent so that your feet are off the ground.			
Standing unsupported external rotation at 90 degrees	Stand with your feet shoulder-width apart. Take a dumbbell in your hand. Put your arm up in 90° and bend your elbow 90°.	1. Rotate your forearm upwards, while your elbow always remains in the same position. Move as far as you can. 2. Rotate your forearm back slowly and control it. 3. Repeat this movement for the specified number of repetitions.	Be sure to always keep your elbow in the same place during the exercise.	3 sets of 10 repetitions
Floor scrubs - left-right - four point	Kneel on the ground on all fours. Your knees should contact the ground and directly under your hips. Your hands should be directly under your shoulders with elbows straight.	1. Shift your weight off your unaffected arm so that you can perform the exercise with the other arm. 2. Quickly slide your hand from left to right in a small horizontal motion on the ground.	The motion should be small – do not move your hand too far out of line with your shoulder. Keep your spine aligned and your chin tucked throughout this exercise. Do not move your back or pelvis.	Hold 1 minute and repeat 5 times
Floor scrubs - up-down - four point	Kneel on the ground on all fours. Your knees should contact the ground and directly under your hips. Your hands should be directly under your shoulders with elbows straight.	1. Shift your weight off your unaffected arm so that you can perform the exercise with the other arm. 2. Quickly slide your hand from left to right in a small horizontal motion on the ground.		Hold 1 minute and repeat 5 times
Standing shoulder active stabilization - circles	Stand in front of a wall with your arm straight out in front of you, holding a small ball against the wall. Your arm should be at shoulder height, with your elbow straight.	1. Roll the ball in small circles (clockwise and counterclockwise), in a slow and controlled manner. 2. Repeat this motion.	The motion should be small – try to keep your arm aligned with your shoulder. Keep your spine aligned and your chin tucked throughout this exercise. Keep your elbow straight.	Hold 1 minute and repeat 5 times

			Avoid: Tensing/hiking your shoulders, activating your upper trapezius	
Standing shoulder active stabilization - horizontal line	Stand in front of a wall with your arm straight out in front of you, holding a small ball against the wall. Your arm should be at shoulder height, with your elbow straight.	1.Roll the ball left to right in a slow and controlled manner. 2.Repeat this motion.	The motion should be small – do not move your hand too far out of line with the shoulder. Keep your spine aligned and your chin tucked throughout this exercise. Keep your elbow straight. Avoid: Tensing/hiking your shoulders, activating your upper trapezius.	Hold 1 minute and repeat 5 times
High speed wall scrubs - up-down	Stand in front of a wall, about 6 inches away, so that your elbow is bent and your palm is flat on the wall. Place a small towel under your palm. Your hand should begin at about shoulder height.	1.Move your arm up and down in short, quick movements. 2.This movement is performed for 1 minute.	Keep your spine aligned and your chin tucked throughout this exercise. Avoid: Tensing/hiking your shoulders, activating your upper trapezius	Hold 1 minute and repeat 5 times
High speed wall scrubs - left-right	Stand in front of a wall, about 6 inches away, so that your elbow is bent and your palm is flat on the wall.	1.Move your arm side to side in short, quick movements.	Keep your spine aligned and your chin tucked	Hold 1 minute and repeat 5 times

	Place a small towel under your palm. Your hand should begin at about shoulder height.	2.This movement is performed for 1 minute.	throughout this exercise Avoid: Tensing/hiking your shoulders, activating your upper trapezius.	
Shoulder flexion stretch - four point	Kneel on the ground on all fours. Your knees should contact the ground and directly under your hips. Your hands should be directly under your shoulders with elbows straight.	1.Slowly move your hips backwards to bring your buttocks towards your heels. 2.Maintain a straight back as you move. 3.You should feel a stretch on the underside of your arms and shoulders. 4. Maintain the stretch and relax.		3 sets of 10 repetitions
Shoulder lat pull down single arm & double arm - one stable arm - sitting leaning back	Anchor the center of a long elastic band either around a sturdy structure or closed in the top of a door with a central knot in the band. The band should be as high as possible. Place a chair under the band, facing the structure/door, and sit down. Grab on to the remaining ends of the band in each hand. There should be some tension in the band prior to the start of the exercise. Start with your arms extended, and palms facing the floor. Your	1.Lean back slightly, moving from the hips and keeping the back straight. 2.Maintaining a grip on the band, pull the band down and out towards your chest with one arm, drawing your shoulder blade toward the ground. 3.The other arm should not move but maintain slight tension in the band throughout the exercise. 4.Keeping your torso leaned back, return your	Keep your shoulders relaxed during this exercise. Keep your abdominals tight and maintain a neutral posture at all times, keeping your torso in a fixed position.	3 sets of 10 repetitions

	arms should be shoulder-width apart. The band should form a 45-degree angle to the door. You may have to move your chair forward or backward to achieve this.	arm to the starting position slowly.		
Shoulder lat pull down single arm & double arm - both moving arms - sitting leaning back	Anchor the center of a long elastic band either around a sturdy structure or closed in the top of a door with a central knot in the band. The band should be as high as possible. Place a chair under the band, facing the structure/door, and sit down. Grab onto the remaining ends of the band in each hand. There should be some tension in the band prior to the start of the exercise. Start with your arms extended and palms facing the floor. Your arms should be shoulder-width apart. The band should form a 45-degree angle to the door. You may have to move your chair forward or backward.	1. Lean back slightly, moving from the hips and keeping the back straight. 2. Maintaining a grip on the band, pull the band down and out towards your chest with both arms, drawing your shoulder blades toward the ground. 3. Keeping your torso leaned back, return your arms to the starting position slowly.	Keep your shoulders relaxed during this exercise. Keep your abdominals tight and maintain a neutral posture at all times, keeping your torso in a fixed position.	3 sets of 10 repetitions
Standing shoulder row exercises single arm & double arm - one stable arm	Anchor an elastic band either around a sturdy structure or closed in a door with a knot. Stand with an upright posture facing the structure/door and adjust the band to the height of your hand when your elbow is bent to 90 degrees. The band should be parallel to the floor. Grab onto the elastic band with both hands. There should be some tension in the band prior to the start of the exercise. Start your arms down by your side, elbows bent to 90 degrees, and palms facing each other.	1. Maintaining a grip on the band, pull the band towards you with one arm, squeezing your shoulder blades together as you pull your arm back. 2. Return to the starting position slowly.	Keep your shoulders relaxed and elbows close to your sides during this exercise. Keep your abdominals tight and maintain a neutral posture at all times, keeping your shoulders over your hips and knees.	3 sets of 10 repetitions

Standing shoulder row exercises single arm & double arm - both moving arms	Anchor an elastic band either around a sturdy structure or closed in a door with a knot. Stand with an upright posture facing the structure/door and adjust the band to the height of your hand when your elbow is bent to 90 degrees. The band should be parallel to the floor. Grab onto the elastic band with both hands. There should be some tension in the band prior to the start of the exercise. Start your arms down by your side, elbows bent to 90 degrees, and palms facing each other.	1.Maintaining a grip on the band, pull the band towards you with both arms, squeezing your shoulder blades together as you pull your arms back. 2.Return to the starting position slowly.	Keep your shoulders relaxed and elbows close to your sides during this exercise. Keep your abdominals tight and maintain a neutral posture at all times, keeping your shoulders over your hips and knees.	3 sets of 10 repetitions
Shoulder W exercise - forward bent	Stand up straight with feet shoulder-width apart. Place weights/dumbbells in both hands. Bend forward by hinging at the hips and keeping your back straight. Your head, neck, and the rest of your back should be in a line. Start with your arms by your side, elbows bent to 90 degrees, and palms facing each other.	1.Rotate your arms outward so they are coming away from your body and up toward the ceiling. Your elbows should remain bent. 2.This motion will move your hands further away from each other, and your palms will now face forward. 3.Return to the starting position.		3 sets of 10 repetitions
Shoulder W exercise - standing	Anchor an elastic band either around a sturdy structure or closed in a door with a knot. The elastic band is positioned at the height of your hand when your elbow is bent to 90 degrees and should be parallel to the floor. Stand up straight, feet shoulder-width apart, and facing the elastic band. Grab onto the elastic band with both hands. There should be some tension in the band prior to the start of the exercise. Start with your arms down by your side, elbows bent to 90	1.Maintaining a grip on the band, rotate your arms outward so they are coming away from your body. Your elbows should remain bent. 2.This motion will move your hands further away from each other, and your palms will now face forward. 3.Return to the starting position.		3 sets of 10 repetitions

	degrees, and palms facing each other.			
Standing shoulder elastic band external rotation - unilateral	Position your arms along the side of your torso and bend your elbows to 90 degrees. Point your forearms straight out in front of yourself so that they are perpendicular to your body. Grab on to an elastic band with both hands, keeping your hands shoulder-width apart and your hands in line with your forearms. There should be some tension in the band prior to the start of the exercise.	1.Externally rotate your affected shoulder by bringing your forearm away from your stomach, your unaffected arm will remain in the same position, and no movement occurs. 2.Both of your upper arms and elbows should remain in contact with the side of your body, and your hands should stay in line with your forearms throughout the movement. 3.Slowly return your arm to the start position, ensuring the band does not quickly pull your arm back.	Avoid: Allowing your elbows to come away from your body. Straightening your elbows rather than rotating your shoulders. Your elbows should stay at a 90-degree angle throughout the exercise. Bending your wrists in either direction during the movement. Your hands should stay aligned with your forearms to ensure you use your shoulder muscles to generate the motion.	3 sets of 10 repetitions
Standing shoulder elastic band external rotation - bilateral	Position your arms along the side of your torso and bend your elbows to 90 degrees. Point your forearms straight out in front of yourself so that they are perpendicular to your body. Grab on to an elastic band with both hands, keeping your hands shoulder-width apart and your hands in line with your forearms. There should be some tension in the band prior to the start of the exercise.	1.At the same time, externally rotate both of your shoulders by bringing your forearms away from your stomach. Your upper arms and elbows should remain in contact with the side of the body and your hands should stay in line with your forearms throughout the movement. 2.Slowly return your arms to the start position, ensuring the band does not quickly pull your arms back.	Allowing your elbows to come away from your body. Straightening your elbows rather than rotating your shoulders. Your elbows should stay at a 90-degree angle throughout the exercise. Bending your wrists in either direction during the movement. Your hands	3 sets of 10 repetitions

			should stay aligned with your forearms to ensure you use your shoulder muscles to generate the motion.	
Standing shoulder elastic band abduction - unilateral	While in the standing position place an elastic band along the crease located just below your buttocks. With your unaffected hand, anchor the band next to or just behind the same side hip. With your affected hand, grab the band next to your side with your thumb pointing towards the same side hip. There should be some tension in the band prior to the start of the exercise.	1.While keeping your elbow straight, lift your affected arm away from your body. 2.Slowly return your affected arm to the start position, ensuring the band does not quickly pull your arm down. 3.The unaffected arm remains at your side and stabilizes the elastic band throughout the movement of the affected arm.	This exercise focuses on working through a small arc of motion. You should only raise your arm 30-45 degrees from your body. This means no higher than halfway to shoulder-level height. Avoid: Allowing the top of your shoulders to move in the direction of your ears. This is referred to as hiking your shoulders up and should be avoided.	3 sets of 10 repetitions
Standing shoulder elastic band abduction	While standing, place an elastic band along the crease located just below your buttocks. With your elbows straight, grab the band on either side of your body with your thumbs pointing towards your hips. There should be some tension in the band prior to the start of the exercise.	1.While keeping your elbows straight, lift both arms away from your body. 2.Slowly return your arms to the start position, ensuring the band does not quickly pull your arms down.	This exercise focuses on working through a small arc of motion. You should only raise your arms 30-45 degrees from your body. This means no higher than halfway to shoulder-level height.	3 sets of 10 repetitions

			Avoid: Allowing the top of your shoulders to move in the direction of your ears. This is referred to as hiking your shoulders up and should be avoided.	
Prone scaption T	Lie down on your chest. Extend your arms to the side at a 90-degree angle to form a T with your body. Palms facing down.	1. While keeping your arms straight, raise them upwards. 2. Come back to the starting position.		3 sets of 10 repetitions
Prone scaption Y	Lie down on your chest. Extend your arms forward at a 45-degree angle to form a Y with your body. Palms facing down.	1. While keeping your arms straight, raise them upwards. 2. Come back to the starting position.		3 sets of 10 repetitions
Prone scaption Y Inverted	Lie down on your chest. Extend your arms to the side at a 45-degree angle to form an inverted Y with your body. Palms facing down.	1. While keeping your arms straight, raise them upwards. 2. Come back to the starting position.		3 sets of 10 repetitions
Standing Push-up - wall height	Stand up straight, facing the wall, and arm's length away. Place your hands flat on the wall at shoulder height, elbows straight.	1. Keeping your shoulders down and back, gradually bend your elbows to bring your face towards the wall to perform a push-up. 2. To return to the starting position, push through your hands, straighten your elbows, and move your face away from the wall.	Make sure to keep your chin tucked, back straight, and abdominals tight while you perform this movement.	3 sets of 10 repetitions

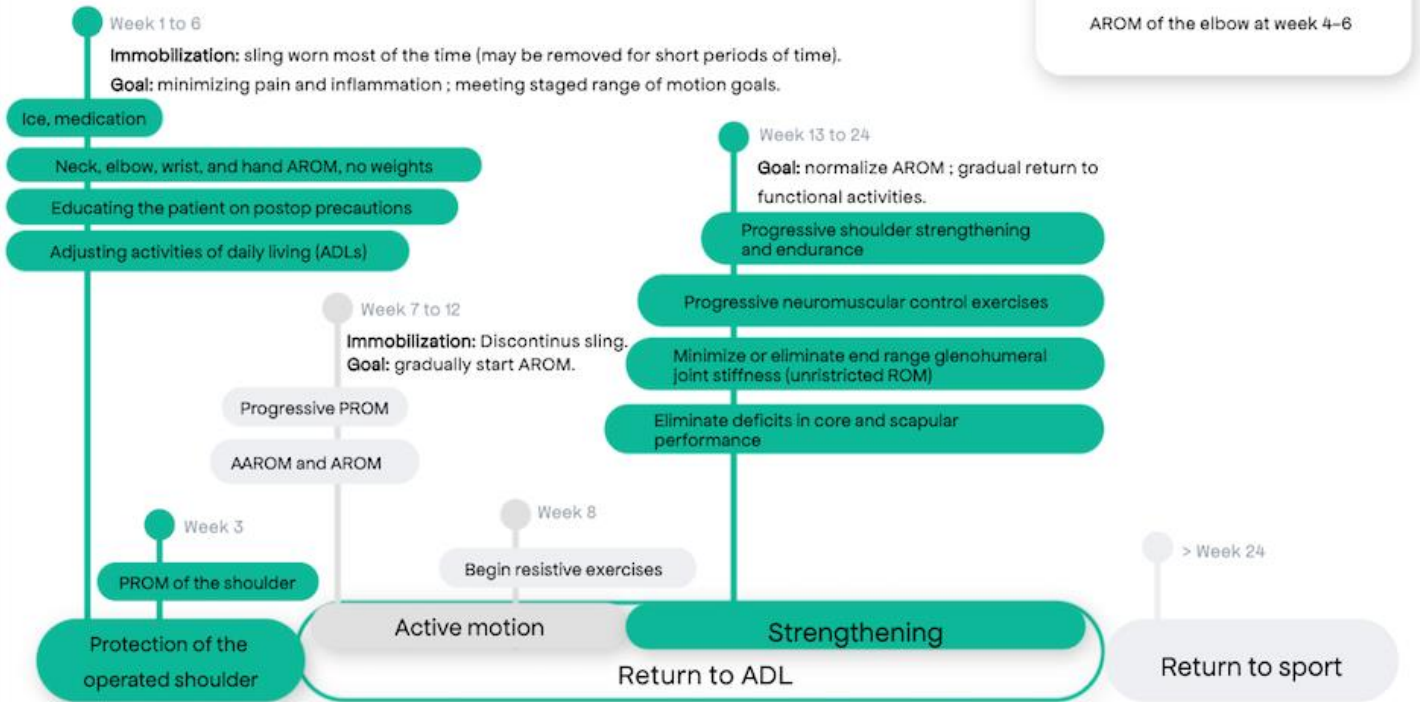
Appendix 4

Filmed videos of some exercises can be found on this Google Drive.

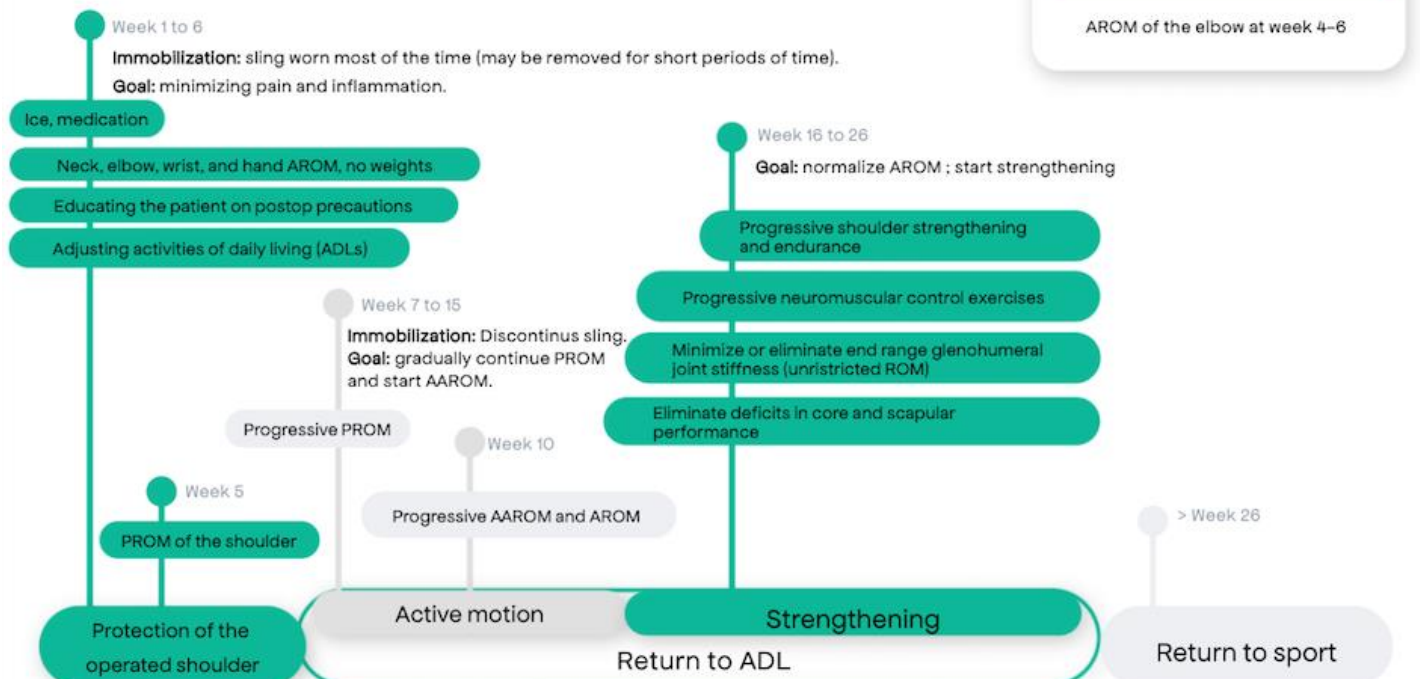
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Appendix 5: Timeline of the exercise program post ARCR for small to medium and large to massive tears

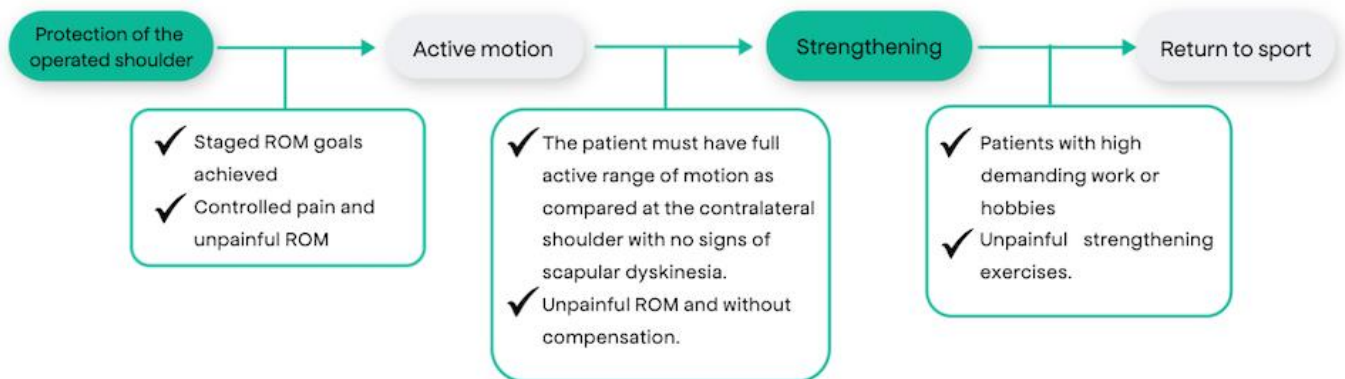
RCR Small to medium tears – Suggested protocol



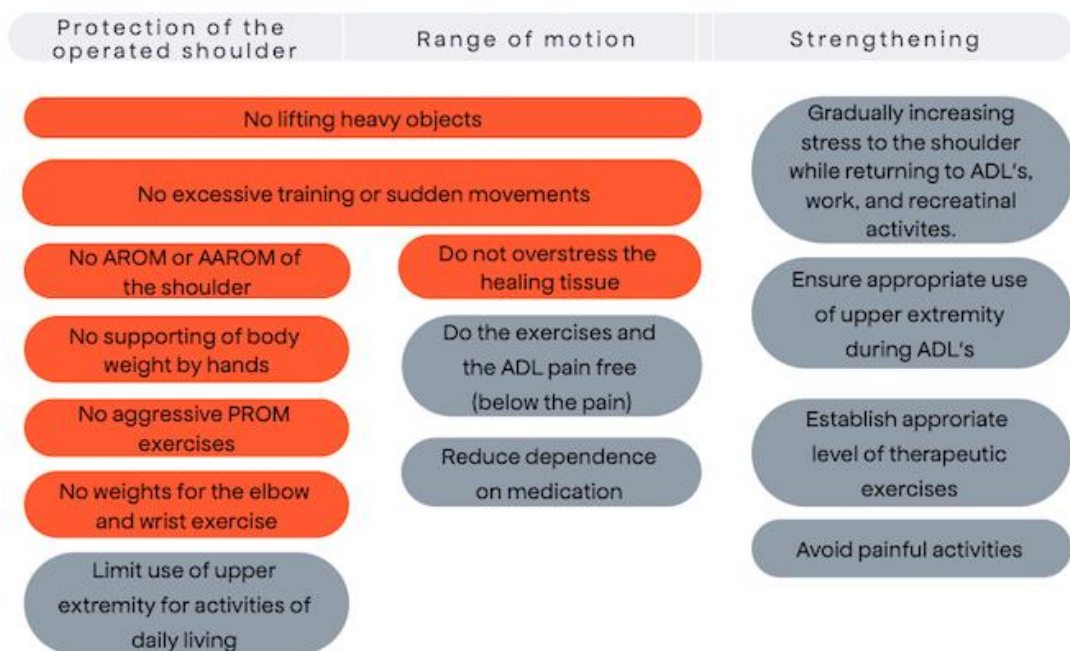
RCR Large to massive tears – Suggested protocol



Progression criteria



Important information



Appendix 6: Rehabilitation post ARCR for small to medium tears

Phase 1: Protection of the operated shoulder		Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13	Week 14	Week 16	Week 18	Week 20	Week 22	Week 24
	Cervical AROM	●	●	●	●	●	●													
	Elbow AROM	●	●	●	●	●	●													
	Wrist AROM	●	●	●	●	●	●													
	Scapula retraction	●	●	●	●	●	●													
	Shoulder roll	●	●	●	●	●	●													
	Sitting forward pendulum					●	●	●	●	●	●	●	●							
	Sitting side pendulum					●	●	●	●	●	●	●	●							
	Standing pendulum					●	●	●	●	●	●	●	●							
	Forward bow					●	●	●	●	●	●	●	●							
	Supine assisted forward elevation with opposite hand					●	●	●	●	●	●	●	●							
Phase 2: Active mobilization of the shoulder	Supine shoulder flexion with cane							●	●	●	●	●	●							
	Supine external rotation with a cane							●	●	●	●	●	●							
	Supine shoulder abduction with a cane							●	●	●	●	●	●							
	Supine shoulder internal rotation with a cane							●	●	●	●	●	●							

Sitting assisted forward elevation with the opposite hand							•	•	•	•	•	•							
Sitting shoulder table slides into abduction- elbow flexed							•	•	•	•	•	•							
Sitting shoulder table slides into abduction							•	•	•	•	•	•							
Sitting shoulder table slides into flexion							•	•	•	•	•	•							
Sitting assisted scaption with towel							•	•	•	•	•	•							
Sitting shoulder gear shift into scaption with a cane							•	•	•	•	•	•							
Sitting shoulder gear shift into external rotation- smaller ROM							•	•	•	•	•	•							
Sitting assisted external rotation with a cane							•	•	•	•	•	•							
Sitting assisted external rotation without a cane							•	•	•	•	•	•							
Supine cane-assisted external							•	•	•	•	•	•							

	Side lying shoulder isotonic abduction – long lever											•	•	•	•	•	•	•	•
Phase 3: Strengthening	Standing wall scrubs- flexion- high speeds														•	•	•	•	•
	Sitting shoulder high speed table slides into scaption												•	•	•	•	•	•	•
	Supine scapular protraction-single arm									•	•	•	•	•	•	•	•	•	•
	Standing shoulder isometric external rotation									•	•	•	•	•	•	•	•	•	•
	Standing shoulder isometric internal rotation									•	•	•	•	•	•	•	•	•	•
	Side lying shoulder external rotation isotonic									•	•	•	•	•	•	•	•	•	•
	Standing shoulder row exercises single arm & double arm - one stable arm												•	•	•	•	•	•	•
	Standing shoulder row exercises single arm & double arm - both moving arms												•	•	•	•	•	•	•
	Standing forward bent shoulder row													•	•	•	•	•	•

exercises single arm & double arm																			
Standing scapular protraction and retraction wall height												•	•	•	•	•	•	•	•
Shoulder wall lift offs - high position													•	•	•	•	•	•	•
Shoulder wall lift offs - intermediate												•	•	•	•	•	•	•	•
Shoulder wall lift offs - low position											•	•	•	•	•	•	•	•	•
Shoulder wall lift offs elastic band - high position														•	•	•	•	•	•
Shoulder wall lift offs elastic band - intermediate position													•	•	•	•	•	•	•
Shoulder wall lift offs elastic band - low position												•	•	•	•	•	•	•	•
Standing Push-up - wall height														•	•	•	•	•	•
Standing Push-up - countertop height															•	•	•	•	•
Push-up - kneeling close grip																•	•	•	•
Push-up - kneeling wide grip																•	•	•	•
Standing unsupported external rotation at 90 degrees															•	•	•	•	•

Floor scrubs - left-right - four point																•	•	•	•
Floor scrubs - up-down - four point																•	•	•	•
Standing shoulder active stabilization - circles													•	•	•	•	•	•	•
Standing shoulder active stabilization - horizontal line													•	•	•	•	•	•	•
High speed wall scrubs - up-down															•	•	•	•	•
High speed wall scrubs - left-right															•	•	•	•	•
Shoulder lat pull down single arm & double arm - one stable arm - sitting leaning back													•	•	•	•	•	•	•
Shoulder lat pull down single arm & double arm - both moving arms - sitting leaning back													•	•	•	•	•	•	•
Shoulder W exercise - forward bent														•	•	•	•	•	•
Shoulder W exercise - standing														•	•	•	•	•	•
Standing shoulder theraband resisted external rotation - unilateral													•	•	•	•	•	•	•

Standing shoulder theraband restisted external rotation - bilateral														•	•	•	•	•	•	•
Standing shoulder theraband resisted abduction - unilateral														•	•	•	•	•	•	•
Standing shoulder theraband resisted abduction														•	•	•	•	•	•	•
Prone scaption T																•	•	•	•	•
Prone scaption Y																•	•	•	•	•
Prone scaption Y inverted																•	•	•	•	•
Stretching exercises	Shoulder flexion stretch - four point														•	•	•	•	•	•
	Standing shoulder internal rotation stretch behind the back													•	•	•	•	•	•	•
	Standing shoulder posterior rotator cuff stretch													•	•	•	•	•	•	•
	Standing shoulder pectoralis													•	•	•	•	•	•	•

[illegible]

Rehabilitation post ARCR for large to massive tears

Phase 1: Protection of the operated shoulder		Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13	Week 14	Week 16	Week 18	Week 20	Week 22	Week 24
	Cervical AROM	●	●	●	●	●	●													
	Elbow AROM	●	●	●	●	●	●													
	Wrist AROM	●	●	●	●	●	●													
	Scapula retraction	●	●	●	●	●	●													
	Shoulder roll	●	●	●	●	●	●													
	Sitting forward pendulum					●	●	●	●	●	●	●	●							
	Sitting side pendulum					●	●	●	●	●	●	●	●							
	Standing pendulum					●	●	●	●	●	●	●	●							
	Forward bow									●	●	●	●							
	Supine assisted forward elevation with opposite hand									●	●	●	●							
Phase 2: Active mobilization of the shoulder	Supine shoulder flexion with cane										●	●	●	●	●					
	Supine external rotation with a cane										●	●	●	●	●					
	Supine shoulder abduction with a cane										●	●	●	●	●					
	Supine shoulder internal rotation with a cane										●	●	●	●	●					
	Sitting assisted forward elevation										●	●	●	●	●					

with the opposite hand																				
Sitting shoulder table slides into abduction- elbow flexed										•	•	•	•	•						
Sitting shoulder table slides into abduction										•	•	•	•	•						
Sitting shoulder table slides into flexion										•	•	•	•	•						
Sitting assisted scaption with towel										•	•	•	•	•						
Sitting shoulder gear shift into scaption with a cane										•	•	•	•	•						
Sitting shoulder gear shift into external rotation- smaller ROM										•	•	•	•	•						
Sitting assisted external rotation with a cane										•	•	•	•	•						
Sitting assisted external rotation without a cane										•	•	•	•	•						
Supine cane-assisted external rotation at 20 degrees abduction										•	•	•	•	•						

	Supine cane-assisted external rotation at 45 degrees abduction											•	•	•	•					
	Supine cane-assisted external rotation at 90 degrees abduction												•	•	•					
	Sitting shoulder gear shift into external rotation – larger ROM											•	•	•	•					
	Rolling a ball against the wall in standing position											•	•	•	•					
	Rolling a ball against the wall- left to right											•	•	•	•					
	Rolling ball against the wall- circles											•	•	•	•					
	Standing wall scrubs flexion- low speed											•	•	•	•					
	Standing wall scrubs - abduction											•	•	•	•					
	Standing wall scrubs-scaption											•	•	•	•					
	Standing Wall scrubs - circles											•	•	•	•					
	Side lying shoulder isotonic abduction – short lever															•	•	•	•	•

	Side lying shoulder isotonic abduction – long lever															•	•	•	•	•
Phase 3: Strengthening	Standing wall scrubs- flexion- high speeds																	•	•	•
	Sitting shoulder high speed table slides into scaption																•	•	•	•
	Supine scapular protraction-single arm															•	•	•	•	•
	Standing shoulder isometric external rotation															•	•	•	•	•
	Standing shoulder isometric internal rotation															•	•	•	•	•
	Side lying shoulder external rotation isotonic															•	•	•	•	•
	Standing shoulder row exercises single arm & double arm - one stable arm															•	•	•	•	•
	Standing shoulder row exercises single arm & double arm - both moving arms															•	•	•	•	•
	Standing forward bent shoulder row																•	•	•	•

exercises single arm & double arm																			
Standing scapular protraction and retraction wall height																•	•	•	•
Shoulder wall lift offs - high position															•	•	•	•	•
Shoulder wall lift offs - intermediate															•	•	•	•	•
Shoulder wall lift offs - low position															•	•	•	•	•
Shoulder wall lift offs elastic band - high position																	•	•	•
Shoulder wall lift offs elastic band - intermediate position																	•	•	•
Shoulder wall lift offs elastic band- low position																	•	•	•
Standing Push-up - wall height																	•	•	•
Standing Push-up - countertop height																		•	•
Push-up - kneeling close grip																			•
Push-up - kneeling wide grip																			•
Standing unsupported external rotation at 90 degrees																•	•	•	•

Floor scrubs - left-right - four point																			•	•
Floor scrubs - up-down - four point																			•	•
Standing shoulder active stabilization - circles																	•	•	•	•
Standing shoulder active stabilization - horizontal line																	•	•	•	•
High speed wall scrubs - up-down																			•	•
High speed wall scrubs - left-right																			•	•
Shoulder lat pull down single arm & double arm - one stable arm - sitting leaning back																	•	•	•	•
Shoulder lat pull down single arm & double arm - both moving arms - sitting leaning back																	•	•	•	•
Shoulder W exercise - forward bent																		•	•	•
Shoulder W exercise - standing																		•	•	•
Standing shoulder theraband resisted external rotation - unilateral															•	•	•	•	•	•

Standing shoulder theraband resisted external rotation - bilateral																●	●	●	●	●
Standing shoulder theraband resisted abduction - unilateral																	●	●	●	●
Standing shoulder theraband resisted abduction																	●	●	●	●
Prone scaption T																			●	●
Prone scaption Y																			●	●
Prone scaption Y inverted																			●	●
Stretching exercises	Shoulder flexion stretch - four point																●	●	●	●
	Standing shoulder internal rotation stretch behind the back																●	●	●	●
	Standing shoulder posterior rotator cuff stretch																●	●	●	●
	Standing shoulder pectoralis																●	●	●	●

		major doorway stretch - upper fiber																			
		Standing shoulder pectoralis major doorway stretch- middle fiber															•	•	•	•	•
		Standing shoulder pectoralis major doorway stretch- low fiber															•	•	•	•	•

Introduction: Arthroscopic rotator cuff repair (ARCR) is a common surgery, where rehabilitation is essential. Utilizing telerehabilitation (TR) for post ARCR recovery offers advantages for both patients and therapists. This study aims to develop a home exercise program using TR with video-based exercises for full thickness tears, facilitating daily activity and enhancing therapy accessibility and patient engagement.

Method: A literature review was conducted to identify relevant studies about rehabilitation post ARCR and guide the development of this program. Additionally, interviews were held with experts; surgeons and physical therapists; to gather practical insights on the rehabilitation program and their perspectives on TR.

Results: The 24-week TR program developed in this study is divided into three phases. The initial phase involves protecting the shoulder through immobilization for 4 to 6 weeks depending on the tear size. Following this, the active mobilization phase lasts from 7 to 13 weeks for small to medium tears, and from 7 to 16 weeks for large to massive tears. Finally, the program transitions to the strengthening phase after 13 weeks for small to medium tears, and after 16 weeks for large to massive tears.

Conclusion: Based on literature and experts' opinion, this TR program post ARCR for full thickness tears was developed. Further research is needed to explore TR program benefits, challenges, and effectiveness in improving patient outcomes and healthcare delivery accessibility.