INVESTIGATING RECOMMENDED REHABILITATION EXERCISES AND THEIR ASSOCIATED BIOMECHANICAL RATIONALE FOR THE CONSERVATIVE MANAGEMENT OF SUBACROMIAL IMPINGEMENT SYNDROME AND/OR ROTATOR CUFF TEARS

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ABSTRACT

Rotator cuff (RC) tears and subacromial impingement syndrome (SAIS) are highly prevalent shoulder conditions among older adults.[1,2] There is currently no consensus on the most effective exercise strategy for the treatment of SAIS and/or RC tears,[3,4] and the biomechanical rationale for proposed exercises is often not described. A systematic literature search was performed and 136 articles were included. Intervention details, results for primary outcomes of interest (pain, self-reported function, strength and biomechanical outcomes), and secondary outcomes (surgical delay, corticosteroid injections/pain-relieving medication, secondary complications) were reported and effect sizes were calculated. A list of 41 exercises identified to improve outcomes of interest was generated with associated biomechanical rationale, subdivided in seven categories based on exercise type, providing a resource for clinicians for the management of SAIS and/or RC tears. Further investigation of identified exercises is required to assess their effect on the management of SAIS and RC tears.

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LIST OF ABBREVIATIONS

3D	3-Dimensional
AAROM	Active-Assisted Range Of Motion
AROM	Active Range Of Motion
DASH	Disabilities of the Arm, Shoulder, and Hand
GP	General Practitioner
KAM	Knee Adduction Moment
LS	Levator Scapula
LT	Lower Trapezius
MT	Middle Trapezius
MVIC	Maximum Voluntary Isometric Contraction
NE	No Exercise control group
NPRS	Numerical Pain Rating Scale
OA	Osteoarthritis
PNF	Proprioceptive Neuromuscular Facilitation
PROM	Passive Range Of Motion
PROSPERO	International Prospective Register of Systematic Reviews
RC	Rotator Cuff
RM	Rhomboid Major and Minor
RoB 2	Revised Cochrane risk-of-bias tool for randomized trials
ROM	Range of Motion
SA	Serratus Anterior
SAIS	Subacromial Impingement Syndrome
SAPDI	Shoulder Pain and Disability Index
TE	Traditional Exercise group
UEFI	Upper Extremity Functional Index
UT	Upper Trapezius
WORC	Western Ontario Rotator Cuff
YE	Yoga Exercise experimental group

AUTHOR CONTRIBUTIONS

This thesis is the result of a collaborative work with Dr. Kendal Marriott and Dr. Jaclyn Chopp-Hurley. The nature of the collaboration is as follows:

Dr. Kendal Marriott contributed in the search strategy development, article review process as one of the two independent reviewers, risk of bias assessment as one of the two independent reviewers and data extraction process.

Dr. Jaclyn Chopp-Hurley contributed in the search strategy development, article review process as a third reviewer and risk of bias assessment as a third reviewer.

1.0 INTRODUCTION

Rotator cuff (RC) tears and subacromial impingement syndrome (SAIS) are highly prevalent shoulder conditions. SAIS and/or RC tears are estimated to account for 44-74% of all shoulder complaints seen in primary care in the adult population, with incidence increasing with age and the sharpest increase seen in the sixth decade.[1,2,5] SAIS results from the narrowing of the space between the superior aspect of the humerus and the acromion process of the scapula, termed the subacromial space.[6] These conditions are inter-dependent as mechanical impingement of the subacromial tissues often precedes RC tears.[6] Individuals with these conditions experience pain, decreased function, loss of independence, and decreased overall quality of life.[1] Therefore, defining an optimal rehabilitation program aimed at preventing or treating SAIS and/or RC tears and the related symptoms is critical for decreasing the burden of these conditions on affected individuals.

SAIS and RC tears are commonly treated conservatively unless surgical intervention is required. Approximately 30% of patients undergo surgical intervention when conservative treatment is unsuccessful.[7] Due to the COVID-19 crisis, wait times for orthopaedic surgeries have increased due to the cancellation or postponement of thousands of elective surgeries across Canada as a measure to limit the spread of the virus and preserve scarce medical resources. In 2021, the median wait time for an initial appointment with an orthopaedic specialist following referral by a general practitioner (GP) was 15.6 weeks in Canada. Following the appointment with the specialist, median wait times for surgical treatment were 20.0 weeks for arthroplasties (including shoulder), and 8 weeks for rotator cuff repairs in Ontario.[8] This means that Ontarians affected by SAIS and/or RC tears are waiting, on average, approximately 6 to 9 months from the point where a GP refers them for an appointment with a specialist to surgical treatment. Therefore, the conservative treatment of these conditions must be optimized to prevent or delay

surgical intervention. Unlike the conservative treatment of other musculoskeletal conditions such as hip and knee osteoarthritis (OA) where clinicians can follow empirical treatment guidelines,[9–12] conservative treatment of SAIS and RC tears is not as clearly defined in the literature: There is currently no consensus on the most effective exercise strategy in the treatment of SAIS and/or RC tears.[13,14]

While several recommended exercises have been proposed in the literature for the prevention and rehabilitation of shoulder pathologies, the biomechanical mechanism that the exercises are intending to restrict or re-train is often not described. Determining whether an exercise is suitable for the treatment of SAIS and/or RC tears requires consideration of its underlying biomechanics (muscle activity, kinematics, and kinetics). The onset of SAIS develops when there is a narrowing of the subacromial space due to kinematic factors such as superior translation of the humeral head and decreased posterior tilting, external rotation and upward rotation of the scapula (known as *scapular dyskinesis*).[15] Therefore, exercises targeted at the treatment of SAIS should focus on correcting underlying causative biomechanical factors and correct abnormal scapular motion to restore full glenohumeral range of motion and dynamic stability.[16]

2.0 LITERATURE REVIEW

2.1 Shoulder Anatomy and Mechanics

The shoulder complex is composed of three bones: the humerus, clavicle, and scapula and 4 joints: the glenohumeral, acromioclavicular, sternoclavicular and scapulothoracic joints. The acromioclavicular joint is a diarthrodial joint between the lateral border of the clavicle and medial edge of the acromion. The sternoclavicular joint is a saddle joint formed by the articulation of the medial end of the clavicle and the upper portion of the sternum. The glenohumeral joint is a ball-and-socket joint formed by the head of the humerus and the glenoid cavity of the scapula. The scapulothoracic joint is the articulation between the posterior thoracic cage and the anterior surface of the scapula, however it is not a true synovial joint.[17] The mobility of the shoulder complex can be attributed to the glenohumeral joint which is highly mobile and inherently unstable.[18] Instability of the glenohumeral joint arises from the shallowness of the glenoid fossa, disproportionate size of the humeral head and glenoid, and poor congruency between articular surfaces.[19] Therefore, the glenohumeral joint is highly dependent on the scapulothoracic joint and surrounding musculature for its stability and normal movement.[20,21] To promote stability of the shoulder complex and serve as "protectors" of the glenohumeral joint, the rotator cuff muscles and scapulothoracic musculature act as stabilizers to limit excessive translation and rotation during motion.[20] The rotator cuff muscles include: the supraspinatus, infraspinatus, subscapularis, and teres minor. The supraspinatus muscle tendon runs through the subacromial space, along with other anatomical structures as demonstrated in Figure 1, making them susceptible to damage from subacromial space narrowing. The supraspinatus originates from the supraspinous fossa of the scapula and inserts forward and laterally at the superior aspect of the greater tuberosity of the humerus. Along with the deltoid, the supraspinatus is responsible for abduction of the arm. The infraspinatus originates from the

infraspinous fossa of the scapula and inserts laterally on the middle facet of the greater tuberosity of the humerus. The teres minor originates from the mid to upper regions of the lateral border of the scapula and inserts laterally on the inferior facet of the greater tuberosity. The infraspinatus and teres minor muscles both act to externally rotate the humerus. The subscapularis muscle originates from the subscapular fossa and inserts laterally on the lesser tuberosity of the humerus. The subscapularis acts to internally rotate the humerus. In addition to their respective actions, the rotator cuff muscles act to stabilize the glenohumeral joint and through asymmetric contraction, act to "steer" the humeral head during dynamic shoulder movement to prevent excessive translation beyond the glenoid cavity.[17] The role of the rotator cuff muscles in stabilizing the humerus in the glenoid cavity during scapular plane abduction has been investigated by Poppen & Walker.[22] These researchers used radiographs of upper quarter specimen to determine muscle vectors, lines of action and lever arms of multiple muscles acting on the glenohumeral joint during scapular plane abduction. Muscle vectors calculated for the rotator cuff muscles: the supraspinatus, infraspinatus, and subscapularis, determined that these muscles serve as compressors of the humeral head into the center of the glenoid, promoting stability of the glenohumeral joint. The compressive action of the rotator cuff muscles counter the upward pull and shearing action of the anterior and middle deltoid.[22,23] Therefore, rotator cuff muscle activity is vital to maintain adequate subacromial spacing during humeral elevation and avoid compression of the anatomical structures within the subacromial space.

The scapulothoracic joint provides stability to the shoulder complex, supporting the high mobility of the glenohumeral joint: The scapula provides a stable base from which glenohumeral mobility occurs.[21] There is no bony attachment between the scapula and the thorax, making this joint susceptible to pathologic movement and highly dependent on the surrounding musculature,

the scapular stabilizers, to provide stability.[19] The primary scapular stabilizer muscles are: the serratus anterior (SA), rhomboid major and minor (RM), levator scapula (LS), and the upper (UT), middle (MT), and lower (LT) portions of the trapezius.[20] The function of these scapular stabilizers is to anchor the scapula throughout the joint range of motion through co-contraction. Normal scapulothoracic rhythm, the coordinated movement between the scapula and humerus, is required to allow for alignment of the glenohumeral joint and maximize its stability.[24] Inman et al observed [25] the healthy scapulothoracic rhythm ratio of glenohumeral elevation to scapulothoracic elevation during arm elevation to be approximately 2:1 of glenohumeral joint elevation relative to scapulothoracic joint elevation throughout almost the entire range of motion. This ratio signifies that for every 2° of glenohumeral joint elevation, the scapulothoracic joint contributes 1°, resulting in 3° total of arm elevation. Further, McClure et al found [26] that in the study of 3-Dimensional (3D) scapular kinematics in healthy participants with no history of impingement, scapular upward rotation, posterior tilting and external rotation; and clavicular elevation and retraction was consistently observed during arm elevation. This general pattern was also found and expanded upon by Ludewig et al.[27] Ludewig et al investigated [27] 3D kinematics of all four joints in the shoulder complex (sternoclavicular, acromioclavicular, scapulothoracic, glenohumeral) during arm elevation in sagittal plane flexion, coronal plane abduction and scapular plane abduction. In all three planes of arm elevation, scapular internal rotation, upward rotation and posterior tilting; glenohumeral elevation and external rotation; clavicular elevation, retraction and posterior axial rotation were consistently observed. While joint angles differed across all three planes, the general pattern held true across all three planes. In addition to its findings of each individual joint, this study also emphasizes the multi-joint interaction within the shoulder complex.[28]

In an electromyographical study of arm elevation by Bagg et al,[29] activity of the scapular stabilizers (UT, MT, LT, SA) was studied during abduction in the scapular plane. This study observed patterns of muscle activity of the UT, MT and LT and lower SA, with plateaus of activity observed across all 4 muscles. The UT demonstrated an initial increase of activity immediately upon initiation of arm elevation, its activity plateauing between 15°- 45° abduction and gradually increasing again once 90°-120° abduction was achieved. The MT demonstrated an initial increase in activity immediately upon initiation of arm elevation, with its activity plateauing between 15°-105°, followed by an increase of activity until termination of elevation. Low activity was observed by the LT from initiation of abduction to approximately 90°. Beyond 90°, the LT demonstrated rapid increases in muscle activity. Finally, the lower SA demonstrated a gradual increase of activity until the 90° position where a brief plateau was observed, followed by an increase of activity. Both the LT and SA demonstrated relatively low activity until about 90° of abduction was reached. These observations suggest that the lower trapezius and lower serratus anterior play a more significant role in stabilizing the scapula during the later stages of arm elevation. The authors of this study suggest that patterns of activity of these muscles may be related to mechanical alternations during arm elevation such as scapulothoracic rhythm and migration of the instantaneous centre of rotation. The shoulder is a complex system of multiple bones, joints and muscles that relies on the interplay of these structures to produce multi-planar movement necessary for daily function. The complexity and instability of the shoulder girdle make it prone to abnormal mechanics and subsequent injury.

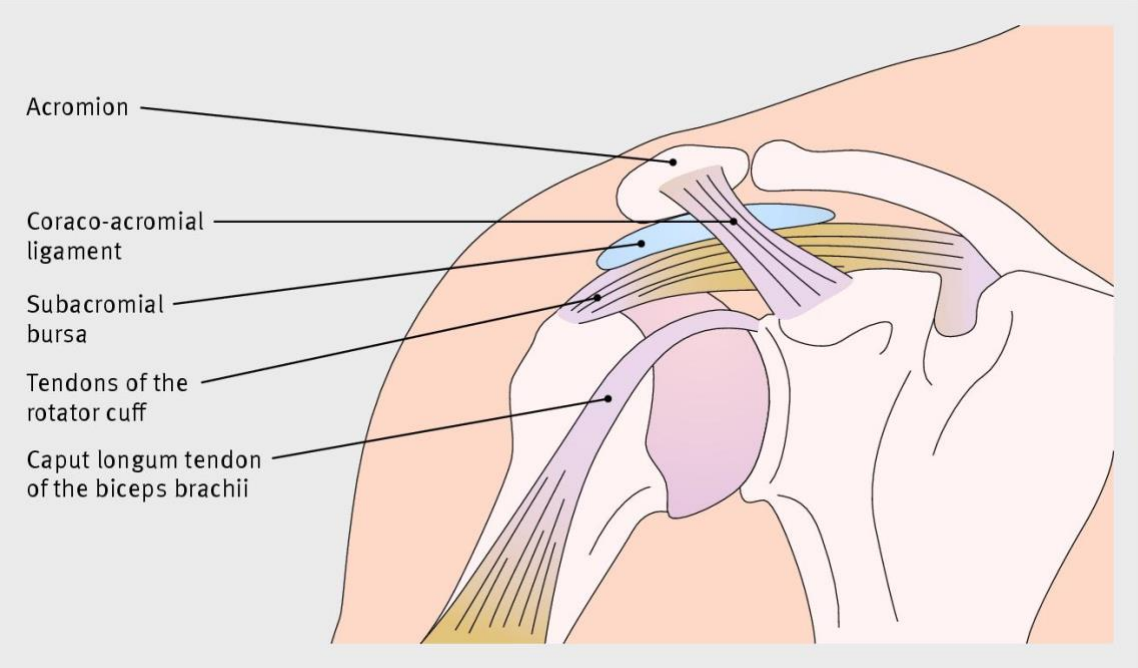

Figure 1. Anatomical structures found within the subacromial space. Multiple structures anatomical structures are found within and in the vicinity of the subacromial space, limiting the amount of space available for these structures and increasing the risk of mechanical impingement. Figure reprinted with permission from Holmgren et al[30]

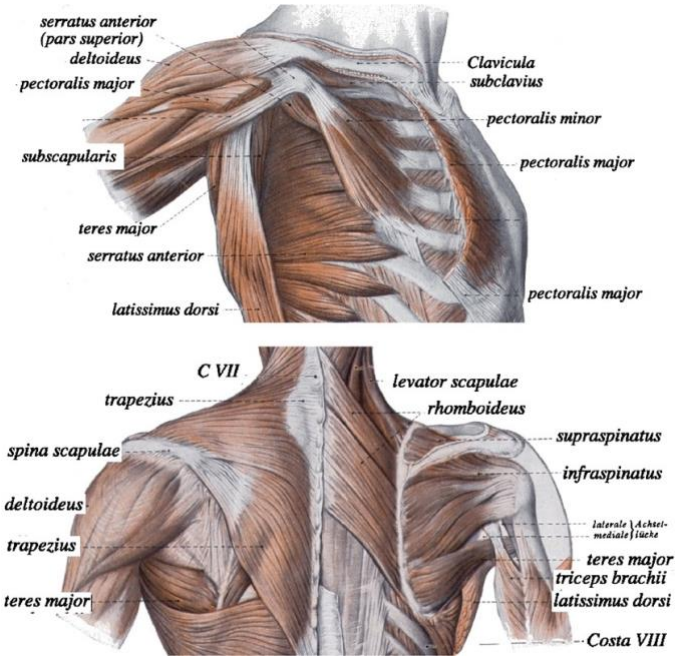

Figure 2. Shoulder joint muscular anatomy. Top: Pectoralis major removed, deep muscles from sagittal view. Bottom: superficial (left) and deep muscles from posterior view. (Figure reprinted with permission from Veeger & van der Helm, adapted from Benninghoff-Goertler [18,31])

2.2 Abnormal Shoulder Mechanics

Abnormal shoulder joint kinematics have been observed in patients with SAIS and/or RC tears in multiple studies.[32–35] One example of abnormal shoulder joint mechanics, scapular dyskinesis (altered scapular kinematics), has been associated with the development of abnormal shoulder biomechanics and resultant injuries.[24] Scapular dyskinesis can be the result of many factors such as bony, neurological, and soft tissue causes.[20] Weakness of the scapulothoracic musculature could potentially lead to abnormal positioning of the scapula, altered scapulothoracic rhythm and overall dysfunction.[34] Increased anterior and superior humeral head translation and decreased scapular posterior tilt, external rotation and upward rotation during arm elevation lead to a decrease in subacromial space and subsequent compression of rotator cuff tendons.[15] In participants with SAIS and/or RC tears, increased superior and anterior translation of the humeral head, decreased external rotation, upward rotation and posterior tilting of the scapula were observed. All of these motions act to bring the greater tuberosity of the humerus closer to the coracoacromial arch.[36] Therefore, decreasing superior or anterior translation of the humeral head, and increasing external rotation, upward rotation, and posterior tilting act to move the humeral head away from the coracoacromial arch. A meta-analysis was conducted by Timmons et al[37] to identify consistent differences in scapular kinematics in patients with SAIS. The results of this meta-analysis demonstrated that patients with SAIS displayed consistently less scapular upward rotation and external rotation, greater clavicle elevation and retraction relative to healthy controls. The authors of this meta-analysis stated that it is unclear whether these differences observed lead to the development of SAIS or, instead, are the consequence of adaptations in scapular kinematics due to SAIS.[37] Increased superior/anterior humeral head translation has additionally been observed in individuals with SAIS. In a radiographic study by Deutsch et al, the position of the humerus relative to the glenoid during abduction was studied[35]

in 3 groups: Participants with no history of SAIS (Group 1), participants with Stage II SAIS (Group 2), and participants with Stage III SAIS or RC tears (Group 3). Group 2 and 3 demonstrated a significant ($p<0.05$) rise in superior humeral head translation (1.2 mm, and 1.0mm; respectively) during active arm abduction. This study also observed alternations in scapulothoracic rhythm of Group 2 and 3 relative to the "normal" Group 1 throughout the entire range of motion from 0° to 120° abduction. Group 2 had an observed ratio of glenohumeral elevation relative to scapulothoracic elevation of 1.6:1, and Group 3 had an observed ratio of 1.3:1 compared to the average ratio of 1.7:1 observed in Group 1 of this study, and the 2:1 ratio observed by Inman et al.[25] Understanding altered joint kinematics is vital in the understanding of muscular dysfunction and/or weakness in individuals with SAIS and/or RC tears. For example, the SA has been shown to play a large role in scapular upward rotation and posterior tipping,[38] opposing scapular mechanics related to decreasing the subacromial space. Decreased activity of this muscle would result in decreased upward rotation and posterior tipping; scapular orientations that reduce the subacromial space and increase risk for SAIS. While this would suggest strengthening the scapular stabilizing musculature would be the optimal strategy for maintaining healthy scapular kinematics, decreased SA activity paired with hyperactivity of UT has been shown to produce decreased upward rotation and reduced posterior tipping, resulting in excessive superior translation of the scapula, as a consequence of the observed "shoulder shrugging" motion.[39] Thus, it is important to consider, not only the activity level of the upper limb musculature but also the relative co-activity of these critical kinematic stabilizers. Abnormal shoulder mechanics have been observed to be associated to the development of SAIS and/or RC tears. Knowledge of these abnormal mechanics and the associated musculature can be

used to develop exercise protocols for the management of these conditions that aim to address these abnormal mechanics and correct the source of these pathologies.

2.3 Rehabilitation programs for chronic musculoskeletal conditions

Several biomechanically-based rehabilitation programs have been developed for the treatment of various musculoskeletal conditions, including osteoarthritis, low back disorders and adhesive capsulitis of the shoulder. In the treatment of knee osteoarthritis (OA), exercise programs focusing on quadriceps strengthening while limiting the knee adduction moment (KAM) which reflects medial knee joint loading, have been recommended.[40,41] Higher KAM has been linked to greater losses of medial tibial cartilage volume over 12 months, leading to accelerated disease progression.[41] Considering these recommendations, Longpré et al[42] identified [42] yoga-based knee strengthening exercises consisting of static poses that elicited high leg muscle activation while maintaining low KAM. Kuntz et al[43] investigated this yoga exercise program in a single blind, three-arm randomized control trial whereby pain, self-reported physical function and mobility performance were compared between the yoga exercise experimental group (YE), traditional exercise group (TE), and a no exercise control group (NE). The YE group demonstrated significantly greater improvements in pain and self-reported physical function compared to the NE group. This yoga exercise program was also studied by Chopp-Hurley et al[44] as a workplace exercise program in older adults with hip and knee OA. Improvements in work ability, self-reported pain, self-reported function, and depressive symptoms were observed after the 12-week specific exercise program.

A biomechanically-based exercise intervention has also been developed for the treatment of chronic low back disorders. McGill developed [45] a progressive, five stage approach consisting of: (1) identifying damaging motor patterns and developing corrective exercises, (2) building

whole body and spine stability, (3) increasing muscular stability endurance, (4) building strength and (5) developing speed, power and agility.[45] Based on this, three exercises have been suggested by McGill in the treatment of lower back pain, coined the "big 3": curl-ups, side bridging and bird dog.[46] This program is centralized upon increasing spine stability by training the flexors, lateral musculature and extensors of the core while imposing low loads on the spine. This program has been documented by Durall et al[47] to prevent new back pain incidents and decrease pain in those with a history of back pain. Further, for the treatment of adhesive capsulitis of the shoulder, exercise-based rehabilitation programs have been investigated. Celik[48] found that a 6-week exercise program aimed at increasing glenohumeral ROM in addition to scapulothoracic strengthening exercises led to significant decreases in pain and glenohumeral ROM by potentially correcting scapulothoracic dyskinesis.[48] Biomechanically-based exercise protocols have been established for many chronic musculoskeletal conditions and have demonstrated to be effective in the management of these conditions.

2.4 Conservative Management of SAIS and/or RC tears

Individuals with SAIS and RC tears can be treated non-operatively through several modalities. Conservative treatment options include exercise, physiotherapy, injection and anti-inflammatory drugs, and often, a combination of these interventions. The majority of patients treated conservatively are treated successfully and avoid surgical intervention.[49,50] Bartolozzi et al[50] found [50] that within a sample of 136 participants with SAIS and/or RC tears treated conservatively, 77% obtained an "excellent" or "good" result after a minimum of 18 months of treatment. This study also determined that the success of conservative treatment is dependent on a number of factors including: rotator cuff tear size, duration of pre-treatment symptoms, functional impairment and exhibited weakness. Based on the results of this study, early surgical

intervention would be warranted if an individual exhibits a duration of symptoms >12 months, severe functional impairment, a rotator cuff tear >1cm^2 or weakness in addition to the rotator cuff tear. Other exceptions that may favor early surgical intervention are the patient's unwillingness to wait or undergo conservative therapy, or if a patient has high physical demands such as a performance athlete. [50] Another factor that may predict an individual's response to conservative management is acromion morphology. Acromion morphology has been classified into 3 categories: Type I acromion having a flat underside, Type II acromion have a smooth, curved underside, and Type III have a hooked underside.[51] Acromion type is an important factor as having a more curved or hooked acromion decreases the space available in the subacromial space for subacromial tissues and when coupled with other factors that act to decrease subacromial space such as improper scapular mechanics and prolonged overhead activity, increases the risk of impingement. Wang et al found [51] a significant relationship between acromial morphology and success of non-operative treatment of SAIS. Individuals with Type I acromion (flat) were more likely to be successfully conservatively managed, while individuals with Type II (curved) or III (hooked) acromion were more likely to require surgical intervention.

Conservative management of SAIS and RC tears through exercise intervention often involves stretching and strengthening exercises. Multiple studies suggest that selected specific exercises lead to improvements of symptoms related to SAIS and/or RC tears.[14,52] The effect of a 12-week specific exercise program focusing on eccentric strengthening of the rotator cuff and scapular stabilizers on the need for arthroscopic subacromial intervention in individuals with SAIS was investigated by Holmgren et al.[52] This study explored the effect of exercises targeting eccentric strengthening of the rotator cuff and scapular stabilizer muscles on shoulder function and pain compared to a control exercise group that received an exercise program consisting of

unspecific movements of the neck and shoulder. A significant reduction in the proportion of patients that required surgery was observed in the specific exercise group (20%) versus the control exercise group (63%) ($p<0.001$). Kuhn et al developed [14] an evidence-based exercise protocol based on a systematic review of 11 articles relating to the conservative management of SAIS. The developed exercise protocol consisted of: postural exercises, glenohumeral ROM beginning with pendulum exercises and progressing to active-assisted and active exercises based on comfort, anterior and posterior shoulder stretching, followed by rotator cuff and scapular stabilizer muscle strengthening exercises with the use of a resistance band. This protocol by Kuhn et al does not provide a comprehensive list of specific exercises or biomechanical rationale, but rather broad guidelines and examples of applicable exercises. Previous literature has aimed to provide an effective exercise protocol for the management of SAIS and/or RC tears, however there remains no consensus for the optimal conservative management of these conditions.

2.5 Summary of literature review

This literature review has demonstrated the complexity of the shoulder complex and its susceptibility to abnormal mechanics, and subsequent development of symptoms and tissue damage consistent with SAIS and/or RC tears. Exercise has been widely used in the management of a variety musculoskeletal conditions, including SAIS and/or RC tears. Current literature suggests that exercise is effective in the management of SAIS and/or RC tears, however there lacks a comprehensive list of specific exercises and outlined biomechanical rationale demonstrated to improve symptoms of these conditions as well as improve underlying mechanics associated with these conditions.

3.0 RESEARCH OBJECTIVES

3.1 Primary Research Objectives:

1. Establish a comprehensive list of exercises recommended for the conservative management of acute phase atraumatic, symptomatic clinically diagnosed with SAIS and/or RC tears.
2. Report and/or deduce the biomechanical basis for each identified exercise.

3.2 Secondary Research Objectives:

1. Report whether certain exercises were successful with respect to delaying surgery, the need for corticosteroid injections or other pain-reducing medication.
2. Determine whether exercises elicited or could potentially lead to disadvantageous consequences to surrounding musculoskeletal structures.

4.0 METHODS

4.1 Systematic review registration

Prior to starting this review, an application was submitted for registration on PROSPERO (International Prospective Register of Systematic Reviews). The PROSPERO registration number for this systematic review is PROSPERO 2020 CRD42020200884.

4.2 Search strategy

A systematic literature search was performed during October 2020 to November 2020 on the following databases: Medline (OVID), Embase, CINAHL and PEDro. The search strategy included key words pertaining to the following three categories: (1) adult population, (2) conservative management, exercise, physical therapy, and rehabilitation, and (3) atraumatic subacromial impingement syndrome and rotator cuff tears. Additionally, subject headings adapted for each individual database were used. The search was filtered for English text, full-text article, and human. There were no restrictions on publication date or study design, however study protocols/proposals, conference abstracts and grey literature were not included.

4.3 Study inclusion

Article screening was performed using Covidence systematic review software (Veritas Health Innovation, Melbourne, Australia). Retrieved articles were initially screened independently based on title and abstract contents in the title and abstract screening phase by two reviewers following pre-specified inclusion and exclusion criteria. If reviewers' decisions conflicted, reviewers deliberated with a third reviewer until a consensus was reached. The full texts of articles screened for inclusion in the title and abstract screening phase were then retrieved and independently screened in the full-text screening stage by the same two reviewers following pre-specified inclusion and exclusion criteria. If reviewers' decisions conflicted,

reviewers deliberated with a third reviewer until a consensus was reached. Reasons for article exclusion were recorded and included full-text articles were included for data extraction and data synthesis.

4.3.1 Inclusion criteria

Study inclusion criteria included: (1) Adult participants (≥ 18 years), (2) clinical diagnosis of SAIS and/or RC tears exhibiting pain and/or weakness, (3) an exercise intervention aimed at the conservative management of SAIS and/or RC tears investigated alone, (4) the inclusion of at least one of the primary or secondary outcome measures of interest.

4.3.2 Exclusion criteria

Studies were excluded if: (1) Participants were not adults (≤ 18 years), (2) Participants were healthy, asymptomatic, suffered a traumatic injury or other clinical shoulder diagnosis such as, but not limited to: labral tear, fracture, dislocation, brachial plexus injury, neural palsy, and osteoarthritis. Studies were also excluded if participants in the exercise intervention group underwent a corticosteroid injection and/or shoulder surgery during the exercise intervention period, or if an exercise intervention was not investigated alone. Additionally, studies were excluded if they failed to report any primary or secondary outcome measures.

4.3.3 Participants/Population

The population of interest were adults (≥ 18 years) with a clinical diagnosis of chronic, atraumatic subacromial impingement syndrome and/or rotator cuff tears exhibiting pain and/or weakness. Clinical diagnostic criteria varied between studies, common indicators were a positive Neer's impingement test, Hawkins-Kennedy impingement sign, painful arc sign, Jobe test, as well as weakness/pain with manual muscle testing of the rotator cuff muscles.

4.3.4 Interventions/Exposures

Interventions of interest were any exercise treatment. This includes exercises targeted at increasing muscle strength and joint range of motion. Other exercise strategies such as those targeted at improving aerobic fitness and flexibility were also included. Exercise therapy may have been independent or combined with education, the application of a heating pad or ice pack. Exercise interventions may have been performed in a clinical or home setting, supervised or unsupervised, and performed individually or in a group setting.

4.4 Outcome measures

Primary outcomes investigated were pain, function and biomechanical outcomes measured by a variety of outcome measure tools.

4.4.1 Pain

Pain was investigated by reporting results of outcome measures such as the Numerical Pain Rating Scale (NPRS) or other scales if NPRS is not reported. Other pain scales were included such as the Shoulder Pain and Disability Index (SPADI), among others.

4.4.2 Self-reported shoulder function

Self-reported shoulder function was reported by reporting results of outcome measures such as Disabilities of the Arm, Shoulder, and Hand (DASH) scale or other scales if DASH scores are not reported. Other shoulder function and disability scales were included the Upper Extremity Functional Index (UEFI), the Western Ontario Rotator Cuff (WORC) Index, the SPADI – Disability subscale, among others.

4.4.3 Strength

Upper limb strength measures, including multiplane elevation and internal/external rotation strength were be reported. Strength was measured using a variety of techniques such as hand-held dynamometry, isokinetic dynamometry, or other force transducers.

4.4.4 Biomechanical outcomes

Biomechanical outcomes varied widely across the literature and included measures such as range of motion/mobility, shoulder kinematics and/or kinetics, muscle activation, muscle co-activation ratios. A variety of assessment tools were used to capture these outcomes including optoelectronic motion capture systems, inertial measurement units, accelerometry, goniometry, force gauges, electromyography.

4.4.5 Secondary outcomes

Secondary outcomes were investigated to assess whether exercise resulted in a delay of surgery, corticosteroid injections or a decrease in use of pain-relieving medication, and/or whether secondary exercise-induced complications were experienced by the participants.

5.0 DATA ANALYSIS

5.1 Risk of bias assessment

Internal and external validity of included randomized trials was evaluated using the Revised Cochrane risk-of-bias tool for randomized trials (RoB 2).[53] Two reviewers independently evaluated risk of bias arising from the following domains: bias arising from the randomization process, bias due to deviations from intended interventions, bias due to missing outcome data, bias in measurement of the outcomes and bias in selection of the reported result. Risk of bias evaluations were made in these domains with the use of signaling questions specified in the RoB2. Response options for signalling questions were: (1) Yes, (2) Probably yes, (3) Probably no, (4) No (5) No information. Responses to signalling questions were used to determine domain-level risk of bias evaluations using the algorithm described in the RoB2. Domain-level evaluations were used to determine overall risk-of-bias judgement following the algorithm in the RoB2. In both instances, risk of bias judgement generated by the algorithm could be overwritten by the reviewer, provided they had a rationale for their judgement. A study was judged to be at a *low risk of bias* if it was judged to be at a low risk of bias for all domains. A study was judged to raise *some concerns* if it was judged to raise some concerns in at least one domain, but not be at high risk of bias in any domain. A study was judged to be at *high risk of bias* if it was judged to be at high risk of bias in at least one domain or if it is judged to have some concerns for multiple domains. If two reviewers disagreed, they deliberated with a third reviewer until a consensus was reached. Studies were categorized based on overall risk of bias assessment, and in-depth sub analysis was conducted on studies judged to be at a low risk of bias to assess data on exercise interventions in studies conducted with high scientific rigor.

5.2 Data extraction

Data from the included studies pertaining to the primary and secondary outcome measures of interest were recorded in a table format. The extracted data included details on the exercise intervention and comparator investigated, outcome measure reported, baseline measures (sample size, mean, standard deviation), post-intervention measures (mean, standard deviation). Specific exercises included in the described exercise interventions were recorded where specified, as well as any description of the exercise, treatment goal of the exercise and biomechanical rationale, if available. If biomechanical rationale was not explicitly stated, rationale was deduced based on previous literature investigating the specified exercises and literature on the management of SAIS and/or RC tears.

5.3 Statistical analysis

Statistical analysis was performed using Microsoft Excel (Version 16.60, Microsoft Office, Redmond, Washington, United states) and R (Version 4.12, The R Foundation for Statistical Computing, Indianapolis, Indiana, United States). To evaluate the effect of exercise on outcomes of interest in the exercise intervention groups, extracted data from all studies with an exercise intervention group, including randomized controlled trials and single groups studies, were used to calculate effect size (Cohen's d), as well as percent change, between pre- and post-intervention measures. To evaluate the effect of exercise on outcomes of interest relative to the investigated comparators, extracted data from included randomized controlled trials were used to calculate effect size (Cohen's d) for the mean difference between the exercise intervention and comparator group. Directionality of effect sizes and percent change values were adjusted to represent a favorable improvement in the context of the management of SAIS and RC tears such that a decrease in pain, increase in function, increase in upper limb strength, increase in favorable

biomechanical outcomes, and decrease in pathology promoting biomechanical outcomes were interpreted as positive changes, and therefore positive effect sizes or percent change. Effect sizes were interpreted as: negligible ($d<0.2$) small ($d=0.2$), medium ($d=0.5$) or large ($d=0.8$).[54]

5.4 Data synthesis

A narrative synthesis of the findings from the included studies was produced, generating a list of recommended exercises for the conservative management of chronic, atraumatic subacromial impingement syndrome and/or rotator cuff tears. This list includes exercises that have been identified to improve pain, function, strength and/or promote injury sparing kinematic changes in more than one study included in this review. The biomechanical rationale and treatment goal of each identified recommended exercise was described, where available. If biomechanical rationale for implemented exercises were not explicitly stated, biomechanical rationale for the exercise was deduced based on the literature, if available. Similarly, if secondary disadvantageous consequences from the investigated exercises were not explicitly stated, they were deduced based on previous literature, if available. Previous literature assessing electromyographical activity of shoulder muscles during the identified exercises as well as previous literature on shoulder anatomy and mechanics were used to deduce biomechanical rationale and secondary disadvantageous consequences.

6.0 RESULTS

6.1 Study inclusion

Six-thousand three-hundred and twenty-nine articles were collectively identified in Medline (OVID) (n=2085), Embase (n=3696), CINAHL (n=498), and PEDro (n=50) from the database search using the developed search strategy. Of those records, 1837 were automatically identified as duplicates and removed when imported into Covidence systematic review software (Veritas Health Innovation, Melbourne, Australia). Four-thousand nine-hundred and ninety-two articles were screened in the title and abstract stage, and 660 articles were screened in the full-text screening stage. Of the full-text articles screened, 524 articles were excluded following exclusion criteria (Figure 4). 136 articles met inclusion criteria, comprised of randomized controlled trials (n=76), systematic reviews/meta-analyses (n=29), single group study designs (n=26) and other study designs (n=5) such as non-randomized trials (Figure 3).

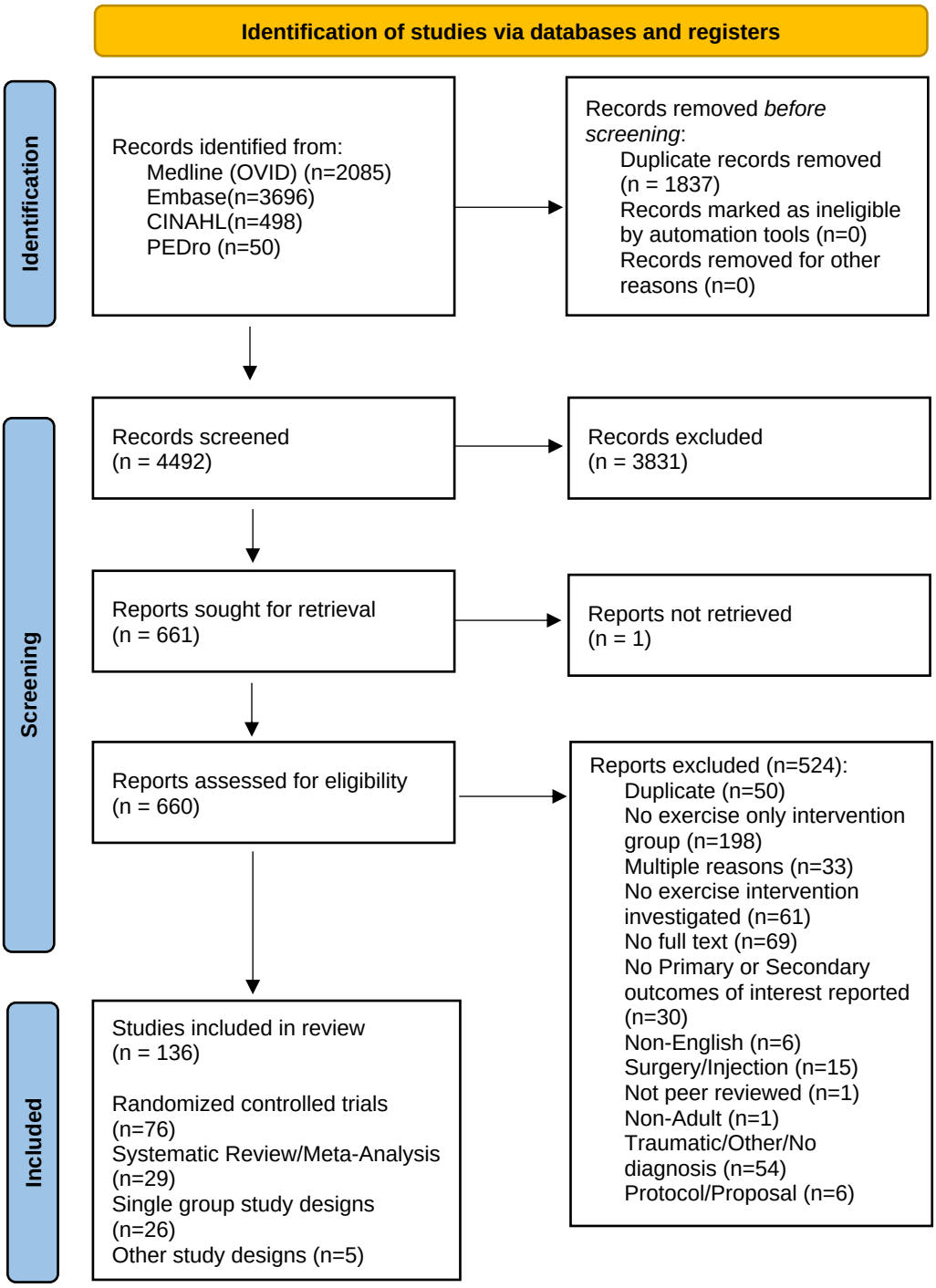

Figure 3. PRISMA 2020 Flow chart adapted to outline the identification of studies to be included in this systematic review to identify recommended rehabilitation exercises and their associated biomechanical rationale for the conservative management of SAIS and/RC tears

6.2 Primary research objectives

In order to determine the effectiveness of exercises on primary outcomes: pain, function, strength and biomechanical outcomes and identify specific, effective exercises for the management of SAIS and/or RC tears, calculated effect sizes from data extracted from all included studies were investigated through a variety of subgroupings.

6.2.1 Effect of exercise interventions on primary outcomes

Ninety-four studies, including 70 randomized controlled trials and 24 single group studies investigated the effects of an exercise intervention on pain, function, strength and biomechanical outcomes pre- and post-intervention and reported numerical data. Study and exercise intervention details are outlined in Appendix A. Twenty-one studies reported pain outcomes, 80 studies reported function outcomes, 21 studies reported strength outcomes and 54 studies reported biomechanical outcomes. All 94 studies reported a positive effect size or positive percent change for at least one primary outcome of interest. Mean percent change, effect sizes and ranges of effect sizes between baseline and follow-up measures for exercise intervention groups per outcome are detailed in Table 1. Large positive mean effect sizes were observed for pain and function outcomes, a medium positive mean effect size was observed for strength and a small positive effect size was observed for biomechanical outcomes. Positive effect sizes and percent change indicate a decrease in pain and biomechanically disadvantageous outcomes and an increase in function, strength, and biomechanically advantageous outcomes (Table 1). Improvements in all outcomes were observed following the investigated exercise interventions. Follow up times varied from immediately after one session of exercise to 13.9 years following the exercise intervention period.

Table 1. Mean effect size, range of effect sizes, mean percent change (%) and range of percent change (%) between baseline and follow-up for exercise intervention groups for primary outcomes in all studies

Outcome	**Pain**	**Function**	**Strength**	**Biomechanical**
Number of studies	63	80	21	54
Mean effect size	1.45	1.18	0.53	0.46
Range	-0.41 - 7.21	-2.69 - 4.36	-0.37 - 2.00	-3.89 - 4.82
Mean percent change (%)	44.77	36.47	25.77	22.72
Range (%)	-100.00 - 156.14	-100.00 - 648.24	-17.570 – 156.98	-127.78 – 700.00

6.2.1.1 Effect of exercise type on primary outcomes

Effect sizes between baseline and follow-up measures for exercise intervention groups for all studies were sub-divided into seven subgroupings based on exercise type: Stretching, range of motion, rotator cuff strengthening, scapular stabilizer strengthening, scapular neuromuscular control training, postural, and other upper limb strengthening exercises. Exercise type subgroupings were formed based on treatment goals or aims of exercises. Studies were grouped into multiple exercise type subgroupings if exercise interventions contained multiple types of exercises.

6.2.1.1.1 Stretching

Thirty-six studies investigated an exercise intervention that included stretching exercises. Stretching exercises were defined as sustained postures aimed at increasing flexibility, muscle length, and decreasing muscle hypertonicity. Identified stretches included: Anterior shoulder stretch, posterior capsule stretch (cross-body stretch), sleeper stretch, towel internal rotation

stretch, upper trapezius stretch, levator scapula stretch, bilateral corner (pectoralis) stretch and unilateral corner (pectoralis) stretch (Table 6). Biomechanical rationale for the identified stretching exercises included stretching specific musculature or other tissues that tightness or hypertonicity has been associated with altered scapular kinematics. For stretching exercises, large mean effect sizes were observed for pain and function outcomes, while small mean effect sizes were observed for strength and biomechanical outcomes (Table 2).

6.2.1.1.2 Range of motion

Thirty-eight studies investigated an exercise intervention that included range of motion (ROM) exercises. ROM exercises were defined as exercises aimed to increase joint movement during dynamic movements, either passive or active in nature. Range of motion exercises identified in this review include PROM (Passive range of motion)/Wand exercises, AAROM (Active-assisted range of motion) exercises, AROM (Active range of motion) exercises and Codman/pendulum exercises (Table 6). Biomechanical rationale for the identified ROM exercises was to improve passive or active range of motion, a common deficit in patient with SAIS and/or RCTs. For exercise interventions implementing ROM exercises, large positive mean effect sizes were observed for pain and function, and medium positive mean effect sizes were observed for strength and biomechanical outcomes (Table 2).

6.2.1.1.3 Rotator cuff strengthening

Sixty-six studies investigated an exercise intervention that included rotator cuff strengthening exercises. Rotator cuff strengthening exercises were defined as exercises aimed at strengthening the rotator cuff muscles: the supraspinatus, infraspinatus, subscapularis, and teres minor. Rotator cuff strengthening exercises identified in this review include: Scaption with external rotation (“Full can”), scaption with internal rotation (“Empty can”), resisted forward

flexion, resisted shoulder abduction, resisted shoulder external rotation and resisted shoulder internal rotation (Table 6). Biomechanical rationale for rotator cuff strengthening exercises was to promote the humeral centering, stabilizing and compressive action of the rotator cuff muscles, limiting the upward translation of the humeral head towards the subacromial space. For exercise interventions implementing rotator cuff strengthening exercises, large positive mean effect sizes for pain and function, a medium positive mean effect size for strength, and a small positive mean effect size for biomechanical outcomes were observed (Table 2).

6.2.1.1.4 Scapular stabilizer strengthening

Fifty-five studies investigated an exercise intervention that included scapular stabilizer strengthening exercises. Scapular strengthening exercises were identified and defined as exercises aimed at the strengthening of the primary scapular stabilizer muscles: The serratus anterior, rhomboid major and minor, levator scapula, the upper, middle, and lower portions of the trapezius. Scapular stabilizer strengthening and scapular control exercises identified in this review include: Rows/Scapular retraction, low rows, prone shoulder extension, horizontal abduction, prone LT/MT lifts (T's & Y's), dynamic hug/scapular protraction, push up plus, serratus anterior strengthening in quadruped, supine press, and wall push ups (Table 6). Biomechanical rationale for these exercises was to strengthen scapular stabilizers and correct co-activation ratios of scapulothoracic musculature in an effort to promote normal kinematics that act to maintain adequate space in the subacromial space during humeral elevation. For exercise interventions including scapular stabilizer strengthening exercises, large positive mean effect sizes were observed for pain and function, and medium positive mean effect sizes were observed for strength and biomechanical outcomes (Table 2).

6.2.1.1.5 Scapular neuromuscular control training

Nineteen studies investigated an exercise intervention that included scapular neuromuscular control training exercises. Scapular neuromuscular control training exercises were exercises aimed at training the conscious activation of dynamic restraints to maintain shoulder stability.[55] Scapular neuromuscular control exercises identified in this review include: wall slides/wall angels, rhythmic stabilization, scapular clock exercises, inferior glide and Proprioceptive Neuromuscular Facilitation (PNF) D1 and D2 patterns (Table 6). Biomechanical rationale for these exercises was to restore the dynamic mechanism of stabilization and proprioception by promoting healthy synergistic activity in an effort to promote normal kinematics that act to maintain adequate space during dynamic shoulder movements.[55] For exercises implementing neuromuscular training exercises, large positive mean effect sizes were observed for pain, function and strength outcomes, and a small positive mean effect size was observed for biomechanical outcomes (Table 2).

6.2.1.1.6 Postural

Six studies investigated an exercise intervention that included postural exercises. Postural exercises were identified and defined as exercises aimed at strengthening postural muscles such as the erector spinae and deep neck musculature. Postural exercises identified in this review were chin tucks and thoracic extensions (Table 6). Biomechanical rationale for postural strengthening exercises was to decrease excessive kyphosis of the thoracic spine and decrease forward translation of the head, postures that have been associated with abnormal scapular mechanics and decreased shoulder range of motion. For exercise interventions implementing postural exercises, large positive mean effect sizes were observed for pain and function, a medium positive mean

effect size was observed for biomechanical outcomes, and a small positive mean effect size was observed for strength outcomes (Table 2).

6.2.1.1.7 Other upper limb muscle strengthening exercises

Eight studies investigated an exercise intervention that included exercises aimed other upper limb muscle strengthening exercises. Exercises aimed at strengthening other upper limb muscles were identified and defined as exercises that aimed at the strengthening of the latissimus dorsi, biceps brachii and triceps brachii. Exercises aimed at strengthening other upper limb muscles identified in this review are seated press-ups, lat pull downs, biceps curls, triceps push downs and overhead triceps extensions (Table 6). Biomechanical rationale for this type of exercises was to strengthen muscles that aid in depressing the humeral head during arm elevation to prevent the upward migration of the humeral head towards the acromion, and therefore decrease risk of impingement of subacromial tissues. Large positive mean effect sizes were observed for pain, function, strength and biomechanical outcomes for exercise interventions implementing exercises focused on strengthening other humeral depressors and stabilizers (Table 2).

6.2.2 Comparators

Of the 76 randomized controlled trials, the effect of exercise interventions on primary outcomes of interest were compared to a variety of comparators. Effect sizes between exercise intervention group measures and comparator intervention group measures for exercise intervention groups for all randomized controlled trials were separated into three subgroupings based on the comparator investigated. The comparator subgroupings were: no treatment and placebo treatment, therapeutic modalities and injections/medication, and surgery. Studies were grouped into multiple comparator subgroupings if multiple comparators were investigated, however, only data for the comparator of interest were included in the analysis.

6.2.2.1 Control and placebo

Nine studies investigated the effects of an exercise intervention alone in comparison to a control group that received no treatment (n=6), or placebo laser treatment (n=3). Study and exercise intervention details and comparator details are outlined in Appendix B**.** Mean effect sizes and ranges of effect size per outcome are detailed in Table 3. For all exercise interventions compared to no treatment or placebo treatment, a large positive mean effect size was observed for pain, a medium positive mean effect size was observed for function, a small positive mean effect size for strength and a negligible positive mean effect size for biomechanical outcomes. Positive effect sizes represent a decrease in pain, disability, and disadvantageous biomechanical outcomes, and an increase in function and advantageous biomechanical outcomes.

Three studies investigated exercise interventions including ROM exercises. Mean effect sizes for exercise interventions including range of motion exercises could not be calculated due to means not being reporting in the original studies. Specific ROM exercises included in these studies were PROM/wand and pendulum exercises.

Three studies investigated exercise interventions including stretching exercises. Stretching exercises investigated in these studies included UT stretch, unilateral corner and bilateral corner (pectoralis) stretches, and posterior shoulder (cross-body) stretch. Large positive mean effect sizes were observed for pain and function, and a negligible negative mean effect size was observed for biomechanical outcomes, strength outcomes were not reported (Table 3).

Seven studies investigated exercise interventions including rotator cuff strengthening exercises. Specific rotator cuff strengthening exercises included scaption (full can), resisted external rotation, internal rotation, and flexion. A large positive mean effect size was observed for pain, a medium positive mean effect size was observed for function, a small positive mean effect size was observed for strength and a negligible positive mean effect size was observed for biomechanical outcomes.

Seven studies investigated exercise interventions including scapular stabilizer strengthening exercises. Specific scapular stabilizer exercises were push up plus, horizontal abduction, scapular protraction, rows/scapular retraction, prone shoulder extension, supine press up. For exercise interventions implementing scapular stabilizer exercises, a large positive mean effect size was observed for pain, a medium positive mean effect size was observed for function, a small positive effect size was observed for strength and a negligible positive mean effect size was observed for biomechanical outcomes. Four studies investigated exercise interventions including neuromuscular training exercises. Neuromuscular control training exercises were inferior glide, scapular clock, D1 and D2 patterns, rhythmic stabilization. Large positive mean effect sizes were observed for pain and function, and a negligible positive mean effect size was observed for biomechanical outcomes.

Table 2. Mean effect size and percent change (%) between baseline and follow-up measures for exercise intention groups for primary outcomes in all studies, divided by exercise type

Outcome / **Exercise Type**	**Number of studies**	**Number of participants**	**Pain**	**Function**	**Strength**	**Biomechanical**
Stretching	38	1062	1.48	1.41	0.44	0.48
			42.84%	30.13%	18.84%	42.10%
ROM	36	1168	1.77	0.98	0.57	0.55
			44.31%	37.63%	20.30%	18.09%
Rotator cuff	66	2088	1.32	1.11	0.51	0.41
			35.21%	41.80%	24.89%	27.96%
Scapular	55	1847	1.41	1.29	0.56	0.51
			34.17%	33.22%	27.17%	35.91%
Neuromuscular	19	416	1.91	1.55	0.87	0.43
			56.93%	35.88%	15.21%	14.43%
Postural	6	228	1.55	1.35	0.42	0.75
			49.92%	55.64%	19.68%	21.74%
Other humeral depressors/stabilizers	8	201	1.96	1.78	0.93	0.81
			54.47%	57.10%	48.30%	19.61%

Table 3. Mean effect size and range of effect sizes between exercise intervention group measures and control or placebo group measures in randomized controlled trials for primary outcomes of interest for all exercise interventions and subdivided by exercise type compared to no treatment or placebo treatment

Outcome **Exercise type**	**Number of studies**	**Number of participants**	**Pain**	**Function**	**Strength**	**Biomechanical**
All	9	253	0.96	0.64	0.27	0.07
			0.42 – 1.75	0.00 – 1.40	0.15 – 0.36	-2.60 – 1.50
ROM	3	91	N/A	N/A	N/A	N/A
			N/A	N/A	N/A	N/A
Stretching	3	96	1.28	1.10	N/A	-0.02
			0.91 – 1.75	0.88 – 1.22	N/A	-2.60 – 1.50
Rotator cuff	7	234	0.96	0.64	0.27	0.07
			0.42 – 1.75	0.00 – 1.40	0.15 – 0.36	-2.60 – 1.50
Scapular	7	179	0.83	0.60	0.27	0.03
			0.42 – 1.20	0.00 – 1.40	0.15 – 0.36	-0.86 – 0.77
Neuromuscular	4	70	1.09	1.30	N/A	0.14
			0.43 – 1.75	1.20 – 1.40	N/A	-2.60 – 1.50

6.2.2.2 Therapeutic modalities and injections/medication

Forty-one studies investigated the effects of an exercise intervention alone in comparison to a variety of modalities or injections/medication. Therapeutic modalities were defined as the administration of thermal, mechanical, electromagnetic, and light energies for a therapeutic effect. Modalities included acupuncture (n=3), thermotherapy (n=1), electrotherapy (n=1), LASER (n=3), manual therapy (n=17), physiotherapy/occupational therapy (n=4), shockwave (n=2), ultrasound therapy (n=3), taping/bracing (n=4). Eight studies investigated injections (n=7) and medication (n=1). Study, exercise intervention details and comparator intervention details are outlined in Appendix C. Modalities were investigated alone (n=12) and in combination with an exercise program (n=31). Mean effect sizes and ranges of effect size per outcome are detailed in Table 4. Small negative mean effect sizes were observed for pain, function, and biomechanical outcomes, and a negligible positive mean effect size for strength.

Table 4. Mean effect sizes and range of effect sizes between exercise intervention groups and modality comparator intervention groups in randomized controlled trials for primary outcomes

Outcome	**Pain**	**Function**	**Strength**	**Biomechanical**
Mean effect size	-0.38	-0.39	0.16	-0.25
Range	-2.34 – 1.94	-6.68 – 10.91	-1.00 – 1.73	-5.89 – 1.06

6.2.2.3 Surgery

Eleven studies investigated the effect of an exercise intervention alone to surgical interventions. Surgical interventions included arthroscopic surgery (bursectomy, acromioplasty, resection of coracoid ligament) (n=8), open acromioplasty (n=8), rotator cuff repair (n=2) and subacromial decompression (n=2). Surgical interventions were all followed by post-operative rehabilitation. Study, exercise intervention and comparator intervention details are outlined in Appendix D**.** Mean effect sizes and range of effect size are detailed in Table 5. A large negative mean effect size was observed for pain, a medium mean effect size was observed for strength, and small mean effect sizes were observed for function and biomechanical outcomes (Table 5).

Table 5. Mean effect size and range of effect sizes between exercise intervention groups and surgical intervention groups in randomized controlled trials for primary outcomes

Outcome	**Pain**	**Function**	**Strength**	**Biomechanical**
Mean effect size	-0.99	-0.44	-0.63	-0.47
Range	-3.79 – 0.06	-4.26 – 0.46	-0.87 – 0.38	-0.71 – 0.20

6.2.3 List of recommended exercises

Forty-one different exercises were identified (Table 2) to increase pain, function, strength, promote advantageous biomechanical changes and decrease injury promoting biomechanical changes. Specific exercises were included if they demonstrated improvements (positive effect sizes or percent change) in outcomes of interest in at least two studies, to reflect commonly implemented exercises in the literature. Identified exercises were grouped into seven categories based on treatment goals: Stretching exercises, ROM exercises, rotator cuff strengthening exercises, scapular stabilizer strengthening exercises, scapular neuromuscular control training exercises, postural exercises, and other upper limb muscle strengthening exercises.

Table 6. Exercises demonstrated to promote improvements of primary outcome measures identified from all investigated studies

Exercise type	Number of studies	Exercise	Description	Biomechanical rationale	Secondary consequences to surrounding musculature
Stretching exercises	36	Anterior shoulder stretch	Palmar surface of hand of affected shoulder placed behind head such that shoulder is externally rotated and abducted, and elbow is flexed[56]	Increase flexibility of anterior shoulder and chest musculature	N/A
		Posterior shoulder stretch (Cross-body stretch)	Elbow of affected arm held in extension with opposite hand in front of body and slowing pulling elbow across the body until a stretch is achieved, humeral elevation below 90°[57]	Decrease posterior glenohumeral capsule tightness, and enhance flexibility[58] Posterior shoulder tightness associated with abnormal scapular kinematics [57] Posterior capsule tightness observed to cause anterior-superior translation of the humerus over the glenoid fossa[59]	N/A
		Sleeper stretch	Side-lying with shoulder 70°-90° abducted and the elbow flexed 90°. The shoulder is then internally rotated passively and held in this position[60]	Increase flexibility of posterior capsule[60] Posterior shoulder tightness associated with abnormal scapular kinematics[57]	N/A

				Posterior capsule tightness observed to cause anterior-superior translation of the humerus over the glenoid fossa[59]	
		Towel internal rotation stretch	Hold a towel with affected arm behind the back and use the other arm to pull the affected arm up the back[61]	Increase flexibility of external rotators Increase internal rotation range of motion	N/A
		Upper Trapezius stretch	Neck is laterally flexed and rotated toward the unaffected shoulder, such that the chin could touch the clavicle proximally. Arm of side being stretched is forced down [62]	Decrease hypertonicity and increase resting of the upper trapezius muscle Excess activation of the upper trapezius muscle associated with abnormal scapular kinematics[62] Increasing upward rotation of scapula by decreasing imbalances between upper trapezius and lower portions of trapezius observed to contribute to decreased upward rotation[32]	N/A
		Levator scapula stretch	Neck is laterally flexed towards the unaffected shoulder, with the hand of the affected arm touching the back of the neck such that the	Decrease hypertonicity of the levator scapula muscle Increased levator scapula muscle stiffness and shortness may lead to	N/A

			shoulder is abducted, and the elbow is flexed[63]	abnormal scapula movement[64]	
		Bilateral Corner stretch	Both hands placed at head height on adjacent walls of a corner, patient instructed to lean into corner[62]	Increase flexibility and length of pectoralis minor Fiber orientation of pectoralis minor favors scapular internal rotation, downward rotation and anterior tilt[65] Pectoralis minor shortness associated with abnormal scapular kinematics[62]	N/A
		Unilateral corner stretch	Palmar surface of hand of affected arm placed on wall such that shoulder is abducted approximately 90° and elbow is flexed. Contralateral leg to shoulder being stretched positioner forward, and weight shifted forward and rotated opposite to side being stretched[66]		N/A
ROM exercises	38	PROM/Cane (abduction, external rotation, flexion)	Holding a stick/cane with affected hand, strength of unaffected hand used to push affected shoulder through range of motion[67]	Increase passive shoulder range of motion	N/A
		AAROM (abduction, external rotation, flexion)	Holding a stick/cane with affected hand, unaffected hand used to assist affected shoulder through range of motion	Increase passive range of motion in direction of movement Initiate strengthening of shoulder musculature	N/A
		AROM (abduction, external rotation, flexion)	Without assistance, shoulder is moved	Increase active range of motion	N/A

			through range of motion against gravity	Strengthening of shoulder musculature	
		Codman/Pendulum	With the unaffected arm resting on a table/bed, arm of affected shoulder hanging down the side, moving slightly in circular motions, forward backwards and side to side[68]	Increase acromiohumeral distance, promote perfusion of nutritional substances [68] Passive mobilization of glenohumeral joint [69] Distraction and oscillation of humeral head in glenoid cavity[68]	N/A
Rotator cuff strengthening exercises	66	Resisted Forward flexion	Sagittal plane humeral elevation, elbow fully extended and humerus externally rotated such that radial aspect of wrist is pointing superiorly[70]	Strengthening of supraspinatus muscle Compressive action of rotator cuff muscles counters upward pull and shearing action of deltoid muscle during elevation, centering humeral head in glenoid fossa[71,72]	N/A
		Scaption/Full can	Scapular plane humeral elevation 30° anterior to the frontal plane with humerus externally rotated such that the radial aspect of the wrist is pointing superiorly[73]	Strengthening supraspinatus rotator cuff muscle Compressive action of rotator cuff muscles counters upward pull and shearing action of deltoid muscle during elevation, centering humeral head in glenoid fossa[71,72]	Very high (>60% MVIC) muscle activity of UT observed above 120 degrees and below 80 degrees [75], promoting relative hyperactivity of UT

				Provides a safer alternative to “empty can” as external rotation clears the greater tuberosity from under the acromion [74]	
		Resisted Shoulder abduction	Coronal plane humeral elevation	Strengthen supraspinatus rotator cuff muscle Compressive action of rotator cuff muscles counters upward pull and shearing action of deltoid muscle during elevation[71,76]	Very high (>60% MVIC) muscle activity of upper trapezius observed [75], promoting relative hyperactivity of UT
		Scaption/Empty can	Scapular plane elevation of humerus, 90° anterior to the frontal plane with internal rotation such that the radial aspect of the wrist is facing inferiorly [77]	Strengthening of the supraspinatus and subscapularis rotator cuff muscles [78] Compressive action of rotator cuff muscles counters upward pull and shearing action of deltoid muscle during elevation, centering humeral head in glenoid fossa[23,72,76]	Internal rotation of the humerus increases risk of impingement of subacromial tissues as this movement brings the greater tuberosity closer to the acromion [74]
		External rotation	Glenohumeral external rotation with towel between arm and trunk, elbow flexed 90° [73]	Strengthening of the infraspinatus and teres minor muscle: Infraspinatus muscle act as humeral depressors by transmitting an inferior translatory force [79]	N/A
		Internal rotation	Glenohumeral internal rotation with towel	Strengthening of the subscapularis rotator cuff	

			between arm and trunk, elbow flexed 90°[73]	muscle: Subscapularis muscle act as humeral depressors by transmitting an inferior translatory force[79]	
Scapular stabilizer strengthening exercises	55	Rows/Scapular retraction	Elbows flexed 90°, shoulder in neutral position and arms by the side, pinching the scapulae together[61]	Strengthening of middle trapezius, lower trapezius, rhomboids[80] Middle trapezius contributes to scapular retraction, lower trapezius contributes to upward rotation, depression, and possibly posterior tilt and external rotation of the scapula, decreasing risk of impingement during elevation[81]	Very high (>60% MVIC) muscle activity in upper trapezius observed[75], promoting relative hyperactivity of UT
		Low rows	Back to a wall, with elbows extended. Hands are folded into fists and ulnar sides of fists are pushed against the wall and scapulae are retracted[60]	Strengthening of the lower trapezius muscle: Lower trapezius contributes to upward rotation, depression, and possibly posterior tilt and external rotation of the scapula[81]	
		Prone Shoulder extension	Prone, with shoulders resting in 90° of forward flexion. From this position, participant performs extension of shoulder to a neutral position with shoulder in neutral rotation[82]	Strengthening of middle trapezius, triceps brachii Middle trapezius contributes to scapular retraction, decreasing risk of impingement[81] The long head of the triceps acts to stabilize the humeral head in the glenoid cavity,	

				helping to prevent displacement of the humerus[83]	
		Horizontal abduction	Prone horizontal abduction of the glenohumeral joint with external rotation of the humerus such that the radial aspect of the wrist is facing upwards[84]	Strengthening of middle and lower trapezius[82] Promotes early activation of the middle trapezius and lower trapezius muscle relative to the upper trapezius[85]	Very high (>60% MVIC) muscle activity in upper trapezius observed[75], promoting relative hyperactivity of UT
		Prone lower/middle trapezius lifts (T's and Y's)	In prone, arms abducted to 90°, then flexed elbows to 90°, scapulae are retracted and arms externally rotated. While maintaining retraction of scapula, arms are lifted above head to form letter Y[86]	Strengthening of the lower and middle trapezius muscle: Middle trapezius contributes to scapular retraction, lower trapezius contributes to upward rotation, depression, and possibly posterior tilt and external rotation of the scapula, decreasing risk of impingement during elevation[81]	
		Scapular protraction/Dynamic hug	Starting with shoulders in neutral position, elbows flexed, patient protracts scapulae, extending elbows[62]	Strengthening of serratus anterior muscle[62] : Serratus anterior has been shown to play a large role in scapular upward rotation and posterior tipping, therefore increasing subacromial space width[38]	
		Push-up plus	In prone, supported at forearm level, trunk is		

			lifted upwards such that scapulae are protracted[56]		
		Serratus anterior strengthening in quadruped	In quadruped position, with the back flat, hips aligned vertically over knees, and hips flexed 90°, patient instructed to push into floor[87]	Strengthening of serratus anterior: Serratus anterior has been shown to play a large role in scapular upward rotation and posterior tipping, therefore increasing subacromial space width[38]	
		Supine press	In supine, arms lifted superiorly such that shoulders are lifted and scapulae are protracted[88]		
		Wall push up	In standing, facing a wall, with palmar aspect of hands on wall, elbows are extended and flexed while keeping body in a straight line[89,90]		N/A
Neuromuscular control training exercises	19	Wall slides/Wall angels	Back to a wall, gliding arms up and down while rotating scapula upward and downward	Strengthening of scapular stabilizer muscles [91] Increase neuromuscular control of scapulothoracic musculature[92:] Improving dynamic scapular kinematics[92]	
		Rhythmic stabilization	Both arms by the side, elbows 90° flexed, scapulae retracted, and chin tucked. With resistance band stretched between hands, both arms are repeatedly abducted to 20°[60]	Increase neuromuscular control of scapulothoracic musculature, improving dynamic scapular kinematics[92]	N/A

		Scapular clock exercise	The hand of the affected arm resting on a ball, patient instructed to draw a clock on a table[55]		
		Inferior glide	Upright sitting position with arm abducted 45° in scapular plane, pressure applied to firm supportive surface with fist clenched[73]	Increase neuromuscular control of scapulothoracic musculature[92] Improving dynamic scapular kinematics[92]	
		PNF D1 Pattern	Affected shoulder begins extended, abducted, and internally rotated. Then, the shoulder is flexed, adducted, and externally rotated. Instructions to "pull wrist up and reach". Arm returns to original position by extending, abducting, and internally rotating the shoulder[56]	Strengthening of the serratus anterior muscle[75] Enhance intermuscular coordination of scapular stabilizers in dynamic movement[93] Serratus anterior has been shown to play a large role in scapular upward rotation and posterior tipping, therefore increasing subacromial space width[38] Improving dynamic scapular kinematics [92]	Very high (>60% MVIC) muscle activity in upper trapezius observed [75], promoting relative hyperactivity of UT
		PNF D2 Pattern	Affected shoulder begins extended, adducted, and internally rotated. Then, the shoulder is flexed, abducted, and externally rotated. Instructions to "pull wrist up and reach". Arm returns to original position by extending,	Strengthening of the subscapularis and teres minor muscle Enhance intermuscular coordination of scapular stabilizers in dynamic movement[93] Subscapularis muscle acts as humeral depressors by	

			adducting, and internally rotating the shoulder[60]	transmitting an inferior translatory force[79] Improving dynamic scapular kinematics[92]	
		Towel slide	Standing next to a firm, flat table, an anterior slide of a towel against the table is performed[55]	Increase neuromuscular control of scapulothoracic musculature Improving dynamic scapular kinematics[92]	
Postural exercises	6	Chin tucks	Apply pressure to the chin with the fingers as the head is pulled back[58]	Strengthening of postural muscles: Forward head posture increases risk of impingement by altering scapular kinematics and promoting scapulothoracic muscle imbalance[94]	N/A
		Thoracic extensions	Arms behind back, retracting shoulder blades, upper trunk lifted relative to flat surface	Strengthening of thoracic extensors, postural correction[95] Thoracic extension posture shown to increase shoulder range of motion[96] "Slouched" posture observed were increased superior translation of the scapula, decreased upward rotation, posterior tilt, and slightly increased internal rotation during arm abduction[97]	N/A

Other upper limb muscle strengthening	8	Seated press-up	In seated position, patient instructed to lift their lower trunk with both hands by pressing against chair[56]	Strengthen latissimus dorsi muscle Latissimus dorsi acts as a humeral depressor by applying an inferior translatory force[79]	N/A
		Lat pull down	Adduction of the shoulder and flexion at the elbow[98]		N/A
		Triceps push down/overhead triceps extension	Holding a straight bar with forearms pronated, full elbow extension[98]	Strengthening of triceps brachii muscle: The long head of the triceps acts to stabilize the humeral head in the glenoid cavity, helping to prevent displacement of the humerus[83]	N/A
		Biceps curl	Standing with arms hanging down, holding weights with palms forward, elbows are bent in an alternating manner[89,90]	Strengthening of biceps brachii muscle: Biceps brachii observed to be an active depressor of the humerus in shoulders with lesions of the rotator cuff[99]	N/A

6.3 Risk of bias assessment

Of the 76 randomized controlled trials assessed for risk of bias, 12 were judged as *low risk of bias*, 11 as raising *some concerns*, and 53 as *high risk of bias* (Figure 2). Studies were categorized based on risk of bias judgement and a sub-analysis of effect sizes was conducted on studies judged to be as *low risk of bias.* Risk of bias judgement was used to inform reviewers on the internal and external validity of a study, and therefore studies judged to be at *a low risk of bias* were interpreted to be of higher scientific rigor and assessed separately to emphasize the results from these studies. The results from this sub-analysis were used to reinforce or draw attention to variability between the results from all included randomized controlled trials and the studies determined to be of higher scientific quality.

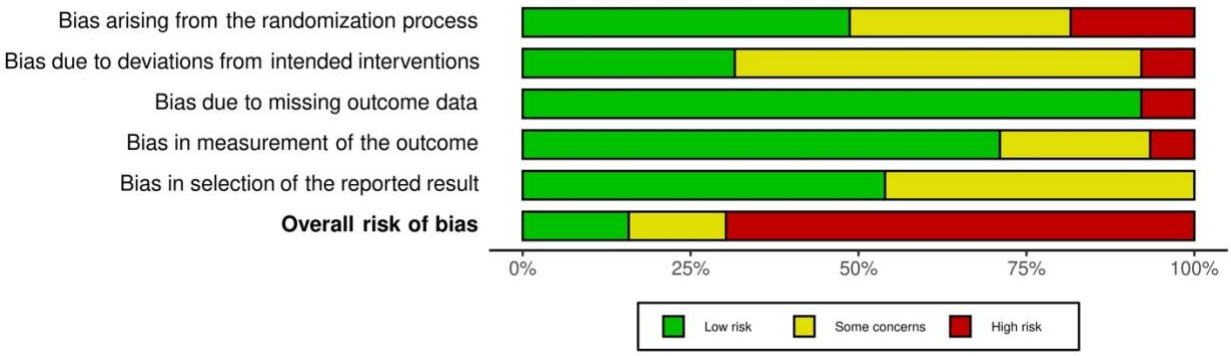

Figure 4. Proportion of included randomized controlled trials in each risk of bias category

6.3.1 Low risk of bias studies

6.3.1.1 Effect of exercise interventions

Twelve randomized controlled trials were judged to be at low risk of bias. Mean effect sizes and percent change between baseline and follow-up measures for primary outcomes for *low risk of bias* randomized controlled trials are outlined in Table 7. Large positive mean effect sizes

were observed for pain and function, a small positive mean effect size was observed for strength, and a negligible mean positive effect size was observed for biomechanical outcomes.

Table 7. Mean effect size, range of effect sizes, mean percent change (%) and range of percent change (%) between baseline and follow-up measures for exercise intervention groups for primary outcomes in *low risk of bias* randomized controlled trials

Outcomes	**Pain**	**Function**	**Strength**	**Biomechanical**
Mean effect size	1.06	1.26	0.43	0.10
Range	-0.41 – 2.17	0.11 – 3.27	0.43 - 0.43	-1.33 – 1.50
Mean % change	40.35%	43.16	34.48 %	8.33
Range	-64.71 - 87.29 %	5.97 – 126.70 %	34.48 – 34.48 %	-79.88 – 50 %

6.3.1.2 Effect of exercise by type

Mean effect sizes and percent change between baseline and follow-up measures for exercise intervention groups for all outcomes in *low risk of bias* randomized controlled trials were divided intro subgroupings based on exercise type. Mean effect sizes and percent change are outlined by exercise type in Table 8. Study and exercise intervention details are described in Appendix E. Four *low risk of bias* studies investigated an exercise intervention including stretching exercises. Large positive effect sizes were observed for pain, function, and biomechanical outcomes. Three low *risk of bias* studies investigated ROM exercises. Large positive mean effect sizes were observed for pain and function, and a negligible positive mean effect size was observed for biomechanical outcomes. Nine studies investigated rotator cuff strengthening exercises. Large positive mean effect sizes were observed for pain and function, and a small positive mean effect size was observed for biomechanical outcomes. Eight studies

investigated scapular stabilizing exercises. Large positive mean effect sizes were observed for pain and function, and a small positive mean effect size was observed for biomechanical outcomes. Five studies investigated neuromuscular control training exercises. A large mean effect size was observed for function, a medium positive mean effect size for pain, a small positive mean effect size for strength and a negligible negative mean effect size for biomechanical outcomes. Three investigated postural exercises. Large positive mean effect sizes were observed for pain and function. One study investigated a program that included strengthening exercises for other upper limb muscles. Large positive mean effect sizes were observed for pain and function.

Table 8. Mean effect size and mean percent change (%) between baseline and follow-up for exercise intervention groups for primary outcomes in *low risk of bias* randomized controlled trials, divided by exercise type

Outcome **Exercise Type**	**Number of studies**	**Pain**	**Function**	**Strength**	**Biomechanical**
Stretching	4	1.68	1.91	N/A	1.45
		68.63%	59.67%	N/A	N/A
ROM	3	1.57	0.94	N/A	0.13
		56.69%	39.85%	N/A	4.37%
Rotator cuff	9	1.17	1.26	N/A	0.30
		39.14%	43.09%	N/A	2.56%
Scapular	8	1.13	1.28	N/A	0.30
		35.10%	45.37%	N/A	2.56%
Neuromuscular	5	0.72	1.12	0.43	-0.14
		47.01%	51.05%	34.38%	-4.76%
Postural	3	1.62	1.39	N/A	N/A
		59.34%	65.83%	65.83%	N/A
Other muscles	1	2.17	2.01	N/A	N/A
		75%	88.97%	N/A	N/A

6.3.1.3 Comparators

Of the 12 studies judged as low risk of bias, five studies investigated the effect of exercises compared to an alternative exercise program[66,100–103], two to manual therapy alone[104,105], two to manual therapy in combination with an exercise program[106,107], three to a

surgical intervention followed by post-operative rehabilitation.[108–110] Study and intervention details are outlined in Appendix F.

Effect sizes between exercise intervention group measures and comparator intervention group measures for primary outcomes for *low risk of bias* randomized controlled trials were subdivided into two categories based on the non-exercise comparators: Manual therapy and surgery. Compared to manual therapy, negligible positive effect sizes were observed for function and strength, a small negative mean effect size was observed for biomechanical outcomes and a negligible negative effect size was observed for pain (Table 9). Compared to surgery, a small negative effect size was observed for biomechanical outcomes, and a negligible negative effect size was observed for pain and function (Table 9).

Table 9. Mean effect size and range of effect size between exercise intervention group measures and comparator intervention groups measures of primary outcomes for *low risk of bias* randomized controlled trials

	Outcome	**Pain**	**Function**	**Strength**	**Biomechanical**
Manual therapy	Mean effect size	-0.09	0.11	0.14	-0.24
	Range	-0.36 – 0.38	-0.37 – 0.40	0.14 – 0.14	-0.98 – 0.21
Surgery	Mean effect size	-0.04	0.00	N/A	-0.21
	Range	-0.14 – 0.06	-0.38 – 0.39	N/A	-0.62 – 0.20

6.3.1.4 List of exercises

Twenty-three exercises were identified to produce positive changes in primary outcomes of interest in studies assessed to be at a low risk of bias. These exercises include two ROM

exercises, three stretching exercises, four rotator cuff strengthening exercises, nine scapular stabilizer strengthening exercises, three neuromuscular control training exercises, one postural exercise, and one exercise focused at strengthening other upper limb muscles.

Table 10. List of exercise identified from studies judged to be at a low risk of bias

Exercise type	Exercise name	Studies	Number of studies
ROM	AAROM	[89]	1
	Pendulum	[89]	1
Stretching	Cross-body stretch	[101,103]	2
	Unilateral corner stretch	[66,101,103]	3
	UT stretch	[106]	1
Rotator cuff strengthening	External rotation	[66,89,100,101,103,107]	6
	Internal rotation	[100,101,107]	3
	Scaption (full-can)	[101,103]	2
	Resisted flexion	[66,89,103]	3
Scapular strengthening	Push up plus	[100,103]	2
	Rows/Scapular retraction	[90,100,103]	3
	Low rows	[103,106,107]	3
	Supine press up	[66]	1
	Dynamic hug	[103]	1
	Scapular protraction	[106,107]	2
	Quadruped serratus anterior strengthening	[106,107]	2
	Wall push ups	[89]	1
	Horizontal abduction	[89]	1
Neuromuscular training	Wall slides	[103]	1
	Scapular clock	[89]	1
	D1 pattern	[89]	1
Postural exercises	Thoracic extensions	[89,106,107]	3
Other upper limb strengthening	Biceps curl	[106]	1

6.4 Secondary Research Objectives

6.4.1 Medication use and surgical intervention

Six studies [23,105,111–114] reported secondary outcome measures. Of these studies, five [23,105,111,113,114] reported changes in use of medication following an exercise intervention, and one [112] reported delays of or withdrawals from surgical intervention. All studies reported a decrease in use of medication or surgical intervention with details outlined in Table 11. Of the studies reporting decreases in use of medication or surgical intervention, three investigated ROM exercises, one investigated stretching exercises, four investigated rotator cuff strengthening exercises, one investigated scapular stabilizer strengthening exercises and one investigated neuromuscular training exercises. Specific exercises are outlined in Table 12.

6.4.2 Disadvantageous consequences of exercises

No studies explicitly stated any disadvantageous consequences due to exercise intervention, however potential consequences of the identified exercises were deduced based on previous literature and EMG data of selected exercises, where available. Deduced secondary complications of the identified exercises were: Eliciting high to very high upper trapezius muscle activity, promoting hyperactivity of upper trapezius muscles, associated with abnormal scapular mechanics, and positioning the humerus in an orientation that increases risk of impingement of subacromial tissues. Deduced disadvantageous consequences for specific exercises are detailed, where applicable, in Table 6.

Table 11. Summary of results of secondary outcomes measures and key findings

First Author, year	Exercise Intervention	Exercise Type	Sample size	Outcome measure	Baseline	Follow-up	Key findings
Beaudreuil, 2011	Dynamic humeral centering exercises	Neuromuscular training	34, follow up 30	Medication use, n participants (% of responses)	8 (23.5%)	1 (3.3%) (3 months)	Decrease in medication use following exercise intervention. Significantly larger decrease compared to control (non-specific mobilizations) group
Engebretsen, 2011	AAROM, resisted external rotation	ROM, rotator cuff strengthening	52, follow up 49	Medication use (daily or weekly), n participants (% of responses)	26 (50%)	13 (27%) (1 year)	Decrease in medication use following exercise intervention. No significant difference in decrease compared to comparator (radial extracorporeal shockwave therapy)
Ketola, 2017	Supervised exercise program (exercises not reported/specified)	Not specified	70, follow up 46	Total days on which NSAIDs (Non-steroidal anti-inflammatory drugs) were consumed per previous 3 months due to shoulder pain, mean	37	7 (12.3 years)	Decrease in use of NSAIDs following exercise intervention. No significant difference in NSAIDs use between exercise intervention and comparator (arthroscopic acromioplasty + post-operative exercise)

Lewis, 2017	Exercises not reported/specified	ROM, Rotator cuff strengthening, scapular stabilizer strengthening	73, follow up 54	Analgesics use, n participants (% of responses)	29 (40%)	14 (25%) (6 weeks)	Decrease in analgesics use following exercise intervention. No significant difference between exercise intervention and comparators (exercise + acupuncture), (exercise + electroacupuncture)
Roe, 2000	PROM, Anterior shoulder stretch, posterior shoulder stretch, unilateral corner (pectoralis) stretch, levator scapula stretch, abduction, external rotation, internal rotation	ROM, stretching, rotator cuff strengthening	10	Participants using pain medication (n)	4	1 (3-6 months)	Decrease in participants using pain medication
Jonsson, 2006	Scaption (empty can) (eccentric)	Rotator cuff strengthening	9	Satisfaction of treatment outcomes (withdrawal from surgery waitlist) (n)	N/A	5 (12 weeks)	Majority of participants sustained (satisfactory) improvement of treatment outcomes and withdrew from surgery waitlist

Table 12. List of exercises identified to decrease use of medication or delay surgical intervention

Exercise type	Exercise name	Number of studies
ROM	PROM	1
	AAROM	1
Stretching	Anterior shoulder stretch	1
	Posterior shoulder (cross-body) stretch	1
	Unilateral corner (pectoralis) stretch	1
	UT stretch	1
	Levator scapula stretch	1
Rotator cuff strengthening	External rotation	2
	Internal rotation	1
	Abduction	1
	Scaption (empty-can)	1
Neuromuscular training	Dynamic humeral centering	1

7.0 DISCUSSION

As a primary objective, this systematic review investigated recommended exercises for the conservative management of SAIS and/or RC tears and identified a comprehensive list of exercises with biomechanical rationale identified to improve pain, function, strength, and biomechanical outcomes in symptomatic adults with a clinical diagnosis of subacromial impingement syndrome and/or rotator cuff tears. The results of this review indicate that exercise is an effective intervention at decreasing pain and increasing function, strength, and positive biomechanical outcomes in individuals with SAIS and/or RC tears, however specific exercises vary broadly in the literature. These findings are consistent with previous systematic reviews on exercise for the conservative management of SAIS and/or RC tears.[4,115] Despite the heterogeneity of specific exercises, exercise interventions in the literature could be generally grouped into seven groups based on treatment goal and associated biomechanical rationale. All exercise type subgroupings were demonstrated to be highly effective at decreasing pain and increasing function, however strength and biomechanical outcomes demonstrated more variability based on exercise type. Additionally, the results of this study indicate that modalities and surgery may be slightly more effective at improving pain, function, strength and biomechanical outcomes than exercise alone, however many of these comparators were combined with an exercise intervention and may provide an additive benefit to an exercise intervention as opposed to being a more effective alternative. As a secondary research objective, this systematic review investigated the effect of exercise in medication use and delay of surgical intervention. Decreases in medication use (analgesics and NSAIDs) and avoidance of surgery following an exercise intervention were observed, indicating that exercise interventions included in this systematic review were effective at decreasing the need for medication or surgical intervention.

7.1 Stretching exercises

Stretching was demonstrated to be highly effective at decreasing pain and improving function in participants with SAIS and/or RC tears. Compared to a control group that received no treatment or placebo treatment, stretching was highly effective at decreasing pain and improving function. In studies conducted with high scientific rigor, stretching was observed to be highly effective at decreasing pain, and improving function and biomechanical outcomes. Stretching exercises were also observed to decrease the use of pain medication. Biomechanical rationale for investigated stretching exercises stated by authors and supported by literature, was to increase muscle length and flexibility of muscles that have been associated with impingement promoting mechanics when shortened or tight.

The most common stretching exercises investigated were the bilateral corner and unilateral corner stretch, both aimed at stretching the pectoralis minor muscle. The pectoralis minor muscle was targeted in exercise programs for the conservative management of subacromial impingement syndrome due to its relationship to scapular kinematics. Short pectoralis minor muscle lengths have been associated to promoting pathological scapular kinematics, as the orientation its fibres favor scapular internal rotation, downward rotation and anterior tilt,[116] scapular orientations that have been observed in individuals with SAIS and promote narrowing of the subacromial space and subsequent impingement of subacromial tissues.[15,32] Rosa et al investigated[65] the effects of the unilateral corner stretch on scapular kinematics in 25 participants with symptoms consistent with shoulder impingement syndrome and pectoralis minor tightness. The investigated intervention consisted of a 6-week stretch protocol of four repetitions of the unilateral corner stretch held for 1 minute, with a 30 second rest interval between repetitions performed daily at home. Rosa et al found significant improvements in pain and function outcomes, but did not observe any changes in scapular

kinematics, or muscle resting length. Another frequently included stretching exercise was the posterior capsule/cross-body stretch. Stretching the posterior shoulder has been proposed to decrease posterior capsule tightness, which has been associated with decreased range of motion in individuals with shoulder impingement.[117] Posterior capsule tightness has also been observed to cause anterior-superior translation of the humerus over the glenoid fossa.[59] The sleeper stretch has also been proposed as a stretch aimed at the posterior shoulder. Tahran et al investigated[118] both the cross-body and sleeper posterior shoulder stretches in addition to a training program, compared to a training program alone. Improvements were observed in pain, posterior shoulder tightness, internal rotation range of motion, function and disability for both stretches. Significantly greater improvements in internal rotation range of motion were observed in the sleeper stretch intervention group compared to the cross-body stretch, but there was no significant observed difference in the improvement of posterior shoulder tightness between the two stretches. The findings of the Tahran et al. study indicate that the sleeper stretch may be more effective at increasing internal rotation range of motion, in addition to effectively decreasing posterior shoulder tightness, while both the cross-body and sleeper stretch are effective at decreasing posterior capsule tightness.

Stretching of the UT was another frequently included stretch on the basis that hyperactivity of the UT has been observed in individuals with SAIS. Increases in upper trapezius activity relative to other portions of the trapezius could lead to an unbalance between upper portions and lower of the trapezius muscle, resulting in the decreased upward rotation of the scapula.[32] It has been suggested that greater trapezius activation also contributes to increased anterior tilt of the scapula through greater clavicular elevation.[119] Increased upper trapezius muscle stiffness has also been observed in individuals with rotator cuff tendinopathy.[120] Taken

together, this literature suggests that decreasing upper fibres trapezius activity and tightness/hypertonicity may be an effective treatment goal for exercise interventions implemented to decrease pathological scapular kinematics, however, there are currently no studies that investigate the effect of upper trapezius stretching alone on scapular kinematics. The findings of the present systematic review indicate that stretching exercises may produce positive biomechanical changes, however further investigation of specific stretches is required.

7.2 Range of motion exercises

Range of motion exercises were demonstrated to be highly effective at decreasing pain and improving function and moderately effective at improving strength and biomechanical outcomes. In studies conducted with high scientific rigor, stretching was observed to be highly effective at improving pain and function. Range of motion exercises were also demonstrated to decrease pain medication use in participants with SAIS and/or RC tears. The biomechanical rationale stated by authors for range of motion exercises was to increase range of motion in a variety of shoulder movements including flexion, abduction, external rotation and internal rotation, a common deficit in participants with SAIS and/or RC tears. All three types of range of motion exercises were identified as commonly implemented exercises in the conservative treatment of subacromial impingement syndrome and rotator cuff tears: Passive range of motion (PROM) where an external force in applied such as another person, or a stick controlled by the contralateral side results in joint movement, active assisted range of motion (AAROM) where an external force is applied to partially assist the individual's muscle force, and active range of motion (AROM) where the force acting to produce joint movement is solely the individual's muscle force and no external force is applied. Typically, range of motion exercises were progressed starting initially with PROM, progressing to AAROM, followed by AROM without

the resistance of gravity, and finally against the resistance of gravity. [121] There is evidence to suggest that range of motion exercises alone can provide improvements in symptoms of pain and disability. Heron et al compared[121] a program consisting of range of motion exercises alone to an open chain resisted band exercise program and closed chain exercises program. A significant improvement in pain and disability (SPADI) scores ($p<0.0002$) with 43% of participants having a minimally clinically important change in SPADI score. Results from this study by Heron et al indicate that range of motion exercises alone have the potential to make clinically significant changes in pain and function.

Another commonly prescribed exercise aimed at improving range of motion is the pendulum exercise, also known as Codman exercise. Pendulum exercises have been widely used with the intention of passively mobilizing the glenohumeral joint without compromising injured tissues. A kinematic analysis of this exercise by Cunningham et al. found [69] minimal glenohumeral and scapulothoracic involvement and suggested that although this exercise may be a safe way of promoting general stretching of the upper limb, it may have minimal use in increasing range of motion. However, in a randomized controlled trial by Akkaya et al,[68] the effect of weighted versus un-weighted pendulum exercises alone on night, activity, and resting pain Visual Analog Scale (VAS), function (SPADI) and ultrasound measured subacromial space width was investigated in individuals with subacromial impingement syndrome. Akkaya et al.found a significant improvement in night, activity, and resting pain VAS scores, as well as SPADI scores ($p<0.05$), with no significant difference between the un-weighted and weighted groups. There was no significant change ($p>0.05$) in ultrasound-measured acromiohumeral distance during abduction in either group, as well as no significant difference between groups. Considering the results of the Cunningham et al and Akkaya et al studies, there is evidence to

suggest that although pendulum exercises may not result in significant biomechanical changes, they may have some benefit in decreasing pain symptoms and disability.

7.3 Strengthening of the rotator cuff muscles

Rotator cuff strengthening exercises were demonstrated to be highly effective at decreasing pain and increasing function, and moderately effective at improving strength. Compared to a control group that received no treatment or placebo treatment, rotator cuff strengthening exercises were highly effective at decreasing pain and moderately effective at improving function. In studies with conducted with high scientific rigor, rotator cuff strengthening exercises were highly effective at reducing pain and increasing function. Rotator cuff strengthening exercises were observed to decrease pain medication use and delay or prevent surgical intervention in participants with SAIS and/or RC tears. Biomechanical rationale stated by authors and supported by previous literature was to strengthen rotator cuff muscles in an effort to promote stability of the glenohumeral joint during dynamic movements, as well as stabilizing the humeral head to counter the upward pull of the deltoid muscle during humeral elevation.[22,23] It has also been proposed that glenohumeral rotators have a depressor function that maintains the humeral head centered on the glenoid fossa during elevation.[26] However, in the present review, only small or negligible effects at improving biomechanical outcomes were observed for rotator cuff strengthening exercises.

The most commonly implemented rotator cuff strengthening exercises included in this review were resisted external and internal rotation. Variations of the external and internal rotation exercises included being side-lying with a free weight or standing with the use of a resistance band. Additionally, the implementation of a starting abduction angle varied study to study. External rotation exercises target the infraspinatus and teres minor muscle as they are the

primary humeral external rotators. However, activity of these muscle has been observed to vary based on abduction angle. Greater muscle activity of the infraspinatus has been observed during external rotation at 0 degrees of abduction, and greater teres minor activity at 90 degrees of abduction.[122] Therefore, specific external rotators can be targeted by varying abduction angle. Internal rotation exercises aim to strengthen the subscapularis muscle. Both the infraspinatus and subscapularis muscle act as humeral depressors by transmitting an inferior translatory force.[79] Considering this, strengthening the infraspinatus, teres minor and subscapularis, should result in promoting widening of the subacromial space during dynamic movement.

Scaption, both in the "Full can" (Externally rotated humerus) and "Empty can" (Internally rotated humerus) exercises, have been implemented with the goal of strengthening the supraspinatus muscle. Both exercises have been demonstrated to produce high levels of electromyographic output for the supraspinatus, with the "Empty can" demonstrating higher supraspinatus muscle activity.[123] However, the full can has been proposed as a safer alternative as external rotation of the humerus clears the greater tuberosity from under the acromion, and therefore decreases the risk of impingement.[74] Resisted forward flexion (sagittal plane elevation) and abduction (coronal plane elevation) are other implemented exercises aimed at strengthening the rotator cuff, specifically the supraspinatus. However, McClure et al. cautions that elevation exercises should be avoided until rotator muscles are strong enough to prevent excessive upward translation of the humerus to avoid aggravating injured tissues.[58] In the context of subacromial impingement syndrome, strengthening the supraspinatus muscle may be biomechanically advantageous in centering the humeral head in the glenoid fossa by producing a compressive force during glenohumeral movements.[72] However, caution should be taken to minimize further

tissue injury to healing tissues. Therefore, exercise parameters, intensity and variations should be considered in the context of the nature of the injury.

7.4 Strengthening of the scapular stabilizers and improving neuromuscular control

Scapular stabilizer strengthening exercises were observed to be highly effective at decreasing pain and improving function, and moderately effective at improving strength and biomechanical outcomes. Compared to a control group that received no treatment or placebo treatment, scapular stabilizer strengthening exercises were highly effective at decreasing pain and moderately effective at improving function. In studies conducted with high scientific rigor, scapular stabilizer strengthening exercises were highly effective at improving function and function. Medication use and delay of surgical intervention was not investigated in studies investigating scapular stabilizer strengthening exercises. Biomechanical rationale stated by authors and supported by previous literature was to strengthen the scapular stabilizers in an effort to promote healthy scapular kinematics and decrease abnormal scapular mechanics that promote subacromial impingement during humeral elevation.

Neuromuscular training exercises were highly effective at decreasing pain, improving function and strength. Compared to a control group the received no treatment or placebo treatment, neuromuscular training exercises were highly effective at decreasing pain and improving function. In studies conducted with high scientific rigor, neuromuscular training exercises were highly effective at improving function and moderately effective at decreasing pain. Neuromuscular training exercises were observed to decrease pain medication use in participants with SAIS and/or RC tears. Biomechanical rationale stated by authors for neuromuscular training exercises was to promote healthy dynamic scapular kinematics by improving neuromuscular control of scapular stabilizer muscles and promote coordination of

scapular stabilizer muscles that favors healthy scapular mechanics. It has also been observed that instability of the scapulothoracic joint results in decreased neuromuscular performance and predisposition to injury of the glenohumeral joint.[20] Exercises identified in this review aimed at promoting increased neuromuscular control by recruiting multiple scapular stabilizers simultaneously through a variety of planes were inferior glide, wall slides/wall angels, rhythmic stabilization, scapular clock and towel slide. Hotta et al investigated[92] the effect of exercises aimed at improving neuromuscular control in addition to scapular strengthening exercises on muscular strength, pain (0-10 scale), disability (SPADI-Br), and scapular kinematics compared to a control group. Of the exercises identified in this review, Hotta et al implemented the towel slide, inferior glide, and scapular clock. Following the 8-week protocol, significant improvements ($p < 0.05$) were observed in strength, pain, disability, as well as scapular kinematics compared to the untreated control group. The experimental group demonstrated decreased resting internal rotation, decreased upward rotation and internal rotation, and anterior tilt during humeral elevation. The results of this study by Hotta et al indicate that neuromuscular control focused exercises in addition to scapular stabilizer strengthening exercises may provide some benefit in altering scapular kinematics, as well as improving other outcomes such as pain, function and strength.

To promote scapular stability, specific muscles targeted by strengthening exercises were the serratus anterior, middle trapezius and lower trapezius. The serratus anterior was specifically targeted with exercises such as scapular protraction/dynamic hug, push up plus, serratus anterior strengthening in quadruped, supine press and wall push ups, D1 and D2 PNF patterns. The serratus anterior works as a protractor of the scapula, as well as to upwardly rotate the scapula. The serratus anterior also acts to stabilize the medial border and inferior angle of the scapula,

limiting excessive internal rotation and anterior tilt,[124] scapular positions that promote impingement. Additionally, decreased serratus anterior activity has been observed in individuals with subacromial impingement syndrome, and therefore serratus anterior muscle function has been suggested as an important consideration in the management of subacromial impingement.[36] High (41%-60% maximum voluntary isometric contraction (MVIC)) to very high (>60% MVIC) serratus anterior muscle activity was observed in the scapular protraction,[125] push ups, push up plus,[80] supine press, and D1[75] and D2[125] PNF patterns, indicating that these are effective exercises for strengthening the serratus anterior.

The lower and middle trapezius are other important muscles in promoting healthy scapular kinematics. The middle trapezius is responsible for scapular retraction, and the lower trapezius is responsible for upward rotation and depression of the scapula. There is also evidence to suggest that due to its fibre orientation, the lower trapezius may also contribute to posterior tilt and external rotation of the scapula as the humerus is elevated,[81] therefore decreasing the narrowing of the subacromial space and subsequent impingement risk. Commonly implemented exercise identified in this review specifically aimed at strengthening the middle and lower fibres of the trapezius muscle are low rows, prone lower/middle trapezius lifts, rows/scapular retraction, shoulder extension and prone horizontal abduction. Rows, prone horizontal abduction,[75,80] prone[80] and standing shoulder extension[125] have been observed to elicit high to very high muscle activity of the middle and lower trapezius. Therefore, these data suggests that these exercises are effective at strengthening the middle and lower trapezius muscle, resulting in favorable kinematic changes to reduce the risk of impingement.

Muscle coactivation ratios between scapular stabilizer muscles is another important consideration when determining if an exercise will yield positive biomechanical changes in the

treatment of subacromial impingement syndrome. It is suggested that abnormal scapular kinematics are the result of imbalances of muscle activity, rather than weakness of all scapulothoracic muscles.[126] Evidence of increased upper trapezius activity combined to reduced serratus anterior activity in individuals with shoulder pain, resulting in a "shoulder shrugging" motion, causing excess superior translation of the scapula and decreased upward rotation and posterior tilt.[127] Therefore, it has been suggested that exercises should be aimed at addressing specific muscle imbalances rather than global strengthening of scapulothoracic muscles.[127] When selecting exercises with the aim of correcting abnormal scapular kinematics, consideration on what muscles are activated, as well as to what extent. As previously discussed, hyperactivity of the upper fibres of the trapezius results relative to other scapulothoracic muscles results in the decreased upward rotation of the scapula, thus increasing the risk of impingement. Exercises aimed at the strengthening of the serratus anterior, middle, and lower trapezius have also been observed to elicit high or very high activity of the trapezius muscle. Of the exercises identified in this review, these include rows, prone horizontal abduction and D1 diagonal pattern.[75,80] Abduction and scaption above 120 degrees and below 80, exercises aimed at strengthening the rotator cuff muscles and increase active range of motion, have also been shown to elicit high or very high upper trapezius muscle activity.[75,80]

7.5 Postural exercises

Postural exercises were highly effective at decreasing pain, improving function and moderately effective at improving biomechanical outcomes. In studies conducted with high scientific rigor, postural exercises were highly effective at decreasing pain and improving function. Medication use and delay of surgical intervention were not investigated in studies that investigated postural exercises. Biomechanical rationale stated by authors and supported by

previous literature for postural correction in the treatment of SAIS is to address alterations in upper body posture, or the presence of "forward head posture", that increase the risk of impingement. It is proposed that changes associated with upper body posture such as increased thoracic kyphosis, changes in scapular position, and the resulting muscular imbalances lead to kinematic changes that promote impingement of subacromial tissues.[94] Thoracic spine posture's effect on scapular three-dimensional kinematics has been investigated by Kebatese et al[97] Scapular kinematic changes observed in a "slouched" posture observed were increased superior translation of the scapula, decreased upward rotation, posterior tilt, and slightly increased internal rotation during arm abduction: Kinematic changes previously established to promote impingement. Hunter et al. observed that compared to age, gender, and dominant arm-matched controls, individuals with subacromial impingement syndrome exhibited greater thoracic kyphosis and less active thoracic extension.[128]

Exercises aimed at increasing postural strength and discouraging forward head posture and decreasing thoracic kyphosis included in this review are chin tucks and active thoracic extensions. Park et al. investigated the effects of an exercise program aimed at improving thoracic spine extension, trunk extensors muscle strength and trunk flexor muscle flexibility on thoracic kyphosis, upper trapezius, pectoralis minor muscle tone and stiffness, passive shoulder range of motion, and pain and disability (SPADI) compared to a manual therapy intervention. The exercise intervention group demonstrated significant ($p<0.05$) improvements in thoracic kyphosis, upper trapezius, pectoralis minor tone and stiffness, shoulder range of motion, pain and disability post-intervention.[95] The results from this study by Park et al. suggest that the benefits of strengthening postural muscles are two-fold: promoting healthy scapulothoracic kinematics

and additionally, decreasing upper trapezius and pectoralis minor tightness. Tightness of both these muscles have been associated with abnormal scapular kinematics.

7.6 Strengthening of other upper limb muscles

Exercises targeting other limb muscles were highly effective at decreasing pain, improving function, strength and biomechanical outcomes. In studies conducted with high scientific rigor, these exercises were highly effective at increasing pain and function. Medication use or delay of surgical intervention were not investigated in studies that investigated strengthening exercises for other upper limb muscles. Biomechanical rationale deduced from previous literature for these exercises was to strengthen other upper limb muscles namely the latissimus dorsi, biceps brachii and triceps brachii due to their roles in humeral depression and stabilization of the humerus in an effort to increase the subacromial space during humeral elevation.

The latissimus dorsi has been observed to be a significant humeral depressor, limiting superior translation of the humeral head.[79] Similarly, the long head of the biceps brachii has also been observed to exert a depression effect on the humerus, both in-vitro and in-vivo.[79,99] The long head of the triceps acts to stabilize the humeral head in the glenoid cavity, helping to prevent displacement of the humerus.[83] The findings from these three studies regarding the role of these muscles suggest that strengthening the latissimus dorsi, teres major, biceps brachii and triceps brachii may be useful in the treatment of subacromial impingement syndrome and rotator cuff tears by promoting glenohumeral stability in the presence of a deficient rotator cuff, as well as limiting the upward translation of the humeral head therefore decreasing risk of impingement.

Exercises identified in this review aimed at strengthening the latissimus dorsi, biceps brachii and triceps brachii were lat pull downs and seated press-ups for the latissimus dorsi,

biceps curl for the biceps brachii and triceps push downs and overhead triceps extension for the triceps brachii. Press-up[123] and lat pull down[129] have both been observed to elicit high latissimus dorsi muscle activity. Weighted biceps curls have also demonstrated to elicit high biceps brachii regardless of shoulder position.[130] Similarly, when EMG activity was compared between different triceps exercises, both the overhead triceps extensions and triceps pushdowns demonstrated high long head of the triceps activity.[131] Taken together, the outcomes of these analyses of EMG activity indicate that the exercises identified in this review are appropriate to be implemented with the aim of strengthening humeral depressors and stabilizers in an exercise program for the conservative management of subacromial impingement syndrome and rotator cuff tears.

7.8 Limitations

There are several limitations for the results of this systematic review. First, the results of the present review are limited by the limitations present in the original included studies and their potential impact on the validity of their reported results. If there were limitations in the methodology used to collect data on outcomes of interest in an original study, the limitations of the results extracted from the study were propagated in the results of the present review. For example, limitations of instrumentation used in the collection of biomechanical data (motion capture, goniometry, electromyography) can affect the validity of the reported data, and therefore may not accurately represent the biomechanical effects of the exercises investigated in this review. Another common limitation of this review's included studies were the small sample sizes. Sample sizes ranged from 1 participant to 77 participants, with 36 studies having less than 20 participants in exercise intervention groups. The small sample sizes may have affected the validity of the results obtained in those studies, also applying to the effects of the present study.

Similarly, 56 studies had an exercise intervention period of 8 weeks or less. This short exercise intervention period may be the result of efforts made to mitigate for issues with adherence to exercise interventions, limited research resources or to decrease the commitment required from participants to aid in study recruitment. This also affects validity of the data because it may not be an accurate representation of long-term effects of an exercise intervention, which is especially important for assessing biomechanical changes, as a longer intervention period may be required to observe significant kinematic changes as they will likely follow changes to muscle strength and changes in neuromuscular control. This may also explain the variability and overall decreased effect sizes observed for biomechanical outcomes. Based on previous literature, clinical practice recommendations for the length of conservative management is typically 3-6 months for SAIS and RC tears,[132,133] however this time varies between individuals based on a multitude of factors that affect the prognosis of these conditions such as rotator cuff tear size, duration of symptoms pre-intervention, and significance of functional impairment at assessment.[50] Based on these factors, recommendations the length of conservative treatment have ranged from 3 months to 18 months in the literature.[50,134,135]

Another limitation is the omission of information in the original studies. For example, many studies did not include a comprehensive description of the administered exercise intervention. Some studies did not include any information on which exercises were used, descriptions of stated exercises, or biomechanical rationale and assumptions were made to deduce that information based on previous literature. There were also omissions and variations in the manner data was reported, which made the calculation of effect size impossible for some outcomes of studies. To mitigate for missing data, percent change was also calculated, if possible, in order to include data from studies that did not report sufficient data to calculate

effect size. Despite this, there remained studies that data could not be calculated for and therefore were not included in the statistical analysis. However, due to the volume of studies included in this review, missing data had a lesser impact on the results of this review.

Another source of compromised validity of the included studies is the presence of bias. 53 of the 76 (70%) randomized controlled trials included in this review were judged as being at a *high risk of bias*, and 12 (16%) were judged as raising *some concerns*. In order to mitigate for the variability in validity of included studies, a sub-analysis was conducted on randomized controlled trials judged to be at a *low risk of bias*, and therefore determined to be of high scientific vigor. The subjective nature of the RoB2 used for the risk of bias assessment is another limitation of our review, as many of the signalling questions used to arrive at a judgement required assumptions and subjective judgement from the reviewers. The effects of this, however, were mitigated by having two reviewers independently assess risk of bias and deliberating with a third reviewer in the case of disagreement until a consensus was reached. Additionally, the subjective nature of this judgement was mitigated by the fact that it was conducted by three reviewers with a specific background in biomechanics, and two of the three reviewers had strong experience with conducting systematic reviews and risk of bias analyses.

Drawing distinct conclusions based on data for specific exercise subgroupings is limited because most studies investigated multiple exercise types within one exercise intervention and therefore the effect sizes calculated for an exercise intervention cannot be attributed to solely one exercise type, but rather reflect the interplay of the multiple exercise types included in that intervention. Similarly, effects of the identified exercises on shoulder musculature and the associated biomechanical rationale are likely not as distinct as described in the literature. For example, exercises identified to strengthen rotator cuff muscles may also strengthen other

shoulder musculature such as the scapular stabilizer muscles, and therefore the effects of these exercises cannot solely be attributed to the strengthening of the rotator cuff muscles and the associated biomechanical changes. Another example of this is the relationship between stretching exercises and range of motion. Stretching exercises may increase range of motion as a result of increasing flexibility of musculature surrounding a joint, and range of motion exercises may increase flexibility of musculature. Therefore, a stretching exercise may produce favorable biomechanical changes due to increasing glenohumeral range of motion as opposed to correcting abnormal scapular mechanics, as the biomechanical rationale for this exercise type suggests. Similarly, drawing conclusions on the effect of exercise compared to a comparator such as surgery or modalities may not be a true reflection of the difference of the effects of these interventions on outcomes of interest as many comparator interventions also included exercises, such as post-operative rehabilitation or the inclusion of an exercise intervention in addition to the modality. Therefore, negative effect sizes compared to comparators may not be a true indication that exercise was not effective, but rather that the addition of modalities may provide an additional benefit to exercise in improving the outcomes of interest. In an effort to provide a clear interpretation of the effect of exercises, a sub-analysis of studies that investigated exercise compared to no intervention or a placebo intervention was performed, as well as an analysis of effect sizes calculated for the exercise intervention group alone.

Finally, the interpretation of calculated effect sizes as large, medium, small and negligible may not provide an accurate interpretation of the magnitude of the effect on our outcomes of interest. The benchmarks used to categorize effect sizes are large (d=0.80), medium (d=0.50), small (d=0.2) and negligible (d<0.2) are arbitrary and may not be a true reflection of the impact of the change on the specific outcome.[136] For example, a “small” effect size for a

biomechanical outcome may be large enough to produce a meaningful biomechanical change beneficial in the treatment of SAIS and/or RCTs. This may be due to variability in the outcome measures. For example, biomechanical outcomes yielded the smallest effect sizes, possibly due to variability that arises with various biomechanical instrumentation techniques such as motion capture and electromyography, as well as variability amongst participants' biomechanical adaptations. The larger variability may result in a smaller effect size, despite a larger observed mean difference that may be clinically relevant. However, the benefit of using these benchmarks to categorize effect sizes is the ability to use one normalized metric and compare between many different outcome measures that could not be compared otherwise.

7.9 Thesis Contributions

7.9.1 Applications to clinical practice

For the management of SAIS and/or RC tears, exercise has been demonstrated in the present study to decrease pain and negative biomechanical outcomes, increase function, strength and positive biomechanical outcomes, with consistent positive outcomes observed for pain and function. Based on the current literature, the results from this review indicate that an exercise program aimed at the conservative management of SAIS and/or RC tears should include a combination of stretching, ROM, rotator cuff strengthening, scapular stabilizer and scapular neuromuscular training exercises, as these exercises were the most commonly implemented exercise types. Although less common in the literature, postural exercises and strengthening of other limb muscles such as the latissimus dorsi, biceps brachii and triceps brachii should be considered by clinicians as they were observed to yield the largest effect sizes for biomechanical outcomes. Additionally, the results from this review suggest that modalities alone or in addition to an exercise program yield a moderate or small improvement of primary outcomes of interest,

therefore exercise interventions should be the prioritized for the conservative management of SAIS and/or RC tears.

Clinicians should also consider other factors when prescribing exercise programs for the management of SAIS and/or RC tears. One such consideration is dosage of the exercises. Many factors such as exercise type, treatment goals, and severity of condition may affect the dosage at which selected exercises are implemented. Similarly, as a patient's condition improves, an exercise protocol must be adapted to promote progression of the patient's condition. Another important consideration for the prescription of an exercise protocol is the patient's individual features and response. A patient's specific deficits, strengths, severity of condition and response to treatment may additionally direct the inclusion or omission of certain exercises or progressions of exercises.

7.9.2 Directions for future research

The findings of this review provide a foundation for the further evaluation of this identified exercise program for the conservative management of SAIS and RC tears. An EMG analysis of the identified exercises is required to assess the activation of intended musculature for each of the exercises, as well as to determine if the exercises are suitable for the treatment of the SAIS and/or RC tears based on the co-activation ratios elicited. Additionally, upper limb kinematics during these exercises should be observed to assess if the exercises produce any disadvantageous kinematics that may cause further injury to healing tissues. These analyses should be performed in healthy, asymptomatic participants as well as participants with a clinical diagnosis of SAIS and/or RC tears to determine if there exists different muscular or kinematic responses to these exercises in adults with SAIS and/or RC tears. The long-term effect of these specific exercises on outcomes of interest such as pain, function, strength, and biomechanical

outcomes in a clinical population should be assessed in a randomized controlled trial to determine the therapeutic value of the identified program. Finally, this comprehensive list of exercises shown to decrease pain, improve function and strength, and promote beneficial biomechanical changes can serve as a “gold standard” exercise protocol to which alternative exercise interventions such as yoga, tai chi and aquatic-based exercises can be compared to.

8.0 CONCLUSION

This systematic review investigated the effects of exercise on the conservative management of SAIS and/or RC tears and its effects on pain, function, strength, biomechanical outcomes, medication use and delay of surgical intervention. The results from this study suggest that there is strong evidence that all exercise types are effective at improving pain and function outcomes, however more variability exists for strength and biomechanical outcomes. Further, heterogeneity exists in the literature on the specific exercises. A list of 41 commonly described exercises effective in the treatment of SAIS and/or RC tears was formulated based on biomechanical rationale. This list of exercises offers a wide variety of exercises that achieve seven main goals that have been proposed and demonstrated in previous literature to produce positive biomechanical changes, and subsequent improvements in pain, function, and strength. These goals include (1) Stretching of specific musculature, (2) Increasing range of motion, (3) Rotator cuff strengthening, (4) Scapular stabilizer strengthening, (5) improvement of scapular neuromuscular control, (6) Postural correction, (7) Strengthening of other upper limb muscles. By identifying exercises that were successfully shown to improve symptoms and physical function, while also highlighting the biomechanical impact of each exercise, this research provides a resource for clinical applications as well as a critical foundation for the future evaluation of these exercises.

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APPENDICES

Appendix A: Data chart with study and intervention details for all exercise interventions, and calculated effect size and % change for primary outcomes

First Author, year	Study Design	Risk of Bias Assessment	Diagnosis	Exercise Intervention	Specific exercises	Exercise type	Details	Number of Subjects (n)	Follow up	Outcome	Outcome Measure	Adjusted effect size	Adjusted % Change
Ager 2019	Pilot RCT	Some concerns	Rotator cuff tendinopathy	Group Supervised Upper Extremity Neuromuscular Training program	Not specified	Rotator cuff strengthening, scapular stabilizer strengthening, neuromuscular training	35-45 minutes/session, 3 times/week, 6 weeks, multi-station, group supervised.	16	6 weeks	Function	WORC-CF	1.47	N/A
										Function	DASH-CF	1.21	N/A
										Strength	MVIC - Abductors	1.71	N/A
										Strength	MVIC - External Rotators (90° abduction)	1.18	N/A
Akkaya 2017	Randomized, controlled, single blind study	High risk	Subacromial Impingement Syndrome	Weighted pendulum exercises	Pendulum	ROM	10 minutes/session, 3 times daily, 4 weeks, 1.5kg weight.	18	4 weeks	Pain	VAS (night)	0.83	49.02
										Pain	VAS (activity)	1.75	46.97
										Pain	VAS (rest)	0.88	62.50
										Function	SPADI	0.60	31.00
				Unweighted pendulum exercises			10 minutes/session, 3 times daily, 4 weeks, no weight.	17		Pain	VAS (night)	0.57	37.50
										Pain	VAS (activity)	0.89	35.59
										Pain	VAS (rest)	0.74	45.16

										Function	SPADI	0.60	31.00
Arias-Buria 2017	Randomized, parallel-group clinical trial	Some concerns	Subacromial Impingement Syndrome	Supraspinatus, infraspinatus, scapular stabilizer musculature strengthening	Not specified	Rotator cuff strengthening, scapular stabilizer strengthening	20-25 minutes/session, 5 sessions (once/week) + twice/day (home), 5 weeks, 3 sets, 12 repetitions, 3 exercises.	25	6 weeks	Pain	NPRS (mean)	0.30	9.09
										Pain	NPRS (worst)	1.32	33.33
										Function	DASH	2.49	29.35
Bac 2020	Randomized Clinical Trial	High risk	Subacromial Impingement, subacromial bursitis, Rotator cuff tendinopathy	Rehabilitation protocol: isometric, active exercises with and without resistance, sensorimotor exercises, PNF	Not specified	ROM, scapular stabilizer strengthening, neuromuscular training	55 minutes/session, 3 times/week, 6 weeks, supervised.	30	6 weeks	Function	UEFI	1.10	25.44
										Biomechanical	Muscle Thickness (supraspinatus)	-0.14	-2.11
										Biomechanical	Muscle Thickness (infraspinatus)	0.04	0.70
										Biomechanical	Muscle Thickness (teres minor)	-0.37	-8.14
										Biomechanical	Muscle Thickness (subscapularis)	0.12	3.23
										Biomechanical	Subacromial Space	-0.24	-4.66

Bal 2009	Prospective Randomized Study	High risk	Subacromial Impingement Syndrome	Home exercise program: Pendulum circumduction, passive stretching, isometric strengthening in all planes, scapular stabilization strengthening, advanced muscle-strengthening exercises	Pendulum, resisted flexion, abduction, external rotation, internal rotation	ROM, rotator cuff strengthening	2 sessions/week, 12 weeks.	20	12 weeks	Pain	VAS (night)	1.13	N/A
										Pain	SPADI (pain)	1.71	N/A
										Function	SPADI (disability)	1.53	N/A
										Function	SPADI (total)	1.75	N/A

Bang 2000	Randomized clinical trial	High risk	Shoulder impingement syndrome, rotator cuff tendinitis, shoulder tendinitis	Exercise	Anterior shoulder stretch, posterior shoulder (cross-body) stretch, resisted flexion, scaption (empty can), rows, horizontal abduction, seated press up, push up plus	Stretching, rotator cuff strengthening, scapular stabilizer strengthening	30 minutes/session, 6 sessions (twice/week), once daily (home), 3 weeks, 30 second hold × 3 repetitions (stretch), 3 sets × 10 repetitions (4 strengthening), 3 sets × 25 repetitions (2 strengthening), supervised.	23	3 weeks	Pain	Abduction AROM (VAS pain)	0.49	25.53
										Pain	Resisted Abduction (VAS pain)	0.09	7.46
										Pain	Resisted External Rotation (VAS pain)	0.26	20.41
										Pain	Resisted Internal Rotation (VAS pain)	0.46	27.60
										Pain	Functional (VAS pain)	0.91	41.44
										Pain	Pain Composite	0.77	35.27
										Function	Functional Assessment Questionnaire	0.70	16.62
										Strength	Abduction Strength (Newtons)	0.21	12.50
										Strength	External Rotation Strength (Newtons)	0.05	2.05
										Strength	Internal Rotation Strength (Newtons)	0.11	4.32
										Strength	Strength Composite	0.16	6.55

Baskurt 2011	Randomized Controlled Trial	High risk	Unilateral shoulder impingement	Scapular stabilizer strengthening	AROM, Pendulum, anterior shoulder stretch, posterior shoulder (cross body) stretch), towel stretch, strengthening of subscapularis, supraspinatus, deltoid (not specified), scapular clock, standing weight shift, double arm balancing, wall push up, wall slides	ROM, Rotator cuff strengthening, scapular stabilizer strengthening, neuromuscular training	3 times/week, 6 weeks, 3 sets × 10 repetitions, supervised, progressive.	20	6 weeks	Pain	VAS pain (rest)	1.84	78.75
										Pain	VAS pain (activity)	3.56	62.73
										Function	WORC	2.79	89.21
										Strength	Lower Trapezius Strength (kg)	0.77	10.60
										Strength	Middle Trapezius Strength (kg)	0.80	11.50
										Strength	Upper Trapezius Strength (kg)	0.86	12.77
										Strength	Serratus Anterior Strength (kg)	0.89	15.93
										Strength	Supraspinatus Strength (kg)	0.90	11.60
										Strength	Subscapularis Strength (kg)	0.49	12.07
										Strength	Infraspinatus Strength (kg)	0.72	14.08
										Biomechanical	Flexion ROM (°)	1.12	5.27
										Biomechanical	Abduction ROM (°)	0.70	5.27
										Biomechanical	Internal Rotation ROM at 90° Abduction (°)	0.91	8.26
										Biomechanical	External Rotation ROM at 90° Abduction (°)	1.07	17.85
										Biomechanical	Joint Position Sense at Internal Rotation Error (°)	1.35	67.42
										Biomechanical	Joint Position Sense at External Rotation Error (°)	1.21	54.84

										Biomechanical	LSST Neutral Position (cm)	1.56	63.41
										Biomechanical	LSST at 45° Abduction (cm)	1.26	61.11
										Biomechanical	LSST at 90° Abduction (cm)	1.97	64.44
				Flexibility and strengthening exercises	AROM, Pendulum, anterior shoulder stretch, posterior shoulder (cross body) stretch), towel stretch, strengthening of subscapularis, supraspinatus, deltoid (not specified)	ROM, stretching, rotator cuff strengthening	EX: Flexibility and Codman exercises, strengthening, 3 times/week, 6 weeks, 3 sets × 10 repetitions, supervised, progressive.	20		Pain	VAS pain (rest)	1.21	67.82
										Pain	VAS pain (activity)	2.86	61.21
										Function	WORC	1.83	91.10
										Strength	Lower Trapezius Strength (kg)	0.37	5.98
										Strength	Middle Trapezius Strength (kg)	0.23	3.24
										Strength	Upper Trapezius Strength (kg)	0.28	4.07
										Strength	Serratus Anterior Strength (kg)	0.31	6.30
										Strength	Supraspinatus Strength (kg)	0.94	19.36
										Strength	Subscapularis Strength (kg)	0.54	14.67
										Strength	Infraspinatus Strength (kg)	0.66	12.38
										Biomechanical	Flexion ROM (°)	0.89	4.69
										Biomechanical	Abduction ROM (°)	0.68	9.26

										Biomechanical	Internal Rotation ROM at 90° Abduction (°)	0.84	10.76
										Biomechanical	External Rotation ROM at 90° Abduction (°)	0.83	19.86
										Biomechanical	Joint Position Sense at Internal Rotation Error (°)	0.61	29.35
										Biomechanical	Joint Position Sense at External Rotation Error (°)	0.54	23.26
										Biomechanical	LSST Neutral Position (cm)	0.11	6.54
										Biomechanical	LSST at 45° Abduction (cm)	0.04	3.00
										Biomechanical	LSST at 90° Abduction (cm)	0.00	0.00
Beaudreuil 2011	Randomized Controlled trial	Low risk	Subacromial Impingement Syndrome	Dynamic humeral centering exercises	Dynamic humeral centering	Neuromuscular training	30 minutes/session, 3 times/week (3 weeks), 2 times/week (3 weeks). HEP: 3 times/day, 10 repetitions, progressive.	34, follow up 30	3 months	Pain	Constant Score (pain)	1.61	58.44
Beaudreuil 2015	Randomized Controlled trial secondary analysis									Function	Constant Score (activity)	1.42	47.75
										Function	Constant Score (mobility)	1.15	49.16
										Function	Constant Score (total)	1.49	48.03
										Strength	Constant Score (strength)	0.43	34.38
										Biomechanical	Flexion AROM (painfree)	0.49	41.07

										Biomechanical	Abduction AROM (painfree)	0.54	50.00
										Biomechanical	Flexion AROM (painful arc)	-1.33	-79.88
										Biomechanical	Abduction AROM (painful arc)	-1.15	-56.04
Blume 2015	Randomized Controlled Trial	High risk	Rotator Cuff Pathology	Eccentric exercises	Eccentric scaption (full can), external rotation, internal rotation, horizontal abduction, prone extension, scapular protraction	Rotator cuff strengthening, scapular stabilizer strengthening	twice/week, 8 weeks, supervised, progressive. HEP: daily, eccentric exercises.	18	8 weeks	Function	DASH	1.16	51.60
										Strength	Abduction Torque (Nm)	0.75	60.00
										Strength	External Rotation Torque (Nm)	0.68	57.64
										Biomechanical	Scapular Elevation AROM (°)	-2.95	27.35
				Concentric exercises	Scaption (full can), external rotation, internal rotation, horizontal abduction, prone extension, scapular protraction	Rotator cuff strengthening, scapular stabilizer strengthening	EX: twice/week, 8 weeks, supervised, progressive. HEP: daily, concentric exercises.	16		Function	DASH	1.75	56.13
										Strength	Abduction Torque (Nm)	0.65	50.84
										Strength	External Rotation Torque (Nm)	0.69	74.77
										Biomechanical	Scapular Elevation AROM (°)	-2.85	15.04

Boudreau 2019	Randomized Controlled trial	Low risk	Rotator cuff tendinopathy	Rotator cuff strengthening, coactivation via EMG biofeedback	Wall push up plus, rows, external rotation, internal rotation, coactivation of latissimus dorsi	Rotator cuff strengthening, scapular stabilizer strengthening, neuromuscular training	EX: 3 sets × 10 repetitions, once daily, 6 days/week, 7 weeks, progressed, supervised.	21, follow up 20	6 weeks	Pain	VAS (rest)	-0.07	-8.97
										Pain	VAS (movement)	0.62	21.10
										Function	DASH	0.26	13.66
										Function	WORC Index	0.63	27.33
										Biomechanical	Acromiohumeral Distance (0°)	0.29	6.48
										Biomechanical	Acromiohumeral Distance (30°)	0.09	1.92
										Biomechanical	Acromiohumeral Distance (60°)	0.12	3.16
				Rotator cuff strengthening + no coactivation	Wall push up plus, rows, external rotation, internal rotation	Rotator cuff strengthening, scapular stabilizer strengthening	EX: Rotator cuff strengthening, no coactivation, 3 sets × 10 repetitions, once daily, 6 days/week, 7 weeks, progressed, supervised.	21, follow up 19		Pain	VAS (rest)	-0.41	-64.71
										Pain	VAS (movement)	1.27	31.15
										Function	DASH	0.11	5.97
										Function	WORC Index	0.49	21.22
										Biomechanical	Acromiohumeral Distance (0°)	-0.18	-3.67
										Biomechanical	Acromiohumeral Distance (30°)	-0.24	-5.71

										Biomechanical	Acromiohumeral Distance (60°)	-0.10	-3.06
Brox 1993	Randomized Clinical Trial	Some concerns	Rotator Cuff Disease	Exercise	Not specified	ROM, rotator cuff strengthening, scapular stabilization	60 minutes/session, twice/week, 3-6 months, progressive, supervised. HEP: 5 times/week.	50	6 months	Pain	Pain score (activity)	N/A	-66.67
										Pain	Pain score (rest)	N/A	14.29
										Pain	Pain score (night)	N/A	10.00
										Pain	Neer Shoulder Score (pain)	N/A	20.00
										Function	Neer Shoulder Score (function)	N/A	4.17
										Biomechanical	Neer Shoulder Score (ROM)	N/A	21.05
Brox 1999	Prospective, randomized, Controlled study	Some concerns	Rotator cuff disease (impingement syndrome stage II)	Exercise	Not specified	ROM, rotator cuff strengthening, scapular stabilization	60 minutes/session, twice/week, 3-6 months, progressive, supervised. HEP: 5 times/week.	33	2.5 years	Pain	Pain score (activity)	N/A	-100.00
										Pain	Pain score (night)	N/A	61.54
										Pain	VAS pain (rest)	N/A	60.00
										Function	Neer Shoulder Score (function)	N/A	36.36
										Biomechanical	Neer Shoulder Score (ROM)	N/A	31.58

Calis 2011	Randomized controlled trial	High risk	Subacromial impingement syndrome	Exercise + moist heat	Not specified	ROM, stretching, rotator cuff strengthening	5 times/week, 3 weeks, 5 repetitions × 5 seconds, supervised. HEAT: 20 minutes.	16	3 weeks	Pain	VAS pain (rest)	0.27	15.20
										Pain	VAS pain (movement)	0.57	14.31
										Pain	VAS pain (night)	0.49	21.04
										Function	Constant Score	0.56	16.15
										Biomechanical	Abduction ROM (°)	1.32	7.02
										Biomechanical	Flexion ROM (°)	1.17	5.59
										Biomechanical	Internal Rotation ROM (°)	0.59	6.64
										Biomechanical	External Rotation ROM (°)	0.60	6.02
Camagro 2015	Randomized controlled trial	High risk	Shoulder impingement syndrome	Exercise alone	UT stretch, posterior shoulder (cross body), bilateral corner (pectoralis) stretch, external rotation, scapular protraction, external rotation, prone extension, scapular protraction	Stretching, rotator cuff strengthening, scapular stabilizer strengthening	3 stretching (30 seconds × 3 repetitions), 3 strengthening (3 sets × 10 repetitions), 4 weeks, supervised, progressive.	23	4 weeks	Pain	VAS pain (rest)	0.62	65.05
										Pain	VAS pain (movement)	1.47	65.46
										Pain	VAS pain (greatest last week)	1.30	50.55
										Pain	VAS pain (least last week)	0.08	9.38
										Function	DASH	0.91	43.75

										Biomechanical	Sagittal Plane - Scapular Internal Rotation	0.25	3.93
										Biomechanical	Sagittal Plane - Scapular Upward Rotation	0.09	6.52
										Biomechanical	Sagittal Plane - Scapular Tilt	0.04	50.00
										Biomechanical	Scapular Plane - Scapular Internal Rotation	0.33	5.53
										Biomechanical	Scapular Plane - Scapular Upward Rotation	0.08	5.97
										Biomechanical	Scapular Plane - Scapular Tilt	0.04	18.75
Chaconas 2017	Randomized controlled trial	High risk	Subacromial Pain syndrome	Eccentric training	Eccentric external rotation, rows/scapular retraction, posterior shoulder (cross body) stretch	Stretching, rotator cuff strengthening, scapular stabilizer strengthening	Eccentric training external rotators + scapular retraction + stretching, 6 weeks, progressive, 3 sets × 15 repetitions, once daily. PT: 4 visits.	25	6 weeks	Pain	NPRS (best)	0.40	39.02
										Pain	NPRS (average)	1.25	62.37
										Pain	NPRS (worst)	1.48	44.57
										Function	WORC	1.38	31.47
										Strength	External Rotation Strength	0.72	17.29
										Strength	Internal Rotation Strength	0.22	8.33
										Strength	Abduction Strength	0.21	8.11
										Strength	Abduction/External Rotation Strength Ratio	0.26	5.88
										Strength	Internal Rotation/Exter	0.23	5.65

											nal Rotation Strength Ratio		
										Biomechanical	Flexion AROM	0.93	8.44
										Biomechanical	Abduction AROM	0.76	12.75
										Biomechanical	External Rotation AROM	0.38	4.88
										Biomechanical	Internal Rotation AROM	0.37	6.78
				General shoulder exercises	Flexion, abduction, rows/scapular retraction, posterior shoulder (cross body) stretch	Stretching, rotator cuff strengthening, scapular stabilizer strengthening	EX: Active stretching, 6 weeks. PT: 4 visits.	23		Pain	NPRS (best)	0.07	7.38
										Pain	NPRS (average)	0.33	18.18
										Pain	NPRS (worst)	0.26	8.71
										Function	WORC	0.33	7.89
										Strength	External Rotation Strength	-0.37	-8.46
										Strength	Internal Rotation Strength	-0.27	-6.38
										Strength	Abduction Strength	-0.15	-5.48
										Strength	Abduction/External Rotation Strength Ratio	0.19	5.50
										Strength	Internal Rotation/External Rotation Strength Ratio	0.15	3.64
										Biomechanical	Flexion AROM	0.56	9.46

										Biomechanical	Abduction AROM	0.29	6.04
										Biomechanical	External Rotation AROM	-0.06	-1.27
										Biomechanical	Internal Rotation AROM	-0.14	-3.33
Cheng 2007	Randomized controlled trial	High risk	Rotator cuff tendinitis	Workplace work hardening	Work hardening	Not specified	Ergonomic education, shoulder stretch, scapular control exercises, shoulder strengthening exercises, job-specific activities, 3 sessions/week.	46	4 weeks	Function	SPADI	1.69	39.45
										Strength	Arm Lift (lbs)	0.67	23.88
										Strength	High Near Lift (lbs)	1.34	56.76
										Strength	Bilateral Pushing (lbs)	0.44	19.98
										Strength	Bilateral Pulling (lbs)	0.46	20.77
										Strength	Bilateral Carrying (lbs)	2.00	103.51
										Strength	Unilateral Lifting Affected Hand (lbs)	0.95	39.52
										Biomechanical	Shoulder Flexion ROM (°)	1.18	5.09
										Biomechanical	Shoulder Extension ROM (°)	0.79	11.66

										Biomechanical	Shoulder Abduction ROM (°)	0.90	4.73
										Biomechanical	Shoulder External Rotation ROM (°)	0.52	5.45
										Biomechanical	Shoulder Internal Rotation ROM (°)	0.64	9.82
				Clinic work hardening	Work hardening	Not specified	EX: Mobilization activities, strength training, endurance training, work simulation, 3 sessions/week.	48		Function	SPADI	0.96	25.35
										Strength	Arm Lift (lbs)	0.31	12.76
										Strength	High Near Lift (lbs)	0.51	21.48
										Strength	Bilateral Pushing (lbs)	0.31	15.25
										Strength	Bilateral Pulling (lbs)	0.40	18.89
										Strength	Bilateral Carrying (lbs)	1.78	88.19
										Strength	Unilateral Lifting Affected Hand (lbs)	0.67	28.67
										Biomechanical	Shoulder Flexion ROM (°)	0.63	3.92
										Biomechanical	Shoulder Extension ROM (°)	0.60	12.36
										Biomechanical	Shoulder Abduction ROM (°)	0.19	2.14
										Biomechanical	Shoulder External Rotation ROM (°)	0.48	5.34

										Biomechanical	Shoulder Internal Rotation ROM (°)	0.32	5.62
Citaker 2005	Randomized controlled trial	High risk	Subacromial impingement syndrome	Passive Neuromuscular Facilitation	Pendulum, PNF exercises not specified	ROM, neuromuscular training	Hot packs, PNF, TheraBand exercises, 20 sessions.	20	20 sessions + 3 weeks	Pain	Pain (night, active)	2.35	76.43
										Pain	Pain (night, motionless)	1.35	71.05
										Pain	Pain (day, active)	2.43	90.77
										Pain	Pain (day, motionless)	1.28	92.75
										Pain	UCLA pain	1.93	156.14
										Function	UCLA function	1.33	92.59
										Strength	UCLA anterior flexion power	0.87	13.95
										Biomechanical	UCLA anterior flexion range	1.00	16.47
										Biomechanical	Flexion ROM (°)	1.40	22.83
										Biomechanical	Abduction ROM (°)	1.29	32.64
										Biomechanical	External Rotation ROM (°)	1.38	52.86
										Biomechanical	Internal Rotation ROM (°)	0.83	22.93
										Biomechanical	Hyperextension ROM (°)	0.64	18.40

Dejaco 2017	Randomized, single blinded, clinical trial	Low risk	Rotator cuff pathology	Eccentric exercises	Eccentric external rotation, eccentric scaption (full-can), posterior shoulder (cross-body) stretch, unilateral corner stretch	Stretching, Rotator cuff strengthening (eccentric)	12 weeks, 2 exercises, HEP once daily, progressive. PT: once/week (6 weeks), once biweekly (6 weeks).	20, follow up 19	12 weeks	Pain	VAS	1.82	75.90
										Function	Constant-Murley	0.87	20.41
				Conventional exercises	External rotation, internal rotation, scaption (full-can) posterior shoulder (cross-body) stretch, unilateral corner stretch	Stretching, Rotator cuff strengthening	EX: 12 weeks, 8 exercises, HEP once daily, progressive. PT: once/week (6 weeks), once biweekly (6 weeks).	16, follow up 15		Pain	VAS	1.04	55.00
										Function	Constant-Murley	1.06	11.03
DiLorenzo 2006	Prospective, randomized, comparison crossover investigation	High risk	Rotator cuff tendinitis	Rehabilitation exercises	Pendulum, AAROM	ROM, stretching, rotator cuff strengthening	EX: ROM + strengthening exercises, progressive.	20		Pain	VAS pain	1.36	29.53
Djordjevic 2012	Double-blind, randomized, cross-sectional study	Some concerns	Shoulder impingement syndrome, rotator cuff lesion with impingement syndrome	Exercise only	Not specified	ROM, rotator cuff strengthening, scapular stabilization	EX: 10 sessions, daily, 1 set × 10 repetitions.	10	10 days	Biomechanical	Flexion ROM (°)	0.91	24.64

										Biomechanical	Abduction ROM (°)	0.97	31.52
Engebretsen 2011	Single-blind randomized controlled study	Some concerns	Subacromial shoulder pain	Supervised exercises	AAROM (abduction/adduction), resisted external rotation	ROM, rotator cuff strengthening	EX: 45 minute session, twice weekly, 12 weeks, supervised, progressive.	52, follow up 49		Pain	Pain (rest)	3.15	38.24
										Pain	Pain (activity)	0.30	37.50
										Function	SPADI	1.13	50.82
										Function	Function (carry)	-0.74	-31.71
										Function	Function (take down)	-1.14	-36.73
Farfaras 2016	Prospective randomized study	High risk	Subacromial impingement syndrome	Non-operative exercise therapy	Not specified	ROM, rotator cuff strengthening	EX: 60 minutes, daily, 3-6 months, supervised, progressive, ROM + strengthening.	21	30 months	Pain	SF36 (bodily pain)	0.83	55.91
										Function	Constant Score (total)	0.27	8.93
										Function	SF36 (physical functioning)	-0.10	-2.58
										Function	SF36 (role physical)	0.81	149.46
										Function	SF36 (general health)	-0.06	-1.93
										Function	SF36 (vitality)	0.28	12.93
										Function	SF36 (social functioning)	0.24	7.23
										Function	SF36 (role emotional)	0.47	27.36
										Function	SF36 (mental health)	0.18	5.17
										Biomechanical	Active Elevation (°)	-0.11	-1.89

Farfaras 2018	Randomized controlled trial	High risk	Subacromial impingement syndrome	Non-operative exercise therapy	Not specified	ROM, rotator cuff strengthening	EX: 60 minutes, daily, 3-6 months, supervised, progressive, ROM + strengthening.	31, follow up 28	13.7-13.9 years	Pain	SF36 (bodily pain)	1.30	94.08
										Function	Constant Score (total)	0.58	16.93
										Function	SF36 (physical functioning)	0.03	0.90
										Function	SF36 (role physical)	1.11	238.51
										Function	SF36 (general health)	-0.09	-3.57
										Function	SF36 (vitality)	0.70	35.84
										Function	SF36 (social functioning)	0.47	12.84
										Function	SF36 (role emotional)	0.31	21.03
										Function	SF36 (mental health)	0.24	7.26
										Strength	Constant Score (elevation strength)	-1.01	-16.98
Gialanella 2018	Randomized controlled pilot study	High risk	Rotator cuff tears	Rehabilitation + cycloergometer	Pendulum, flexion, abduction, external rotation, internal rotation, cycloergometer	ROM, rotator cuff strengthening	EX: 10 sessions, 30 minutes/session, 5 sessions/week, 2 weeks, supervised, pendulums + ROM exercises. CYC: 20 minutes/session, twice daily, 6 months.	19	6 months	Pain	VNS Pain (activity)	1.30	33.04
										Function	Constant Score (total)	2.22	648.24
										Biomechanical	Passive Forward Elevation ROM (°)	0.35	7.48
										Biomechanical	Passive Extension ROM (°)	0.22	2.99

										Biomechanical	Passive Abduction ROM (°)	0.41	11.90
										Biomechanical	Passive External Rotation ROM (°)	0.29	8.99
										Biomechanical	Passive Internal Rotation ROM (°)	0.13	2.50
										Biomechanical	Active Forward Elevation ROM (°)	0.16	17.26
										Biomechanical	Active Abduction ROM (°)	0.32	16.52
										Biomechanical	Active External Rotation ROM (°)	0.65	86.78
										Biomechanical	Active Internal Rotation ROM (°)	1.05	81.34
				Rehabilitation only	Pendulum, flexion, abduction, external rotation, internal rotation	ROM, rotator cuff strengthening	EX: 10 sessions, 30 minutes/session, 5 sessions/week, 2 weeks, supervised, pendulums + ROM exercises.	19		Pain	VNS Pain (activity)	0.28	5.13
										Function	Constant Score (total)	0.25	12.83
										Biomechanical	Passive Forward Elevation ROM (°)	-0.15	-3.52
										Biomechanical	Passive Extension ROM (°)	-0.22	-2.84
										Biomechanical	Passive Abduction ROM (°)	-0.14	-3.97
										Biomechanical	Passive External Rotation ROM (°)	0.04	0.82
										Biomechanical	Passive Internal Rotation ROM (°)	-0.21	-1.50

										Biomechanical	Active Forward Elevation ROM (°)	0.08	4.16
										Biomechanical	Active Abduction ROM (°)	0.02	3.77
										Biomechanical	Active External Rotation ROM (°)	0.04	8.09
										Biomechanical	Active Internal Rotation ROM (°)	0.41	57.14
Giombini 2006	Randomized Controlled Study	Some concerns	Supraspinatus tendinopathy	Exercise	Pendulum	ROM	EX: 5 minutes/session, twice/day, daily, 4 weeks, pendulums + passive ROM exercises, weekly, supervised.	11	4 weeks	Pain	VAS Pain	1.03	13.11
										Function	Constant Score	0.49	2.94
Granviken 2015	Randomized trial	Low risk	subacromial impingement syndrome	Supervised Exercises	Not specified	ROM, Rotator cuff strengthening, scapular stabilizer strengthening	EX: 10 sessions + HEP, 4-6 exercises, twice daily, 6 weeks, 3 sets × 30 repetitions, progressive, supervised.	23, follow up 23	6 weeks	Pain	Pain (0 to 10, past week)	0.84	30.51
										Function	SPADI	0.82	33.33
										Function	FABQ (physical activity)	0.30	11.11
										Function	FABQ (work)	0.44	15.53

										Biomechanical	Flexion ROM (°)	0.20	3.31
										Biomechanical	Abduction ROM (°)	0.29	11.01
										Biomechanical	External Rotation ROM (°)	0.17	6.35
										Biomechanical	Internal Rotation ROM (°)	0.00	0.00
				Home exercise	Not specified	ROM, Rotator cuff strengthening, scapular stabilizer strengthening	EX: 1 session + HEP, 4-6 exercises, twice daily, 6 weeks, 3 sets × 30 repetitions, progressive.	23, follow up 21		Pain	Pain (0 to 10, past week)	1.12	31.75
										Function	SPADI	1.26	34.69
										Function	FABQ (physical activity)	0.73	24.29
										Function	FABQ (work)	0.24	16.06
										Biomechanical	Flexion ROM (°)	0.18	2.67
										Biomechanical	Abduction ROM (°)	0.22	7.56
										Biomechanical	External Rotation ROM (°)	-0.05	-1.54
										Biomechanical	Internal Rotation ROM (°)	0.07	1.61
GunayUcurum 2018	Prospective randomized controlled trial	High risk	Shoulder impingement syndrome	Hot pack + exercises	PROM/Wand, Cadman exercises	ROM, rotator cuff strengthening	EX: 3 days/week + HEP daily, 4 weeks, supervised, progressive.	19	4 weeks	Pain	VAS Pain (rest)	0.28	27.54
										Pain	VAS pain (activity)	1.26	25.51
										Function	SF36 (physical component)	1.02	19.46
										Function	SF36 (mental component)	0.04	0.91

										Function	DASH	0.72	19.84
Gutierrez-Espinoza 2019	Randomized controlled trial	Low risk	Subacromial pain syndrome	Exercise + stretching	Resisted flexion, supine press-up, external rotation, unilateral corner stretch	Stretching, rotator cuff strengthening, scapular stabilizer strengthening	EX: 3 sessions/week, 12 weeks, 8-10 repetitions, supervised, progressive. HEP: 6 exercises, twice daily. STRETCH: 1 minute × 10 repetitions.	40	12 weeks	Function	Constant Murley	2.85	N/A
										Function	DASH	2.53	N/A
										Biomechanical	Pectoralis Minor Resting Length (cm)	1.50	N/A
										Biomechanical	Pectoralis Minor Index (%)	1.40	N/A
				Exercise only	Resisted flexion, supine press-up, external rotation	Rotator cuff strengthening, scapular stabilizer strengthening	3 sessions/week, 12 weeks, 8-10 repetitions, supervised, progressive. HEP: 6 exercises, twice daily.	40		Function	Constant Murley	2.72	N/A
										Function	DASH	3.27	N/A
										Biomechanical	Pectoralis Minor Resting Length (cm)	1.00	N/A
										Biomechanical	Pectoralis Minor Index (%)	0.60	N/A
Haider 2018	Randomized controlled trial	High risk	Subacromial impingement syndrome	Exercise only	AROM, resisted external rotation, seated press up, flexion	ROM, rotator cuff strengthening, other upper limb muscle strengthening	EX: 6 sessions, 3 sessions/week, 2 weeks mobility + strengthening exercises.	20	2 weeks (6 sessions)	Pain	NPRS	2.87	57.01
										Function	SPADI	3.16	47.74

Heron 2017	Parallel group randomised clinical trial	High risk	Rotator cuff tendinopathy/Shoulder impingement syndrome	Minimally loaded range of motion exercises	PROM, AROM	ROM	EX: 3 sessions, 6 weeks, supervised, progressive. HEP: 3 sets × 10 repetitions, twice/day.	40	6 weeks	Function	SPADI	N/A	17.65
				Open chain loading	External rotation, internal rotation, abduction	Rotator cuff strengthening	3 sessions, 6 weeks, supervised, progressive. HEP: 3 sets × 10 repetitions, twice/day.	40		Function	SPADI	N/A	24.49
				Closed chain loading	wall push up, seated press up, quadruped serratus anterior strengthening	Scapular stabilizer strengthening, other upper limb muscle strengthening	3 sessions, 6 weeks, supervised, progressive. HEP: 3 sets × 10 repetitions, twice/day.	40		Function	SPADI	N/A	16.98
Hotta 2018	Quasi-experimental design	N/A	Subacromial pain syndrome	Neuromuscular training	Towel slide, inferior glide, scapular clock, D1 pattern, push-up plus, scaption (full can), horizontal abduction, external rotation, D2 pattern, scapular protraction, rows	Rotator cuff strengthening, scapular stabilizer strengthening, neuromuscular training	EX: 1 hour sessions, 3 times/week, 8 weeks, progressive, neuromuscular + strengthening exercises.	25	8 weeks	Pain	NPS Pain	0.71	50.67
										Function	SPADI	2.58	71.14

Jain 2019	Cohort study	High risk	Rotator cuff tears	Physical therapy	Not specified	Stretching, rotator cuff strengthening, scapular stabilizer strengthening	PT: RC strengthening, scapular stabilization, capsular stretching.	77	18 months	Function	SPADI	0.82	41.86
										Function	ASES	N/A	-41.34
Ketola 2015	Randomized controlled trial	High risk	Subacromial Impingement Syndrome	Exercise program	Not specified	Not specified	Not specified	70, follow up 43		Pain	VAS Self-Reported Pain	N/A	72.31
										Pain	VAS Night Pain	N/A	81.25
										Function	VAS Disability	N/A	80.00
										Function	VAS Working Ability	N/A	35.59
										Function	SDQ Score	N/A	79.27
Ketola 2017	Randomized controlled trial	High risk	Rotator cuff tendinopathy	Exercise program	Not specified	Not specified	Not specified	70, follow up 46		Pain	VAS Self-Reported Pain	N/A	72.31
										Pain	VAS Night Pain	N/A	73.44
										Function	VAS Disability	N/A	69.23
										Function	VAS Working Ability	N/A	-22.03
										Function	SDQ Score	N/A	67.07
Kim 2017	Randomized controlled trial	High risk	Shoulder Impingement syndrome	Visual scapular stabilization exercises	Not specified	Scapular stabilizer strengthening	EX: 20 minute sessions, 3 times/week, 4 weeks.	20	4 weeks	Pain	NPRS	2.12	57.28
										Function	Quick DASH	0.84	37.02
										Strength	Strength (kg)	0.84	27.67
										Biomechanical	ROM (°)	1.41	15.48
				Non-visual scapular stabilization exercise	Not specified	Scapular stabilizer strengthening	EX: 20 minute sessions, 3 times/week, 4 weeks.	20		Pain	NPRS	0.83	27.64
										Function	Quick DASH	0.66	20.28

										Strength	Strength (kg)	0.26	10.88
										Biomechanical	ROM (°)	0.69	10.14
Kim 2019	Prospective, open-label comparative study	N/A	Rotator cuff tendinopathy	Rotator cuff strengthening exercise	Not specified	Rotator cuff strengthening, scapular stabilizer strengthening	EX: 20 minute sessions, 4 days/week.	15, follow up 10	6 weeks	Pain	NRS	N/A	8.33
										Function	ASES	N/A	10.85
										Function	Constant-Murley	N/A	0.37
Kim 2020	Single-blind, randomized , parallel-group study	High risk	Subacromial impingement syndrome	Neurac technique	Shoulder extension, push ups, shoulder abduction, external rotation	Rotator cuff strengthening, scapular stabilizer strengthening	EX: 4 exercises, 3 days/week, 4 weeks, 3 sets × 4 repetitions, progressive.	13	4 weeks	Pain	VAS (mm)	4.06	57.83
										Function	SPADI	1.57	37.63
										Strength	Shoulder External Rotation 60°/s (%)	1.63	112.50
										Strength	Shoulder External Rotation 180°/s (%)	1.48	156.98
										Strength	Shoulder Internal Rotation 60°/s (%)	1.41	73.23
										Strength	Shoulder Internal Rotation 180°/s (%)	1.40	105.60
										Biomechanical	External Rotation ROM (°)	0.59	15.74
										Biomechanical	Internal Rotation ROM (°)	1.16	26.61
Krischak 2013	Prospective randomized controlled trial	High risk	Rotator cuff tear	Home exercise program	Not specified	Not specified	EX: 4-7 exercises, 30 minutes/session, twice/day, 8 weeks.	16	8 weeks	Pain	VAS Pain	0.65	32.69
										Function	Constant-Murley	0.73	18.71

										Function	EQ-5D Quality of Life	0.45	2.09
										Function	EQ-5D Current State of Health	1.06	33.09
										Strength	Abduction Peak Torque (60°/s) (Nm)	0.52	20.57
										Strength	Abduction Peak Torque (120°/s) (Nm)	0.36	11.87
										Strength	External Rotation Peak Torque (60°/s) (Nm)	0.26	12.78
										Strength	External Rotation Peak Torque (180°/s) (Nm)	0.25	10.59
										Biomechanical	Abduction ROM (°)	0.69	21.26
										Biomechanical	Flexion ROM (°)	0.29	6.13
										Biomechanical	External Rotation ROM (°)	0.45	18.30
Kromer 2013	Randomized controlled trial	Low risk	Shoulder impingement	Individually adapted exercises	Low row, internal rotation, scapular protraction, quadruped serratus anterior strengthening, thoracic extension	Rotator cuff strengthening, scapular stabilizer strengthening, postural	EX: 15-20 minutes/session, 10 sessions, first 5 of 12 weeks. HEP: 3 times/week, last 7 of 12 weeks.	44	5 weeks	Pain	Pain SPADI	1.00	36.49
										Pain	VNRS	1.00	34.00
										Function	Total SPADI	0.83	35.11
										Function	Function SPADI	0.58	32.83
										Function	Generic Patient Specific Scale	1.24	57.50
									12 weeks	Pain	Pain SPADI	1.30	51.41
										Pain	VNRS	1.50	54.00
										Function	Total SPADI	1.18	52.06
										Function	Function SPADI	0.93	52.89

										Function	Generic Patient Specific Scale	1.83	85.00
Kromer 2014	Randomized controlled trial	Low risk	Shoulder impingement	Individually adapted exercises	Low row, external rotation, internal rotation, scapular protraction, quadruped serratus anterior strengthening, thoracic extensions, biceps curl, UT stretch	Stretching, rotator cuff strengthening, scapular stabilizer strengthening, postural, strengthening of other upper limb muscles	EX: 15-20 minutes/session, 10 sessions, first 5 of 12 weeks. HEP: 3 times/week, last 7 of 12 weeks.	44, follow up 43	52 weeks	Pain	Pain SPADI	2.17	75.00
										Function	Total SPADI	1.93	75.30
										Function	Function SPADI	1.49	76.60
										Function	Generic Patient Specific Scale	2.63	115.00
Kukkonen 2015	Randomized, controlled, superiority trial	Low risk	Rotator cuff tear	Physiotherapy	Not specified	ROM, rotator cuff strengthening, scapular stabilizer strengthening	EX: ROM/scapular retraction (first 6 weeks) + strengthening (6 weeks to 6 months) + 10 PT sessions, 6 months, progressive.	55	24 months	Function	Constant Murley	1.10	29.77
										Biomechanical	Supraspinatus Tendon Tear Size (mm)	0.10	8.33
Letafatkar 2020	Randomized controlled trial	Some concerns	Shoulder impingement syndrome	Exercise only	UT stretch, unilateral (pectoralis) stretch, posterior shoulder (cross-body) stretch, resisted external rotation, prone shoulder extension, scapular protraction	Stretching, rotator cuff strengthening, scapular stabilizer strengthening	EX: 1 hour sessions, 3 days/week, 8 weeks, supervised.	40, follow up 37	8 weeks	Pain	NRS	1.07	35.59
										Function	DASH	0.88	32.91

										Biomechanical	Sagittal Plane Elevation - Scapular Internal Rotation	0.16	2.52
										Biomechanical	Sagittal Plane Elevation - Scapular Upward Rotation	0.29	18.07
										Biomechanical	Sagittal Plane Elevation - Scapular Posterior Tilt	-0.88	460.00
										Biomechanical	Sagittal Plane Elevation - Scapular Internal Rotation	0.24	3.68
										Biomechanical	Sagittal Plane Elevation - Scapular Upward Rotation	0.15	7.28
										Biomechanical	Sagittal Plane Elevation - Scapular Posterior Tilt	-0.34	140.00
Lewis 2017	Randomized clinical trial	High risk	Subacromial pain syndrome	Advice + exercise	Not specified	ROM, Rotator cuff strengthening, scapular stabilizer strengthening	EX: 50-55 minutes/session, 6 sessions, 6 weeks, supervised.	73, follow up 54	6 weeks	Function	Oxford Shoulder Score	-1.09	-20.53
										Biomechanical	Shoulder Flexion ROM (°)	0.75	22.15
										Biomechanical	Shoulder Abduction ROM (°)	0.64	24.37
										Biomechanical	Shoulder Lateral Rotation (°)	0.10	1.73
Littlewood 2016	Unblinded parallel group randomized controlled trial	Some concerns	Rotator cuff tendinopathy	Self managed loaded exercise	Not specified	Not specified	EX: 3 sets × 10-15 repetitions, twice/day, progressive.	42, follow up 27	3 months	Pain	SF36 Bodily Pain	0.65	27.16
										Function	SPADI	0.88	34.01

										Function	SF36 Physical Functioning	-0.14	-5.18
										Function	General Self-Efficacy Scale	N/A	1.23
Lombardi 2008	Randomized Controlled Trial	Some concerns	Shoulder Impingement syndrome	Progressive resistance training	Resisted flexion, extension, external rotation, internal rotation	Rotator cuff strengthening, scapular stabilizer strengthening	EX: twice/week, 8 weeks, progressive.	30	2 months	Pain	VAS (rest)	0.80	42.86
										Pain	VAS (movement)	1.39	29.73
										Pain	SF36 Pain	0.66	25.40
										Function	DASH 2	0.87	42.14
										Function	DASH 3	0.59	24.55
										Function	SF36 Physical Function	0.49	17.34
										Function	SF36 Physical Role Limitation	0.13	15.77
										Function	SF36 General Health	0.03	0.68
										Function	SF36 Vitality	0.10	4.58
										Function	SF36 Social Function	0.24	10.20
										Function	SF36 Emotional Role Limitation	0.55	55.55
										Function	SF36 Mental Health	0.40	17.57
										Strength	Peak Torque Flexion (Nm)	0.30	14.51
										Strength	Total Work Flexion (Joules)	0.30	16.09
										Strength	Peak Torque Extension (Nm)	0.18	9.28
										Strength	Total Work Extension (Joules)	0.19	11.03
										Strength	Peak Torque Abduction (Nm)	0.19	10.27
										Strength	Total Work Abduction (Joules)	0.09	6.95
										Strength	Peak Torque Adduction (Nm)	0.26	15.75
										Strength	Total Work Adduction (Joules)	0.16	13.37
										Strength	Peak Torque Medial Rotation (Nm)	0.28	12.10
										Strength	Total Work Medial Rotation (Joules)	0.34	17.13

										Strength	Peak Torque Lateral Rotation (Nm)	0.20	9.09
										Strength	Total Work Lateral Rotation (Joules)	0.40	36.45
										Biomechanical	Flexion ROM (°)	0.42	8.21
										Biomechanical	Abduction ROM (°)	0.76	17.21
										Biomechanical	Medial Rotation with shoulder at 90° abduction ROM (°)	0.38	13.25
										Biomechanical	Lateral Rotation with shoulder at 90° abduction ROM (°)	0.38	9.39
										Biomechanical	Lateral Rotation with arm alongside body ROM (°)	0.23	5.65
										Biomechanical	Extension ROM (°)	0.72	13.07
Ludewig 2003	Randomized controlled trial	Some concerns	Shoulder pain and impingement syndrome	Home exercise program	Posterior shoulder (cross-body) stretch, bilateral corner stretch, supine press-up, external rotation	Stretching, rotator cuff strengthening, scapular stabilizer strengthening	EX: 3 days/week, 8 weeks, progressive.	34	8 weeks	Pain	Work Related Pain	1.20	41.67
										Function	Shoulder Rating Questionnaire	0.97	18.36
										Function	Work Related Disability	0.93	39.02
Martins 2012	Randomized controlled clinical trial	High risk	Rotator cuff disorder	Proprioceptive exercise	Pendulum, PROM/Wand, rhythmic stabilization	ROM, neuromuscular training	EX: 2 sessions/week, 6 weeks, progressive (stretching, strengthening, proprioceptive exercises).	8	8 weeks	Function	WORC Physical Symptoms	N/A	N/A

										Function	WORC Sports/Recreation	N/A	N/A
										Function	WORC Work	N/A	N/A
										Function	WORC Lifestyle	N/A	N/A
										Function	WORC Emotions	N/A	N/A
										Function	WORC Overall QOL	N/A	N/A
Marzetti 2014	Randomized, non-inferiority clinical trial	High risk	Shoulder impingement syndrome (Neer stage I)	Neurocognitive therapeutic exercise	Not specified	Neuromuscular	EX: 1 hour session, 15 sessions, 3 sessions/week, 5 weeks.	24	5 weeks	Pain	VAS (rest)	N/A	60.58
										Pain	VAS (movement)	N/A	20.81
										Function	Quick DASH	N/A	24.39
										Function	Constant Murley	N/A	15.90
										Function	ASES	N/A	31.12
				Traditional therapeutic exercise	Not specified	ROM, stretching, rotator cuff strengthening, scapular stabilizer strengthening	EX: 1 hour session, 15 sessions, 3 sessions/week, 5 weeks.	24		Pain	VAS (rest)	N/A	-4.29
										Pain	VAS (movement)	N/A	23.51
										Function	Quick DASH	N/A	18.20
										Function	Constant Murley	N/A	6.24
										Function	ASES	N/A	5.73
Merolla 2013	Non-randomized comparative study	N/A	Rotator cuff tendinopathy	Physiotherapy	Not specified	Stretching, rotator cuff strengthening, neuromuscular training	EX: 3 times/week, 30 days.	25	4 weeks	Pain	VAS (overall)	0.69	11.58
										Pain	VAS (night)	1.05	14.73

										Pain	VAS (activity)	1.28	16.25
										Function	Constant Murley	3.16	11.91
										Function	Oxford Shoulder Score	-2.69	-11.14
Moezy 2014	Randomized clinical trial	High risk	Subacromial impingement syndrome	Exercise	External rotation, D2 patten, protraction, trapezius lifts, scapular clock, sleeper stretch, bilateral corner (pectoralis) stretch, posterior shoulder (cross-body) stretch	Stretching, rotator cuff strengthening, scapular stabilizer strengthening, neuromuscular training	EX: 3 sets × 10 repetitions, 3 times/week, 6 weeks, supervised, progressive.	33		Pain	VAS	2.72	62.95
										Biomechanical	Shoulder Abduction ROM (°)	1.41	20.13
										Biomechanical	Shoulder External Rotation ROM (°)	0.94	24.40
										Biomechanical	Scapular Protraction	0.07	0.56
										Biomechanical	Scapular Rotation	0.08	0.38
										Biomechanical	Scapular Symmetry	0.00	0.00
										Biomechanical	Forward Shoulder Translation	0.31	2.76
										Biomechanical	Forward Head Posture	-0.46	-2.66
										Biomechanical	Mid Thoracic Curve	0.34	3.42
										Biomechanical	Pectoralis Minor Length	0.42	4.09

Moslehi 2020	Randomized controlled trial	High risk	Subacromial impingement syndrome	Scapula focused treated + feedback	Not specified	Stretching, rotator cuff strengthening, scapular stabilizer strengthening	EX: 8 weeks.	25	8 weeks	Pain	VAS	1.79	62.50
										Function	DASH	0.99	29.10
										Biomechanical	Sagittal Plane Elevation - Scapular Internal Rotation	0.24	4.79
										Biomechanical	Sagittal Plane Elevation - Scapular Upward Rotation	0.59	24.14
										Biomechanical	Sagittal Plane Elevation - Scapular Posterior Tilt	-2.32	440.00
										Biomechanical	Sagittal Plane Elevation - Scapular Internal Rotation	0.92	5.21
										Biomechanical	Sagittal Plane Elevation - Scapular Upward Rotation	0.93	9.80
										Biomechanical	Sagittal Plane Elevation - Scapular Posterior Tilt	-0.52	160.00
				Scapula focused treatment + no feedback	Not specified	Stretching, rotator cuff strengthening, scapular stabilizer strengthening	EX: 8 weeks.	25		Pain	VAS	1.76	49.18
										Function	DASH	1.56	50.00
										Biomechanical	Sagittal Plane Elevation - Scapular Internal Rotation	0.37	5.94
										Biomechanical	Sagittal Plane Elevation - Scapular Upward Rotation	1.29	44.44
										Biomechanical	Sagittal Plane Elevation - Scapular Posterior Tilt	-2.67	550.00
										Biomechanical	Sagittal Plane Elevation - Scapular Internal Rotation	0.69	2.77

										Biomechanical	Sagittal Plane Elevation - Scapular Upward Rotation	3.82	35.09
										Biomechanical	Sagittal Plane Elevation - Scapular Posterior Tilt	-0.98	700.00
Nakra 2013	Pretest-post test experimental group	High risk	Secondary shoulder impingement	Conventional treatment + PNF	Anterior shoulder stretch, external rotation, internal rotation, seated press up, push up plus, scaption (empty can), D1 pattern	Stretching, rotator cuff strengthening, scapular stabilizer strengthening, neuromuscular training, other upper limb muscle strengthening	EX: 3 sets × 10 repetitions, 9 sessions, 3 weeks, supervised. PNF: 3 sets × 10 repetitions, 9 sessions, 3 weeks, supervised.	15	3 weeks	Function	SPADI	3.16	52.63
										Biomechanical	Overhead Reach (cm)	1.31	19.58
				Conventional treatment	Anterior shoulder stretch, external rotation, internal rotation, seated press up, push up plus, scaption (empty can)	Stretching, rotator cuff strengthening, scapular stabilizer strengthening, other upper limb muscle strengthening	EX: 3 sets × 10 repetitions, 9 sessions, 3 weeks, supervised.	15		Function	SPADI	0.86	18.39
										Biomechanical	Overhead Reach (cm)	0.52	8.58

Nejati 2017	Randomized controlled trial	High risk	Subacromial impingement syndrome	Exercise therapy	PROM/Wand, AAROM, abduction, external rotation, internal rotation, extension, rows/scapular retraction	ROM, Rotator cuff strengthening, scapular stabilizer strengthening	EX: Once/week, 3 months, supervised. HEP: Daily, 4 times/week, 6 months, unsupervised.	20	6 months	Pain	VAS	1.70	40.00
										Function	Total WORC	1.99	70.08
										Function	DASH	1.73	48.12
										Biomechanical	Shoulder Flexion ROM (°)	1.37	40.05
										Biomechanical	Shoulder Extension ROM (°)	1.58	26.14
										Biomechanical	Shoulder Abduction ROM (°)	2.32	82.90
										Biomechanical	Shoulder Internal Rotation ROM (°)	4.82	232.62
										Biomechanical	Shoulder External Rotation ROM (°)	0.95	25.33
Notarnicola 2020	Randomized clinical trial	High risk	Partial Rotator Cuff tear	Therapeutic exercise	Not specified	Rotator cuff strengthening	EX: 5 times/week, 12 weeks, progressive.	15	3 months	Pain	VAS	0.59	8.00
										Function	ASES	0.31	11.71
										Strength	Manual Muscle Strength Testing Scale	-0.31	-6.06
										Biomechanical	Length of Lesion - Longitudinal Axis (mm)	0.11	3.13
										Biomechanical	Length of Lesion - Transversal Axis (mm)	0.04	1.82

										Biomechanical	Length of Lesion - Anteroposterior Axis (mm)	0.44	13.79
Oledzka 2017	Not specified	N/A	Subacromial impingement syndrome	PNF exercises	PNF exercises - not specified	Neuromuscular	EX: 40 minutes/session, 1 session.	11	40 minutes	Biomechanical	Active Shoulder Flexion ROM (°)	N/A	13.39
										Biomechanical	Passive Shoulder Flexion ROM (°)	N/A	11.48
										Biomechanical	Active Shoulder Abduction ROM (°)	N/A	13.83
										Biomechanical	Passive Shoulder Abduction ROM (°)	N/A	17.14
										Biomechanical	Active Shoulder External Rotation ROM (°)	N/A	47.06
										Biomechanical	Passive Shoulder External Rotation ROM (°)	N/A	31.82
										Biomechanical	Active Shoulder Internal Rotation ROM (cm)	N/A	-9.52
										Biomechanical	Passive Shoulder Internal Rotation ROM (cm)	N/A	-10.26
Osteras 2010 (The Open Orthopaedics Journal)	Randomized clinical trial	High risk	Shoulder impingement syndrome	High dose progressive resistance exercise	Not specified	Not specified	EX: 11 exercises, 3 sets × 30 repetitions, HR 70-80% maximum, 3 times/week, 12 weeks, supervised, progressive.	29, follow up 27	12 weeks	Pain	VAS	1.96	56.58
										Function	SRQ	2.12	43.29

										Biomechanical	Flexion ROM (°)	1.68	41.33
										Biomechanical	Abduction ROM (°)	0.97	38.33
Osteras 2010 (Physiotherapy Research International)	Randomized, controlled clinical trial	High risk	Primary shoulder impingement	High dose progressive resistance exercise	Not specified	Not specified	EX: 11 exercises, 3 sets × 30 repetitions, HR 70-80% maximum, 3 times/week, 12 weeks, supervised, progressive.	31	3 months	Pain	VAS	2.17	63.79
										Function	Shoulder Rating Questionnaire	2.06	58.12
				Low dose progressive resistance exercise	Not specified	Not specified	EX: 6 exercises, 2 sets × 10 repetitions, HR 70-80% maximum, 3 times/week, 12 weeks, supervised, progressive.	27, follow up 25		Pain	VAS	1.11	32.79
										Function	Shoulder Rating Questionnaire	0.56	17.58
Paavola 2018	Randomized, double blind sham controlled study	High risk	Shoulder impingement syndrome	Exercise therapy	Not specified	Not specified	EX: 15 sessions, 12 weeks, supervised, progressive. HEP: Daily, 12 weeks.	71, follow up 68	24 months	Pain	VAS (rest)	2.47	69.30
										Pain	VAS (activity)	3.79	61.19
										Function	Constant-Murley	2.18	102.27
										Function	Simple Shoulder Test	1.04	102.08

Paavola 2020	Randomized, controlled superiority trial	Low risk	Shoulder impingement syndrome	Exercise therapy	Scapular retraction, AAROM (all directions), wall push ups, thoracic extensions, external rotation, internal rotation, flexion, pendulum, scapular clock, PNF D1 pattern, horizontal abduction	ROM, Rotator cuff strengthening, scapular stabilizer strengthening, neuromuscular training, postural	EX: 15 sessions, 12 weeks, supervised, progressive. HEP: Daily, 12 weeks.	71, follow up 62	5 years	Pain	VAS (rest)	1.58	87.29
										Pain	VAS (activity)	2.76	77.21
										Function	Constant-Murley	2.75	126.70
										Function	Simple Shoulder Test	1.28	122.92
										Function	SF36 (physical health)	1.01	15.59
										Function	SF36 (mental health)	0.39	8.33
Park 2020	Randomized controlled pilot study	High risk	Subacromial impingement syndrome	Exercise alone	Foam roller stretches, marching on roller, thoracic extension, neck and chest stretch (not specified)	Stretching, postural	EX: 15 minutes/session, 3 sessions/week, 4 weeks, thoracic spine, supervised.	10	4 weeks	Pain	SPADI (pain)	1.08	25.56
										Function	SPADI (disability)	0.66	19.38
										Function	SPADI (total)	0.81	21.77
										Biomechanical	Thoracic Kyphosis Angle (°)	1.16	6.12
										Biomechanical	Upper Trapezius Muscle Tone (Hz)	0.85	6.86
										Biomechanical	Upper Trapezius Muscle Stiffness (N/m)	0.91	8.38
										Biomechanical	Pectoralis Minor Muscle Tone (Hz)	0.69	5.33
										Biomechanical	Pectoralis Minor Muscle Stiffness (N/m)	0.70	6.79

										Biomechanical	Shoulder Flexion ROM (°)	0.48	5.62
										Biomechanical	Shoulder Abduction ROM (°)	0.76	6.92
										Biomechanical	Shoulder Medial Rotation (°)	0.27	5.66
										Biomechanical	Shoulder Lateral Rotation (°)	0.30	3.59
Pekyavas 2016	Single blind randomized control trial	High risk	Subacromial impingement syndrome	Exercise alone	Not specified	ROM, stretching, rotator cuff strengthening, scapular stabilizer strengthening	EX: 10-15 minutes/sessions, 7 times/week, 15 days.	15	15 days	Pain	SPADI (pain)	7.21	94.05
										Function	SPADI (disability)	2.54	80.30
										Function	SPADI (total)	0.34	13.44
										Biomechanical	Shoulder External Rotation ROM (°)	0.37	4.65
										Biomechanical	Shoulder Abduction ROM (°)	0.37	2.66
										Biomechanical	Shoulder Flexion ROM (°)	0.37	1.89
Senbursa 2007	Prospective, randomized clinical trial	High risk	Shoulder Impingement syndrome	Self-training program with ROM, stretching, strengthening exercises	Not specified	ROM, stretching, rotator cuff strengthening	EX: 10-15 minutes/sessions, 7 times/week, 4 weeks, supervised, progressive.	15	4 weeks	Pain	VAS (night)	2.79	80.33
										Pain	VAS (motion)	1.74	60.32
										Pain	VAS (rest)	0.77	55.00

Seven 2017	Randomized prospective comparative trial	High risk	Chronic rotator cuff injury	Exercise	Not specified	Not specified	EX: 30 minutes/session, 3 sessions/week, 12 weeks. HEP: 3 times/day, 4 days/week, 12 weeks.	44	12 weeks	Pain	VAS	1.88	45.65
										Function	WORC	1.71	75.11
										Function	SPADI	1.54	45.72
										Biomechanical	Flexion ROM (°)	1.12	23.36
										Biomechanical	Abduction ROM (°)	1.19	26.35
										Biomechanical	Internal Rotation ROM (°)	0.74	16.10
										Biomechanical	External Rotation ROM (°)	0.52	9.18
Shah 2014	Randomized controlled trial	High risk	Shoulder Impingement syndrome	Conventional therapy + scapular stabilization exercises	PROM/Wand exercises, Unilateral corner (pectoralis) stretch, external rotation, internal rotation, scapular clock, horizontal abduction, push up plus, posterior shoulder (cross-body) stretch, wall push ups, levator scapula stretch	ROM, stretching, rotator cuff strengthening, scapular stabilizer strengthening, neuromuscular training	EX1: Strengthening exercises, daily, 3 sets × 8 repetitions, 6 days/week, 4 week. EX2: Scapular stability exercises, daily, 3 sets × 8 repetitions, 6 days/week, 4 weeks.	30	4 weeks	Pain	VAS	6.90	54.33
										Function	SPADI	4.36	57.33

										Biomechanical	Lateral Scapular Slide Test	0.95	17.06
				Conventional therapy	PROM/Wand exercises, Unilateral corner (pectoralis) stretch, external rotation, internal rotation	ROM, stretching, rotator cuff strengthening	EX1: Strengthening exercises, daily, 3 sets × 8 repetitions, 6 days/week, 4 week.	30		Pain	VAS	4.72	42.41
										Function	SPADI	3.93	37.13
										Biomechanical	Lateral Scapular Slide Test	0.54	7.42
Srivastava 2018	Randomized clinical trial	High risk	Shoulder Impingement syndrome	Exercise + cryotherapy	Not specified	Stretching, rotator cuff strengthening	EX: Isometric strengthening exercises (3 sets × 15 repetitions), stretching exercises (30 seconds × 3 repetitions), 6 sessions.	11	6 sessions	Pain	VAS (cm)	2.65	54.93
										Function	SPADI	1.63	57.75
										Biomechanical	Scaption ROM (°)	1.45	20.34

Turkmen 2020	Randomized controlled clinical trial	High risk	Rotator cuff tears	Video-based rehabilitation program	Not specified	Not specified	EX: 3 sessions/day, 10 repetitions, 6 weeks, progressive.	15	6 weeks	Pain	VAS (rest)	0.89	100.00
										Pain	VAS (activity)	4.59	77.28
										Pain	VAS (night)	2.57	94.74
										Function	ASES	3.53	47.73
										Function	Physical Component Score	2.40	30.60
										Function	Mental Component Score	1.16	14.64
										Function	DASH	2.48	83.51
										Biomechanical	Flexion ROM (°)	1.96	24.50
										Biomechanical	Abduction ROM (°)	1.92	39.23
										Biomechanical	Internal Rotation ROM (°)	1.25	22.75
										Biomechanical	External Rotation ROM (°)	1.50	39.81
				Supervised rehabilitation program	Not specified	Not specified	EX: 2 days/week (clinic), 3 sessions/day (home), 5 days/week (home), 10 repetitions (clinic, home), 6 weeks, progressive, supervised.	15		Pain	VAS (rest)	1.71	96.25
										Pain	VAS (activity)	4.18	81.51
										Pain	VAS (night)	3.77	98.75
										Function	ASES	3.53	74.23
										Function	Physical Component Score	3.15	34.40
										Function	Mental Component Score	1.17	17.03
										Function	DASH	2.38	85.31

										Biomechanical	Flexion ROM (°)	2.08	35.57
										Biomechanical	Abduction ROM (°)	2.31	45.39
										Biomechanical	Internal Rotation ROM (°)	1.13	29.14
										Biomechanical	External Rotation ROM (°)	1.65	59.96
Valles-Carrascosa 2018	Randomized clinical trial	High risk	Subacromial syndrome	Painful eccentric: Rotator cuff strengthening and scapular stabilization exercise	Scaption (full can), external rotation, internal rotation, dynamic hug, inferior glide, UT stretch	Stretching, rotator cuff strengthening, scapular stabilizer strengthening	EX: 30 minutes/session, 5 sessions/week, 4 weeks, supervised.	11	4 weeks	Pain	VAS	N/A	67.57
										Biomechanical	Flexion ROM (°)	N/A	30.43
										Biomechanical	Extension ROM (°)	N/A	100.00
										Biomechanical	Abduction ROM (°)	N/A	22.22
										Biomechanical	Adduction ROM (°)	N/A	50.00
										Biomechanical	External Rotation ROM (°)	N/A	100.00
										Biomechanical	Internal Rotation ROM (°)	N/A	84.21
				Non-painful eccentric: Rotator cuff strengthening and scapular stabilizer strengthening exercises	Scaption (full can), external rotation, internal rotation, dynamic hug, inferior glide, UT stretch	Stretching, rotator cuff strengthening, scapular stabilizer strengthening	EX: 30 minutes/session, 5 sessions/week, 4 weeks, supervised.	11		Pain	VAS	N/A	49.09
										Biomechanical	Flexion ROM (°)	N/A	33.33

										Biomechanical	Extension ROM (°)	N/A	50.00
										Biomechanical	Abduction ROM (°)	N/A	44.44
										Biomechanical	Adduction ROM (°)	N/A	100.00
										Biomechanical	External Rotation ROM (°)	N/A	150.00
										Biomechanical	Internal Rotation ROM (°)	N/A	36.00
Vinuesa-Montoya 2017	Preliminary Randomized Clinical Trial	High risk	Shoulder impingement syndrome	Home exercise program	Flexion, extension, seated press-up	Rotator cuff strengthening, scapular stabilizer strengthening, other upper limb muscle strengthening	HEP: 60 minutes/day, daily, 5 weeks.	20, follow up 19	5 weeks	Pain	VAS (cm)	0.53	17.54
										Function	Shoulder Disability Questionnaire	0.62	19.75
										Biomechanical	Flexion ROM (°)	0.56	7.58
										Biomechanical	Extension ROM (°)	0.51	18.11
										Biomechanical	External Rotation ROM (°)	0.46	17.18
										Biomechanical	Internal Rotation ROM (°)	0.36	10.12
										Biomechanical	Adduction ROM (°)	0.76	50.26
										Biomechanical	Abduction ROM (°)	0.57	16.42

Walther 2004	Prospective, randomized study	High risk	Subacromial impingement syndrome	Standardized self-training	Rows/scapular retraction, low rows, UT stretch, pendulum	ROM, stretching, scapular stabilizer strengthening	EX: 4 sessions (clinic), 10-15 minutes/session, 5 times/week, 12 weeks (home).	20	12 weeks	Strength	Constant Murley (maximum strength)	0.18	9.26
Ainsworth 2006	Cohort study	N/A	Full thickness rotator cuff tear	Torbay rehabilitation program	AROM, resisted flexion, external rotation, flexion, wall slides	ROM, rotator cuff strengthening, scapular stabilization	EX: 30mins/week (in clinic) HEP: 3 exercises, 2-3x/day, progressed	25	8 weeks	Function	Oxford Shoulder Score	N/A	30.99
										Function	SF36 (physical health)	N/A	40.00
										Function	SF36 (role emotional)	N/A	-28.75
										Function	SF36 (general health)	N/A	-12.86
Baumer 2016	Controlled laboratory study	N/A	Full-thickness rotator cuff tear	Standard physical therapy protocol	Not specified	ROM, rotator cuff strengthening, scapular stabilization	PT: 2-3x/week, 8 weeks; HEP: ROM 1x/day, rotator cuff strengthening and scapulothoracic retraining exercises 3x/week	25	12 weeks	Pain	VAS	0.87	55.26
										Function	WORC	1.20	73.15
										Strength	Normalized strength (%) ABD	-0.12	-6.43
										Strength	Normalized strength (%) ELEV	-0.49	-24.78
										Strength	Normalized strength (%) ER	0.56	20.78
										Strength	Normalized strength (%) IR	0.34	12.26
										Biomechanical	Active ROM (%) ABD	0.87	25.25
										Biomechanical	Active ROM (%) ELEV	0.74	20.40
										Biomechanical	Active ROM (%) ER	0.70	20.56
										Biomechanical	Active ROM (%) IR	0.64	37.81
										Biomechanical	Passive ROM (%) ABD	0.67	21.52

										Biomechanical	Passive ROM (%) ELEV	0.87	21.35
										Biomechanical	Passive ROM (%) ER	0.64	18.98
										Biomechanical	Passive ROM (%) IR	0.60	27.70
										Biomechanical	ST ROM (deg) Internal/External rotation	0.08	4.85
										Biomechanical	ST ROM (deg) AP tilt	0.70	23.00
										Biomechanical	ST ROM (deg) Upward/downward rotation	0.35	15.13
										Biomechanical	GH ROM (deg) Elevation	0.72	27.84
										Biomechanical	Joint contact path length (% glenoid height)	0.41	23.60
										Biomechanical	Mean SI position (% glenoid height)	-0.07	-25.00
										Biomechanical	Mean AP position (% glenoid width)	-0.01	2.08
										Biomechanical	SI range (% glenoid height)	0.48	29.09
										Biomechanical	AP range (% glenoid width)	0.41	23.94
										Biomechanical	Acromiohumeral distance	-0.19	-7.32
Bernhardsson 2011	Single-subject research design with baseline and treatment phases (AB design)	N/A	Subacromial impingement syndrome	Eccentric rotator cuff strengthening exercises	Scapular retraction, shoulder shrugs, external rotation, abduction, UT stretch	Stretching, rotator cuff strengthening, scapular stabilizer strengthening	EX: 3 sets x 15 repetitions, 2x/day, 7days/week, 12 weeks	11	12 weeks	Pain	VAS (mm) (median)	N/A	49.12
										Function	PSFS (pts) median	N/A	92.31
Camargo 2009	Single group - study design not specified	N/A	Subacromial impingement syndrome	Exercise	UT stretch, posterior shoulder (cross body), bilateral corner (pectoralis) stretch, external rotation, scapular protraction, external rotation, abduction, scapular retraction	Stretching, rotator cuff strengthening, scapular stabilizer strengthening	EX: 3sets x 10reps (strengthening exercises), 2x/day, alternate days, 8 weeks	14	8 weeks	Function	DASH (total)	0.96	56.81
										Function	DASH (work)	0.82	55.75
Camargo 2012	Case series	N/A	Shoulder impingement syndrome	Eccentric training of shoulder abductors	Eccentric shoulder abduction	Rotator cuff strengthening	EX: 2 days/week, 3setsx10reps, 3 min rets	20	6 weeks	Function	DASH (total)	1.68	32.07

										Biomechanical	60deg/s Peak Torque (concentric) (Nm)	0.58	4.79
										Biomechanical	60deg/s Peak Torque (eccentric) (Nm)	0.74	6.47
										Biomechanical	60deg/s Total Work (concentric) (J)	0.42	3.72
										Biomechanical	60deg/s Total Work (eccentric) (J)	1.63	31.79
										Biomechanical	60deg/s Acceleration time (concentric) (ms)	2.41	24.71
										Biomechanical	60deg/s Acceleration time (eccentric) (ms)	-1.46	-20.63
										Biomechanical	120deg/s Peak Torque (concentric) (Nm)	1.06	8.62
										Biomechanical	120deg/s Peak Torque (eccentric) (Nm)	0.56	5.35
										Biomechanical	120deg/s Total Work (concentric) (J)	0.94	7.75
										Biomechanical	120deg/s Total Work (eccentric) (J)	1.05	16.00
										Biomechanical	120deg/s Acceleration time (concentric) (ms)	-0.42	-2.43
										Biomechanical	120deg/s Acceleration time (eccentric) (ms)	-1.56	-20.15
DeMey 2012	Case series	N/A	Mild Impingement symptoms	Home exercise program	Horizontal abduction, external rotation, forward flexion, prone extension	Rotator cuff strengthening, scapular stabilizer strengthening	HEP: 3sets x 10reps, 1 min rest between sets, daily, 6 weeks	47	6 weeks	Function	SPADI	1.18	61.15
										Biomechanical	Mean EMG activity during MVIC - Upper Trapezius	-0.55	-44.59
										Biomechanical	Mean EMG activity during MVIC - Middle Trapezius	0.36	26.73
										Biomechanical	Mean EMG activity during MVIC - Lower Trapezius	0.48	32.54
										Biomechanical	Mean EMG activity during MVIC - Serratus Anterior	0.13	10.42

Ferrer 2018	Prognostic study	N/A	Supraspinatus tears	Exercise therapy focused on ROM, strengthening rotator cuff, scapular stabalizer muscles	PROM/Wand, scaption (full can), prone extension, biceps curl, triceps push down, lat pull down, rythmic stabilization, AAROM, external rotation, internal rotation towel stretch, sleeper stretch, rows/scapular traction, posterior shoulder stretch, internal rotation, scapular protraction, wall push up plus	ROM, stretching, rotator cuff strengthening, scapular stabilizer strengthening, other upper limb muscle strengthening	EX: first 6 weeks supervised, 45-60min/session, 2 sessions/week HEP: 1x/day, 6 weeks	5	12 weeks	Function	ASES	2.09	73.77
										Function	DASH	2.25	84.00
										Function	WORC	2.30	71.24
										Strength	External Rotation @0 deg abduction Strength (N)	1.09	54.80
										Strength	Internal Rotation @ 0def abductionStrength (N)	0.70	30.97
										Strength	External Rotation @90 deg abduction Strength (N)	1.23	73.88
										Strength	Scaption @ 90deg abduction Strength (N)	0.91	54.36

										Biomechanical	SI contact centre range (% glenoid SI height)	0.00	0.21
										Biomechanical	AP contact centre range (% glenoid AP width)	0.86	52.91
										Biomechanical	Contact path length (% glenoid height)	-0.16	-11.56
Goldberg 2001	Single group - study design not specified	N/A	Rotator cuff tear	Exercise: Stretching and strengthening rotator cuff, deltoid, pectoalis major and tapezius muscles	AROM, posterior shoulder (cross body) stretch, supine press	ROM, stretching, scapular stabilizer strengthening	Not specified	46	6 months	Function	Simple shoulder test function - comfortable at side	N/A	11.94
										Function	Simple shoulder test function - sleep on side	N/A	81.08
										Function	Simple shoulder test function - tuck shirt behind	N/A	48.15
										Function	Simple shoulder test function - hand behind head	N/A	5.71
										Function	Simple shoulder test function - place coin on shelf	N/A	30.00
										Function	Simple shoulder test function - place 8lbs on shelf	N/A	18.75
										Function	Simple shoulder test function - carry 20lbs	N/A	-3.70
										Function	Simple shoulder test function - Toss underhand	N/A	0.00
										Function	Simple shoulder test function - Throw overhead	N/A	48.78
										Function	Simple shoulder test function - wash opposite shoulder	N/A	38.46
										Function	Simple shoulder test function - do usual work	N/A	-5.95
										Function	SF36 - physical role	N/A	21.12
										Function	SF36 - comfort	N/A	-17.33
										Function	SF36 - vitality	N/A	-20.03
										Function	SF36 - physical function	N/A	0.96
										Function	SF36 - emotional role	N/A	-7.90
										Function	SF36 - social function	N/A	-5.07
										Function	SF36 - mental health	N/A	-20.42

										Function	SF36 - general health	N/A	-9.07
										Function	SF36 - physical component summary	N/A	-3.51
Hotta 2018	Single group - study design not specified	N/A	Shoulder impingement syndrome	Exercises focused on scapular stabilizer strengthening and neuromuscular control	Resisted flexion, towel slide, scapular clock	Rotator cuff strengthening, neuromuscular training	EX: each exercise repeated 4 times	26	Immediately after exercise	Biomechanical	Posterior tilt - elevation 30deg	0.10	-6.94
										Biomechanical	Posterior tilt - elevation 60deg	0.16	-13.04
										Biomechanical	Posterior tilt - elevation 90deg	0.17	-13.48
										Biomechanical	Anterior/Posterior tilt - elevation 110deg	0.04	-4.55
										Biomechanical	Posterior tilt - lowering 30deg	-0.09	10.75
										Biomechanical	Posterior tilt - lowering 60deg	-0.04	3.70
										Biomechanical	Posterior tilt - lowering 90deg	-0.14	12.12
										Biomechanical	Posterior tilt - lowering 110deg	-0.18	14.08
										Biomechanical	Internal rotation - elevation 30deg	-0.25	11.40
										Biomechanical	Internal rotation - elevation 60deg	-0.20	4.60
										Biomechanical	Internal rotation - elevation 90deg	-0.13	1.96
										Biomechanical	Internal rotation - elevation 110deg	-0.09	1.30
										Biomechanical	Internal rotation - lowering 30deg	-0.03	0.37
										Biomechanical	Internal rotation - lowering 60deg	-0.06	1.06
										Biomechanical	Internal rotation - lowering 90deg	-0.24	6.60
										Biomechanical	Internal rotation - lowering 110deg	-0.33	15.08
										Biomechanical	Upward rotation - elevation 30deg	-0.46	-7.08
										Biomechanical	Upward rotation - elevation 60deg	-0.41	-6.52

										Biomechanical	Upward rotation - elevation 90deg	-0.27	-5.66
										Biomechanical	Upward rotation - elevation 110deg	-0.14	-3.94
										Biomechanical	Upward rotation - lowering 30deg	-0.11	-3.69
										Biomechanical	Upward rotation - lowering 60deg	-0.24	-5.51
										Biomechanical	Upward rotation - lowering 90deg	-0.32	-5.66
										Biomechanical	Upward rotation - lowering 110deg	-0.38	-6.17
Jonsson 2006	Pilot study group study - design not specified	N/A	Chronic painful impingement syndrome	Eccentric training of supraspinatus muscle	Eccentric scaption (empty can)	Rotator cuff strengthening	EX: 3 setsx15 reps, 2x/day, 7 days/week, 12 wks	9	12 weeks	Pain	VAS (mm)	1.21	43.56
										Function	Constant Score	0.62	20.04
Kachanathu 2019	Single group - design not specified	N/A	Shoulder impingement syndrome	Dynamic shoulder stabilization intervention	Sleeper stretch, low row, rhythmic stabilization, D2 pattern	Stretching, scapular stabilizer strengthening	EX: 3x/week, 4 wks, supervised	16	4 weeks	Strength	Hand grip strength (kg)	0.60	39.26
McClure 2004	Repeated-measures design	N/A	Shoulder impingement syndrome	Exercise intervention focused on stretching of posterior capsule/pectoralis minor/thoracic spine, strengthening rotator cuff and scapular stabilizers, postural awareness	PROM/Wand, External rotation, internal rotation, extension, abduction, flexion, scapular retraction, internal rotation towel stretch, posterior shoulder (cross-body) stretch, bilateral corner (pectoralis) stretch, chin tucks, thoracic extension	ROM, stretching, rotator cuff strengthening, scapular stabilizer strengthening, postural	EX: 2 or 3sets x10reps, 1x/day, stretches: 30sec hold, 3reps	39	6 weeks	Pain	Pennsylvania Shoulder Scale Score - Pain subscale	1.51	49.11
										Function	Pennsylvania Shoulder Scale - functional subscale	0.95	19.91
										Strength	Internal rotation isometric force (N)	0.54	26.65
										Strength	Extremal rotation isometric force (N)	0.46	16.78
										Strength	Abduction isometric force (N)	0.27	15.62
										Biomechanical	Thoracic Posture (deg)	0.11	5.93
										Biomechanical	Internal rotation ROM (vertebral level) (deg)	-0.57	-20.45
										Biomechanical	External rotation ROM (deg)	0.50	7.40
										Biomechanical	External rotation ROM @ 90deg ABD (deg)	0.56	15.70

										Biomechanical	Elevation ROM (deg)	0.19	2.61
Miller 2016	Single group - study design not specified	N/A	Full-thickness supraspinatus tear	Exercise therapy focused on ROM, strengthening rotator cuff, scapular stabilizer muscles	PROM/Wand, scaption (full can), prone extension, biceps curl, triceps push down, lat pull down, rhythmic stabilization, AAROM, external rotation, internal rotation towel stretch, sleeper stretch, rows/scapular traction, posterior shoulder stretch, internal rotation, scapular protraction, wall push up plus	ROM, stretching, rotator cuff strengthening, scapular stabilizer strengthening, other upper limb muscle strengthening	EX: first 6 weeks supervised, 45-60min/session, 2 sessions/week HEP: 1x/day, 6 weeks	5	12 weeks	Function	ASES	2.09	73.77
										Function	DASH	2.25	84.00
										Function	WORC	-2.30	-71.24
										Strength	External Rotation @0 deg abduction Strength (N)	1.09	54.80
										Strength	Internal Rotation @ 0def abduction Strength (N)	0.70	30.97
										Strength	External Rotation @90 deg abduction Strength (N)	1.23	73.88

										Strength	Scaption @ 90deg abduction Strength (N)	0.91	54.36
Osteras 2010 (Journal of Bodywork & Movement Therapies)	Case series	N/A	Subacromial pain syndrome	High dosage exercise therapy	Not specified	Not specified	EX: 3sets x 30 repetitions, 30sec rest	6	3 months	Pain	VAS	1.96	56.58
										Function	SRQ	2.12	43.29
										Biomechanical	ROM flexion (deg)	1.68	41.33
										Biomechanical	ROM abduction (deg)	0.97	38.33
										Biomechanical	Supraspinatus Tendon Diameter (mm)	0.00	0.00
Peteraitis 2020	Case report	N/A	Subacromial impingement syndrome	Proprioceptive Neuromuscular Facilitation	D1 pattern, D2 pattern	Neuromuscular training	EX: 2x/week, 45 mins/session	1	5 weeks	Function	PSFS	N/A	43.40
										Function	SPADI	N/A	75.38
										Function	ASES	N/A	76.20
										Function	PSC Office binders	N/A	-71.43
										Function	PSC cupboard	N/A	-71.43

										Function	PSC tuck in shirt	N/A	-85.71
Roe 2000	Before-after trial	N/A	Rotator tendinosis	Supervised exercise program including stretching, range of motion exercises and rotator cuff strengthening	PROM, Anterior shoulder stretch, posterior shoulder stretch, unilateral corner (pectoralis) stretch, levator scapula stretch, abudction, external rotation, internal rotation	ROM, stretching, rotator cuff strengthening	EX: 3setsx20 reps, 2x/week, 1 hour/session, HEP: 1x/day	10	3-6 months	Pain	VAS	2.32	37.04
										Pain	Pain during activity (score)	N/A	30.00
										Pain	Pain at rest (score)	N/A	66.67
										Pain	Pain at night (score)	N/A	66.67
										Biomechanical	Trapezius Absolute Value of Average rectified EMG during MVC	2.53	62.69
										Biomechanical	Deltoid Absolute Value of Average rectified EMG during MVC	-3.89	-127.78
										Biomechanical	Infraspinatus Absolute Value of Average rectified EMG during MVC	1.67	69.64

Rohit 2010	Single group - study design not specified	N/A	Shoulder impingement syndrome	Supervised exercise program including strengthening of rotator cuff and scapular stabalizers, stretching, postural awareness, education	External rotation, internal rotation, extension, internal rotation towel stretch, posterior shoulder stretch, UT stretch, chin tucks, scaption (full can), rows, unilateral corner (pectoralis) stretch, external rotation stretch	Stretching, rotator cuff strengthening, scapular stabilizer strengthening, postural	EX: 5 visits/week, 4 weeks	30	4 weeks	Function	Penn shoulder scale	2.07	40.47
										Biomechanical	Scapular upward rotation - 30 deg elevation saggital plane	0.59	52.08
										Biomechanical	Scapular upward rotation - 60 deg elevation saggital plane	0.68	36.17
										Biomechanical	Scapular upward rotation - 90 deg elevation saggital plane	0.72	22.69
										Biomechanical	Scapular upward rotation - 120 deg elevation saggital plane	1.06	26.37
										Biomechanical	Scapular upward rotation - 30 deg elevation scapular plane	1.58	126.67
										Biomechanical	Scapular upward rotation - 60 deg elevation scapular plane	1.59	68.42
										Biomechanical	Scapular upward rotation - 90 deg elevation scapular plane	1.47	39.20
										Biomechanical	Scapular upward rotation - 120 deg elevation scapular plane	1.93	40.12

Rosa 2017	Parallel-group intervention with repeated measures	N/A	Symptoms consistent with subacromial impingement syndrome	Pectoralis Minor stretching	Unilateral corner (pectoralis) stretch	Stretching	HEP: 4 reps, 1 min hold, 30 sec rest	25	6 weeks	Function	DASH	0.77	49.84
										Biomechanical	Muscle length - rest (cm)	0.22	2.43
										Biomechanical	Muscle length - retraction (cm)	0.32	3.28
Roy 2009	Single-subject design	N/A	Impingement syndrome	Exercises foced on shoulder neuromuscular control	External rotation, internal rotation, wall push up, horizontal abduction	Rotator cuff strengthening, scapular stabilizer strengthening	EX: 3 sessions/week, progressive + HEP (not specified)	8		Function	SPADI	3.52	100.00
Sahinoglu 2020	Retrospective study	N/A	Rotator cuff disease	Stretching protocol, supervised rotator cuff strengthening exercises, education; Home exercises focused on ROM, stretching, postural and rotator cuff strengthening	Seated press-ups, rows, internal rotation, external rotation, scaption (full can)	Rotator cuff strengthening, scapular stabilizer strengthening, other upper limb muscle strengthening	EX: 3days/week, 6 weeks, HEP: 1x/day, 6 weeks	39	12 weeks	Pain	SPADI (pain)	2.25	68.34
										Function	SPADI (disability)	1.89	73.68
										Function	SPADI (total)	2.13	71.27
										Function	WORC	1.97	87.84
										Strength	Forward flexion strength (kg)	0.92	46.58
										Strength	Abduction strength (kg)	0.93	51.50
										Strength	Full can strength (kg)	0.81	45.99
										Strength	Internal rotation strength (kg)	0.81	31.32
										Strength	External rotation strength (kg)	0.74	24.54
										Biomechanical	Forward flexion ROM (deg)	2.01	13.23
										Biomechanical	Abduction ROM (deg)	1.85	30.61
										Biomechanical	Internal rotation ROM (deg)	1.49	38.59
										Biomechanical	External rotation ROM (deg)	1.01	22.26

Seitz 2019	Prospective case-control pilot study	N/A	Rotator cuff related shoulder pain	Prone horizontal abduction exercises	Horizontal abduction	Scapular stabilizer strengthening	EX: daily, 3 weeks	11	3 weeks	Strength	Abduction normalized strength (% of BW)	0.54	16.67
										Strength	Prone elevation normalized strength (% of BW)	1.11	33.33
										Strength	Flexion normalized strength (% of BW)	0.37	10.11
										Biomechanical	Concentric UT Baseline EMG amplitude	0.37	10.91
										Biomechanical	Eccentric UT Baseline EMG amplitude	0.53	23.33
										Biomechanical	Concentric LT Baseline EMG amplitude	-0.71	-25.00
										Biomechanical	Eccentric LT Baseline EMG amplitude	-0.72	-27.78
Turgut 2018	Single group pretest posttest design	N/A	Subacromial impingement syndrome	Stretching exercise protocol	Unilateral corner (pectoralis) stretch, posterior shoulder (cross body) stretch, levator scapula stretch, latissimus dorsi stretch	Stretching	EX: 3 sets x 5 reps, 30sec hold	18	6 weeks	Pain	VAS (cm) - rest	0.44	74.07
										Pain	VAS (cm) - activity	1.79	64.86
										Pain	VAS (cm) - night	0.75	71.66
										Pain	SPADI (pain)	1.25	47.24
										Function	SPADI (disability)	0.95	47.55
										Function	SPADI (total)	1.10	47.52
										Biomechanical	Posterior capsule tightness	1.00	63.58
										Biomechanical	Pectoralis Minor Tightness	0.85	53.26

Virta 2009	Non-experimental study	N/A	Subacromial impingement syndrome	Supervised exercise program: ROM, rotator cuff strengthening	PROM/Wand, AROM, external rotation, abduction	ROM, rotator cuff strengthening	EX: 2x/week, 1hour/session, HEP: 1x/day	Age group 24-39: 16		Function	UCLA	N/A	88.24
								Age group 40-59: 23		Function	UCLA	N/A	93.75
								Age group 60-80: 13		Function	UCLA	N/A	100.00
Wirth 1997	Single group - study design not specified	N/A	Full-thickness tears of the rotator cuff	Supervised exercise program including ROM exercises, stretching, rotator cuff strengthening and scapular stabilizer strengthening	Not specified	ROM, stretching, rotator cuff strengthening, scapular stabilizer strengthening	Not specified	60	2 years	Function	UCLA	N/A	119.40

Appendix B: Data chart with study and intervention details for studies that investigated exercise compared to no treatment or placebo treatment

First Author, year	Study Design	Diagnosis	Specific exercises	Exercises type	Details	Number of Subjects (n)	Comparator	Number of Subjects (n)	Follow up	Outcome	Outcome Measure	Normalized effect size	Risk of Bias Assessment
Brox 1993	Randomized Clinical Trial	Rotator Cuff Disease	Not specified	ROM, Rotator cuff strengthening, Scapular stabilizer strengthening	60 minutes/session, twice/week, 3-6 months, progressive, supervised. HEP: 5 times/week.	50	Placebo laser	30	6 months	Pain	Pain score (activity)	N/A	Some concerns
										Pain	Pain score (rest)	N/A	
										Pain	Pain score (night)	N/A	
										Pain	Neer Shoulder Score (pain)	N/A	
Brox 1999	Prospective, randomized, Controlled study	Rotator cuff disease (impingement syndrome stage II)	Not specified	ROM, Rotator cuff strengthening, Scapular stabilizer strengthening	60 minutes/session, twice/week, 3-6 months, progressive, supervised. HEP: 5 times/week.	33	Placebo laser	13	2.5 years	Pain	Pain score (activity)	N/A	Some concerns
										Pain	Pain score (night)	N/A	
										Pain	VAS pain (rest)	N/A	
Hotta 2018	Randomized control trial	Subacromial pain syndrome	Towel slide, inferioir glide, scapular clock, D1 pattern, push-up plus, scaption (full can), horizontal abduction, external rotation, D2 pattern, scapular protraction, rows	Rotator cuff strengthening, scapular stabilizer strengthening, neuromuscular training	EX: 1 hour sessions, 3 times/week, 8 weeks, progressive, neuromuscular + strengthening exercises.	25	No treatment	25	8 weeks	Pain	NPS Pain	0.43	N/A
										Function	SPADI	1.40	
										Biomechanical	Resting Position (°) (upward/downward rotation)	N/A	

										Biomechanical	Resting Position (°) (anterior/posterior tilt)	N/A	
										Biomechanical	Resting Position (°) (internal/external rotation)	N/A	
										Biomechanical	Coronal Plane Scapular Movement (°) (upward/downward rotation, lowering, 90°)	N/A	
										Biomechanical	Coronal Plane Scapular Movement (°) (internal/external rotation, elevation, 30°)	N/A	
										Biomechanical	Coronal Plane Scapular Movement (°) (internal/external rotation, elevation, 90°)	N/A	
										Biomechanical	Coronal Plane Scapular Movement (°) (internal/external rotation, elevation, 120°)	N/A	
										Biomechanical	Sagittal Plane Scapular Movement (°) (upward/downward rotation, elevation, 60°)	N/A	
										Biomechanical	Sagittal Plane Scapular Movement (°) (upward/downward rotation, elevation, 90°)	N/A	
										Biomechanical	Sagittal Plane Scapular Movement (°) (upward/downward rotation, elevation, 120°)	N/A	
										Biomechanical	Sagittal Plane Scapular Movement (°) (upward/downward rotation, lowering, 60°)	N/A	
										Biomechanical	Sagittal Plane Scapular Movement (°) (upward/downward rotation, lowering, 30°)	N/A	
										Biomechanical	Sagittal Plane Scapular Movement (°) (internal/external rotation, elevation, 30°)	N/A	
										Biomechanical	Sagittal Plane Scapular Movement (°) (internal/external rotation, elevation, 60°)	N/A	

										Biomechanical	Sagittal Plane Scapular Movement (°) (internal/external rotation, elevation, 90°)	N/A	
										Biomechanical	Sagittal Plane Scapular Movement (°) (internal/external rotation, elevation, 120°)	N/A	
										Biomechanical	Sagittal Plane Scapular Movement (°) (internal/external rotation, lowering, 90°)	N/A	
										Biomechanical	Sagittal Plane Scapular Movement (°) (internal/external rotation, lowering, 60°)	N/A	
										Biomechanical	Sagittal Plane Scapular Movement (°) (internal/external rotation, lowering, 30°)	N/A	
										Biomechanical	Sagittal Plane Scapular Movement (°) (anterior/posterior tilt, elevation, 120°)	N/A	
										Biomechanical	Scapular Plane Scapular Movement (°) (upward/downward rotation, elevation, 120°)	N/A	
Letafatkar 2020	Randomized controlled trial	Shoulder impingement syndromme	UT stretch, unilateral corner stretch, posterior shoulder stretch, external rotation, prone shoulder extension, scapular protraction	Stretching, rotator cuff strengthening, scapular stabilizer strengthening	EX: 1 hour sessions, 3 days/week, 8 weeks, supervised.	40, follow up 37	No treatment	40	8 weeks	Pain	NRS	1.18	Some concerns
										Function	DASH	1.22	
										Biomechanical	Sagittal Plane Elevation - Scapular Internal Rotation	-0.08	
										Biomechanical	Sagittal Plane Elevation - Scapular Upward Rotation	0.32	
										Biomechanical	Sagittal Plane Elevation - Scapular Tilt	-0.86	
										Biomechanical	Sagittal Plane Elevation - Scapular Internal Rotation	-0.28	

										Biomechanical	Sagittal Plane Elevation - Scapular Upward Rotation	0.24	
										Biomechanical	Sagittal Plane Elevation - Scapular Tilt	-0.37	
Lombardi 2008	Randomized Controlled Trial	Shoulder Impingement syndrome	Resisted flexion, extension, external, internal rotation	Rotator cuff strengthening, scapular stabilizer strengthening	EX: twice/week, 8 weeks, progressive.	30	No treatment	30	2 months	Pain	VAS (rest)	0.84	Some concerns
										Pain	VAS (movement)	1.20	
										Pain	SF36 Pain	0.42	
										Function	DASH 2	0.70	
										Function	DASH 3	0.48	
										Function	SF36 Physical Function	0.44	
										Function	SF36 Physical Role Limitation	0.00	
										Function	SF36 General Health	0.13	
										Function	SF36 Vitality	0.13	
										Function	SF36 Social Function	0.51	
										Function	SF36 Emotional Role Limitation	0.50	
										Function	SF36 Mental Health	0.32	
										Strength	Peak Torque Flexion (Nm)	0.33	
										Strength	Total Work Flexion (Joules)	0.26	
										Strength	Peak Torque Extension (Nm)	0.28	
										Strength	Total Work Extension (Joules)	0.36	
										Strength	Peak Torque Abduction (Nm)	0.26	
										Strength	Total Work Abduction (Joules)	0.22	
										Strength	Peak Torque Adduction (Nm)	0.22	
										Strength	Total Work Adduction (Joules)	0.22	

										Strength	Peak Torque Medial Rotation (Nm)	0.24	
										Strength	Total Work Medial Rotation (Joules)	0.34	
										Strength	Peak Torque Lateral Rotation (Nm)	0.15	
										Strength	Total Work Lateral Rotation (Joules)	0.34	
										Biomechanical	Flexion ROM (°)	-0.03	
										Biomechanical	Abduction ROM (°)	0.77	
										Biomechanical	Medial Rotation with shoulder at 90° abduction ROM (°)	0.19	
										Biomechanical	Lateral Rotation with shoulder at 90° abduction ROM (°)	0.16	
										Biomechanical	Lateral Rotation with arm alongside body ROM (°)	-0.07	
										Biomechanical	Extension ROM (°)	0.39	
Ludewig 2003	Randomized controlled trial	Shoulder pain and impingement syndrome	Posterior shoulder stretch, bilteral corner stretch, supine press up, resisted external rotation	Stretching, rotator cuff strengthening, scapular stabilizer strengthening	EX: 3 days/week, 8 weeks, progressive.	34	No treatment	33	8 weeks	Pain	Work Related Pain	0.91	Some concerns
										Function	Shoulder Rating Questionnaire	1.09	
										Function	Work Related Disability	0.88	

Martins 2012	Randomized controlled clinical trial	Rotator cuff disorder	PROM/Wand, pendulum, rythmic stabilization	ROM, Scapular stabilizer strengthening, neurmuscular training	EX: 2 sessions/week, 6 weeks, progressive (stretching, strengthening, proprioceptive exercises).	8	No treatment	8	8 weeks	Function	WORC Physical Symptoms	N/A	High risk
										Function	WORC Sports/Recreation	N/A	
										Function	WORC Work	N/A	
										Function	WORC Lifestyle	N/A	
										Function	WORC Emotions	N/A	
										Function	WORC Overall QOL	N/A	
Moslehi 2020	Randomized controlled trial	Subacromial impingement syndrome	Not specified	Stretching, rotator cuff strengthening, neuromuscular training	EX: 8 weeks.	25	No treatment	25	8 weeks	Pain	VAS	1.75	High risk
										Function	DASH	1.20	
										Biomechanical	Sagittal Plane Elevation - Scapular Internal Rotation	0.31	
										Biomechanical	Sagittal Plane Elevation - Scapular Upward Rotation	0.74	
										Biomechanical	Sagittal Plane Elevation - Scapular Posterior Tilt	-2.60	
										Biomechanical	Sagittal Plane Elevation - Scapular Internal Rotation	1.12	
										Biomechanical	Sagittal Plane Elevation - Scapular Upward Rotation	1.50	
										Biomechanical	Sagittal Plane Elevation - Scapular Posterior Tilt	-0.25	

Oledzka 2017	Not specified	Subacromial impingement syndrome	PNF exercises (not specified)	Neuromuscular training	EX: 40 minutes/session, 1 session.	11	Placebo laser	12	40 minutes	Biomechanical	Active Shoulder Flexion ROM (°)	N/A	N/A
										Biomechanical	Passive Shoulder Flexion ROM (°)	N/A	
										Biomechanical	Active Shoulder Abduction ROM (°)	N/A	
										Biomechanical	Passive Shoulder Abduction ROM (°)	N/A	
										Biomechanical	Active Shoulder External Rotation ROM (°)	N/A	
										Biomechanical	Passive Shoulder External Rotation ROM (°)	N/A	
										Biomechanical	Active Shoulder Internal Rotation ROM (cm)	N/A	
										Biomechanical	Passive Shoulder Internal Rotation ROM (cm)	N/A	

Appendix C: Data chart with study and intervention details for studies that investigated exercise compared to modalities

First Author, year	Study Design	Risk of Bias Assessment	Diagnosis	Exercise Intervention	Details	Number of Subjects (n)	Comparator	Comparator details	Number of Subjects (n)	Follow up	Outcome	Outcome Measure	Effect Size	Improvement direction	Normalized effect size
Ager 2019	Pilot RCT	Some concerns	Rotator tendinopathy	Group Supervised Upper Extremity Neuromuscular Training program	35-45 minutes/session, 3 times/week, 6 weeks, multi-station, group supervised	16	Usual physiotherapy care	PT + HEP: 30-60 minutes/session, 2-3 times/week, 6 weeks.	15	6 weeks	Function	WORC-CF	-0.88	Positive	-0.88
											Function	DASH-CF	0.56	Negative	-0.56
											Strength	MVIC - Abductors	-0.07	Positive	-0.07
											Strength	MVIC - External Rotators (90° abduction)	-0.10	Positive	-0.10
Akan 2019	Randomized and comparative clinical trial	High risk	Rotator Cuff Tear	Home exercise program	3 days/week	30	Platelet rich plasma injection (full thickness) + exercise		30	12 months	Pain	VAS score	N/A	Negative	N/A
											Function	Constant Score	N/A	Positive	N/A
							Platelet rich plasma injection (partial thickness) + exercise				Function	SPADI	N/A	Negative	N/A
											Function	Quick-DASH	N/A	Negative	N/A
											Biomechanical	Range of motion	N/A	Positive	N/A

Arias-Buria 2017	Randomized, parallel-group clinical trial	Some concerns	Subacromial Impingement Syndrome	Supraspinatus, infraspinatus, scapular stabalizer musculature strengthening	20-25 minutes/session, 5 sessions (once/week) + twice/day (home), 5 weeks, 3 sets, 12 repetitions, 3 exercises.	25	Exercise + Dry needling	EX: 20-25 minutes/session, 5 sessions (once/week) + twice/day (home), 5 weeks, 3 sets, 12 repetitions, 3 exercises. DN: 2-3 sessions	25	6 weeks	Pain	NPRS (mean)	0.34	Negative	-0.34
											Pain	NPRS (worst)	0.00	Negative	0.00
											Function	DASH	3.04	Negative	-3.04
Bac 2020	Randomized Clinical Trial	High risk	Subacromial Impingement, subacromial bursitis, Rotator cuff tendinopathy	Rehabiliation protocol: isometric, active exercises with and without resistance, sensorimotor exercises, PNF	55 minutes/session, 3 times/week, 6 weeks, supervised.	30	Taping/bracing + exercise	EX + TAPE: 55 minutes/session, 3 times/week, 6 weeks, supervised.	30	6 weeks	Function	UEFI	-0.20	Positive	-0.20
											Biomechanical	Muscle Thickness (supraspinatus)	0.36	Positive	0.36
											Biomechanical	Muscle Thickness (infraspinatus)	0.06	Positive	0.06
											Biomechanical	Muscle Thickness (teres minor)	0.02	Positive	0.02
											Biomechanical	Muscle Thickness (subscapularis)	0.08	Positive	0.08
											Biomechanical	Subacromial Space	-0.29	Positive	-0.29

Bal 2009	Prospective Randomized Study	High risk	Subacromial Impingement Syndrome	Home exercise program: Pendulum circumduction, passive stretching, isometric strengthening in all planes, scapular stabilization strengthening, advanced muscle-strengthening exercises	2 sessions/week, 12 weeks.	20	Laser + exercise	EX: 2 sessions/week, 12 weeks. LASER: 10 minutes/session, 5 times/week, 2 weeks.	20	12 weeks	Pain	VAS (night)	0.88	Negative	-0.88
											Pain	SPADI (pain)	-0.18	Negative	0.18
											Function	SPADI (disability)	-0.19	Negative	0.19
											Function	SPADI (total)	-0.23	Negative	0.23

Bang 2000	Randomized clinical trial	High risk	Shoulder impingement syndrome, rotator cuff tendinitis, shoulder tendinitis	Exercise	30 minutes/session, 6 sessions (twice/week), once daily (home), 3 weeks, 30 second hold × 3 repetitions (stretch), 3 sets × 10 repetitions (4 strengthening), 3 sets × 25 repetitions (2 strengthening), supervised.	23	Manual Therapy + exercise	EX + MT: 30 minutes/session, 6 sessions (twice/week), once daily (home), 3 weeks, 30 second hold × 3 repetitions (stretch), 3 sets × 10 repetitions (4 strengthening), 3 sets × 25 repetitions (2 strengthening), supervised.	27	3 weeks	Pain	Abduction AROM (VAS pain)	0.77	Negative	-0.77
											Pain	Resisted Abduction (VAS pain)	0.63	Negative	-0.63
											Pain	Resisted External Rotation (VAS pain)	0.71	Negative	-0.71
											Pain	Resisted Internal Rotation (VAS pain)	0.28	Negative	-0.28
											Pain	Functional (VAS pain)	0.89	Negative	-0.89
											Pain	Pain Composite	0.90	Negative	-0.90
											Function	Functional Assessment Questionnaire	-0.90	Positive	-0.90
											Strength	Abduction Strength (Newtons)	-0.17	Positive	-0.17
											Strength	External Rotation Strength (Newtons)	-0.64	Positive	-0.64
											Strength	Internal Rotation Strength (Newtons)	-0.22	Positive	-0.22
											Strength	Strength Composite	-0.34	Positive	-0.34

Beaudreuil 2011	Randomized Controlled trial	Low risk	Subacromial Impingement Syndromme	Dynamic humeral centering exercises	30 minutes/session, 3 times/week (3 weeks), 2 times/week (3 weeks). HEP: 3 times/day, 10 repetitions, progressive.	34, follow up 30	Mobilization	MT: 30 minutes/session, 3 times/week (3 weeks), 2 times/week (3 weeks)	35, follow up 32	3 months	Pain	Constant Score (pain)	0.36	Negative	-0.36
Beaudreuil 2015	RCT Follow up	Low risk	Subacromial Impingement Syndromme	Dynamic humeral centering exercises	30 minutes/session, 3 times/week (3 weeks), 2 times/week (3 weeks). HEP: 3 times/day, 10 repetitions, progressive.	34, follow up 30	Mobilization	MT: 30 minutes/session, 3 times/week (3 weeks), 2 times/week (3 weeks).	35, follow up 32	3 months	Function	Constant Score (activity)	0.37	Positive	0.37
											Function	Constant Score (mobility)	0.27	Positive	0.27
											Function	Constant Score (total)	0.36	Positive	0.36
											Strength	Constant Score (strength)	0.14	Positive	0.14
											Biomechanical	Flexion AROM (painfree)	0.21	Positive	0.21
											Biomechanical	Abduction AROM (painfree)	0.19	Positive	0.19
											Biomechanical	Flexion AROM (painful arc)	-0.98	Positive	-0.98
											Biomechanical	Abduction AROM (painful arc)	-0.38	Positive	-0.38
Calis 2011	Randomized controlled trial	High risk	Subacromial impingement syndrome	Exercise + moist heat	5 times/week, 3 weeks, 5 repetitions × 5 seconds, supervised. HEAT: 20 minutes.	16	Exercise + Ultrasound + Moist Heat	EX: 5 times/week, 3 weeks, 5 repetitions × 5 seconds, supervised. HEAT + US: 20 minutes.	21	3 weeks	Pain	VAS pain (rest)	0.26	Negative	-0.26
											Pain	VAS pain (movement)	0.88	Negative	-0.88
											Pain	VAS pain (night)	0.89	Negative	-0.89
											Function	Constant Score	-0.27	Positive	-0.27

											Biomechanical	Neer Shoulder Score (ROM)	N/A	Positive	N/A
											Biomechanical	Neer Shoulder Score (ROM)	N/A	Positive	N/A
											Biomechanical	Abduction ROM (°)	-0.23	Positive	-0.23
											Biomechanical	Flexion ROM (°)	0.05	Positive	0.05
											Biomechanical	Internal Rotation ROM (°)	-1.18	Positive	-1.18
											Biomechanical	External Rotation ROM (°)	-0.76	Positive	-0.76
		N/A					Exercise + Laser + Moist Heat	EX: 5 times/week, 3 weeks, 5 repetitions × 5 seconds, supervised. HEAT + LASER: 20 minutes.	15		Pain	VAS pain (rest)	0.26	Negative	0.26
											Pain	VAS pain (movement)	0.62	Negative	0.62
											Pain	VAS pain (night)	0.52	Negative	0.52
											Function	Constant Score	-0.04	Positive	-0.04
											Biomechanical	Neer Shoulder Score (ROM)	N/A	Positive	N/A
											Biomechanical	Neer Shoulder Score (ROM)	N/A	Positive	N/A
											Biomechanical	Abduction ROM (°)	-0.03	Positive	-0.03
											Biomechanical	Flexion ROM (°)	-0.19	Positive	-0.19

											Biomechanical	Internal Rotation ROM (°)	-0.41	Positive	-0.41
											Biomechanical	External Rotation ROM (°)	-0.76	Positive	-0.76
CAMARGO 2015	Randomized controlled trial	High risk	Shoulder impingement syndrome	Exercise alone	3 stretching (30 seconds × 3 repetitions), 3 strengthening (3 sets × 10 repetitions), 4 weeks, supervised, progressive.	23	Exercise + Manual Therapy	EX + MT: 3 stretching (30 seconds × 3 repetitions), 3 strengthening (3 sets × 10 repetitions), 4 weeks, supervised, progressive.	23	4 weeks	Pain	VAS pain (rest)	0.37	Negative	-0.37
											Pain	VAS pain (movement)	0.97	Negative	-0.97
											Pain	VAS pain (greatest last week)	0.11	Negative	-0.11
											Pain	VAS pain (least last week)	0.84	Negative	-0.84
											Function	DASH	0.31	Negative	-0.31
											Biomechanical	Sagittal Plane - Scapular Internal Rotation	-0.10	Negative	0.10
											Biomechanical	Sagittal Plane - Scapular Upward Rotation	-0.03	Positive	-0.03
											Biomechanical	Sagittal Plane - Scapular Tilt	0.44	Positive	0.44
											Biomechanical	Scapular Plane - Scapular Internal Rotation	0.00	Negative	0.00
											Biomechanical	Scapular Plane - Scapular Upward Rotation	-0.01	Positive	-0.01
											Biomechanical	Scapular Plane - Scapular Tilt	0.31	Positive	0.31

Centeno 2020	Prospective, Randomized controlled, crossover study	High risk	Partial to full thickness supraspinatus tear	Home exercise program	3 months.	11, follow up 0 (cross-over)	Injection	EX + INJ: 3 months.	14, follow up 24 (cross-over)		Pain	Numeric Pain Scale	N/A	Negative	N/A
											Function	DASH	N/A	Negative	N/A
Citaker 2005	Randomized controlled trial	High risk	Subacromial impingement syndrome	Passive Neuromuscular Facilitation	Hot packs, PNF, theraband exercises, 20 sessions.	20	Mobilization	EX + MT: Hot packs, mobilization, theraband exercises, 20 sessions.	20		Pain	Pain (night, active)	-0.28	Negative	0.28
											Pain	Pain (night, motionless)	0.05	Negative	-0.05
											Pain	Pain (day, active)	-0.06	Negative	0.06
											Pain	Pain (day, motionless)	-0.02	Negative	0.02
											Pain	UCLA pain	-0.56	Positive	-0.56
											Function	UCLA function	-0.56	Positive	-0.56
											Function	UCLA anterior flexion range	0.07	Positive	0.07
											Function	UCLA anterior flexion power	0.39	Positive	0.39
											Function	UCLA patient satisfaction	N/A	Positive	N/A
											Function	UCLA total	-0.56	Positive	-0.56
											Biomechanical	Flexion ROM (°)	0.22	Positive	0.22
											Biomechanical	Abduction ROM (°)	-0.01	Positive	-0.01
											Biomechanical	External Rotation ROM (°)	0.24	Positive	0.24
											Biomechanical	Internal Rotation ROM (°)	0.18	Positive	0.18

											Biomechanical	Hyperextension ROM (°)	0.23	Positive	0.23
Devereaux 2016	Randomized, controlled assessor-blind parallel design trial	High risk	Subacromial impingement syndrome	Exercise	4 sessions (1 one hour, 3 half hour), 2 weeks.	38	Tape + exercise	EX + TAPE: 4 sessions (1 one hour, 3 half hour), 2 weeks.	33	2 weeks (4 sessions)	Pain	NPRS pain (rest)	N/A	Negative	N/A
											Pain	NPRS pain (elevation)	N/A	Negative	N/A
											Function	Simple Shoulder Test	N/A	Positive	N/A
											Function	Constant Score	N/A	Positive	N/A
							NSAID + exercise	EX + NSAID: 4 sessions (1 one hour, 3 half hour), 2 weeks.	29		Pain	NPRS pain (rest)	N/A	Negative	N/A
											Pain	NPRS pain (elevation)	N/A	Negative	N/A
											Function	Simple Shoulder Test	N/A	Positive	N/A
											Function	Constant Score	N/A	Positive	N/A
DiLorenzo 2006	Prospective, randomized, comparison crossover investigation	High risk	Rotator cuff tendinitis	Rehabilitation exercises	EX: ROM + strengthening exercises, progressive.	20	Suprascapular nerve block	EX + SSNB: ROM + strengthening, progressive.	20		Pain	VAS pain	1.43	Negative	-1.43
Djordjevic 2012	Double-blind, randomized, cross-sectional study	Some concerns	Shoulder impingement syndrome, rotator cuff lesion with impingement syndrome	Exercise only	EX: 10 sessions, daily, 1 set × 10 repetitions.	10	Mobilization + Tape	MT + TAPE: 10 sessions.	10	10 days	Biomechanical	Flexion ROM (°)	-4.37	Positive	-4.37
											Biomechanical	Abduction ROM (°)	-5.89	Positive	-5.89

Engebretsen 2011	Single-blind randomized controlled study	Some concerns	Subacromial shoulder pain	Supervised exercises	EX: 45 minute session, twice weekly, 12 weeks, supervised, progressive.	52, follow up 49	Shockwave therapy	SW: once weekly, 4-6 weeks.	52, follow up 48		Pain	Pain (rest)	-0.27	Negative	0.27
											Pain	Pain (activity)	-0.33	Negative	0.33
											Function	SPADI	-0.33	Negative	0.33
											Function	Function (carry)	-0.32	Positive	-0.32
											Function	Function (take down)	0.00	Positive	0.00
Giombini 2006	Randomized Controlled Study	Some concerns	Supraspinatus tendinopathy	Exercise	EX: 5 minutes/session, twice/day, daily, 4 weeks, pendulums + passive ROM exercises, weekly, supervised.	11	Hyperthermia	Hyperthermia 30 minutes/session, 12 sessions, 3 sessions/week, 4 weeks.	14	4 weeks	Pain	VAS Pain	3.83	Negative	-3.83
											Function	Constant Score	-4.60	Positive	-4.60
							Ultrasound	Ultrasound: 15 minutes/session, 12 sessions, 3 sessions/week, 4 weeks.	12		Pain	VAS pain	3.24	Negative	-3.24
											Function	Constant Score	0.20	Positive	0.20
GunayUcurum 2018	Prospective randomized controlled trial	High risk	Shoulder impingement syndrome	Hot pack + exercises	EX: 3 days/week + HEP daily, 4 weeks, supervised, progressive.	19	Hot pack + exercise + IFC	3 days/week + HEP daily, 4 weeks, supervised, progressive.	20	4 weeks	Pain	VAS Pain (rest)	0.27	Negative	-0.27
											Pain	VAS pain (activity)	0.19	Negative	-0.19

											Function	SF36 (physical component)	0.00	Positive	0.00
											Function	SF36 (mental component)	-0.31	Positive	-0.31
											Function	DASH	0.08	Negative	-0.08
							Hot pack + Exercise + TENS	3 days/week + HEP daily, 4 weeks, supervised, progressive.	20		Pain	VAS Pain (rest)	-0.10	Negative	-0.10
											Pain	VAS pain (activity)	0.30	Negative	0.30
											Function	SF36 (physical component)	0.07	Positive	0.07
											Function	SF36 (mental component)	-0.08	Positive	-0.08
											Function	DASH	0.15	Negative	-0.15
							Hot pack + Exercise + Ultrasound	3 days/week + HEP daily, 4 weeks, supervised, progressive.	20		Pain	VAS Pain (rest)	0.14	Negative	0.14
											Pain	VAS pain (activity)	-0.09	Negative	-0.09
											Function	SF36 (physical component)	0.22	Positive	0.22
											Function	SF36 (mental component)	-0.07	Positive	-0.07
											Function	DASH	-0.01	Negative	0.01
Haider 2018	Randomized controlled trial	High risk	Subacromial impingement syndrome	Exercise only	EX: 6 sessions, 3 sessions/week, 2 weeks mobility + strengthening exercises.	20	Exercise + Thoracic manipulation	6 sessions, 3 sessions/week, 2 weeks mobility + strengthening exercises. TM: 4 manipulation techniques.	20	2 weeks (6 sessions)	Pain	NPRS	1.11	Negative	-1.11
											Function	SPADI	0.91	Negative	-0.91
Kachingwe 2008	Randomized Controlled Pilot Clinical Trial	High risk	Shoulder impingement Syndrome	Exercise only	EX: once/week, 6 weeks, supervised. HEP: once/day, 6 weeks.	8	Mobilization + Exercise	EX + MT: once/week, 6 weeks, supervised. HEP: once/day, 6 weeks.	9	Not specified	Pain	VAS Pain	N/A	Negative	N/A
											Function	SPADI	N/A	Negative	N/A

											Biomechanical	Flexion ROM	N/A	Positive	N/A
											Biomechanical	Scaption ROM	N/A	Positive	N/A
							Mobilization with movement + Exercise	EX + MWM: once/week, 6 weeks, supervised. HEP: once/day, 6 weeks.	9		Pain	VAS Pain	N/A	Negative	N/A
											Function	SPADI	N/A	Negative	N/A
											Biomechanical	Flexion ROM	N/A	Positive	N/A
											Biomechanical	Scaption ROM	N/A	Positive	N/A
Kim 2019	Prospective, open-label comparative study	N/A	Rotator cuff tendinopathy	Rotator cuff strengthening exercise	EX: 20 minute sessions, 4 days/week.	15, follow up 10	Platelet-rich plasma injection		15, follow up 12	6 weeks	Pain	NRS	N/A	Negative	N/A
													N/A		
											Function	ASES	N/A	Positive	N/A
											Function	Constant-Murley	N/A	Positive	N/A
											Biomechanical	Tendon Thickness (mm)	N/A	Positive	N/A
Kim 2020	single-blind, randomized , parallel-group study	High risk	Subacromial impingement syndrome	Neurac technique	EX: 4 exercises, 3 days/week, 4 weeks, 3 sets × 4 repetitions, progressive.	13	Manual therapy		13	4 weeks	Pain	VAS (mm)	-0.60	Negative	0.60
											Function	SPADI	-0.39	Negative	0.39
											Strength	Shoulder External Rotation 60°/s (%)	1.73	Positive	1.73

											Strength	Shoulder External Rotation 180°/s (%)	0.94	Positive	0.94
											Strength	Shoulder Internal Rotation 60°/s (%)	0.93	Positive	0.93
											Strength	Shoulder Internal Rotation 180°/s (%)	0.89	Positive	0.89
											Biomechanical	External Rotation ROM (°)	-0.04	Positive	-0.04
											Biomechanical	Internal Rotation ROM (°)	0.47	Positive	0.47
Krischak 2013	Propsective randomized controlled trial	High risk	Rotator cuff tear	Home exercise program	EX: 4-7 exercises, 30 minutes/session, twice/day, 8 weeks.	16	Occupational therapy + exercise	OT + EX: 3 times/week, 8 weeks.	22	8 weeks	Pain	VAS Pain	-0.22	Negative	0.22
Kromer 2013	Randomized controlled trial	Low risk	Shoulder impingement	Individually adapted exercises	EX: 15-20 minutes/session, 10 sessions, first 5 of 12 weeks. HEP: 3 times/week, last 7 of 12 weeks.	44	Manual therapy + individually adapted exercises	MT+ EX: 20-30 minutes/session, 10 sessions, first 5 of 12 weeks. HEP: 3 times/week, last 7 of 12 weeks.	46	5 weeks	Pain	Pain SPADI	-0.01	Negative	0.01
										12 weeks	Pain	Pain SPADI	0.11	Negative	-0.11
											Pain	VNRS	0.35	Negative	-0.35
											Pain	VNRS	0.11	Negative	-0.11
											Pain	Pain Catastrophizing Scale (total)	N/A	Negative	N/A
											Pain	Pain Catastrophizing Scale (total)	N/A	Negative	N/A
											Function	Total SPADI	0.10	Negative	-0.10
											Function	Total SPADI	0.12	Negative	-0.12
											Function	Function SPADI	0.20	Negative	-0.20
											Function	Function SPADI	0.11	Negative	-0.11

											Function	FABQ (total)	N/A	Negative	N/A
											Function	FABQ (total)	N/A	Negative	N/A
											Function	Generic Patient Specific Scale	-0.37	Positive	-0.37
											Function	Generic Patient Specific Scale	0.10	Positive	0.10
Kromer 2014	Randomized controlled trial	Low risk	Shoulder impingement	Individually adapted exercises	EX: 15-20 minutes/session, 10 sessions, first 5 of 12 weeks. HEP: 3 times/week, last 7 of 12 weeks.	44, follow up 43	Manual therapy + individually adapted exercises	MT+ EX: 20-30 minutes/session, 10 sessions, first 5 of 12 weeks. HEP: 3 times/week, last 7 of 12 weeks.	46, follow up 44	52 weeks	Pain	Pain SPADI	-0.38	Negative	0.38
											Function	Total SPADI	-0.38	Negative	0.38
											Function	Function SPADI	-0.37	Negative	0.37
											Function	Generic Patient Specific Scale	0.40	Positive	0.40
Letafatkar 2020	Randomized controlled trial	Some concerns	Shoulder impingement syndromme	Exercise only	EX: 1 hour sessions, 3 days/week, 8 weeks, supervised.	40, follow up 37	Exercise + Tape	EX: ROM/scapular retraction (first 6 weeks) + strengthening (6 weeks to 6 months) + 10 PT sessions, 6 months, progressive.	40, follow up 36	8 weeks	Pain	NRS	0.57	Negative	-0.57
											Function	DASH	0.58	Negative	-0.58
											Biomechanical	Sagittal Plane Elevation - Scapular Internal Rotation	-0.02	Negative	0.02
											Biomechanical	Sagittal Plane Elevation - Scapular Upward Rotation	-0.30	Positive	-0.30
											Biomechanical	Sagittal Plane Elevation - Scapular Posterior Tilt	0.70	Positive	0.70
											Biomechanical	Sagittal Plane Elevation - Scapular Internal Rotation	0.07	Negative	-0.07

											Biomechanical	Sagittal Plane Elevation - Scapular Upward Rotation	-0.25	Positive	-0.25
											Biomechanical	Sagittal Plane Elevation - Scapular Posterior Tilt	0.49	Positive	0.49
Lewis 2017	Randomized clinical trial	High risk	Subacromial pain syndrome	Advice + exercise	EX: 50-55 minutes/session, 6 sessions, 6 weeks, supervised.	73, follow up 54	Advice + exercise + accupuncture	EX: 50-55 minutes/session, 6 sessions, 6 weeks, supervised. ACU: 6 sessions (twice/week, 3 weeks).	77, follow up 67	6 weeks	Function	Oxford Shoulder Score	0.12	Negative	-0.12
											Biomechanical	Shoulder Flexion ROM (°)	0.21	Positive	0.21
											Biomechanical	Shoulder Abduction ROM (°)	0.08	Positive	0.08
											Biomechanical	Shoulder Lateral Rotation (°)	-0.11	Positive	-0.11
							Advice + exercise + electroaccupuncture	EX: 50-55 minutes/session, 6 sessions, 6 weeks, supervised. ELEACU: 6 sessions (twice/week, 3 weeks).	77, follow up 69		Function	Oxford Shoulder Score	-0.19	Negative	0.19
											Biomechanical	Shoulder Flexion ROM (°)	-0.18	Positive	-0.18
											Biomechanical	Shoulder Abduction ROM (°)	-0.26	Positive	-0.26
											Biomechanical	Shoulder Lateral Rotation (°)	-0.05	Positive	-0.05

Littlewood 2016	Unblinded parallel group randomized controlled trial	Some concerns	Rotator cuff tendinopathy	Self managed loaded exercise	EX: 3 sets × 10-15 repetitions, twice/day, progressive.	42, follow up 27	Physiotherapy		43, follow up 33	3 months	Pain	SF36 Bodily Pain	-0.17	Positive	-0.17
											Function	SPADI	0.08	Negative	-0.08
											Function	SF36 Physical Functioning	-0.27	Positive	-0.27
											Function	General Self-Efficacy Scale	N/A	Positive	N/A
Merolla 2013	Non-randomized comparative study	N/A	Rotator cuff tendinopathy	Physiotherapy	EX: 3 times/week, 30 days.	25	Injection		25	4 weeks	Pain	VAS (overall)	1.95	Negative	-1.95
											Pain	VAS (night)	2.24	Negative	-2.24
											Pain	VAS (activity)	2.34	Negative	-2.34
											Function	Constant Murley	-6.42	Positive	-6.42
											Function	Oxford Shoulder Score	-10.91	Negative	10.91
Moezy 2014	Randomized clinical trial	High risk	Subacromial impingement syndrome	Exercise	EX: 3 sets × 10 repetitions, 3 times/week, 6 weeks, supervised, progressive.	33	Physiotherapy		35		Pain	VAS	-0.15	Negative	0.15
											Biomechanical	Shoulder Abduction ROM (°)	0.46	Positive	0.46
											Biomechanical	Shoulder External Rotation ROM (°)	0.51	Positive	0.51
											Biomechanical	Scapular Protraction	-0.08	Negative	0.08
											Biomechanical	Scapular Rotation	-0.07	Negative	0.07

											Biomechanical	Scapular Symmetry	0.00	Positive	0.00
											Biomechanical	Forward Shoulder Translation	-0.27	Negative	0.27
											Biomechanical	Forward Head Posture	0.43	Negative	-0.43
											Biomechanical	Mid Thoracic Curve	-0.27	Negative	0.27
											Biomechanical	Pectoralis Minor Length	0.20	Positive	0.20
Nejati 2017	Randomized controlled trial	High risk	Subacromial impingement syndrome	Exercise therapy	EX: Once/week, 3 months, supervised. HEP: Daily, 4 times/week, 6 months, unsupervised.	20	PRP Injection		22	6 months	Pain	VAS	0.55	Negative	-0.55
											Function	Total WORC	0.42	Positive	0.42
											Function	DASH	-0.23	Negative	0.23
											Biomechanical	Shoulder Flexion ROM (°)	-0.23	Positive	-0.23
											Biomechanical	Shoulder Extension ROM (°)	-0.03	Positive	-0.03
											Biomechanical	Shoulder Abduction ROM (°)	0.64	Positive	0.64
											Biomechanical	Shoulder Internal Rotation ROM (°)	0.39	Positive	0.39

											Biomechanical	Shoulder External Rotation ROM (°)	1.06	Positive	1.06
Notarnicola 2020	Randomized clinical trial	High risk	Partial Rotator Cuff tear	Therapeutic exercise	EX: 5 times/week, 12 weeks, progressive.	15	Shockwave therapy		15	3 months	Pain	VAS	1.95	Negative	-1.95
											Function	ASES	-1.23	Positive	-1.23
											Strength	Manual Muscle Strength Testing Scale	-1.00	Positive	-1.00
											Biomechanical	Length of Lesion - Longitudinal Axis (mm)	0.42	Negative	-0.42
											Biomechanical	Length of Lesion - Transversal Axis (mm)	0.43	Negative	-0.43
											Biomechanical	Length of Lesion - Anteroposterior Axis (mm)	0.68	Negative	-0.68
Park 2020	Randomized controlled pilot study	High risk	Subacromial impingement syndrome	Exercise alone	EX: 15 minutes/session, 3 sessions/week, 4 weeks, thoracic spine, supervised.	10	Mobilization alone		10	4 weeks	Pain	SPADI (pain)	-0.06	Negative	0.06
											Function	SPADI (disability)	0.09	Negative	-0.09
											Function	SPADI (total)	0.04	Negative	-0.04
											Biomechanical	Thoracic Kyphosis Angle (°)	0.35	Negative	-0.35
											Biomechanical	Upper Trapezius Muscle Tone (Hz)	0.09	Negative	-0.09
											Biomechanical	Upper Trapezius Muscle Stiffness (N/m)	0.16	Negative	-0.16
											Biomechanical	Pectoralis Minor Muscle Tone (Hz)	0.02	Negative	-0.02

											Biomechanical	Pectoralis Minor Muscle Stiffness (N/m)	0.07	Negative	-0.07
											Biomechanical	Shoulder Flexion ROM (°)	0.01	Positive	0.01
											Biomechanical	Shoulder Abduction ROM (°)	-0.03	Positive	-0.03
											Biomechanical	Shoulder Medial Rotation (°)	0.04	Positive	0.04
											Biomechanical	Shoulder Lateral Rotation (°)	0.04	Positive	0.04
							Exercise + mobilization	EX: 15 minutes/session, 3 sessions/week, 4 weeks, thoracic spine, supervised.	10		Pain	SPADI (pain)	0.43	Negative	-0.43
											Function	SPADI (disability)	0.45	Negative	-0.45
											Function	SPADI (total)	0.45	Negative	-0.45
											Biomechanical	Thoracic Kyphosis Angle (°)	1.06	Negative	-1.06
											Biomechanical	Upper Trapezius Muscle Tone (Hz)	0.61	Negative	-0.61
											Biomechanical	Upper Trapezius Muscle Stiffness (N/m)	0.48	Negative	-0.48
											Biomechanical	Pectoralis Minor Muscle Tone (Hz)	0.09	Negative	-0.09
											Biomechanical	Pectoralis Minor Muscle Stiffness (N/m)	0.06	Negative	-0.06
											Biomechanical	Shoulder Flexion ROM (°)	-0.29	Positive	-0.29

											Biomechanical	Shoulder Abduction ROM (°)	-0.21	Positive	-0.21
											Biomechanical	Shoulder Medial Rotation (°)	-0.18	Positive	-0.18
											Biomechanical	Shoulder Lateral Rotation (°)	-0.34	Positive	-0.34
Pekyavas 2016	Single blind randomized control trial	High risk	Subacromial impingement syndrome	Exercise alone	EX: 10-15 minutes/sessions, 7 times/week, 15 days.	15	Exercise + tape	EX: 10-15 minutes/sessions, 7 times/week, 15 days.	20	15 days	Pain	SPADI (pain)	-1.94	Negative	1.94
											Function	SPADI (disability)	-1.26	Negative	1.26
											Function	SPADI (total)	1.07	Negative	-1.07
											Biomechanical	Shoulder External Rotation ROM (°)	-0.02	Positive	-0.02
											Biomechanical	Shoulder Abduction ROM (°)	-0.02	Positive	-0.02
											Biomechanical	Shoulder Flexion ROM (°)	-0.10	Positive	-0.10
							Exercise + tape + manual therapy	EX: 10-15 minutes/sessions, 7 times/week, 15 days.	16		Pain	SPADI (pain)	0.81	Negative	-0.81
											Function	SPADI (disability)	1.59	Negative	-1.59
											Function	SPADI (total)	5.51	Negative	-5.51
											Biomechanical	Shoulder External Rotation ROM (°)	-1.65	Positive	-1.65
											Biomechanical	Shoulder Abduction ROM (°)	-1.46	Positive	-1.46
											Biomechanical	Shoulder Flexion ROM (°)	-1.50	Positive	-1.50

							Exercise + tape + manual therapy + laser	EX: 10-15 minutes/sessions, 7 times/week, 15 days.	19		Pain	SPADI (pain)	1.31	Negative	-1.31
											Function	SPADI (disability)	2.20	Negative	-2.20
											Function	SPADI (total)	6.68	Negative	-6.68
											Biomechanical	Shoulder External Rotation ROM (°)	-1.62	Positive	-1.62
											Biomechanical	Shoulder Abduction ROM (°)	-1.71	Positive	-1.71
											Biomechanical	Shoulder Flexion ROM (°)	-1.71	Positive	-1.71
Rizzo 2017	Pilot pseudo-randomized controlled trial	High risk	Shoulder impingement syndrome	Conventional therapy	EX: 30-40 minutes/session, 2 days/week, 6 weeks, supervised, progressive. HEP: Twice/day, 6 weeks.	8	Conventional therapy	EX: 30-40 minutes/session, 2 days/week, 6 weeks, supervised, progressive. HEP: Twice/day, 6 weeks.	6						
Senbursa 2007	Prospective, randomized clinical trial	High risk	Shoulder Impingement syndrome	Self-training program with ROM, stretching, strengthening exercises	EX: 10-15 minutes/sessions, 7 times/week, 4 weeks, supervised, progressive.	15	Manual therapy + exercise	PT: 3x/week, 4 weeks, HEP: same as EX intervention	15	4 weeks	Pain	VAS (night)	-0.74	Negative	0.74
											Pain	VAS (motion)	-0.40	Negative	0.40
											Pain	VAS (rest)	0.79	Negative	-0.79

Senbursa 2011	Prospectice, randomized clinical trial	High risk	Patial supraspiantus tear and/or Subacromial Impingement Syndrome	Supervised exercise program: ROM, stretching, strengthening exercises	EX: Daily, 3 sets × 10 repetitions, supervised 3 times/week, 12 weeks.	30	Manual therapy + exercise	EX + MT: Daily, 3 sets × 10 repetitions, supervised 3 times/week, 12 weeks.	22	4 weeks	Pain	VAS (night)	N/A	Negative	N/A
											Pain	VAS (rest)	N/A	Negative	N/A
											Pain	VAS (movement)	N/A	Negative	N/A
											Function	MASES	N/A	Positive	N/A
Seven 2017	Randomized prospective comparative trial	High risk	Chronic rotator cuff injury	Exercise	EX: 30 minutes/session, 3 sessions/week, 12 weeks. HEP: 3 times/day, 4 days/week, 12 weeks.	44	Prolotherapy		57	12 weeks	Pain	VAS	1.24	Negative	-1.24
											Function	WORC	-1.55	Positive	-1.55
											Function	SPADI	1.52	Negative	-1.52
											Function	SPADI	-1.83	Negative	1.83
											Biomechanical	Flexion ROM (°)	-0.52	Positive	-0.52
											Biomechanical	Abduction ROM (°)	-0.38	Positive	-0.38
											Biomechanical	Internal Rotation ROM (°)	0.07	Positive	0.07
											Biomechanical	External Rotation ROM (°)	-0.24	Positive	-0.24
											Biomechanical	Lateral Scapular Slide Test	-0.64	Negative	0.64

Srivastava 2018	Randomized clinical trial	High risk	Shoulder Impingement syndrome	Exercise + cryotherapy	EX: Isometric strengthening exercises (3 sets × 15 repetitions), stretching exercises (30 seconds × 3 repetitions), 6 sessions.	11	Mobilization + exercise	EX: Isometric strengthening exercises (3 sets × 15 repetitions), stretching exercises (30 seconds × 3 repetitions), 6 sessions.	11	6 sessions	Pain	VAS (cm)	-0.48	Negative	0.48
											Function	DASH	0.38	Negative	-0.38
											Biomechanical	Scaption ROM (°)	-0.13	Positive	-0.13
Vinuesa-Montoya 2017	Preliminary Randomized Clinical Trial	High risk	Shoulder impingement syndrome	Home exercise program	HEP: 60 minutes/day, daily, 5 weeks.	20, follow up 19	Exercise + manual therapy	MT: Twice/week, 5 weeks. HEP: 60 minutes/day, daily, 5 weeks.	21	5 weeks	Pain	VAS (cm)	-0.03	Negative	0.03
											Function	Shoulder Disability Questionnaire	0.05	Negative	-0.05
											Biomechanical	Flexion ROM (°)	-0.14	Positive	-0.14
											Biomechanical	Extension ROM (°)	-0.14	Positive	-0.14
											Biomechanical	External Rotation ROM (°)	-0.12	Positive	-0.12
											Biomechanical	Internal Rotation ROM (°)	-0.23	Positive	-0.23
											Biomechanical	Adduction ROM (°)	0.32	Positive	0.32
											Biomechanical	Abduction ROM (°)	0.30	Positive	0.30

Walther 2004	Prospective, randomized study	High risk	Subacromial impingement syndrome	Staendardized self-training	EX: 4 sessions (clinic), 10-15 minutes/session, 5 times/week, 12 weeks (home).	20	Conventional physiotherapy	PT: 10 sessions, 2-3 times/week, 12 weeks (clinic).	20	12 weeks	Strength	Constant Murley (maximum strength)	0.43	Positive	0.43
							Functional brace		20		Strength	Constant Murley (maximum strength)	-0.28	Positive	-0.28

Appendix D: Data chart with study and intervention details, and effect sizes for studies that investigated an exercise intervention compared to surgery

First Author, year	Risk of Bias Assessment	Study Design	Diagnosis	Exercise Intervention	Details	Number of Subjects (n)	Comparator	Number of Subjects (n)	Follow up	Outcome	Outcome Measure	Effect Size	Improvement direction	Adjusted Effect Size
Brox 1993	Some concerns	Randomized Clinical Trial	Rotator Cuff Disease	Exercise	60 minutes/session, twice/week, 3-6 months, progressive, supervised. HEP: 5 times/week.	50	Arthroscopic surgery	45	6 months	Pain	Pain score (activity)	N/A	Negative	N/A
										Pain	Pain score (rest)	N/A	Negative	N/A
										Pain	Pain score (night)	N/A	Negative	N/A
										Pain	Neer Shoulder Score (pain)	N/A	Positive	N/A
Brox 1999	Some concerns	Prospective, randomized, Controlled study	Rotator cuff disease (impingement syndrome stage II)	Exercise	60 minutes/session, twice/week, 3-6 months, progressive, supervised. HEP: 5 times/week.	33	Arthroscopic surgery	31	2.5 years	Pain	Pain score (activity)	N/A	Negative	N/A
										Pain	Pain score (night)	N/A	Negative	N/A
										Pain	VAS pain (rest)	N/A	Negative	N/A
Farfaras 2016	High risk	Prospective randomized study	Subacromial impingement syndrome	Non-operative exercise therapy	EX: 60 minutes, daily, 3-6 months, supervised, progressive, ROM + strengthening.	21	Open surgery	15	30 months	Pain	SF36 (bodily pain)	-0.72	Positive	-0.72

										Function	Constant Score (total)	-1.06	Positive	-1.06
										Function	SF36 (physical functioning)	-2.02	Positive	-2.02
										Function	SF36 (role physical)	-0.42	Positive	-0.42
										Function	SF36 (general health)	-0.02	Positive	-0.02
										Function	SF36 (vitality)	-0.39	Positive	-0.39
										Function	SF36 (social functioning)	-0.12	Positive	-0.12
										Function	SF36 (role emotional)	0.24	Positive	0.24
										Function	SF36 (mental health)	-0.18	Positive	-0.18
										Biomechanical	Active Elevation (°)	-0.34	Positive	-0.34
								Arthroscopic surgery	19		Pain	SF36 (bodily pain)	-0.43		-0.43
											Function	Constant Score (total)	-0.29	Positive	-0.29
											Function	SF36 (physical functioning)	-0.63	Positive	-0.63
											Function	SF36 (role physical)	0.00	Positive	0.00
											Function	SF36 (general health)	-0.63	Positive	-0.63
											Function	SF36 (vitality)	-0.56	Positive	-0.56
											Function	SF36 (social functioning)	-0.62	Positive	-0.62
											Function	SF36 (role emotional)	-0.74	Positive	-0.74
											Function	SF36 (mental health)	-0.88	Positive	-0.88
											Biomechanical	Active Elevation (°)	-0.65	Positive	-0.65
Farfaras 2018	High risk	Randomized controlled trial	Subacromial impingement syndrome	Non-operative exercise therapy	EX: 60 minutes, daily, 3-6 months, supervised, progressive, ROM + strengthening.	31, follow up 28	Open surgery	23, follow up 20	13.7-13.9 years	Pain	SF36 (bodily pain)	-0.32	Positive	-0.32

										Function	Constant Score (total)	-1.42	Positive	-1.42
										Function	SF36 (physical functioning)	0.07	Positive	0.07
										Function	SF36 (role physical)	-0.18	Positive	-0.18
										Function	SF36 (general health)	0.30	Positive	0.30
										Function	SF36 (vitality)	0.21	Positive	0.21
										Function	SF36 (social functioning)	0.00	Positive	0.00
										Function	SF36 (role emotional)	0.46	Positive	0.46
										Function	SF36 (mental health)	0.02	Positive	0.02
										Strength	Constant Score (elevation strength)	-0.87	Positive	-0.87
										Biomechanical	Active Elevation (°)	-0.68	Positive	-0.68
								Arthroscopic surgery	23, follow up 18	Pain	SF36 (bodily pain)	-0.09	Positive	-0.09
										Function	Constant Score (total)	-0.67	Positive	-0.67
										Function	SF36 (physical functioning)	-0.35	Positive	-0.35
										Function	SF36 (role physical)	-0.09	Positive	-0.09
										Function	SF36 (general health)	-0.44	Positive	-0.44
										Function	SF36 (vitality)	-0.08	Positive	-0.08
										Function	SF36 (social functioning)	0.12	Positive	0.12
										Function	SF36 (role emotional)	-0.51	Positive	-0.51
										Function	SF36 (mental health)	-0.40	Positive	-0.40
										Strength	Constant Score (elevation strength)	-0.38	Positive	-0.38
										Biomechanical	Active Elevation (°)	-0.71	Positive	-0.71
Jain 2019	High risk	Cohort study	Rotator cuff tears	Physicaly therapy	PT: RC strengthening, scapular stabilization, caspular stretching.	77	Surgery	50	18 months	Function	SPADI	1.50	Negative	-1.50

										Function	FABQ Physical Activity Score	N/A	Negative	N/A
										Function	ASES	N/A	Positive	N/A
										Strength	External Rotation Strength Ratio	N/A	Positive	N/A
										Strength	Isolated Abduction Strength Ratio	N/A	Positive	N/A
Ketola 2015	High risk	Randomized Control Trial	Subacromial Impingement Syndrome	Exercise program	Not specified	70, follow up 43	Arthroscopic acromioplasty	70, follow up 43		Pain	VAS Self-Reported Pain	N/A	Negative	N/A
										Pain	VAS Night Pain	N/A	Negative	N/A
										Function	VAS Disability	N/A	Negative	N/A
										Function	VAS Working Ability	N/A	Negative	N/A
										Function	SDQ Score	N/A	Negative	N/A
Ketola 2017	High risk	Randomized controlled trial	Rotator cuff tendinopathy	Exercise program	Not specified	70, follow up 46	Arthroscopic acromioplasty	70, follow up 44		Pain	VAS Self-Reported Pain	N/A	Negative	N/A
										Pain	VAS Night Pain	N/A	Negative	N/A
										Function	VAS Disability	N/A	Negative	N/A
										Function	VAS Working Ability	N/A	Negative	N/A
										Function	SDQ Score	N/A	Negative	N/A
Kukkonen 2014	Low risk	Randomized, controlled, superiority trial	Rotator cuff tear	Physiotherapy	EX: ROM/scapular retraction (first 6 weeks) + strengthening (6 weeks to 6 months) + 10 PT sessions, 6 months, progressive.	55	Acromioplasty + physiotherapy	57	12 months	Function	Constant Murley	-0.04	Positive	-0.04
										Biomechanical	Supraspinatus Tendon Tear Size (mm)	N/A	Negative	N/A

							Repair + acromioplasty + physiotherapy	55		Function	Constant Murley	-0.20	Positive	-0.20
										Biomechanical	Supraspinatus Tendon Tear Size (mm)	N/A	Negative	N/A
Kukkonen 2015	Low risk	Randomized, controlled, superiority trial	Supraspinatus tear	Physiotherapy	EX: ROM/scapular retraction (first 6 weeks) + strengthening (6 weeks to 6 months) + 10 PT sessions, 6 months, progressive.	55	Acromioplasty + physiotherapy	58	24 months	Function	Constant Murley	0.00	Positive	0.00
										Biomechanical	Supraspinatus Tendon Tear Size (mm)	0.62	Negative	-0.62
							Repair + acromioplasty + physiotherapy	54		Function	Constant Murley	0.00	Positive	0.00
										Biomechanical	Supraspinatus Tendon Tear Size (mm)	-0.20	Negative	0.20
Paavola 2018	High risk	Randomized, double blind sham controlled study	Shoulder impingement syndrome	Exercise therapy	EX: 15 sessions, 12 weeks, supervised, progressive. HEP: Daily, 12 weeks.	71, follow up 68	Arthroscopic subacromial decompression	59	24 months	Pain	VAS (rest)	2.47	Negative	-2.47
										Pain	VAS (activity)	3.79	Negative	-3.79
										Function	Constant Murley	-4.26	Positive	-4.26
										Function	Simple Shoulder Test	-1.70	Positive	-1.70

Paavola 2020	Low risk	Randomized, controlled superiority trial	Shoulder impingement syndrome	Exercise therapy	EX: 15 sessions, 12 weeks, supervised, progressive. HEP: Daily, 12 weeks.	71, follow up 62	Arthroscopic subacromial decompression	59, follow up 53	5 years	Pain	VAS (rest)	-0.06	Negative	0.06
										Pain	VAS (activity)	0.14	Negative	-0.14
										Function	Constant Murley	-0.38	Positive	-0.38
										Function	Simple Shoulder Test	0.02	Positive	0.02
										Function	SF36 (physical health)	0.17	Positive	0.17
										Function	SF36 (mental health)	0.39	Positive	0.39

Appendix E: Data chart with study, intervention details, effect sizes and % change for exercise interventions investigated in low risk of bias studies

First Author, year	Diagnosis	Exercise Intervention	List of exercises	Exercise category	Details	Number of Subjects (n)	Follow up	Outcome	Outcome Measure	Adjusted effect size	Adjusted % Change
Beaudreuil 2011	Subacromial Impingement Syndrome	Dynamic humeral centering exercises	Dynamic humeral centering exercises	Neuromuscular training	30 minutes/session, 3 times/week (3 weeks), 2 times/week (3 weeks). HEP: 3 times/day, 10 repetitions, progressive.	34, follow up 30	3 months	Pain	Constant Score (pain)	1.61	58.44
Beaudreuil 2015	Subacromial Impingement Syndrome	Dynamic humeral centering exercises	Dynamic humeral centering exercises	Neuromuscular training	30 minutes/session, 3 times/week (3 weeks), 2 times/week (3 weeks). HEP: 3 times/day, 10 repetitions, progressive.	34, follow up 30	3 months	Function	Constant Score (activity)	1.42	47.75
								Function	Constant Score (mobility)	1.15	49.16
								Function	Constant Score (total)	1.49	48.03
								Strength	Constant Score (strength)	0.43	34.38
								Biomechanical	Flexion AROM (painfree)	0.49	41.07
								Biomechanical	Abduction AROM (painfree)	0.54	50.00
								Biomechanical	Flexion AROM (painful arc)	-1.33	-79.88
								Biomechanical	Abduction AROM (painful arc)	-1.15	-56.04

BOUDREAU 2019	Rotator cuff tendinopathy	Rotator cuff strengthening, coactivation via EMG biofeedback	Wall push up plus, rows, external rotation, internal rotation, coactivation of latissiumus dorsi	Rotator cuff strengthening, scapular stabilizer strengthening, neuromuscular training	EX: 3 sets × 10 repetitions, once daily, 6 days/week, 7 weeks, progressed, supervised.	21, follow up 20	6 weeks	Pain	VAS (rest)	-0.07	-8.97
								Pain	VAS (movement)	0.62	21.10
								Function	DASH	0.26	13.66
								Function	WORC Index	0.63	27.33
								Biomechanical	Acromiohumeral Distance (0°)	0.29	6.48
								Biomechanical	Acromiohumeral Distance (30°)	0.09	1.92
								Biomechanical	Acromiohumeral Distance (60°)	0.12	3.16
		Rotator cuff strengthening + no coactivation	Wall push up plus, rows, external rotation, internal rotation	Rotator cuff strengthening, scapular stabilizer strengthening	EX: Rotator cuff strengthening, no coactivation, 3 sets × 10 repetitions, once daily, 6 days/week, 7 weeks, progressed, supervised.	21, follow up 19		Pain	VAS (rest)	-0.41	-64.71
								Pain	VAS (movement)	1.27	31.15
								Function	DASH	0.11	5.97
								Function	WORC Index	0.49	21.22

								Biomechanical	Acromiohumeral Distance (0°)	-0.18	-3.67
								Biomechanical	Acromiohumeral Distance (30°)	-0.24	-5.71
								Biomechanical	Acromiohumeral Distance (60°)	-0.10	-3.06
Dejaco 2017	Rotator cuff pathology	Eccentric exercises	Eccentric external rotation, eccentric scaption (full-can), posterior shoulder (cross-body) stretch, unilateral corner stretch	Stretching, Rotator cuff strengthening (eccentric)	12 weeks, 2 exercises, HEP once daily, progressive. PT: once/week (6 weeks), once biweekly (6 weeks).	20, follow up 19	12 weeks	Pain	VAS	1.82	75.90
								Function	Constant-Murley	0.87	20.41
		Conventional exercises	External rotation, internal rotation, scaption (full-can) posterior shoulder (cross-body) stretch, unilateral corner stretch	Stretching, Rotator cuff strengthening	EX: 12 weeks, 8 exercises, HEP once daily, progressive. PT: once/week (6 weeks), once biweekly (6 weeks).	16, follow up 15		Pain	VAS	1.04	55.00
								Function	Constant-Murley	1.06	11.03
Granviken 2015	subacromial impingement syndrome	Supervised Exercises	Not specified	ROM, Rotator cuff strengthening, scapular stabilizer strengthening	EX: 10 sessions + HEP, 4-6 exercises, twice daily, 6 weeks, 3 sets × 30 repetitions, progressive, supervised.	23, follow up 23	6 weeks	Pain	Pain (0 to 10, past week)	0.84	30.51
								Function	SPADI	0.82	33.33

								Function	FABQ (physical activity)	0.30	11.11
								Function	FABQ (work)	0.44	15.53
								Biomechanical	Flexion ROM (°)	0.20	3.31
								Biomechanical	Abduction ROM (°)	0.29	11.01
								Biomechanical	External Rotation ROM (°)	0.17	6.35
								Biomechanical	Internal Rotation ROM (°)	0.00	0.00
		Home exercise	Not specified	ROM, Rotator cuff strengthening, scapular stabilizer strengthening	EX: 1 session + HEP, 4-6 exercises, twice daily, 6 weeks, 3 sets × 30 repetitions, progressive.	23, follow up 21		Pain	Pain (0 to 10, past week)	1.12	31.75
								Function	SPADI	1.26	34.69
								Function	FABQ (physical activity)	0.73	24.29
								Function	FABQ (work)	0.24	16.06
								Biomechanical	Flexion ROM (°)	0.18	2.67
								Biomechanical	Abduction ROM (°)	0.22	7.56
								Biomechanical	External Rotation ROM (°)	-0.05	-1.54
								Biomechanical	Internal Rotation ROM (°)	0.07	1.61

Gutierrez-Espinoza 2019	Subacromial pain syndrome	Exercise + stretching	Resisted flexion, supine press-up, external rotation, unilateral corner stretch	Stretching, rotator cuff strengthening, scapular stabilizer strengthening	EX: 3 sessions/week, 12 weeks, 8-10 repetitions, supervised, progressive. HEP: 6 exercises, twice daily. STRETCH: 1 minute × 10 repetitions.	40	12 weeks	Function	Constant Murley	2.85	N/A
								Function	DASH	2.53	N/A
								Biomechanical	Pectoralis Minor Resting Length (cm)	1.50	N/A
								Biomechanical	Pectoralis Minor Index (%)	1.40	N/A
		Exercise only	Resisted flexion, supine press-up, external rotation	Rotator cuff strengthening, scapular stabilizer strengthening	3 sessions/week, 12 weeks, 8-10 repetitions, supervised, progressive. HEP: 6 exercises, twice daily.	40		Function	Constant Murley	2.72	N/A
								Function	DASH	3.27	N/A
								Biomechanical	Pectoralis Minor Resting Length (cm)	1.00	N/A
								Biomechanical	Pectoralis Minor Index (%)	0.60	N/A
Juul-Kristensen 2019	Subacromial pain syndrome	Neuromuscular exercise + biofeedback	Rows, low rows, external rotation, push up plus, wall slides, dynamic hug, unilateral corner stretch, flexion, scaption (full can), posterior shoulder (cross body) stretch	Stretching, rotator cuff strengthening, scapular stabilizer strengthening, neuromuscular training	EX: 8 weeks, biofeedback	23	8 weeks	Pain	NPRS (past 7 days)	N/A	N/A
								Pain	NPRS (now)	N/A	N/A
								Pain	NPRS (past 24 hours)	N/A	N/A
								Function	DASH (total)	N/A	N/A

								Function	DASH (work)	N/A	N/A
								Function	DASH (sport)	N/A	N/A
								Function	Oxford Shoulder Score	N/A	N/A
								Strength	UT Elevation %MVE	N/A	N/A
								Strength	UT Lowering %MVE	N/A	N/A
								Strength	LT Elevation %MVE	N/A	N/A
								Strength	LT Lowering %MVE	N/A	N/A
								Strength	SA Elevation %MVE	N/A	N/A
								Strength	SA Lowering %MVE	N/A	N/A
		Neuromuscular exercise alone	Rows, low rows, external rotation, push up plus, wall slides, dynamic hug, unilateral corner stretch, flexion, scaption (full can), posterior shoulder (cross body) stretch	Stretching, rotator cuff strengthening, scapular stabilizer strengthening, neuromuscular training	EX: 8 weeks.	26		Pain	NPRS (past 7 days)	N/A	N/A
								Pain	NPRS (now)	N/A	N/A
								Pain	NPRS (past 24 hours)	N/A	N/A
								Function	DASH (total)	N/A	N/A
								Function	DASH (work)	N/A	N/A
								Function	DASH (sport)	N/A	N/A
								Function	Oxford Shoulder Score	N/A	N/A
								Strength	UT Elevation %MVE	N/A	N/A
								Strength	UT Lowering %MVE	N/A	N/A
								Strength	LT Elevation %MVE	N/A	N/A
								Strength	LT Lowering %MVE	N/A	N/A
								Strength	SA Elevation %MVE	N/A	N/A
								Strength	SA Lowering %MVE	N/A	N/A

Kromer 2013	Shoulder impingement	Individually adapted exercises	Low row, internal rotation, scapular protraction, quadruped serratus anterior strengthening, thoracic extension	Rotator cuff strengthening, scapular stabilizer strengthening, postural	EX: 15-20 minutes/session, 10 sessions, first 5 of 12 weeks. HEP: 3 times/week, last 7 of 12 weeks.	44	5 weeks	Pain	Pain SPADI	1.00	36.49
								Pain	VNRS	1.00	34.00
								Function	Total SPADI	0.83	35.11
								Function	Function SPADI	0.58	32.83
								Function	Generic Patient Specific Scale	1.24	57.50
							12 weeks	Pain	Pain SPADI	1.30	51.41
								Pain	VNRS	1.50	54.00
								Function	Total SPADI	1.18	52.06
								Function	Function SPADI	0.93	52.89
								Function	Generic Patient Specific Scale	1.83	85.00
Kromer 2014	Shoulder impingement	Individually adapted exercises	Low row, external rotation, internal rotation, scapular protraction, quadruped serratus anterior strengthening, thoracic extensions, biceps curl, UT stretch	Stretching, rotator cuff strengthening, scapular stabilizer strengthening, postural, strengthening of other upper limb muscles	EX: 15-20 minutes/session, 10 sessions, first 5 of 12 weeks. HEP: 3 times/week, last 7 of 12 weeks.	44, follow up 43	52 weeks	Pain	Pain SPADI	2.17	75.00
								Function	Total SPADI	1.93	75.30
								Function	Function SPADI	1.49	76.60
								Function	Generic Patient Specific Scale	2.63	115.00

Kukkonen 2014	Rotator cuff tear	Physiotherapy	Not specified	ROM, rotator cuff strengthening, scapular stabilizer strengthening	EX: ROM/scapular retraction (first 6 weeks) + strengthening (6 weeks to 6 months) + 10 PT sessions, 6 months, progressive.	55	12 months	Function	Constant Murley	1.10	29.77
								Biomechanical	Supraspinatus Tendon Tear Size (mm)	0.10	8.33
Kukkonen 2015	Supraspinatus tear	Physiotherapy	Not specified	ROM, rotator cuff strengthening, scapular stabilizer strengthening	EX: ROM/scapular retraction (first 6 weeks) + strengthening (6 weeks to 6 months) + 10 PT sessions, 6 months, progressive.	55	24 months	Function	Constant Murley	1.10	29.77
								Biomechanical	Supraspinatus Tendon Tear Size (mm)	0.10	8.33
Paavola 2020	Shoulder impingement syndrome	Exercise therapy	Scapular retraction, AAROM (all directions), wall push ups, thoracic extensions, external rotation, internal rotation, flexion, pendulum, scapular clock, PNF D1 pattern, horizontal abduction	ROM, Rotator cuff strengthening, scapular stabilizer strengthening, neuromuscular training, postural	EX: 15 sessions, 12 weeks, supervised, progressive. HEP: Daily, 12 weeks.	71, follow up 62	5 years	Pain	VAS (rest)	N/A	87.29
								Pain	VAS (activity)	N/A	77.21
								Function	Constant Murley	2.75	126.70
								Function	Simple Shoulder Test	1.28	122.92
								Function	SF36 (physical health)	1.01	15.59
								Function	SF36 (mental health)	0.39	8.33

Appendix F: Data chart with study and intervention details for low risk of bias studies that investigated exercise compared to comparators

First Author, year	Study Design	Diagnosis	Exercise Intervention	Exercises	Tx Goal	Details	Number of Subjects (n)	Comparator	Comparator exercise intervention details (if applicable)	Number of Subjects (n)	Follow up	Outcome	Outcome Measure	Normalized effect size
Beaudreuil 2011	Randomized Controlled trial	Subacromial Impingement Syndrome	Dynamic humeral centering exercises	Dynamic humeral cantering	Neuromuscular training	30 minutes/session, 3 times/week (3 weeks), 2 times/week (3 weeks). HEP: 3 times/day, 10 repetitions, progressive.	34, follow up 30	Mobilization	MT: 30 minutes/session, 3 times/week (3 weeks), 2 times/week (3 weeks)	35, follow up 32	3 months	Pain	Constant Score (pain)	-0.36
Beaudreuil 2015	RCT Follow up	Subacromial Impingement Syndrome	Dynamic humeral centering exercises	Dynamic humeral centering	Neuromuscular training	30 minutes/session, 3 times/week (3 weeks), 2 times/week (3 weeks). HEP: 3 times/day, 10 repetitions, progressive.	34, follow up 30	Mobilization	MT: 30 minutes/session, 3 times/week (3 weeks), 2 times/week (3 weeks).	35, follow up 32	3 months	Function	Constant Score (activity)	0.37
												Function	Constant Score (mobility)	0.27
												Function	Constant Score (total)	0.36
												Strength	Constant Score (strength)	0.14
												Biomechanical	Flexion AROM (painfree)	0.21
												Biomechanical	Abduction AROM (painfree)	0.19
												Biomechanical	Flexion AROM (painful arc)	-0.98
												Biomechanical	Abduction AROM (painful arc)	-0.38

Kromer 2013	Randomized controlled trial	Shoulder impingement	Individually adapted exercises	Low row, internal rotation, scapular protraction, quadruped serratus anterior strengthening, thoracic extension	Rotator cuff strengthening, scapular stabilizer strengthening, postural	EX: 15-20 minutes/session, 10 sessions, first 5 of 12 weeks. HEP: 3 times/week, last 7 of 12 weeks.	44	Manual therapy + individually adapted exercises	MT+ EX: 20-30 minutes/session, 10 sessions, first 5 of 12 weeks. HEP: 3 times/week, last 7 of 12 weeks.	46	5 weeks	Pain	Pain SPADI	0.01
												Pain	VNRS	-0.35
												Pain	Pain Catastrophizing Scale (total)	N/A
												Function	Total SPADI	-0.10
												Function	Function SPADI	-0.20
												Function	FABQ (total)	N/A
												Function	Generic Patient Specific Scale	-0.37
											12 weeks	Pain	Pain SPADI	-0.11
												Pain	VNRS	-0.11
												Pain	Pain Catastrophizing Scale (total)	N/A
												Function	Total SPADI	-0.12
												Function	Function SPADI	-0.11
												Function	FABQ (total)	N/A
												Function	Generic Patient Specific Scale	0.10
Kromer 2014	Randomized controlled trial	Shoulder impingement	Individually adapted exercises	Low row, external rotation, internal rotation, scapular protraction, quadruped serratus anterior strengthening, thoracic extensions, biceps curl, UT stretch	Stretching, rotator cuff strengthening, scapular stabilizer strengthening, postural, strengthening of other upper limb muscles	EX: 15-20 minutes/session, 10 sessions, first 5 of 12 weeks. HEP: 3 times/week, last 7 of 12 weeks.	44, follow up 43	Manual therapy	MT+ EX: 20-30 minutes/session, 10 sessions, first 5 of 12 weeks. HEP: 3 times/week, last 7 of 12 weeks.	46, follow up 44	52 weeks	Pain	Pain SPADI	0.38

												Function	Total SPADI	0.38
												Function	Function SPADI	0.37
												Function	Generic Patient Specific Scale	0.40
Kukkonen 2014	Randomized, controlled, superiority trial	Rotator cuff tear	Physiotherapy	Not specified	ROM, rotator cuff strengthening, scapular stabilizer strengthening	EX: ROM/scapular retraction (first 6 weeks) + strengthening (6 weeks to 6 months) + 10 PT sessions, 6 months, progressive.	55	Acromioplasty + physiotherapy		57	12 months	Function	Constant Murley	-0.04
												Biomechanical	Supraspinatus Tendon Tear Size (mm)	N/A
								Repair + acromioplasty + physiotherapy		55		Function	Constant Murley	-0.20
												Biomechanical	Supraspinatus Tendon Tear Size (mm)	N/A

Kukkonen 2015	Randomized, controlled, superiority trial	Supraspinatus tear	Physiotherapy	Not specified	ROM, rotator cuff strengthening, scapular stabilizer strengthening	EX: ROM/scapular retraction (first 6 weeks) + strengthening (6 weeks to 6 months) + 10 PT sessions, 6 months, progressive.	55	Acromioplasty + physiotherapy		58	24 months	Function	Constant Murley	0.00
												Biomechanical	Supraspinatus Tendon Tear Size (mm)	-0.62
								Repair + acromioplasty + physiotherapy		54		Function	Constant Murley	0.00
												Biomechanical	Supraspinatus Tendon Tear Size (mm)	0.20
Paavola 2020	Randomized, controlled superiority trial	Shoulder impingement syndrome	Exercise therapy	Scapular retraction, AAROM (all directions), wall push ups, thoracic extensions, external rotation, internal rotation, flexion, pendulum, scapular clock, PNF D1 pattern, horizontal abduction	ROM, Rotator cuff strengthening, scapular stabilizer strengthening, neuromuscular training, postural	EX: 15 sessions, 12 weeks, supervised, progressive. HEP: Daily, 12 weeks.	71, follow up 62	Arthroscopic subacromial decompression		59, follow up 53	5 years	Pain	VAS (rest)	0.06
												Pain	VAS (activity)	-0.14
												Function	Constant Murley	-0.38
												Function	Simple Shoulder Test	0.02
												Function	SF36 (physical health)	0.17
												Function	SF36 (mental health)	0.39
								Diagnostic arthroscopy		63, follow up 55		Pain	VAS (rest)	0.13
												Pain	VAS (activity)	0.20
												Function	Constant Murley	0.04
												Function	Simple Shoulder Test	0.11
												Function	SF36 (physical health)	0.04

												Function	SF36 (mental health)	0.26