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The role of scapular dyskinesis on rotator cuff tears: a review of the current knowledge

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Ortopedia

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The role of scapular dyskinesis on rotator cuff tears: a review of the current knowledge

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À minha mãe, ao meu pai e à avó Clo,
os meus pilares.

À restante família e amigos,
pelo carinho e apoio incondicionais.

The role of scapular dyskinesis on rotator cuff tears: a review of the current knowledge

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Abstract

- Scapular dyskinesis can be present in healthy individuals as in patients with shoulder pathology.
- It is no consensual if the altered patterns of scapular kinematics cause or exacerbate rotator cuff tears pathology.
- Regardless of being the cause or the consequence of rotator cuff tear, scapular dyskinesis impairs shoulder function, worsens the symptoms, and compromises the clinical intervention success.
- The first recommended treatment for rotator cuff tears is physical therapy, and it should address scapular dyskinesis whenever it is present. Surgery is reserved for non-responsive cases.
- Post-surgical physical therapy protocols after rotator cuff repair must consider scapular dyskinesia to improve the outcomes.

Keywords

"Shoulder", "Scapula", "Scapular dyskinesis", "Rotator cuff tear", "kinematics".

Introduction

Scapular dyskinesis (SD) is described as any alteration on scapular position or motion and can impair shoulder stability and function. (1, 2) SD can be found in healthy individuals (2), and statics revealed a higher prevalence in overhead (61%) than in non-overhead athletes (33%). (3) Increased SD prevalence is also found in elderly individuals, in whom overuse injuries and degenerative pathology of the shoulder are more frequent.

Rotator cuff (RC) disorders are a subject of great relevance in clinical practice as they are a relevant cause of shoulder pain and loss of function that is potentially treatable. (4)

Besides being both frequent, there is a lack of studies on the association between rotator cuff tears (RCT) and SD. It is still unclear if SD is the cause, consequence, or a compensatory mechanism of the RC lesion.

To review the current knowledge of SD, plus the clinical and treatment implications on RCT, we performed an electronic database search using *PubMed, Web of Science*, and *Scopus* of studies published in the last five years, using various combinations of the search terms: "shoulder", "kinematics", "scapular dyskinesis", "rotator cuff tear", "treatment" and "outcome". Studies that were more relevant to the subject were retrieved and their bibliographies searched by hand. The search was limited to articles in English.

Scapular dyskinesis: definition and classification

SD is defined by the altered rest position and dysfunctional motion of the scapula. It is best seen as impaired optimal shoulder function, rather than pathology, once it can be present in asymptomatic individuals. (2)

There is a four-type classification for SD, based on the aspect of the medial border of the scapula with the arm at rest or during arm motion in forward flexion. (1) In type IV, both position and scapular motion are normal and symmetrical, while the other three types represent dyskinetic patterns. (1, 2) Type I is characterized by the prominence of the inferomedial angle of the scapula due to abnormal posterior tilt. In type II, there is an entire medial border prominent due to excessive external rotation, and type III shows prominence of the superomedial border, with upward migration of the scapula. (1, 2)

These patterns represent the net effect of different etiologies and often require the countervailing mechanisms of the surrounding musculature to achieve the desired function, predisposing them to injury. (5) Type III is often associated with subacromial impingement and injuries to cuff tendons. (2)

More than one type can coexist, making clinical evaluation challenging.

The yes/no method is used as a simple screening tool with a sensitivity of 74-78% and categorizes the three abnormal patterns into the "yes" category, and type IV into the "no" category. (6, 7)

Scapular dyskinesis: etiology and diagnosis

SD etiology may be neurological, such as cervical radiculopathy, long thoracic or spinal accessory nerve palsies. (8, 9)

There are also musculoskeletal etiologies, like tightness of the pectoralis minor and biceps short head, posterior shoulder inflexibility, periscapular muscles lesions, muscular activation alterations and strength imbalances, clavicle fracture, and acromioclavicular and glenohumeral joints instability. (8, 9)

Posture abnormalities, such as thoracic kyphosis, can also be related to SD. (8, 9)

SD is a clinical diagnosis. Clinical examination is preferred to static imaging techniques to diagnose SD, due to its important dynamic component. (9) An adequate physical examination must assess all possible contributors to dyskinesis. (10) In the presence of suggestive symptoms, computed tomography or magnetic resonance imaging scans can help find an etiological diagnosis of SD. (9)

Scapular dyskinesis causing shoulder lesion

SD contributes to the decrease of the subacromial space, which may precipitate the most frequent shoulder pathologies. It also contributes to the increased strain on the anterior glenohumeral ligaments and decreased RC strength. (8, 9)

The scapula is a critical connecting element of the kinetic chain that allows the transfer of strength from the body core to the arm. (1) The concept of "shoulder at risk, introduced by S. S. Burkhart *et al.* (2003), refers to the increased predisposition to injury and impaired optimal function that incur of the shoulder with high functional demand and structural and kinetic chain alterations. (10, 11)

The disabled throwing shoulder results from the successive kinetic chain alterations that occur in response to the high demands of throwing or hitting, which can impair the optimal shoulder function SD is present in 94% of athletes with a disabled throwing shoulder and is associated with 67%-100% of all shoulder injuries. (10)

Therefore, a clinical evaluation of scapula should be done routinely in all athletes with shoulder symptoms. Early diagnosis and adequate treatment of SD help in the prevention of shoulder lesions.

Alteration of scapular kinematics in rotator cuff tears

The normal 3D kinematics pattern of the scapula (relatively to the thorax) during arm elevation is upward rotation, posterior tilting, and external rotation. It is basilar for the optimal activation of the scapula and RC muscles, preventing the RC compression. (12)

There is no consensual scapular kinematics pattern for RCT.

Previous studies on RC tendinopathy characterized SD as protraction, excessive internal rotation, anterior tilting, and increased or decreased upward rotation of the scapula. (12-15) (Table 1) Insufficient scapular upward rotation and posterior tilt limit glenohumeral joint internal rotation and contribute to impingement and RC tendinopathy. (12-14)

R. Keshavarz *et al.* (2017) in a systematic review, presented that, during arm elevation, patients with full-thickness RCT had greater scapular than humeral elevation, when compared to tendinopathy and healthy groups. No differences were reported for posterior tilt and protraction. (Table 1) Those patients had also a lower range in flexion and less power in abduction and external rotation. Differences found between the tendinopathy and RCT groups favor the loss of cuff function instead of pain as the main cause of SD, as both the groups were symptomatic. (16)

Differently, T. Kijima *et al.* (2015), when comparing 3D scapular and glenohumeral kinematics during scapular-plane abduction among symptomatic, asymptomatic RCT and healthy shoulders, demonstrated significant lower posterior tilt of the scapula in the symptomatic RCT than in healthy shoulders, and less humeral external rotation compared to the healthy shoulders and asymptomatic tears. (Table 1) The absence of kinematics differences among the asymptomatic and healthy shoulders hints at a correlation between kinematic changes in symptomatic RCT and the development of symptoms. (17)

A strong prevalence of asymmetry in scapular movements, both in symptomatic and asymptomatic individuals, implies that asymmetry does not determine per se the clinical relevance of SD (6), so other factors must be considered.

Rotator cuff tears and scapular dyskinesis

RCT is age-related, with a prevalence of 22% at the age of 65 years, to more than 62% in a population older than 80 years, resulting from the normal progressive tendon degeneration. (18)

RC lesions are also a common cause of pain and dysfunction in athletes across all sports, being particularly frequent in overhead and contact athletes. (19)

The mechanisms responsible for scapular alterations coexisting in RCT remain not clarified.

Besides the known possibility that SD might lead to the RC rupture, due to the kinematics changes involved, new hypotheses have been raised. (8)

SD can be associated with the inhibitory effect that pain RCT-related has on the individual muscle activation capacity, with disruption of normal activation patterns. Therefore, dyskinesia may also arise in RCT as a result of the eviction and limitations imposed by pain. It is also acceptable that SD can appear like an adaptation mechanism after RCT, acting as a compensatory strategy to optimize the elevation of the injured arm, with a weakened or absent RC activation. (8)

Muscular activation patterns in scapular dyskinesis and rotator cuff tears

Shoulder joints' coordination depends on the pattern of muscular activation. The scapula must be dynamically stabilized in a retracted position during movement of the arm to an optimal activation of periscapular muscles, and the main scapular stabilizers are the upper and lower portions of trapezius and serratus anterior muscles. (20)

SD is related to weakness and imbalanced scapular muscles activation, which were documented in athletes with RC tendinopathy associated with scapular kinematics changes and narrowing of the subacromial space. (14)

Previous studies on patients with pain associated with shoulder impingement and overhead athletes with SD or RC tendinopathy report strength deficits and reduced electromyography (EMG) activity of the serratus anterior and delayed activity onset and activation of middle and lower trapezius relative to the upper trapezius. (Table 1) Those force coupling alterations were associated with the loss of posterior tilt and upward rotation of the scapula. (8, 12, 14)

When SD is clinically diagnosed, identifying altered scapular muscles activation patterns may aid in the development of rehabilitation strategies for the prevention and treatment of RC disorders.

Impact of scapular dyskinesis and rotator cuff tear on the shoulder

Two main factors may explain the negative impact of SD and RCT on the shoulder function: structural damage and pain avoidance. (21) The kinematic and muscular activation pattern changes described above for SD can also be interpreted as acquired adaptive or compensatory mechanisms in the context of a RC injury and associated pain.

An excessive protraction and internal rotation of the scapula lead to microinstability and can be associated with impingement syndrome and RC tendon changes. The decreased scapular abduction and external rotation compromise the dynamic concavity and compression function that optimize the shoulder stability during the throwing, with a less efficient force transference and less protection of the glenohumeral joint. (10)

Although shoulder pain seemed to limit scapular upward rotation (16), previous studies also revealed an increased scapulothoracic joint contribution on arm elevation, with an increased scapular upward rotation and posterior tilt, to compensate for the glenohumeral movement lost in RC pathology. (21) (Table 1)

Overhead athletes displayed increased scapular upward movement during the throwing motion, which is believed to be an adaptive change to preserve subacromial space and thereby avoid RC compression. (14)

A. Kolk *et al.* (2016) demonstrated that patients after a repaired RCT presented a normalization of scapulothoracic rotations toward the motion patterns found in the contralateral asymptomatic shoulder, which reinforces the deviation from normal kinematics as an adaptation in the context of the RCT suffered. (22) (Table 1)

Studies on electromyographic activity of scapular muscles during shoulder abduction showed an early muscular activation in athletes without RC tendinopathy and deficits in those with RC tendinopathy. (12) (Table 1)

The early muscular activation may arise from the need of stabilizing the scapula and keeping a stable base for the scapulohumeral muscles during arm movements in overhead athletes during the increased demands of the sport. All muscles became simultaneously activated on EMG to stabilize the scapula in patients with tendinopathy, but not in asymptomatic ones. (12)

Although the compensatory mechanisms keep the correct function of the shoulder in certain cases, when they are no longer effective, they can contribute to an exacerbation of the shoulder's previous condition and symptoms. (23)

Shoulder pain and loss of function

SD even if initially asymptomatic, considerably raises the risk of developing shoulder pain. (24)

SD, when symptomatic, clinically manifests as the SICK syndrome, characterized by **s**capular malposition, **i**nferior medial border prominence, **c**oracoid pain and malposition, and dys**k**inesis of scapular motion. (2)

Patients with RCT and/or SD frequently claim an inability to lift or perform overhead work and shoulder pain. There is still limited clinical evidence about how shoulder pain *per se* influences shoulder function. In this context, pain models are valuable tools for clarifying the effect of pain, regardless of injury and the presence of SD. (25)

Pain not only limits but also modifies shoulder function in healthy participants with experimental pain induction and individuals symptomatic or asymptomatic for the same shoulder pathology. During arm elevation, patients with symptomatic RCT, besides demonstrating less scapular rotation, have significantly increased activation of supraspinatus, infraspinatus, and upper trapezius, whereas asymptomatics have a greater subscapularis activity. (12, 16)

Besides pain, differences in the sensorimotor processing, proprioceptive changes, and deficits in the dynamic control of the scapula were proposed by Leong *et al.* (2017) as potential explicative factors for the changes observed in the presence of symptoms. (12)

Importance of early identification of scapulothoracic dysfunction

Independently of the possible cause-effect relationship, SD contributes to the maintenance and exacerbation of the dysfunction and symptoms of any shoulder pathology. As it can deeply affect shoulder functional scores, SD assessment should always be part of the shoulder routine examination and rehabilitation, in order to improve outcomes. (26)

The quantification of dyskinesis seemed to have prognostic value. (26)

A.G. Cutti *et al.* (2016) pointed out the limitation of the application of the Constant-Murley score (CMS) to assess the shoulder function in the presence of SD and suggested a modified version, namely the Scapula-Weighted CMS (SW-CMS). To avoid misclassification of those patients, SW-CMS weights the points attributed to the humerothoracic elevation, according to the affected-to-contralateral side difference in scapula-humeral coordination. That way it ensures SD is considered when evaluating the shoulder function. (26)

A recent clinical case report of one athlete with a supraspinatus tendon tear proposed for conservative treatment showed that early identification and treatment of the scapulothoracic dysfunction in the rehabilitation of this patient resulted in satisfactory outcomes. (24)

There is a great potential for rehabilitative efforts directed at restoration of scapulothoracic motion to improve the function of shoulders with previous loss of motion, and it is consensual that neglecting SD compromises the effectiveness of the overall treatment. (26, 27)

SD evaluation and specific rehabilitation programs in the approach of the patient with RCT aim to improve the functional outcome and decrease the risk of re-injury. (26)

Treatment outcomes of patients with rotator cuff tear and scapular dyskinesis

The treatment must be chosen considering the lesion type, its size and location, severity, the patient context, age and shoulder functional demand, and other possible concomitant injuries. When it comes to athletes, especially elite ones, this management is even more difficult, once performance limitations, timing, and financial concerns must be taken into account. (19)

Current evidence favors surgery in patients with RCT after the failure of conservative treatment. (4, 28)

The reported retear risk following RCT surgical reparation varied from 10.3% to 94%. (29-31) This disparity present across studies probably results from a non-uniformity regarding the retear definition, tear sizes considered, surgical and postoperative imaging techniques, and many other criteria, and reflects the multifactorial character of retearing. (29-31)

Several predictors of worse postoperative outcomes have already been identified: older age, lower baseline functional scores, increased tear size, preoperative fatty infiltration, tendon retraction, shoulder stiffness, muscle atrophy, among others. (32)

Further research is required to identify the modifiable factors that compromise tendon healing and contribute to repair failure. SD could be one of them.

Scapular dyskinesis and retear risk

The healing process of the repaired tendon is multifactorial.

A rat model was used to verify the effect of SD on supraspinatus tendon healing following repair. (33) They evaluated shoulder function, passive joint mechanics, and tendon properties and concluded that SD, besides altering joint function, compromises supraspinatus tendon properties, diminishing its mechanical properties, altering histology, and decreasing tendon organization. (Table 1) SD overloads, compresses, and submits tendon to shear stress, affecting optimal tendon-to-bone healing. (33)

While low activity and loading are known to promote healing, excessive or abnormal joint loading increase the risk of re-rupture. (33, 34)

Conservative treatment of rotator cuff tears and scapular dyskinesis

The current evidence recommends initially physical therapy for symptomatic degenerative RCT, although specific exercises for the aging population are not yet established, and it is controversial if it should promote the loading or unloading of the RC muscles.

For athletes with RCT, it is also recommended to begin with a nonsurgical therapeutic approach (19), that is based on interrupting all throwing activities, therapy with nonsteroidal anti-inflammatory drugs, and a rehabilitation program. (35, 36)

After shoulder symptoms improve, more sport-specific training programs can be implemented. Rehabilitation is also important following surgical treatment to minimize joint stiffness and to strengthen the RC and scapular muscles. (35, 36)

In a recent review, L. J. Weiss *et al.* (2018), defended that the RC injury rehabilitation program should be gradual, with different phases that will complement each other to best prepare the athlete for the return to competition. This program included early rehabilitation, an intermediate phase, and advanced/late-stage rehabilitation, and aimed to progressively reduce symptoms, restore the normal range of motion, gain flexibility, enhance proximal stability, and work on proprioception. (19)

The entire kinetic chain should be strengthened, and disturbances might be causing patient symptoms, such as soft tissue tightness, postural abnormalities, or SD, addressed. (36)

Regarding SD, the best current treatment is also the conservative one: physical therapy to correct positional and muscular force abnormalities, with specific exercises for scapular stabilization and muscular strengthening to optimize scapular kinematics. (5, 24) (Table 1)

Scapular posture abnormalities can be addressed with exercises that increase muscle flexibility (9)

Shoulder strengthening exercises change the activation patterns of the scapulothoracic muscles, decrease pain and improve shoulder function. Initial treatment should focus on the proximal kinetic chain, with exercises for core musculature stabilization, and then distally, on the strengthening of scapular stabilizers. (5, 19) Stretching and strengthening exercises improve proprioception and contribute to scapular stabilization. (5, 9, 37)

In the recent literature, there is still controversy about conservative treatment in RCT patients.

G. Baumer *et al.* (2016) demonstrated that physical therapy has a beneficial impact on clinical outcomes in patients with RCT, by reducing pain, increasing the shoulder range of motion, and improving functional scores, but it had a subtle effect on glenohumeral and scapulothoracic motion patterns. (38) (Table 1)

Aaron Turner (2019) suggested that treating SD in RCT might be more effective than surgery, by reporting a case of one non-throwing athlete with RCT, whose treatment protocol addressing scapular dysfunction alleviated pain and dysfunction and led to a faster return to the full level of sport, when comparing to surgical interventions. (24)

A meta-analysis by H. Saito *et al.* (2018) showed that patients receiving scapular focused interventions significantly improve pain (MD [95% CI] = −0.88 [−1.19 to −0.58]) and shoulder function (MD [95% CI] = −11.31 [−17.20 to −5.41]), comparing to the control group, although they had considered those improvements not so clinically relevant. (13)

H. Saito *et al.* (2018) also suggested that symptom relief might be ephemeral, so further research intervention was needed, to determine how to maintain it after cessation of scapular-focused interventions. (13)

The best start timing of rehabilitation is yet to define, but it is somehow evident that tear severity is a determining factor: individualized early rehabilitation protocols may be the best approach to promote an early functional shoulder on small to medium tears, but a delayed therapy is preferred for large tears in the postoperative period, to provide adequate time for tendon healing. (30)

Surgical treatment

Surgical reconstruction of RCT can effectively restore the biomechanical stability of the shoulder, normalizing scapular kinematics. (15, 22) (Table 1)

Current clinical practice guidelines support surgery for persistent shoulder pain and dysfunction, being the arthroscopic repair generally preferred to the open surgery but do not support a specific surgical technique over another, as it depends on several factors including surgeon experience and preference, tear and patient-specific factors. (19)

The outcome differs according to the population studied: results are more satisfactory in the general population than in high-level athletes. (19) For elite overhead athletes, particularly those without full-thickness tears, outcomes following surgery are not predictable. (35) The high failure of recovering and returning to the same performance level discourages surgery: more than 75% return to sport, but less than half achieve the pre-injury level of play. (35)

Most cuff retears are well tolerated by the patient, not requiring further intervention. (39)

P. Desmoineaux (2019) highlights that the work-up of a failed cuff repair must slightly differ from the initial one and address all the possible diagnostic and technical failures during the first intervention, as well postsurgical conditioners, such as an inadequate rehabilitation. (39)

Concomitant abnormalities should be diagnosed and treated properly. (39)

Some patient´s related factors (smoking habits, existing comorbidities, poor motivation, and adherence) are of major importance and cannot be controlled by the clinicians. (39) Those can be significant contributors to high retear rates.

Final considerations

At the time of writing, there is a predominance of reports of athletes with RCT treated by surgical intervention and postsurgical rehabilitation, clearly not applicable to the general population.

The best conservative treatment for RCT remains unclear: randomized controlled trials and detailed exercise protocols are scarce. While conservative treatment may be enough for managing some SD causative factors, others necessarily require a surgical approach followed by proper rehabilitative strategies. (40) Both interventions ultimately aim the same: to restore the scapular position and dynamics. (9)

Shoulder rehabilitation seeks to restore the muscular force balance of the shoulder joint, enhance humeral head stabilization on the glenoid, and avoid subacromial impingement syndrome; Surgical RC repair intents being as anatomical as possible and creating a biomechanically favorable environment for tendon healing, to prevent retearing. (41)

Conclusion

This review gathers relevant studies and their findings on RCT and SD.

A summary of the main findings is displayed in Table 1.

The literature search was not conducted systematically, therefore other pertinent studies may have been inadvertently omitted. The lack of studies assessing the simultaneous presence of RCT and SD limited this review.

This review identified existing evidence gaps, which may be addressed in future studies. More quality evidence is further needed to clarify abnormal scapular kinematics in RCT, investigate the changes in scapular muscles activation pattern, and establish rehabilitation strategies for the prevention and management of RC disorders when SD is clinically diagnosed. Further research is also required to identify the modifiable factors that compromise tendon healing and contribute to repair failure, to improve the effectiveness of the different treatment modalities and patient outcomes.

Topic	Study	Type of study (level of evidence, if available)	Study population	Methods	Results	Conclusion
Scapular kinematics	H. T. Leong et al,[12] 2017	Observational, case-control study.	43 male volleyball players (17 asymptomatic and 26 with rotator cuff (RC) tendinopathy) between 18-35 years of age (mean age = 22.9 ± 3.5 years).	Vicon v-370 3-D motion analysis system and acromial marker cluster method to detect scapular motion. RC tendinopathy diagnosed by clinical tests and ultrasound (US) imaging	Athletes with RC tendinopathy with less scapular upward rotation in the early phase of shoulder abduction from 0° to 30° vs asymptomatic athletes (6.6 ± 2.3 vs. 8.2 ± 1.1°, p= 0.021).	Rotator cuff tendinopathy alters scapular kinematics.
Scapular kinematics	X. Fu et al,[14] 2020	Systematic Review.	9 articles included (a total of 332 athletes between 18-32 years of age (mean age= 23.41 ± 2.62 years)). 4 studies compared dominant (throwing) vs nondominant shoulders of overhead athletes; 3 studies compared overhead sports athletes vs nonathlete controls; 4 studies compared athletes with vs without RC tendinopathy.	PRISMA guidelines; Published articles about scapular kinematics (SK) in overhead athletes with and without RC tendinopathy. RC tendinopathy diagnosed by clinical tests and/or conventional imaging; Motion analyzer or similar kinematic methods to calculate SK.	Increased scapular anterior tilting and internal rotation in the dominant shoulders vs nondominant shoulders of overhead athletes; Increased scapular upward rotation during arm elevation in athletes vs nonathletes; No consensual SK pattern in athletes with RC tendinopathy when compared with healthy controls.	Scapular kinematics is changed in overhead athletes.
Scapular kinematics	R. Keshavarz et al, [16] 2017	Systematic Review	20 articles included, of which 2 systematic reviews on RC tears (RCT) (a total of 116 subjects between 30-74 years of age (mean age= 48± 8.69 years)).	PRISMA guidelines; Published articles about SK in patients with shoulder musculoskeletal disorders (SMD). SMD confirmed by clinical examinations; Motion analyzer or similar kinematic methods to study SK.	Patients with RCT had scapula moving more than the humerus during arm elevation vs healthy or patients with tendinopathy; Scapular elevation during arm elevation in patients with RCT vs healthy and patients with tendinosis. No differences were reported for posterior tilt and protraction.	The RC pathology affects the shoulder rhythm during arm elevation in scapular and sagittal planes. Increased scapular upward rotation and posterior tilt compensate glenohumeral movements in RCT. No clear causal relationship between scapular alteration and a specific pathology.
Scapular kinematics	T. Kijima et al,[17] 2015	Observational, case-control study. (Basic Science Study, Kinesiology)	7 healthy subjects between 55-65 years of age (mean age=62 years), 5 symptomatic RCT between 66-74 years of age (mean age=70 years), and 7 asymptomatic RCT between 62-72 years of age (mean age= 67 years).	RCT were confirmed by magnetic resonance imaging (MRI); 3D/2D model-image registration techniques: shoulder computed tomography derived 3D bone models and fluoroscopic images of scapular-plane abduction.	Less posterior tilt of the scapula in the symptomatic RCT vs healthy shoulders (3.1º ± 1.8º vs. 10.4º ± 0.8°, p= 0.049); Less humeral external rotation relative to the scapula during activity in the symptomatic RCT vs healthy shoulders and asymptomatic RCTs (p=0.006 and p=0.028, respectively); No differences between the asymptomatic RCT and healthy shoulders.	Possible association between kinematic changes and the development of symptoms in RCT.

Muscular activation pattern	H. T. Leong et al,[12] 2017	Observational, case-control study.	43 male volleyball players (17 asymptomatic and 26 with RC tendinopathy) between 18-35 years of age (mean age = 22.9 ± 3.5 years).	Electromyography to access the activity onset of the upper (UT), middle (MT), lower trapezius (LT), and serratus anterior (SA), during arm abduction.	Delayed activity onset of LT relative to UT (14.1 ± 31.4 ms vs. 74.4 ± 45.1 ms, p<0.001) and SA (44.9 ± 26.0 ms vs. 23.0 ± 25.2 ms, p<0.001) in the tendinopathy vs the asymptomatic group. Patients with RC tendinopathy with a tight EMG activation in time (particularly UT, MT, and LT), which did not happen in the asymptomatic group.	The control of the scapular upward rotation is related to the activity onset of the scapular muscles in athletes. The idea of the muscular activation adaptability in RC tendinopathy deserves further investigation.
Functional limitation	X. Robert-Lachaine et al,[21] 2016	Observational, cohort study. (Basic Science Study, Kinesiology)	14 patients (mean age=56.4 ± 6.3 years) with RCT in need of surgery and 14 healthy individuals (mean age=25.2 ± 4.1 years). 2 categories of patients considered: category A for a maximal arm elevation of 85° and category B for a maximal arm elevation of 40º.	RCT diagnosed by shoulder US or MRI; Optoelectronic system to measure the scapulohumeral rhythm; DASH and WORC questionnaires to evaluate subjective shoulder symptoms.	Category A patients showed inferior scapulohumeral rhythm (p = 0.032); Category B patients´ scapulohumeral rhythm increased more during arm elevation vs the healthy individuals (p = 0.044).	Pathologies affecting the RC perturb shoulder joints' coordination; A decrease in glenohumeral motion is compensated by an increase of the scapulothoracic joint contribution.
Functional limitation	J. E. Hsu et al,[27] 2018	Retrospective cohort study (Level III Prognostic Study)	12 healthy subjects between 26-62 years of age (mean age=34.6 years), and 352 patients with shoulder pathology before elective surgery.	The Kinect system to assess active scapulothoracic (ST) and humerothoracic (HT) abduction; Simple shoulder test (SST) for patient self-assessment of shoulder function.	Limitation of ST abduction in patients with glenohumeral pathology unable to perform standardized shoulder functions (12 ± 10° or 17% of the active HT abduction) vs healthy shoulders (26 ± 7° or 19% of the active HT abduction); Patients with self-assessed loss of shoulder function with decreased ST and HT abduction (p<0.001).	ST motion is an important component of active shoulder motion and function in both healthy and pathological shoulders.
Functional limitation	T. G. Baumer et al,[38] 2016	Controlled laboratory study.	25 patients between 48-79 years of age (mean age= 60.2±8.4 years) with symptomatic RCT, and 25 asymptomatic control subjects between 51-74 years of age (mean age=59.0±5.5 years).	RCT documented by shoulder US or MRI; Shoulder motion measured by a biplane radiography imaging system; Strength assessed by a Biodex dynamometer; Patient-reported outcomes assessed by WORC questionnaire and visual analog scale (VAS) pain score.	Patients with symptomatic RCT with worse pain/function scores, less range of motion (ROM), lower abduction, external and internal rotation, strength (p<0.01), less scapulothoracic posterior tilt (p=.05), and lower glenohumeral joint elevation (p< 0.01) vs control subjects.	Symptomatic full-thickness RT impairs shoulder function.
Retear risk	K. E. Reuther et al,[33] 2015	Randomized controlled trial (Basic Science, in-vivo Animal Study)	A rat model of scapular dyskinesis (SD) was used. 70 adult male Sprague-Dawley rats (400-450 g) were randomized into 2 groups: nerve	All rats underwent unilateral detachment and repair of the supraspinatus tendon and were sacrificed at 2, 4, and 8 weeks after surgery.	SD altered joint function and compromised supraspinatus tendon properties: it diminished mechanical properties, altered histology, and decreased tendon organization.	SD alters the shoulder loading environment (type of loading the more than its amount/magnitude) and increases the risk of re-rupture

			transection of the accessory and long-thoracic nerves or sham nerve transection (control).	Elastic and viscoelastic mechanical properties of the supraspinatus tendon determined by uniaxial tensile testing; cellular and organizational changes by histologic analysis and the distribution of extracellular matrix proteins by immunohistochemical techniques.		of the healing supraspinatus tendon following repair. The functional consequences associated with SD may compromise supraspinatus tendon healing following repair by diminishing some tendon mechanical properties.
Conservative treatment	T. G. Baumer et al,[38] 2016	Controlled laboratory study.	25 patients between 48-79 years of age (mean age= 60.2±8.4 years) with symptomatic RCT, and 25 asymptomatic control subjects between 51-74 years of age (mean age=59.0±5.5 years).	RCT documented by shoulder US or MRI; Shoulder motion measured by a biplane radiography imaging system; Strength assessed by a Biodex dynamometer; Patient-reported outcomes assessed by WORC questionnaire and visual analog scale (VAS) pain score. A standardized physical therapy (PT) protocol was prescribed for patients with symptomatic RCT. Patients' data acquired before and after 8 weeks of PT and acquired at 1-time point for the control subjects.	PT improved pain/function scores ($p< 0.01$), increased ROM ($p< 0.02$), increased scapulothoracic posterior tilt ($p=0.05$), increased glenohumeral joint elevation ($p=0.01$), and decreased acromiohumeral distance ($p=0.02$).	PT has a positive effect on clinical outcomes in patients with RC pathology.
Conservative treatment	L.U.Giuseppe et al,[9] 2020	Systematic Review	127 articles included.	PRISMA guidelines; Published articles about scapular dyskinesis (SD), its causes and effects, clinical examination, and treatments.	Specific exercises for scapular rehabilitation include exercises to optimize scapular kinematics: flexibility exercises to decrease traction and neutralize scapular positions, and scapular stabilization exercises, based on stretching and strengthening scapular stabilizers, to improve muscle strength and proprioception.	A large variety of SD alterations can be managed by an individualized rehabilitation protocol based on clinical and isokinetic tests. SD conservative treatment aims to restore scapular kinematics, reinforce the scapular muscles and guarantee the optimal length–tension relationship of RC muscles.
Surgical treatment	Y. Ueda et al,[15] 2019	Observational, case-control study.	14 healthy controls (mean age= 24.7±4.5 years) and 16 patients with RCT surgically treated: 10 patients with small RCT (mean age= 62.7±7.7 years) and 6 with massive* RCT (mean age= 64.5±9.5 years)	All RCT treated by McLaughlin procedure. Fluoroscopic imaging to analyze scapular motion. RCT patients´ motion analyses were performed in the preoperational stage, at 2 and 5 months after surgery.	Before surgery: Both rotator cuff groups with greater scapular upward rotation vs healthy controls ($p< 0.01$); No significant difference was observed between the 2 RCT groups ($p =0 .17$). At 2 months after surgery: significant greater scapular upward rotation only in patients with small RCT vs healthy controls at arm elevations of 90º (40.7º ± 5.5º vs. 34.2º ± 4.0°,	Tear size affects scapular motion: massive RCT are associated with greater scapular upward rotation. The rehabilitation program should consider the tear size.

			*Massive tear was defined as "the conditions that L × H is > 5.6 cm2 (where L is the length of the tear region at the attachment site of the tendon and H is the depth to the tendon end; >=2 tears are present and the diameter of exposed humeral head is > 3 cm or the circumstance of the ruptured region is > 9 cm)".		p=0.02); but for both RCT groups (small, massive RCT) vs healthy controls for arm elevations of 120º (61.2°, 61.3° vs 48.2º, p<0 .01). At 5 months after surgery: Significant differences still existed in healthy controls vs both rotator cuff groups. For the patients with small, but not for massive RCT ones, the scapular upward rotation decreased over time (2–5 months) at arm elevations of 120º (from 61.2° to 52.4°, p= 0.01), but did not return to the same level of the healthy controls (48.2º).	
Surgical treatment	A. Kolk et al,[22] 2016	Observational case series (Level IV)	26 patients with RCT proposed to surgical treatment, between 46-73 years of age (mean age= 60 years); The asymptomatic contralateral shoulder was used as the control.	RCT were confirmed by magnetic resonance or computed tomography; Shoulder kinematics was analyzed before and 1 year after RC repair by 3D electro-magnetic motion analysis (Flock of Birds).	Surgery improved mean arm abduction by 20° (118º ± 37.3º vs. 138º ± 20.0°, p=0.025) and forward flexion by 13° (127º ± 31.4º vs. 140º ± 15.6°, p=0.044) and decreased mean scapular protraction and lateral rotation during abduction by 3° (95% CI, 0.0°-5.2°; p=0.046) and 4° (95% CI, 1.6°-8.4°; p=0.042), respectively. Glenohumeral elevation increased by 5° (95% CI, 0.6°-9.7°; p=0.028) at 80° to 90º of abduction, after RC repair. Humeral ROM increased when scapular lateral rotation decreased, and posterior tilt increased. No differences in scapular motion before vs after surgery, in the asymptomatic contralateral shoulders.	Scapular kinematics normalize after RC repair toward the scapular motion patterns observed in the asymptomatic contralateral shoulder. Changes in scapular kinematics after surgery are associated with an increased overall ROM, suggesting the restored function of shoulder muscles.

Table 1- Summary of the main findings.

Abbreviations

CMS: Constant-Murley Score; EMG: electromyography; RC: Rotator Cuff; RCT: Rotator Cuff Tears; SD: Scapular Dyskinesis; SW-CMS: Scapula-Weighted CMS.

Conflicts of Interest

The authors declare no conflict of interest.

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ANEXOS

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Page 3: "Besides being both frequent, there is a lack of studies on the association between rotator cuff tears (RCT) and SD. It is still to clarify if SD is the cause, consequence, or a compensatory mechanism of the RC lesion."

Page 13: "This review identified existing evidence gaps, which may be addressed in future studies. More quality evidence is further needed to clarify abnormal scapular kinematics in RCT, investigate the changes in scapular muscles activation pattern, and establish rehabilitation strategies for the prevention and management of RC tendinopathy when SD is clinically diagnosed. Further research is also required to identify the modifiable factors that compromise tendon healing and contribute to repair failure, to improve the effectiveness of the different treatment modalities and patient outcomes."

2) Statement of concrete aims or formulation of questions

One or more concrete aims or questions are formulated.______________________________2

Page 3: "To review the current knowledge of SD, as the clinical and treatment implications on RCT, we performed an electronic database search (…)"

3) Description of the literature search

The literature search is described in detail, including search terms and inclusion criteria.______________________________2

Page 3: "(…) we performed an electronic database search using PubMed, Web of Science, and Scopus of studies published in the last five years, using various combinations of the search terms: "shoulder", "kinematics", "scapular dyskinesis", "rotator cuff tear", "treatment" and "outcome". Studies that were more relevant to the subject were retrieved and their bibliographies searched by hand. The search was limited to articles in English."

4) Referencing

Key statements are supported by references.______________________________2

Page 3: "Scapular dyskinesis (SD) is described as any alteration on scapular position or motion and can impair shoulder stability and function. (1, 2) SD can be found in healthy individuals (2), and statics revealed a higher prevalence in overhead (61%), than in non-overhead athletes (33%).(3)"

Page 5: "The normal 3D kinematics pattern of the scapula (relatively to the thorax) during arm elevation is upward rotation, posterior tilting, and external rotation. It is basilar for the optimal activation of the scapula and RC muscles, preventing the RC compression. (12)"

5) Scientific reasoning

Appropriate evidence is generally present.____2

Page 5: “R. Keshavarz et al. (2017) in a systematic review, presented that, during arm elevation, patients with full-thickness RCT had greater scapular than humeral elevation, when compared to tendinopathy and healthy groups. No differences were reported for posterior tilt and protraction.”

Table 1, Pages 14-17 :

Topic	Study	Type of study (level of evidence, if available)	Study population	Methods	Results	Conclusion
Scapular kinematics	H. T. Leong et al. (2017)	Observational, case-control study.	43 male volleyball players (17 asymptomatic and 26 with rotator cuff (RC) tendinopathy) between 18-35 years of age (mean age = 22.9 ± 3.5 years).	Vicon v-370 3-D motion analysis system and acromial marker cluster method to detect scapular motion. RC tendinopathy diagnosed by clinical tests and ultrasound (US) imaging	Athletes with RC tendinopathy with less scapular upward rotation in the early phase of shoulder abduction from 0° to 30° vs asymptomatic athletes (6.6 ± 2.3 vs. 8.2 ± 1.1°, p= 0.021).	Rotator cuff tendinopathy alters scapular kinematics.
Scapular kinematics	X. Fu et al. (2020)	Systematic Review.	9 articles included (a total of 332 athletes between 18-32 years of age (mean age= 23.41 ± 2.62 years)). 4 studies compared dominant (throwing) vs nondominant shoulders of overhead athletes; 3 studies compared overhead sports athletes vs nonathlete controls; 4 studies compared athletes with vs without RC tendinopathy.	PRISMA guidelines; Published articles about scapular kinematics (SK) in overhead athletes with and without RC tendinopathy. RC tendinopathy diagnosed by clinical tests and/or conventional imaging; Motion analyzer or similar kinematic methods to calculate SK.	Increased scapular anterior tilting and internal rotation in the dominant shoulders vs nondominant shoulders of overhead athletes; Increased scapular upward rotation during arm elevation in athletes vs nonathletes; No consensual SK pattern in athletes with RC tendinopathy when compared with healthy controls.	Scapular kinematics is changed in overhead athletes.

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In table 1

6) Appropriate presentation of data

Relevant outcome data are generally presented appropriately.______________________________2

Page 11: “A meta-analysis by H. Saito et al. (2018) showed that patients receiving scapular focused interventions significantly improve pain (MD [95% CI] = −0.88 [−1.19 to −0.58]) and shoulder function (MD [95% CI] = −11.31 [−17.20 to −5.41]), comparing to the control group, although they had considered those improvements not so clinically relevant.”

Sumscore : 12