International Journal of Advanced Engineering Research and Science (IJAERS)
Peer-Reviewed Journal
ISSN: 2349-6495(P) | 2456-1908(O)
Vol-9, Issue-3; Mar, 2022
Journal Home Page Available: https://ijaers.com/
Article DOI: https://dx.doi.org/10.22161/ijaers.93.18

Effects of eccentric exercises on tendinopathy of the shoulder rotator cuff: A systematic review

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Received: 20 Jan 2022,
Received in revised form: 02 Mar 2022,
Accepted: 13 Mar 2022,
Available online: 28 Mar 2022

***Keywords*— Shoulder Impact Syndrome; Therapeutic Exercise; Physiotherapy Modalities.**

***Abstract*—** *Introduction:Rotator cuff injuries are among the main causes of joint pain and disfunction. Eccentric exercise is commonly used in tendinopathies.Objective:To evaluate the effects of administering eccentric exercises on the rehabilitation of rotator cuff tendinopathy.Material and Method: This is a systematic review based on randomized clinical trials found in Pubmed/MEDLINE, Science Direct, PEDro and Cochrane Library databases, published in all languages with adult patients, aged 18 to 80 years, presenting signs and symptoms suggestive of rotator cuff tendinopathy. Results: Eccentric exercises have been shown to be effective in the treatment of rotator cuff tendinopathy, however, they are not relevant when compared to other exercise modalities.*

I. INTRODUCTION

Rotator cuff (RC) muscles provide movement, nutrition, and dynamic stability to the shoulder joint, comprising the supraspinatus, subscapular, infraspinatus, and smaller round.[1] Tendon involvement of this important muscle complex is among the main causes of joint pain and dysfunction.[2] Thus, as the size of the ruptures, RC degeneration has been increasing along with age 4, up to 54% of adults over 60 years of age have some type of RC rupture.[2]

RC tendinopathy is one of the main causes of pain and disability in society, and musculoskeletal disease is more commonly diagnosed.[3,4] It is not necessarily symptomatic, being of multifactorial ethology, including intrinsic, extrinsic and traumatic factors.[2-4] Among these factors are age, sex, environment and occupation, extrinsic structural changes that can generate mechanical shock, inadequate blood supply, with degenerative alteration as the predominant lesion.[2-4]

Physiotherapy aims to reduce the impact exerted on RC tendons and when installed, stimulate the regeneration process of injured tendons, in addition to focusing on reducing impact, should also treat tendon degeneration.[5]The implementation of therapeutic exercise programs, which diversify muscle strengthening, aim to reduce pain, reduce the inflammatory process, promote healing, preserve and gain range of motion (ROM) and restore glenohumeral and scapular-thoracic balance.[2]

Eccentric exercise is commonly used in physical therapy interventions for tendinopathy.6 Eccentric load exercises include the active stretching of the myotendinous unit, exposing the tendon to a greater load than concentric exercise and, it seems, ends up generating a restorative effect after the production of muscle microruptures.[2]

Therefore, this systematic review aimed to identify the effects of eccentric exercises when compared to traditional and concentric exercises in relation to pain, function and strength of patients with rotator cuff tendinopathy.

II. MATERIALS AND METHODS

This is a systematic review conducted through searches of bibliographic references of relevant studies in online databases of Pubmed/MEDLINE, Science Direct, PEDro and Cochrane Library, published between 2010 and 2020 in English and Portuguese.

The inclusion criteria adopted were ECRs published from 2010 to 2020, conducted with adult patients (18 to 80 years) presenting signs and symptoms suggestive of rotator cuff tendinopathy, defined as symptom duration greater than three months, minimal pain at rest, widely preserved shoulder ROM, pain consistently exacerbated by resisted tests and without cervical spine involvement.

The primary result measure was the measurement of shoulder pain intensity and the secondary ones were ROM, muscle strength and function. Studies addressing combined interventions, lack of definition of inclusion or exclusion criteria in the RCT, absence of complete data from the beginning to the end of the follow-up and articles published prior to 2010 were excluded.

Four electronic databases were searched (Cochrane Library, PubMed, PEDro and Science Direct) from October 1 to January 9, 2021. The search strategies are described in Table 1. Thus, based on the published findings, the most relevant data for the construction of this study were collected (Table 1).

Table 1. Flowchart of the Search Strategy in literature.

Database	**Strategy**	**Terms**
Pubmed/Medline Cochrane Library	#1	"Rotator Cuff Injuries" [Mesh] OR "Cuff Injury Rotator" [Mesh] OR "Disorders, Temporomandibular Joint" [Mesh] OR "Injuries, Rotator Cuff" [Mesh] OR "Injury, Rotator Cuff" [Mesh] OR "Rotator Cuff Injury" [Mesh] OR "Rotator Cuff Tears" [Mesh] OR "Rotator Cuff Tear" [Mesh] OR "Tear, Rotator Cuff" [Mesh] OR "Tears, Rotator Cuff" [Mesh] OR "Rotator Cuff Tendinosis" [Mesh] OR "Rotator Cuff Tendinoses" [Mesh] OR "Tendinoses, Rotator Cuff" [Mesh] OR "Tendinosis, Rotator Cuff" [Mesh] OR "Rotator Cuff Tendinitis" [Mesh] OR "Rotator Cuff Tendinitides" [Mesh] OR "Tendinitis, Rotator Cuff"
	#2	"Exercise" [Mesh] OR "Exercises" [Mesh] OR "Activities, Physical" [Mesh] OR "Activity, Physical" [Mesh] OR "Physical Activities" [Mesh] OR "Exercise, Physical" [Mesh] OR "Exercises, Physical" [Mesh] OR "Physical Exercise" [Mesh] OR "Physical Exercises" [Mesh] OR "Acute Exercise" [Mesh] OR "Acute Exercises" [Mesh] OR "Exercise, Acute" [Mesh] OR "Exercises, Acute" [Mesh] OR "Exercise Training" [Mesh] OR "Exercise Trainings" [Mesh] OR "Training, Exercise" [Mesh] OR "Trainings, Exercise" [Mesh] OR "Eccentric Exercise"
	#3	Combining #1 e #2.
Science Direct	#1	"Rotator Cuff Injuries" [Mesh] OR "Rotator Cuff Injury" [Mesh] OR "Rotator Cuff Tendinosis" [Mesh] AND "Exercise" [Mesh] OR "Exercise Training" [Mesh] OR "Exercises" [Mesh] OR "Physical Exercise" [Mesh] OR "Eccentric Exercise" [Mesh]
PEDro	#1	"Rotator Cuff" AND "Eccentric Exercise"

To determine the eligibility of the identified articles, the collaborators independently selected titles, abstracts and performed the final analysis of the contents of these articles. Differences of opinion among evaluators on the eligibility of the studies were resolved by discussion and judged by a third evaluator, if necessary.

The risk of bias was assessed using the PEDroscale[7]. Two independent researchers assessed the risk of bias.

The differences were resolved by discussion and judged, if necessary. The results of the methodological quality of the ECRs included in the review are presented in Table 2.

The collaborators extracted data on the characteristics of the sample, design of the intervention and estimates of the effect of the exercise in each study. The studies were described in terms of the design of the assay (sample size, follow-up period) characteristics of the sample (age, control group, tendinopathy status), intervention components (amount of supervision, exercises adjusted in type or intensity, exercise dose) and program adem. Estimates of the effect of the exercise on the results measurements were extracted from each clinical trial.

The present study dispenses with the approval of the Research Ethics Committee, due to the use of data taken from studies already published in the literature, and there is, therefore, no intervention or direct approach to human beings, according to resolution 466/12.

III. RESULTS AND DISCUSSION

Based on the searches carried out in the online databases (Medline, Bvs Lilacs, Scielo, and Google Scholar), no articles were found to compare acupuncture and myofascial release techniques in the same study, thus the research was conducted directing the application of each technique.

The crossing of the descriptors and the use of the filters made it possible to obtain a total of 128 references of which 98 werediscarded because they did not fit the inclusion criteria. Thus, the sample of this study had 30 references, according to theinclusion criteria and keywords. The tables below show an overview of the reading of the articles chosen for discussion.

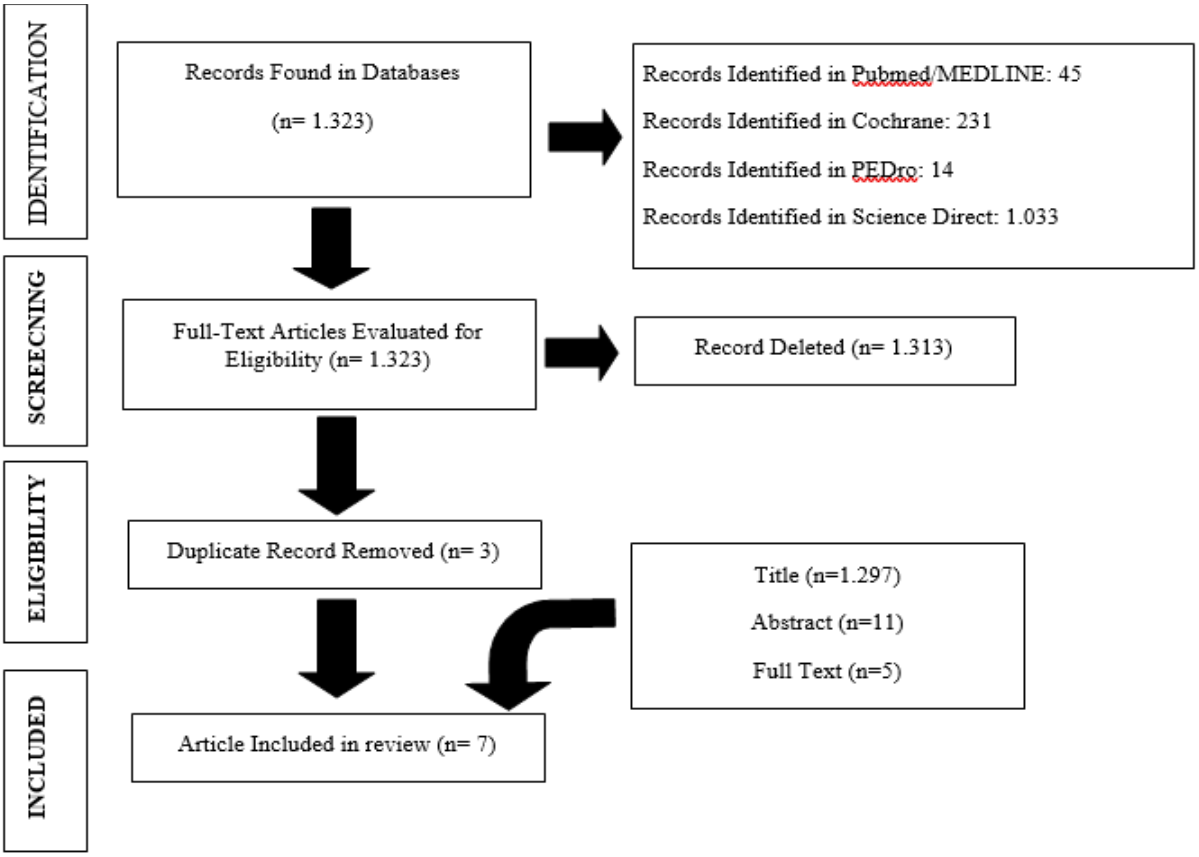

Fig.1 – PRISMA flowchart with the strategy of searching the articles.

Table 2. Characteristics of the studies included in the review.

Author, year	Characteristics of Participants	Intervention Groups	Characteristics of the Exercise Program	Results Measures	Results Obtained	Conclusion
Maenhout et al., 2012[5]	61 patients with subacromial	Traditional RC training	Both groups received one physiotherapy	Abduction isometric force	Isometric strength	Adding eccentric heavy load training

	impact syndrome	group GTT (n=30); Traditional training group + GTTE eccentrics (n=31)	session per week for six weeks. After, one session every two weeks for more weeks, totaling 9 physiotherapy sessions for 12 weeks; Traditional group: 2 resistance exercises for internal and external rotation, 3 x 10 rep 1 x daily, 6 sec per repetition; Traditional + eccentric group: same exercises with addition of an eccentric load lasting 5 sec, 3 x 15 rep. 2 x a day; Load increase of 0.5 kg if painless since the last session;	and internal and external rotation (manual dynamometry); SPADI;	increased significantly in all directions; SPADI score decreased significantly in both groups; GTTE showed an over-the-million-bit gain 15% of abduction force	resulted in a greater gain of strength isometric of abduction, but was not superior to lessen the pain and improving shoulder function
Hallgren et al., 2014[8]	97 patients (36 women and 61 men), age 52 years (30-65) with clinical signs of subacromial pain without complete rupture.	Eccentric Exercise Group (n=51) and nonspecific group (n=46)	Three months of home exercises, with weekly visits from the physiotherapist in the first 2 weeks and after, every 2 weeks; Non-specific group: six exercises for head and shoulder without progression for 10 weeks. Eccentric Group: exercises for RC and a combination of eccentric and concentric exercises for scapular stabilizers with load progression.	Radiographic evaluation; Ultrasound; Constant Murley; Pain (VAS); EuroQol: DASH.	Improvement of Constant-Murley scores in all patients; Rate of patients who underwent surgery in 1 year was 63% in the nonspecific group and 24% in the eccentric group.	Eccentric exercises should be the first line of treatment for subacromial pain.
he et al., 2015[9]	atients, age 50 years (23-84) with SIS .	Concentric Exercises Group (n=16);	2 x week for four weeks both groups 2 initial weeks idem for	Pain (NPRS); DASH;	No significant difference in any measure of result between the two	Both eccentric and concentric programs resulted in improved

		Eccentric Exercises Group (n=18)	both groups with 3 x 20 rep. each exercise; 3rd week - differentiated exercises in each group with 3 x 12 rep each exercise with 70% 1RM; 3rd week - differentiated exercises in each group with 2 x 12 rep each exercise with 80% 1RM;	Active range of motion; Abduction muscle strength and external shoulder rotation (dynamometry)	groups; Both groups with significant improvements in all outcome measures from the beginning to the week five ($p < 0,0125$); Significant improvements also from week five to week eight ($p < 0.0125$) for all result measurements, except adm elevation of the scapular plane.	function, ROM and strength in patients with SIS. No difference was found between the two exercise modes.
co et al., 2016[10]	36 patients with RC tendinopathy	Eccentric Group, 50.2 ± 10.8 years (n=20); Conventional Group, 48.6 ± 12.3 years (n=16);	Daily exercises for 12 weeks; Conventional Group: 8 daily exercises (abduction in the scapular plane up to 90°, external and internal rotation at 0° abduction; Eccentric Group: 2 exercises (external rotators and abduction), 6 to 8 sec per repetition with progressive load increase; Three sets of 8 repetitions for each initial group, increasing to 15 repetitions with increased load;	Constant-Murley score; Pain (VAS); Active ADM; Isometric abduction force;	Both groups showed a significant increase in constant murley's score and decrease in EVA scores; No difference was found between the groups, for any of the outcome measures;	A 12-week isolated eccentric training program rc is beneficial for shoulder function and pain; However, it is no more beneficial than a conventional exercise program for CR and scapular muscles.

Vallés-Carrascosa et al., 2017[11]	22 patients with subacromial syndrome, mean age of 59 years.	Non-painful Eccentric Group (GEND); Painful Eccentric Group (GED);	Exercises for RC: 1. Eccentric exercise for RC,3 x 10 rep; 2. Exercise for external and internal rotation, 3 x 10 rep; Scapular stabilization exercises: 1. Dynamic Hug exercise, 3 x 10 rep; 1. Lower Glide exercise. 3 x 10 rep, each contraction of 5 sec; 2. Upper trapezoid elongation, 3 x 30 sec; groups 5 x week for 4 weeks; Same protocol in both groups, GED with exercise causing pain up to 4 in VAS. GEND without causing pain;	Pain (VAS); ADM; Constant-Murley score;	Both groups improved significantly in all outcome measures (P <0.05); The comparison between the groups did not show significant differences;	Os results suggest that painful exercise does not add benefit in comparison with pain-free exercise.
Chaconas et al., 2017[12]	48 patients with chronic shoulder pain, mean age of 46.8 ± 17.29 years	Experimental group (EG) (n=25); Control group (CG) (n=23)	EG: eccentric exercises for 6 weeks; 1. Eccentric exercise for external rotators with thera-band, 3 x 15 rep with 3 sec in eccentric phase 1 x daily; 2. Scapular retraction exercise with thera-band, 2 x 10 rep 1 x daily; 1. Progressive increase of load; 1. Capsule stretching posterior shoulder, 3 x 30-45 sec 1 x daily;	Western Ontario Rotator Cuff Index (WORC); Pain (NPRS); Muscle strength of external rotators, internal and abduction; Active ADM; Upper Quarter Y-balance test	Improvement of worc score in eG at three weeks (p=0.003), six weeks (p=0.001) and six months (p=0.007); Pain improvement at six months in EG (p=0.006); Improvement of muscle strength in the EG with six months for external rotator (p <0.001),	An eccentric program aimed at external rotators was superior to a general exercise program for strength, pain and function after six months; The results suggest that eccentric training may be effective in improving function and strength.

			CG: conventional exercises for 6 weeks; 1. Active lifting exercise in scapula plane without resistance, 2 x 10 rep 1 x daily; 2. Scapular retraction exercise with thera-band, 2 x 10 rep 1 x daily; 3. Stretching of posterior shoulder capsule, 3 x 30-45 sec 1 x per day.	(UQYBT); Global Rating of Change (GROC);	internal rotator (p = 0.02) and abductor strength (p <0,001);	
Macías-Hernandez et al., 2020[13]	26 patients with partial RC rupture	Eccentric Group (EG) (n=12); Control Group (CG) (n=14);	GE: • Eccentric exercises for deltoid, internal and external rotators, biceps, triceps, pectorals and trapezoids, 3 x 12 rep with eccentric phase of 12 sec duration; • 20 sessions, 5 x week, 4 weeks; GC: • Concentric muscle strengthening for deltoid, internal and external rotators, biceps, triceps, pectorals and trapezoid, 3 x 12 rep.; 1. 20 sessions, 5 x week, 4 weeks;	Pain (VAS); Constant-Murley score; Ultrasound (cross-section area);	Intergroup differences in the Constant scale at 1 and 3 months (p <0.05); Intergroup differences in strength in months 1 and 3 (p <0.05); Structural differences in the tendon (healing) between groups at 3 and 12 months.	Both exercise programs show early improvement in pain, functionality and tendon structure; Eccentric training seems to be more effective than concentric in the early improvement of tendon functionality, strength and healing.

NPRS: numeric pain rating scale; RM: maximum resistance; ADM: range of motion; SIS: subacromial impact syndrome; RC: rotator cuff; rep: repetitions; mon: seconds;

Regarding the intervention protocols, six studies compared the exercise protocol with a control group[8-11,13,14]. Only one study compared a non-painful exercise program with a group performing painful exercises.[12]

Most studies used the daily exercise protocol10 or five times a week for four weeks[11,13] and six weeks[12]. One study performed the interventions twice a week for four weeks[9]. Another study used one session per week for the first six weeks and then another six weeks with one session every two weeks[5]. One study does not make clear

the frequency of exercises[8].

The eccentric training protocol was applied in all studies included in the review, with three sets of 10 to 20 repetitions.[8-13] Progressive load increase was indicated in four studies.[8,10,11,13] Scapular activation exercises have been added to the eccentric shoulder program in four studies.[9,11-13]

Of the seven articles selected in the search, six evaluated pains through the Visual Analog Scale (VAS)[8,10,11,13] or the Numeric Pain Rating Scale (NPRS)[9,12]. Four studies evaluated muscle strength through manual dynamometry[5,9,10,12]. Four studies evaluated range of motion (ROM)[9-12]. All studies evaluated shoulder function, four of which used the Constant-Murley score[8,10,11,13], a study used the Shoulder Pain and Disability Index (SPADI)[5], two used the DASH questionnaire[8,9] and finally, one study used the EuroQolInstrument (EQ-5D and EQ VAS) [8] and another the Western Ontario Rotator Cuff Index (WORC)[12]. Only one study used the objective functional test Upper Quarter Y-Balance Test[12]. As for image analysis, one study used radiography[8] and two studies used ultrasound[8,13].

Regarding the pain outcome, all six studies that analyzed pain demonstrated significant pain improvement with eccentric exercises. However, four of these studies[9-11,13] reported no significant difference compared to the control protocol. Two studies[8,12] found significant differences in pain reduction favorable to the eccentric protocol.

Regarding the amplitude of motion outcome, of the four studies that analyzed range of motion, only two studies[9,11]demonstrated significant improvement with eccentric exercises, although they did not report significant difference compared to the control protocol. Two studies[10,12] found no significant differences in the increase in the range of motion favorable to the eccentric protocol.

As for muscle strength outcome, four studies[5,9,12,13] of the five who analyzed strength showed a significant improvement with eccentric exercises, and of these a study[9] showed no significant difference compared to the control protocol and another study[13] presented relevance for the eccentric exercise group when compared to the concentric exercise group. Only 1 study[10] showed no significant difference in strength increase in any of the groups.

With respect to function outcome, all studies showed a significant improvement after eccentric exercises. Of these, four studies[5,9-11] found no significant differences compared to the control protocol. Two studies[12,13] presented a significant improvement superior with eccentric exercises when compared to the control protocol.

The mean PEDro score obtained in the studies was [6.8], which demonstrates a moderate quality of the selected studies. Of the studies included, one study did not meet the random distribution criteria (14,28%). Two did not present information on blind allocation criteria (28,56%). Four studies met the criteria for blind evaluation (57,12%), none for blind participants and none for blind intervenors. Regarding the descriptions of losses and exclusions, all studies met this criterion (100%). The results of the bias risk assessment are presented in Table 3.

Table 3. Evaluation of the quality of the articles included in the review

	Maenhout et al., 2013[5]	Hallgren et al., 2014[8]	Blume et al., 2015[9]	Dejaco et al., 2016[10]	Vallés-Carrascosa et al., 2017[11	Chaconas et al., 2017[12]	Macías-Hernandez et al., 2020[13]
1. Eligibility criteria	**S**	**S**	**S**	**S**	**S**	**N**	**S**
2. Random distribution	**S**	**S**	**S**	**S**	**S**	**S**	**S**
3. Blind allocation	**N**	**S**	**S**	**S**	**S**	**N**	**S**
4. Equality between pre-treatment groups	**S**	**S**	**S**	**S**	**S**	**S**	**S**
5. Blind participants	**N**	**N**	**N**	**N**	**N**	**N**	**N**
6. Blind intervenors	**N**	**N**	**N**	**N**	**N**	**N**	**N**
7. Blind appraisers	**N**	**S**	**S**	**N**	**N**	**S**	**S**
8. Results in 85% of the sample	**S**	**S**	**S**	**S**	**S**	**S**	**S**

9. All subjects received the selected treatment	**S**	**N**	**S**	**S**	**S**	**N**	**N**
10. Statistics	**S**	**S**	**S**	**S**	**S**	**S**	**S**
11. Measures of accuracy and variability	**S**	**S**	**S**	**S**	**S**	**S**	**S**
PEDro Score	**6/10**	**7/10**	**8/10**	**7/10**	**7/10**	**6/10**	**7/10**

Maenhout et a[15] conducted a study in which the value of adding eccentric heavy load training to conservative treatment in patients with RC tendinopathy was verified. A protocol of resistance exercises of internal and external rotation of the shoulder was introduced, while the experimental group performed the same exercises with the addition of eccentric heavy load exercise. It was demonstrated that both groups presented increased isometric strength, decreased pain and improved function after 12 weeks of treatment, without presenting significant differences between groups.

Blume et al [9] found similar results, where eccentric exercises were analyzed compared to concentric exercises in 38 participants complaining of CR tendinopathy, randomly distributed in two groups. Both eccentric and concentric programs showed improvement in function, ROM and shoulder strength, without finding relevant differences when compared to the two modes of exercises.

However, Dejaco et al [10] reported that after 26 weeks of an eccentric versus conventional training program there was improvement in pain and shoulder function, without presenting statistically significant difference when comparing the groups, but did not find any relevant improvement in strength and shoulder ROM in both groups. The eccentric exercise program consisted of eccentric exercises isolated along with stretching, while the other group included scapular stabilization exercises, concentric strengthening exercises of the RC muscles and stretching.

Chaconas et al [12] the sample was forty-eight individuals with RCtendinopathy, performing an eccentric exercise protocolfor external rotators along with scapular retraction and a general protocol of active flexion shoulder exercises, abduction, scapular retraction and stretching of the posterior musculature. It was verified that after the eccentric exercise protocol there was an improvement in pain, function and shoulder strength in both groups and a relevance was evident in the group of eccentric exercises when compared to the general protocol of shoulder exercises.

Second exposed by Macías-Hernández et al [13], a protocol of eccentric exercises for deltoid, internal and external rotators, biceps, triceps, pectorals and trapezoid and a protocol of concentric exercises for the same muscle grouping were effective in terms of pain, function and strength in both groups, and the treatment group with eccentric exercises reached a greater statistical significance in all outcome variables, resembling the study of Chaconas et al [12].

Hallgren et al[8]investigated whether an eccentric exercise program considered effective after 3 months, maintained the results after one year or if the patients eventually chose to have surgery. The eccentric exercise program consisted of concentric and eccentric exercises of the CRmuscles,all with load progression, while the control group performed active movement exercises for the neck and shoulder without any load or progression. One year after inclusion, the number of patients who chose to perform surgery in each group was compared and it was found that in the control group there was a greater number of patients who chose to do the surgery, showing that the short-term positive results of eccentric exercises, pain reduction and improved function, maintained after one year.

Vallés-Carrascosa et al [11] analyzed 22 patients applying in one group a protocol of painful eccentric exercises, with painful implement that reached up to 4 on the visual analog scale (VAS), and another group that performed eccentric exercises without causing pain. After the application of the protocol, the groups alone improved pain, function and ROM, showing no relevant difference between the groups and showing that painful exercise does not add benefit when compared to pain-free exercise.

IV. Conclusion

It is notorious that eccentric exercises in the treatment of rotator cuff tendinopathy are relevant within the physiotherapeutic approaches. Among the studies analyzed, eccentric exercises were shown to be effective in the treatment of patients with R Ctendinopathy, however, when compared to other modalities of exercises such as resistance, concentric and isometric exercises, it was observed that one did not present relevance over the other, where they also achieved the objectives of physical

therapy rehabilitation on RC tendinopathy, it was observed that one did not present relevance over the other, where they also achieved the objectives of physical therapy rehabilitation on THE tendinopathy of CR , reducing pain, recovering ROM, improving strength capacity and providing an early improvement in shoulder functionality and tendon healing.

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