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PHYSICAL THERAPY OF ROTATOR CUFF INJURIES OF OLYMPIC WEIGHTLIFTERS – A SYSTEMATIC LITERATURE REVIEW

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ABSTRACT

From an injury-rate standpoint, Olympic weightlifting is a relatively safe sport. Despite that, a large number of repetitions, the ballistic nature of the lifts and the high forces sustained by the shoulder joint during their execution can lead to shoulder injuries, specifically rotator cuff injuries. The purpose of this paper was to investigate the scientifically proven physiotherapy methods and what their indications are when dealing with rotator cuff injuries of Olympic weightlifters.

A qualitative literature review method was used, and the following online databases were included: PubMed, Scopus, Wiley, and PEDro in ResearchGate. The keywords in the literature search were: rotator cuff, shoulder, injury, physiotherapy, sport, weightlifting and Olympic weightlifting. The final analysis included fully published and accessible research papers in English from 2012 onwards, focusing on the physiotherapy of rotator cuff injuries.

In total, 16 research papers were included in the final review. Management of rotator cuff injuries is a complex process, especially in sports with overhead movements. We found that the success and effectiveness of the physiotherapy process can be improved through a proper combination of kinesiotherapy, physical agent modalities, manual methods and other forms of therapy.

The choice of the specific methods and their duration depends on the pathology of the individual injury. Further research focusing on Olympic weightlifting is needed to

create precise and conclusive guidelines for rehabilitation, especially for sport specific phases occurring later in the rehabilitation process.

Keywords: *Olympic weightlifting, rotator cuff, rehabilitation, injuries, physiotherapy.*

FIZIOTERAPIJA PO POŠKODBAH ROTATORNE MANŠETE PRI OLIMPIJSKIH DVIGALCIH UTEŽI – SISTEMATIČNI PREGLED LITERATURE

POVZETEK

Olimpijsko dviganje uteži je z vidika pogostnosti poškodb relativno varen šport. Kljub temu veliko število ponovitev, balistična narava športa in visoka sila na ramenski sklep lahko povzročijo poškodbe ramena, še posebej rotatorne manšete. Namen tega dela je s pregledom literature raziskati, katere fizioterapevtske metode so dokazano učinkovite in kakšne so njihove indikacije za obravnavo posameznih tipov poškodb rotatorne manšete pri olimpijskih dvigalcih uteži.

V kvalitativni pregled literature so bile vključene te podatkovne baze: PubMed, Scopus, Wiley, PEDro in ResearchGate. Ključne besede pri iskanju literature so bile: »Rotator cuff«, »Shoulder«, »Injury«, »Physiotherapy«, »Sport«, »Weigltlifting« in »Olympic Weightlifting«. V končno raziskavo smo vključili v celoti objavljene in dostopne raziskave v angleškem jeziku, ki so bile objavljene od leta 2012 in neposredno raziskujejo fizioterapevtsko rehabilitacijo poškodb rotatorne manšete.

V končno analizo je bilo vključenih 16 raziskav. Obravnava poškodb rotatorne manšete je kompleksen proces, še posebej kadar gre za športe z aktivnostmi nad glavo. Ugotovili smo, da je izboljšanje uspešnosti rehabilitacije omenjenih poškodb mogoče doseči s pravilno kombinacijo kinezioterapije, fizičnih dejavnikov, manualnih in drugih metod obravnave.

Izbira posameznih metod in njihovo trajanje sta odvisna od patologije posamezne poškodbe. Jasno je, da so za izoblikovanje natančnih smernic celotne rehabilitacije, predvsem v poznejših športno specifičnih fazah, potrebne raziskave usmerjene samo v dvigalce uteži.

Ključne besede: *olimpijsko dviganje uteži, rotatorna manšeta, rehabilitacija, poškodbe, fizioterapija.*

INTRODUCTION

Olympic weightlifting is often misinterpreted as a very dangerous sport. While it is true that athletes in this sport are constantly lifting relatively heavy weights, this alone cannot be the reason to label a sport as dangerous. This is clear if we consider that the execution, volume and intensity of the sessions and movements in this sport can be often tracked and managed better than for example in team sports. Aasa, Svartholm, Andersson and Berglund (2017) concluded that the injury rate in weightlifting is between 2.4 to 3.3 injuries/1000 hours of training. We can compare this to American football where the injury rate is much higher at 9.3 injuries/1000 hours of training or even 35.9 injuries/1000 hours of competition (Hootman, Dick & Agel, 2007). Even when comparing these numbers to the injury rate of 3.57 injuries/1000 hours of exposure to non-contact sports like track and field (Jacobsson et al., 2013), Olympic weightlifting is a relatively safe sport.

Researchers found that the most injured anatomical regions within weightlifting were the lower back, shoulder and knee joints (Calhoon & Fry, 1999; Raske & Norlin, 2002). In terms of the severity and nature of those injuries, we found conflicting results. Calhoon and Fry (1999) found that most of the injuries to the mentioned regions required less than one day of missed training, suggesting that most of the injuries and associated pain were minor. On the other hand, Raske and Norlin (2002) reported the injuries to be more severe, requiring more than one month to recover. For comparison, the majority of track and field injuries were severe, requiring more than three weeks of missed training (Jacobsson et al., 2013). The most common diagnosis was tendinitis, muscle spasms, muscle tears and ligament tears (Calhoon & Fry, 1999).

Since Olympic weightlifting includes ballistic movements with weight overhead, athletes can be expected to be at a higher risk for subacromial impingement (Page, 2011; Escalante, 2016). This is in line with claims that repetitive lifting overhead presents a certain risk for soft tissue shoulder injuries (Van der Wall et al., 1999; Raske & Norlin, 2002; Bedi, 2011). Escalante (2016) and Gross, Brenner, Esformes and Sonzogni (1993) claim that the primary reason for risk with those movements is increased stress on the inferior glenohumeral ligament while the upper extremity is abducted and externally rotated. The required catch and stabilization of the weight overhead in the end shoulder range of motion and the involvement of shoulder musculature practically throughout the whole Olympic lifts are also important risk factors to consider (Serrano, 2020).

During the lift-off, the first pull and transition phases of snatch and clean shoulder muscles are contracting primarily isometrically. During the explosive second pull and turnover phases, they are contracting concentrically, as they do during the drive phase of the jerk. Lastly, the greatest shoulder musculature isometric force requirements are present during the catch phase of the snatch and jerk. The required dynamic glenohumeral stability and humeral head centralization during those phases depend primarily on the rotator cuff muscles and the long head of the *musculus biceps brachii* (Serrano, 2020). Any limitations or deficiencies in shoulder range of motion and passive or active stability may compromise the technical execution of the lifts and contribute to or lead to injuries (Henoch, 2017).

When assessing a patient with shoulder pain, the first goal should be to determine the underlying cause of the pain. This is usually performed through a combination of an interview, palpation, diagnostic imaging, pain-provoking and range of motion tests. Treatment plans and physiotherapeutic methods should be based on that information (Ristori et al., 2018; Serrano, 2020). One of the primary goals of diagnostics is determining whether the pain is specific or non-specific and if surgical treatment is needed. Additional assessments of shoulder stability, thoracic mobility and scapula movement all provide physiotherapists with additional crucial information that should be used to guide interventions (Moser 2014; Panagiotopoulos & Crowther, 2019)

When dealing with the majority of specific rotator cuff injuries, researchers suggest starting with conservative treatment and opting for surgery only when conservative treatment fails (Ryösä et al., 2017; Nazari, MacDermid, Bryant & Athwal, 2019; Millett, Wilcox, O'Holleran & Warner, 2006). Ristori et al. (2018) suggested that both diagnostic imaging and pain-provoking tests should be interpreted only in association with functional activity and pain. The main reasons for this are the often large discrepancies found between diagnostic results, actual functional limitations and pain.

In the past authors proposed similar models of rotator cuff rehabilitation. The main difference between the 3-phase post-operative (Sgroi & Cilenti, 2018) model proposed for the general population and the 4-phase (Millett et al., 2006) or 5-phase (Serrano, 2020) models for athletes, is that the latter two usually last longer as they define sport specific phases. Cools et al. (2021) emphasized the importance of a comprehensive return to sports protocol for athletes, which should be able to detect and correct possible asymmetries in shoulder range of motion, stability and strength.

Today we have a good amount of clinical research on effective physiotherapeutic modalities for rotator cuff treatment. There is however virtually no cli-

nical research specifically done on Olympic weightlifters. The 5-phase model proposed by Serrano (2020) is a rare work that focuses on collecting existing research and knowledge on rotator cuff injuries and forming rehabilitation guidelines specifically for Olympic weightlifters.

The goal of our work was to focus primarily on the role of the physiotherapist in the process of the aforementioned rehabilitation. We wanted to highlight clinically proven effective physiotherapeutic interventions and how they could be used specifically for the rehabilitation of Olympic weightlifters with rotator cuff injuries.

METHODS

We systematically reviewed the literature using a systematic qualitative literature review method. Data was extracted from the online databases PubMed, Scopus, Wiley, PEDro, and ReserchGate during the period between 25 May 2022 and 3 June 2022. In conjunction with the operator AND and/or OR, the following keywords were used: rotator cuff, shoulder, injury, physiotherapy, sport, weightlifting and Olympic weightlifting.

Articles were first evaluated based on title, followed by the abstract, then a quick full-text overview and lastly based on the inclusion and exclusion criteria. The inclusion criteria were: i) fully accessible clinical studies, ii) fully written in the English language, iii) published after 2012, and iv) investigating physiotherapeutic interventions during the rehabilitation of rotator cuffs. The exclusion criteria were: i) meta-analysis, systematic literature reviews and case studies, ii) studies investigating the efficiency of pharmaceutical interventions, iii) choosing between operative and conservative treatment, iv) entirely home-based unsupervised kinesiotherapy, v) research in which all subjects were older than 50 years or the average age was higher than 55 years were also excluded.

Microsoft Office Excel 2016 (Microsoft Corporation, New York, USA) was used to collect and present the summary of the results with tables. The search process and the final selection of articles were performed using the PRISMA 2020 guidelines (Page et al., 2021).

Additionally, we used additional filters when searching the databases as shown in Table 1.

Table 1: Additional search filters applied in the online databases

Database	Search filters
PubMed	Articles published between 2012 and 2022, randomized control studies and clinical trials
Scopus	English articles published between 2012 and 2022
Wiley	Articles published between 2012 and 2022
PEDro	PEDro grade at least 5/10 and articles published after 2012
ReserchGate	Not able to choose additional search filters within the database

RESULTS

The initial search in databases returned 1302 hits. After applying additional search parameters from Table 1, the search results included 248 hits. Next, after reviewing the titles and abstracts we narrowed our search to 49 studies. Lastly, we eliminated duplicates and read the full articles. After reviewing the content, we eliminated an additional 33 articles and thus analyzed 16 relevant studies. The systematic review process is presented in Figure 1.

A total of 724 individuals with rotator cuff injuries were included in the analyzed studies. Out of the 16 studies, 14 provided information on participants' gender, with women representing a slightly larger share (54%). The duration of the studies varied from one week up to a year. Most of the studies, their eligibility requirements and the period between checkups were in line with the following differentiation based on the length of the symptoms (Koç et al., 2020):

- Acute pain: symptoms lasting less than 6 weeks
- Sub-acute pain: symptoms lasting between 6–12 weeks
- Chronic pain: symptoms lasting more than 12 weeks

Chronic injuries were the most researched within our sample. Seven studies investigated exclusively chronic rotator cuff injuries, while six other studies also included them among others. Sub-acute injuries were exclusively investigated within one study while they were included among others in eight other studies. There was no research focusing exclusively on acute injuries, but they were part of six mixed studies. Only one of the studies specifically defined that all of the patients underwent surgical intervention.

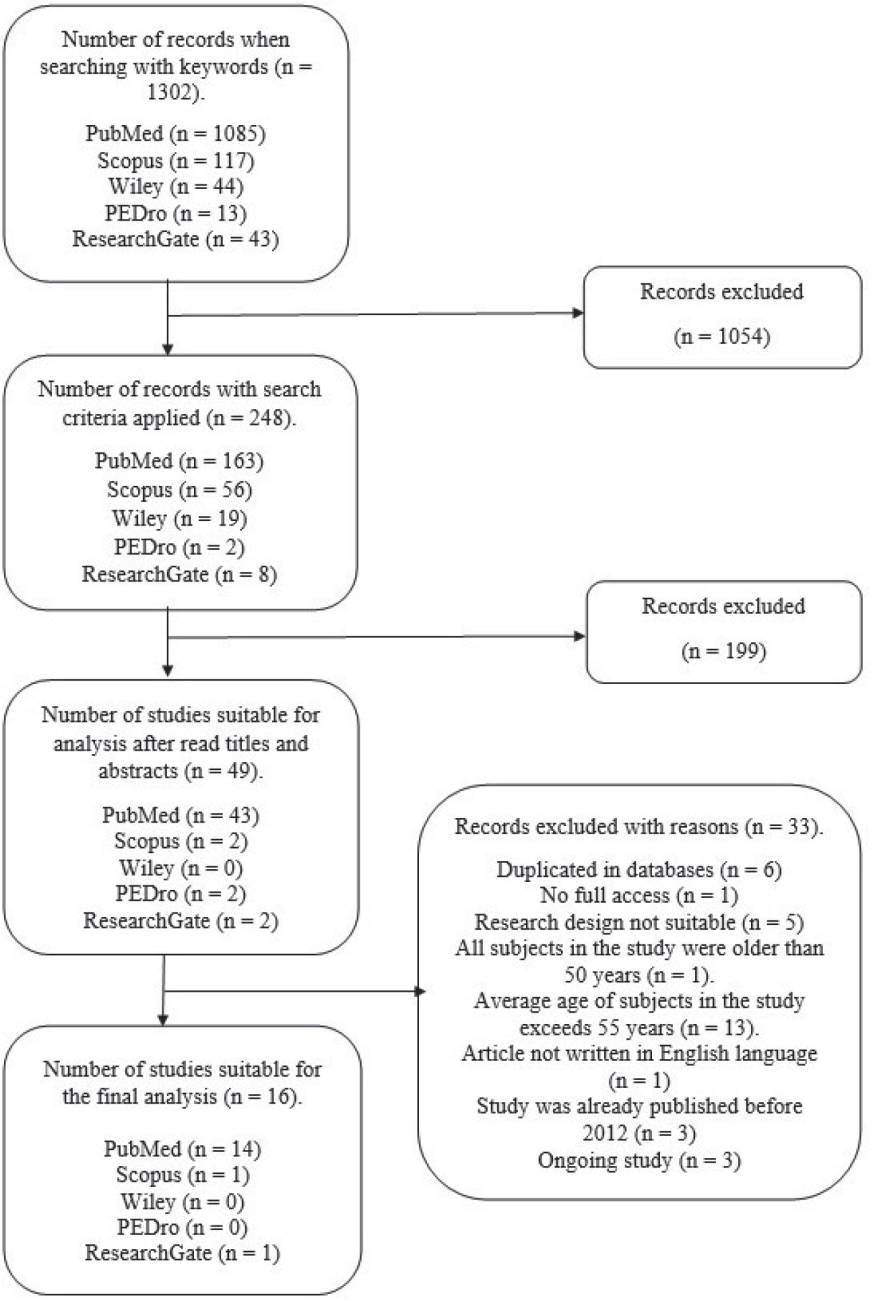

Figure 1: Systematic review process

Table 2: Summary of the included articles and results

Author(s) and year of publ.	**Article title**	**Research sample**	**Article type**	**Results**
De Oliveira et al. (2020)	Kinesiotaping for the Rehabilitation of Rotator Cuff-Related Shoulder Pain	52 people (22 females and 30 males) with pain, restricted range of motion, and function as a result of a rotator cuff pathology.	Randomized clinical trial	Both in the medium- and long-term, the addition of kinesiotaping to 6-week-long kinesiotherapy did not result in a statistically significant effect on reducing pain and improving ROM in the shoulder joint.
Parle et al. (2017)	Acute rotator cuff tendinopathy: does ice, low load isometric exercise, or a combination of the two produce an analgaesic effect?	20 people (13 females and 7 males) with unilateral shoulder pain persisting less than 12 weeks. All subjects had ultrasound-confirmed rotator cuff tendinosis or bursitis.	Randomized clinical trial	A statistically significant short-term effect on reducing pain and improving function of the shoulder joint. The combination of both methods was not found advantageous.
Boudreau et al. (2019)	The Addition of Glenohumeral Adductor Coactivation to a Rotator Cuff Exercise Program for Rotator Cuff Tendinopathy	42 people (22 females and 20 males) with confirmed rotator cuff tendinopathy and symptoms persisting longer than a month. Painful arc, pain with resisted isometric external rotation and abduction.	Randomized clinical trial	No statistically significant improvement in shoulder function and pain reduction after 6 weeks of additional glenohumeral adductor coactivation.
Guan et al. 2020	Decreased Synovial Fluid Biomarkers Levels Are Associated with Rehabilitation of Function and Pain in Rotator Cuff Tear Patients Following Electroacupuncture Therapy	54 people (38 females and 16 males) with a small to medium-sized rotator cuff rupture and at least 6 months of conservative treatment.	Randomized clinical trial	Synovial fluid biomarkers levels are reliable indicators of a successful rehabilitation. Electroacupuncture therapy is an effective conservative method delivering a reduction of inflammatory cytokines, pain and improving shoulder function.

Author(s) and year of publ.	Article title	Research sample	Article type	Results
Muth et al. 2012	The effects of thoracic spine manipulation in subjects with signs of rotator cuff tendinopathy	30 people (14 females and 16 males) with signs of rotator tendinopathy and symptoms which lasted on average for 4,2 months. Primarily high-level athletes from disciplines involving overhead movements.	Laboratory controlled trial	No statistically significant effect on scapular kinematics, with the exception of slightly smaller scapular lateral rotation. Statistically significant higher activation of the middle *musculus trapezius*, pain reduction, and improving the function 7-10 days after the manipulation.
Zhang et al. 2020	Influence of Scapula Training Exercises on Shoulder Joint Function After Surgery for Rotator Cuff Injury	46 people (20 females and 26 males) after the arthroscopic surgery of partial or full thickness tear of the rotator cuff.	Randomized clinical trial	A combination of traditional physiotherapy and specific scapular exercises is effective in reducing the dysfunctions after the surgery. After 6 weeks specific scapular exercises have a statistically significant effect on reducing shoulder pain, improving ROM and function. After 12 weeks the positive effect of those exercises is also seen on muscle strength testing.
Menek, Tarakci, & Algun 2019	The effect of Mulligan mobilization on pain and life quality of patients with Rotator cuff syndrome	30 people (12 females and 18 males) with partial rotator cuff rupture, acute symptoms, and without surgical treatment.	Randomized clinical trial	6-week-long treatment protocol with Mulligan mobilization results in a statistically significant pain reduction, improving function and ROM.
Frassanito et al. 2018	Effectiveness of Extracorporeal Shock Wave Therapy and kinesio taping in calcific tendinopathy of the shoulder	42 people (26 females and 16 males) with diagnosed calcific rotator cuff tendinopathy, and functional issues persisting at least 2 weeks.	Randomized clinical trial	The addition of kinesiotaping to extracorporeal shock wave therapy adds to pain and inflammation reduction in the short term. This addition thus potentially helps to reduce the rehabilitation time.

Author(s) and year of publ.	Article title	Research sample	Article type	Results
Akbaba et al. 2019	The effectiveness of trigger point treatment in rotator cuff pathology	41 people with diagnosed partial rotator cuff tear, at least 3 active shoulder trigger-points, and symptoms persisting at least 3 months.	Randomized clinical trial	Additional trigger-point treatment does not result in statistically significant improvement of rehabilitation outcomes.
Klüter et al. 2018	Electromagnetic transduction therapy and shockwave therapy in 86 patients with rotator cuff tendinopathy	86 people (45 females and 41 males) with diagnosed rotator cuff tendinopathy, symptoms lasting at least 3 months, pain graded at least 5 on a VAS scale, and failed previous conservative treatment.	Randomized clinical trial	A combination of electromagnetic transduction therapy and shockwave therapy has a statistically significant superior effect on pain reduction and improving function than shockwave therapy only. This was the case 6, 12, and 24 weeks after the last therapy.
Li et al. 2021	Effectiveness of Focused Shockwave Therapy versus Radial Shockwave Therapy for Noncalcific Rotator Cuff Tendinopathies	46 people (25 females in 19 males) with MRI-diagnosed non-calcific rotator cuff tendinopathy without rupture. Subjects had symptoms lasting at least 3 months, restricted ROM, pain with overhead movements and graded their pain with at least 5 on a VAS scale.	Randomized clinical trial	No statistically significant difference in pain reduction within 24 weeks of the intervention between focused and radial shockwave therapy. Focused shockwave therapy results in superior longer-term pain reduction.
Koç et al. 2020	Does balneotherapy provide additive effects to physical therapy in patients with subacute supraspinatus tendinopathy?	90 people (53 females and 37 males) with MRI diagnosed unilateral sub-acute unilateral tendinopathy of musculus Supraspinatus, at least one positive pain-provocative test and full ROM.	Randomized clinical trial	A statistically significant improvement of shoulder ROM, function, grip strength, quality of life and pain reduction with the addition of balneotherapy to the traditional physiotherapy protocol.

Author(s) and year of publ.	Article title	Research sample	Article type	Results
Elsodany et al. 2018	Long-Term Effect of Pulsed Nd:YAG Laser in the Treatment of Patients with Rotator Cuff Tendinopathy	60 people with diagnosed rotator cuff tendinopathy, pain persisting for over 3 months, and positive pain provocative tests that indicate rotator cuff pathology. Subjects were also dealing with impaired shoulder abduction, internal and external rotation ROM.	Randomized clinical trial	Rehabilitation program combining HILT and exercise intervention program was more effective in restoring shoulder function, ROM, and reducing pain than exercise intervention program alone.
Carlisi et al. 2018	Focused extracorporeal shock wave therapy combined with supervised eccentric training for supraspinatus calcific tendinopathy	22 people (14 females and 8 males) with shoulder pain persisting for more than 6 weeks, clinical signs of sub-acromial impingement, and full passive ROM. All of the subjects also had a confirmed calcific tendinopathy of the supraspinatus tendon.	Randomized clinical trial	Focused extracorporeal shock wave therapy is an effective method for reducing shoulder pain and improving function. Additional shoulder abductor eccentric exercise protocol does not provide statistically significant improvement in treatment outcomes compared to focused extracorporeal shock wave therapy alone.
Chou et al. 2018	Comparative outcomes of extracorporeal shockwave therapy for shoulder tendinitis or partial tears of the rotator cuff in athletes and non-athletes	35 people (19 females and 16 males). 13 professional athletes and 22 non-athletes, diagnosed and symptomatic chronic rotator cuff tendinitis, with or without rupture, and previously failed conservative treatment.	Retrospective study	Extracorporeal shockwave therapy is effective both for athletes and non-athletes. Its use should be considered for athletes with long-lasting tendinitis or partially torn rotator cuff before opting for arthroscopy.
Coşkun et al. 2018	Effectiveness of Kinesiologic Tape Application in Rotator Cuff Injuries	30 people (13 females and 17 males) with rotator cuff injury, either tendinitis or acute injury with persistent pain, reduced ROM and associated reduced life quality.	Randomized clinical trial	The addition of kinesiotaping to traditional physiotherapy methods results in superior pain, inflammation and rehabilitation time reduction. It also enables better improvements in ROM and shoulder function compared to only traditional physiotherapy interventions.

DISCUSSION

Evaluation and diagnostics

Reviewed studies analyzed symptoms differently both at the beginning and during check-ups. This indicates that there is a lack of consensus on how to screen patients with potential rotator cuff pathology (Ristori et al., 2018). Despite that, all of the researchers used a combination of different questionnaires about the pain and function of the shoulder joint. Eleven studies used the Visual Analogue Scale (VAS), while the Numeric Rating Scale (NRC) was the second most commonly used. Concerning functional assessment, the Disabilities of the Arm, Shoulder, and Hand (DASH) questionnaire was the most common, with a full version in seven pieces of research and a shortened version used within two more. The second most commonly used was the Constant-Murley Score (CMS).

Nine out of sixteen included studies used different physiotherapeutic assessments to test the active and passive range of motion (ROM), muscle strength and function. Among those, the passive range of motion assessment was the most commonly used in six studies. Half of the studies also used pain-provoking tests to confirm rotator cuff pathology, but only one study used those tests during control check-ups. Half of the research also included at least one diagnostic imaging method, with magnetic resonance imaging (MRI) used within seven, ultrasound within six and X-ray within three studies.

We believe that the basic assessment of injured Olympic weightlifters should not be significantly different than that of the general population and should focus on diagnosing the underlying mechanisms of pain. This includes the interview with the athlete, diagnostic imaging, pain-provoking testing, passive and/or active ROM assessment, and function and pain assessment. Based on that information the therapist should be able to determine if the pain is the result of the rotator cuff symptomatic and what would be the appropriate course of action. A physiotherapist has to consider how long and how severe is the pain, and especially how it affects the function and performance. It is crucial to look at an individual's training load and plan to identify possible injury-contributing factors. Physiotherapists must thus collaborate closely with the coach and athlete to modify both training load and activities to ensure alignment with the rehabilitation plan.

Physical Agent Modalities

Some authors have included similar physical agent modalities in the "traditional physiotherapy" for rotator cuff injuries (Zhang et al., 2020; Menek, Tarakci & Algun 2019; Koç et al., 2020; Coşkun et al., 2018). Those models consisted of ultrasound, cryotherapy or thermotherapy and transcutaneous electrical nerve stimulation (TENS). Cryotherapy as a modality seems to be primarily suitable for acute and subacute injuries. Parle, Riddiford-Harland, Howitt & Lewis (2017) found that cryopak is an effective method for reducing pain sensation and improving the function of the shoulder joint when dealing with non-traumatic acute or subacute pain. Zhang et al. (2020) found that a combination of 5 to 20 minutes of cryotherapy within the first four weeks after the operation and 5 to 10 minutes of moving method ultrasound therapy with the dosage of 1.5–2.5 W/cm^2 between the 4th and 12th week is effective in reducing the pain and improving the function of the shoulder joint after the arthroscopic surgery. Similarly, Menek et al. (2019) observed significant improvements in function and reduction of pain after 6 weeks of using a combination of cryotherapy, 6-minute ultrasound therapy at a frequency of 1.5 MHz and TENS at a frequency of 100 Hz after partial rotator cuff tears. Koç et al. (2020), using the same parameters for the ultrasound and 20-minute TENS at a frequency of 60–80 Hz for three weeks also demonstrated pain reduction and improved function in patients suffering from subacute supraspinatus tendinopathy. A similar protocol with a 20-minute TENS and 10-minute ultrasound therapy at 1.5 MHz frequency was also successfully used for a week by Coşkun et al. (2018) with patients dealing with various rotator cuff injuries. Interventions in all of the mentioned studies were carried out at least five times per week. We should emphasize that the "traditional physiotherapy" model always included some form of kinesiotherapy. Most of the studies also indicate that even though the improvements with "traditional physiotherapy" are significant, it can be expected that combining those methods with other physiotherapeutic modalities leads to superior patient outcomes.

Elsodany, Alayat, Ali & Khaprani (2018) found that for the treatment of rotator cuff tendinopathy high-intensity laser therapy (HILT) combined with exercises provides superior results in terms of pain reduction, increasing shoulder ROM and function compared to performing exercises alone. Chou et al. (2018) found that one to two sessions of extracorporeal shockwave therapy (ESWT) enabled all 13 included overhead athletes to return to a competitive level within 3 months after the intervention. 3000 impulses of the shockwave at 0.32 mJ/mm^2 energy flux density were applied to the affected shoulder under ultrasonographic

guidance during the sessions. The inclusion criteria in this study were an at least three-month-long unsuccessful conservative treatment. The recurrence rate was quite high at 62% though, much higher than the 18% observed in the non-athlete group, which shows the importance of comprehensive sport-specific phases of rehabilitation. Carlisi et al. (2018) found that three focused ESWT sessions with 1-week breaks in between were effective in terms of reducing shoulder pain and improving joint function in individuals dealing with sub-acute or chronic pain resulting from supraspinatus calcific tendinopathy. The amount of energy influx during a single therapy was lower, 0.15 mJ/mm^2 applied with 1700 impulses. Four sessions with focused ESWT, 3000 impulses at 0.09 ± 0.018 mJ/mm^2 energy flux density applied, and a 5-to-9-day break between them, have been proven more successful in the treatment of non-calcific supraspinatus tendinopathy than a protocol with radial ESWT (Li et al., 2021). Three ESWT sessions with 2000 impulses at 0.32 mJ/mm^2 energy flux density within two weeks also resulted in shoulder pain reduction and function improvements within a group of patients with non-calcific rotator cuff tendinopathy.

Combining ESWT therapy with 8 sessions of electromagnetic transduction therapy within 4 weeks resulted in superior results. Each electromagnetic transduction therapy treatment lasted 20 minutes at 80 mT, with an impulse frequency of 3 Hz and a discharge voltage of 30 KV (Klüter et al., 2018). Chou et al. (2018) and Klüter et al. (2018) also monitored long-term ESWT results and both concluded that the improvements are greater in the long-term.

Manual methods

Adding 12 sessions of rotator cuff myofascial trigger-point release to standard conservative treatment does not significantly improve outcomes of the patients with symptomatic rotator cuff ruptures (Akbaba et al., 2019). The addition of Mulligan mobilization to all 30 sessions of "traditional physiotherapy" within six weeks results in superior outcomes. Menek et al. (2019) observed both pain reduction, an increase in shoulder ROM and an improvement of shoulder function after the described addition of an approximately 20-minute-long protocol of Mulligan mobilization. Muth, Barbe, Lauer and McClure (2012) found that a single intervention of thoracic spine and cervicothoracic junction manipulation is effective for reducing pain and improving shoulder function in patients with chronic rotator cuff pathology. Manipulation resulted in improvements both immediately after and 7–10 days after the intervention.

Exercise interventions

Different combinations of passive, active, actively assisted and range of motion exercises were used. The addition of scapular mobilization, stabilization and surrounding musculature strengthening to the standard physiotherapeutic protocol results in superior outcomes 12 weeks after the surgical repair of partial rotator cuff tears (Zhang et al., 2020). In this study, active exercises for surrounding joints and corresponding musculature were applied to all patients a day after the operation, while Codman pendulum exercises were introduced after a week. Four weeks after the surgery, actively-assisted exercises were introduced and after six weeks exercises in a closed kinetic chain. Similar exercise protocols including pendulum exercises, actively-assisted exercises, strengthening and ROM exercises were used in other included studies emphasizing conservative treatment (Menek et al., 2019; Elsodany et al., 2018). Both of those studies concluded that another physiotherapy method, specifically Mulligan mobilization or HILT, results in additional improvements in shoulder function and pain reduction for patients with rotator cuff tendinopathy. De Oliveira, de Fontenay, Bouyer Desmeule, and Roy (2020) concluded that individualized six-week kinesiotherapy with an emphasis on sensorimotor control, strengthening and education significantly improves ROM, and function and reduces pain associated with the symptomatic rotator cuff. This was evident not only in the short- and mid-term, but also in the long-term.

Some studies also defined the number of sets and repetitions executed in the respected protocols. All used three sets of 10 repetitions (Carlisi et al., 2018; Menek et al., 2019; Boudreau, Gaudreault, Roy, Bédard & Balg, 2019), while Carlisi et al. (2018) additionally defined a progressive number of sets and repetitions at the initial two weeks. Carlisi et al. (2018) and Boudreau et al. (2019) stated that mild pain (<4 on the VAS scale) was allowed during the performance of the exercises.

Parle et al. (2017) found that isometric exercises (10–20 second holds in three to five series, executed daily) are a viable and effective short-term option to reduce acute or subacute shoulder pain as a result of rotator cuff tendinopathy. Boudreau et al. (2019) found a 6-week-long intervention of strengthening exercises focusing on *m. serratus anterior*, *m. trapezius* and rotator cuff muscles result in reduced movement pain, while the pain at rest and shoulder function do not improve significantly. Additional strengthening of glenohumeral adductors in this study also did not contribute to better outcomes. Carlisi et al. (2018) also found no benefits with the addition of eccentric shoulder ab-

ductor training for calcific supraspinatus tendinopathy during a 9-week-long treatment protocol combined with ESWT.

Other physiotherapeutic interventions and methods

The addition of balneotherapy to the "traditional physiotherapy" model is effective for patients with subacute supraspinatus tendinopathy. Koç et al. (2020) found it improves ROM, pain reduction, and shoulder function. Guan et al. (2020) found improvements in shoulder function and reduced inflammation with the addition of Electroacupuncture Therapy to "traditional physiotherapy" twice per week. The 6-week, 3-day-per-week intervention was carried out on a population with full-thickness rotator cuff tears, with failed six months of conservative treatment.

Kinesiotaping is also a potentially applicable method for symptomatic rotator cuff injury treatment. A 1-week-long addition of kinesiology tape results in improved function and pain reduction compared to "traditional physiotherapy" only (Coşkun et al., 2018). The authors of this study pointed to enhanced sensorimotor and proprioceptor effects as the likely mechanisms for those improvements. Frassanito, Cavalieri, Maestri and Felicetti (2018) found that the addition of kinesiotaping reduces the required rotator cuff calcific tendinopathy treatment response time compared to when using only ESWT. The improvements of kinesiology tape addition were seen both in short- and medium-term outcome results. During their 6-week long study, De Oliveira et al. (2020) found that adding kinesiotaping to the established rehabilitation program with an emphasis on sensorimotor training does not provide superior medium- or long-term outcomes for individuals with rotator cuff-related shoulder pain. The study identified the greater influence of exercise and the absence of a more detailed diagnosis as possible reasons for those results.

Guidelines for rotator cuff injury treatment for Olympic Weightlifters

While we can conclude that "traditional physiotherapy" is suitable for addressing the majority of rotator cuff injuries, physiotherapists should use additional methods to improve outcomes. This is vital with Olympic weightlifters, whose primary goal is usually to return to training as soon as possible after sustaining an injury.

Kinesiotaping and thoracic spine mobilization are two easily applied methods that may improve treatment outcomes of a wide range of rotator cuff pathologies. Mulligan mobilization can be added if the individual is dealing with a partial rotator cuff tear, while electroacupuncture may be more suitable for small to medium full-thickness tears.

ESWT seems to be a very effective method for addressing sub-acute and especially chronic rotator cuff tendinopathies, and its effectiveness can be enhanced with the addition of electromagnetic transduction therapy. HILT and balneotherapy are other methods that can be utilized for chronic pathologies if ESWT is not available.

We believe that comprehensive exercise intervention is an essential part of any shoulder rotator cuff injury rehabilitation, but is especially crucial for Olympic weightlifters. A suitable exercise program should be based on the results of the initial diagnostic testing which should provide information about shoulder ROM, stability and both periscapular and rotator cuff muscle strength imbalances and deficits. Even minimal, 1–2 millimetres of uncontrolled shoulder joint translation can result in pain and shoulder symptomatic (Horsley & Ashworth, 2016). Addressing found deficits should thus be the physiotherapist's priority along with methods for reducing pain, inflammation and swelling (Weiss, Wang, Hendel, Buzzerio & Rodeo, 2018).

Any possible exercise technique flaws that may be connected with the symptoms should also be identified and addressed in collaboration with coaches, while the activities that cause the pain should be discontinued or at least modified (Escalante, 2016). Additionally, an examination of possible spikes in weightlifters' training loads should also be performed as those correlate with injury incidence (Jones, Griffiths & Mellalieu, 2017).

If the shoulder pain is severe and accompanied by any kind of functional impairment or if the primary interventions failed to solve the issues within a short period, more detailed imaging diagnostics should be prioritized. It is crucial to assess if the pain is associated with structural rotator cuff damage, which would warrant a larger modification of the training plan. Determining if the continuation of the specific overhead activities presents a risk for further complications or more severe injury is also warranted. Based on the diagnosis, utilizing the appropriate combination of the aforementioned physiotherapeutic methods is vital for the most effective rehabilitation.

Lastly, if surgical treatment is chosen to treat the rotator cuff injury, physiotherapists can improve functional outcomes by adding scapular training exercises to "traditional physiotherapy" protocols within the first 12 weeks after the injury (Zhang et al., 2020). Based on multiple sources, Serrano (2020) recom-

mends introducing basic overhead activities approximately 16–20 weeks and more weightlifting-specific activities approximately 20–26 weeks after the surgery. It should be emphasized that the exact timeline for these activities should be tailored to each individual's progression and capabilities.

CONCLUSIONS

With appropriate diagnostic tests and an optimal combination of physiotherapeutic methods, the rehabilitation effects of acute, sub-acute, and chronic rotator cuff injuries can be improved. While "traditional physiotherapy" involving kinesiotherapy coupled with ultrasound, TENS and cryotherapy or thermotherapy is effective, the addition of ESWT or Mulligan mobilization results in superior outcomes for chronic and sub-acute rotator cuff pathologies. Furthermore, combining ESWT with electromagnetic transduction therapy and kinesiotaping seems to provide additional benefits. Early-stage shoulder injury rehabilitation of Olympic weightlifters may not be significantly different from that for the general population. Shoulder ROM, rotator cuff and periscapular musculature strengthening are all critical for later more sport-specific stages of rehabilitation, during which gradual exercise and training load progression are crucial for returning to full weightlifting training.

The main limitation of this work is that practical research on physical therapy protocols specifically for Olympic weightlifters dealing with rotator cuff injuries is very limited. This must be considered especially when interpreting the results and deciding on optimal physiotherapeutic interventions in later, more sport-specific stages of the rehabilitation process.

We believe that future research on rotator cuff injury rehabilitation in Olympic weightlifting should focus on effective sport-specific late-rehabilitation stage protocols and long-term post-operative rehabilitation protocols. Lastly, defining a unified approach with comprehensive diagnostic testing, both for guiding the progressions through phases of rehabilitation and identifying sport-specific issues and pain within the shoulder joint is essential. This enables practitioners and coaches to better understand and identify the rotator cuff injury risk factors that may originate from the training process itself.

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