Rotator cuff related shoulder pain: Assessment, management and uncertainties.

Abstract

Introduction:

Rotator cuff related shoulder pain (RCRSP) is an over-arching term that encompasses a spectrum of shoulder conditions, including; subacromial pain (impingement) syndrome, rotator cuff tendinopathy, and symptomatic partial and full thickness rotator cuff tears. For those diagnosed with RCRSP one aim of treatment is to achieve symptom free shoulder movement and function. Findings from published high quality research investigations suggest that a graduated and well-constructed exercise approach confers at least equivalent benefit as that derived from surgery for; subacromial pain (impingement) syndrome, rotator cuff tendinopathy, partial thickness RC tears and atraumatic full thickness rotator cuff tears. However considerable deficits in our understanding of RCRSP persist. These include; (i) cause and source of symptoms, (ii) establishing a definitive diagnosis, (iii) establishing the epidemiology of symptomatic RCRSP, (iv) knowing which tissues or systems to target intervention, and (v) which interventions are most effective.

Purpose:

The aim of this masterclass is to address a number of these areas of uncertainty and it will focus on; (i) RC function, (ii) symptoms, (iii) aetiology, (iv) assessment and management, (v) imaging, and (vi) uncertainties associated with surgery.

Implications:

Although people experiencing RCRSP should derive considerable confidence that exercise therapy is associated with successful outcomes that are comparable to surgery, outcomes may be incomplete and associated with persisting and recurring symptoms. This underpins the need for ongoing research to; better understand the aetiology, improve methods of assessment and management, eventually prevent these conditions.

1. Introduction

In most cases assessing an individual presenting with a musculoskeletal shoulder problem involves making clinical decisions in highly ambiguous situations (Lewis et al. , In Press). As part of the assessment process, clinicians need determine if the symptoms are:

(i) Referred or related to another cause (e.g. from the cervical, thoracic, abdominal regions, neural and vascular tissues)?
(ii) Primarily related to a stiff shoulder (e.g. frozen shoulder, osteoarthritis, locked dislocation, neoplasm-such as osteosarcoma)?
(iii) Due to shoulder instability?
(iv) Related to the soft tissues (e.g. rotator cuff, bursa)?
(v) Due to combinations of the above?

In addition to this, clinicians need to; exclude serious pathology, consider pain mechanisms, determine the relationship and influence of other co-morbidities, and, discern the contribution from often profound, obscured and interwoven psychosocial factors. The process is complicated and becomes more so with the emergence of new research information from a multitude of specialities, which is frequently incomplete, and often contradictory.

The purpose of this Masterclass is to focus on one musculoskeletal shoulder problem, rotator cuff related shoulder pain, and discuss; function, pain, aetiology, imaging, surgery, assessment and management.

2. Rotator cuff function

The rotator cuff (RC) muscles and tendons are commonly considered to be recruited synchronously and equally to dynamically stabilise the humeral head onto the glenoid fossa during shoulder movement. This precept has been challenged and laboratory data suggest that the supra- and infraspinatus are recruited preferentially during shoulder flexion and subscapularis is recruited at higher levels during extension. Higher supra- and infraspinatus activation during shoulder flexion may contribute to reducing anterior glide of the humeral head during activities involving shoulder flexion, and subscapularis activity to reducing posterior glide during extension (Wattanaprakornkul et al. , 2011). This asynchronous activity may potentially be used to inform exercise prescription. In addition, in higher ranges of shoulder elevation, such as unsupported abduction, the stabilising function of the cuff may be replaced by the deltoid which may be better oriented to stabilise the humeral head onto the glenoid fossa while allowing the RC to externally and internally rotate the glenohumeral joint (Boettcher et al. , 2010). In addition, the belief that supraspinatus initiates abduction appears to be incorrect (Reed et al. , 2013).

Clinically, rotator cuff tests have been developed to assess each of the individual tendons by placing the shoulder into defined positions and applying a force to the arm requiring the muscle tissue to contract (Magee, 2014). However the design of the RC does not permit the assessment of an individual musculotendinous unit. The tendons of the RC fuse into one structure near their origin, with the supraspinatus and infraspinatus fusing inseparably near their insertion. The muscular portion of teres minor and infraspinatus also fuse inseparably just proximal to the musculotendinous junction. The subscapularis and supraspinatus tendons fuse to form a sheath that surrounds the biceps tendon, and the RC tendons are tightly adherent to the glenohumeral joint capsule (Clark et al. , 1990, Clark and Harryman, 1992). Although the interwoven nature of RC, capsule and ligament tissue would improve resistance to failure under load, it negates the possibility of testing individual structural units. The inability to test the RC musculotendinous units in isolation is further evidenced in electromyography which has demonstrated that during the 'full' and 'empty' can tests designed to implicate supraspinatus pathology 8 and 9 other muscles were respectively reported to be equally active (Boettcher et al. , 2009).

3. Rotator cuff related shoulder pain

RCRSP refers to the clinical presentation of pain and impairment of shoulder movement and function usually experienced during shoulder elevation and external rotation. Although numerous factors, including; genetics (Harvie et al. , 2004), hormonal influences (Magnusson et al. , 2007), lifestyle factors such as smoking (Baumgarten et al. , 2010) alcohol consumption (Passaretti et al. , 2015), comorbidities and level of education (Dunn et al. , 2014), biochemical, patho-anatomical, peripheral and central sensitisation, sensory-motor cortex changes (Lewis et al. , 2015a) and a raft of psychosocial factors (Dean and Söderlund, 2015) have the potential to contribute to RCRSP, excessive and mal-adaptive load imposed on the tissues appears to be a major influence (Cook et al. , 2015, McCreesh and Lewis, 2013).

On-going debate persists pertaining to; (i) the cause of RCRSP, (ii) the tissue(s) and mechanism(s) responsible for the sensation of pain, (iii) the relationship between symptoms and structural failure observed within the RC tendons, and (iv) the role and extent of inflammation (Lewis, 2009a, Lewis, 2011, 2015, Lewis and Ginn, 2015, Scott et al. , 2015, Seitz et al. , 2011). These symptoms are commonly termed RC tendinopathy which implicates the tendon as the source of symptoms, although this may be the case, there is no definitive way of incriminating the tendons as the painful structures and the possibility exists that the symptoms are derived from the tendons and their related tissues. As such, and in keeping with other musculoskeletal conditions where a definitive structural diagnosis is often elusive, such as in low back pain (Waddell, 2004), deriving a definitive structural pathognomonic label maybe unachievable, and terms such as; subacromial or rotator cuff pain syndrome or rotator cuff related shoulder pain (RCRSP) may be more appropriate.

4. Aetiology

With respect to mechanism, Neer (Neer, 1972, 1983) argued that 95% of all RC pathology occurred as a result of irritation onto subacromial bursa and rotator cuff tendons from the under-surface of the over-lying anterior aspect of the acromion. This hypothesis has also been embraced by physiotherapists (Grimsby and Gray, 1997). Once diagnosed, Neer (1983) recommended 12 months of non-surgical treatment for those aged over 40 years with persistent and disabling symptoms, and advocated that if non-surgical treatment was unsuccessful, a subacromial decompression (SAD), also known as an acromioplasty, should be considered. This operation has become one of the most commonly performed musculoskeletal surgical procedures, with a reported 746% increase in the number of SADs in England from 2001 to 2010 (Judge et al. , 2014). In England and the USA there has been a concurrent increase in RC repairs. In the USA there has been a 141% increase in RC repairs between 1996 to 2006 and embedded within this figure is a 600% increase in repairs performed arthroscopically (Colvin et al. , 2012). The reasons for this are uncertain as arthroscopic repairs have been associated with a higher re-tear rate (46.4%) than open repairs (38.6%) and clinically with no significant difference in outcome (Carr et al. , 2015).

The relevance of the acromion to the development of symptoms and RC tears also remains uncertain. The argument that acromial irritation leads to RC pathology is not supported by observational studies. Payne et al., (1997) reported 91% (39 /43) of RC tears occurred on the inferior (articular or joint) side of the tendon with only 9% (n=4) occurring on the bursal side (ie the side under the acromion). Fukada et al., (1987) reported that 82% (n=27) of tears were joint side or intratendinous and 28% (n=6) were located on the bursal side. Ellman (1990) reported that from a total of 126 intra-operative investigations of the rotator cuff, 76% (n=96) were found to have articular side tears, 14% (n= 17) bursal side, and 10% (n=13) had both. This repeated and consistent finding that tears are predominantly located within the tendon or on the articular side does not support the acromial impingement model. Of relevance, already in 1934, Codman identified articular side tears calling them 'rim rents', stating; '…I am confident that these rim rents account for the majority of sore shoulders. It is my unproved opinion that many of these lesions never heal, although the symptoms caused by them usually disappear within a few months.' In reality, whether these tears cause pain or not, has never been established.

Observed variations in RC morphology may explain some of these findings. Hashimoto et al., (2003) reported greater fibre degeneration and disorientation in the middle and deeper fibres of the RC and argued that degeneration was the primary cause of RC tears. Nakajima et al., (1994) reported that the deeper fibres of the RC had a relatively smaller cross-sectional area than the articular side fibres and the lower fibres failed at approximately half the tensile load of those located superiorly. Bey et al., (2002) reported strain within the supraspinatus tendon that increased with increasing joint elevation between 15° to 60° abduction with no significant difference in strain between the upper and lower fibres. As the lower fibres are relatively weaker, the suggestion being that the joint-side fibres are more vulnerable to a tensile load than the bursal-side fibres (Nakajima et al. , 1994) during shoulder elevation and as such more susceptible to failure and this may be independent to acromion irritation. Bigliani et al., (1986) described three distinct acromial shapes (flat, curved and hooked) attributing the differences to morphological variations and argued those with a Type III or hooked acromion would be more likely to experience subacromial pain symptoms and suffer a RC tear. Definitive causation has not been established and there appears to be a poor correlation between acromial shape and symptoms (Gill et al. , 2002, Snow et al. , 2009, Worland et al. , 2003) further challenging the acromial model of RC tendinopathy. In addition, if the acromion is the cause for impingement and this eventuates in RC tears, a SAD should halt this process. This hypothesis has been disputed in studies that have demonstrated that a SAD provides no clinically important effect over a structured and supervised exercise programme (Ketola et al. , 2013), and others reporting the development of RC tears following an acromioplasty for people diagnosed with impingement syndrome (Hyvonen et al. , 1998). Additionally, contact between the acromion and RC has been investigated (Chang et al. , 2006) with reconstructed MR images challenging the construct that osseous impingement by the acromion is the primary cause of subacromial impingement syndrome and RC tears. If comparable clinical improvement can be achieved with an exercise program without performing a SAD, and if RC tears occur following an acromioplasty, the hypotheses supporting the acromial impingement model are substantively challenged. These issues have been previously discussed in detail (Lewis, 2011, 2015). The importance of the acromion is further challenged.

(Henkus et al. , 2009) randomised 57 people with subacromial impingement syndrome to acromioplasty and bursectomy or bursectomy alone. At a mean 2.5 year follow up both groups reported comparable results with no significant difference in Constant score, Simple Shoulder test, and visual analogue scores for pain and function. They argued their results supported an intrinsic degenerative model for RC pathology rather than an extrinsic irritation model. Detailed descriptions of normal tendon composition, structure and function, and, changes associated with tendinopathy have been published (Cook and Purdam, 2009, Cook, Rio, 2015, Lewis, 2009a, 2010, McCreesh and Lewis, 2013, Scott, Backman, 2015, Screen, 2015).

Osteophytes have been observed on the acromial but not the coracoid side of the coracoacromial ligament (Edelson and Taitz, 1992). The development of osteophytic spurs may be a secondary phenomenon (Chambler et al. , 2003a) resulting from increased tension in the coracoacromial ligament as the arm is abducted (Chambler et al. , 2003b). As the coracoacromial ligament is more trapezoid in shape, the smaller area of insertion on the acromial side may account for relative increase in tension and be the mechanism stimulated osteophyte growth at this location. If this hypothesis is correct then the Type II (curved) and Type III (hooked) acromion (Bigliani, Morrison, 1986, Bigliani et al. , 1991) may not be morphological variants, but may result from strain in the coracoacromial ligament disproportionally affecting the relatively smaller area of insertion on the acromial side. Chronic strain under the coracoacromial ligament may result from increases in RC tendon volume with significant differences being demonstrated in people diagnosed with RC tendinopathy (McCreesh et al. , 2014) as well as RC fatigue or failure leading to superior translation of the humeral head during arm elevation (Mura et al. , 2003). The coracoacromial ligament is a potential source of symptoms in people diagnosed with RC pain syndrome with significant increases in nociceptive nerve fibres identified in this structure in this patient group (Tamai et al. , 2000). As a causal relationship between acromial shape , acromial irritation and rotator cuff pathology has not been demonstrated clinicians in discussion with patients should not implicate the acromion as the cause of RC tears or symptoms, and the term 'impingement' may create an incorrect perception of pathogenesis.

5. Relationship between imaging and symptoms

Clinical diagnoses are established through discussion with patients and clinical assessment procedures that may be supported by imaging studies and laboratory investigations (Hegedus et al. , 2014, Hegedus and Lewis, 2015, Lewis, Hegedus, In Press). The reliance on imaging may be problematic, with investigations reporting substantial numbers of people without symptoms demonstrating RC structural failure (Table 1) (Frost et al. , 1999, Girish et al. , 2011, Milgrom et al. , 1995, Sher et al. , 1995).

Table 1 near here

These findings have profound clinical implications. The sensitivity, specificity, predictive values and likelihood ratios for clinical tests are based on gold standard reference tests that have identified structural failure and these findings are then compared with the responses produced using special orthopaedic tests such as the battery of rotator cuff tests and test for impingement. The gold standard tests are generally considered to include; US, MRI and direct observation during surgery. However, the substantial numbers of people without symptoms who demonstrate structural failure largely invalidates US, MRI and direct intra-operative observation as gold standard reference tests. In addition, these findings also invalidate the majority of special orthopaedic tests and combinations of these tests as procedures to definitive rule in the structure that is causing the patient's symptoms. If anything, these tests should be considered as symptom provocation procedures (Lewis, 2009b).

The implication of a lack of a real 'gold-standard' comparator is that many people with shoulder symptoms who are given a structural diagnosis based on clinical orthopaedic tests and / or imaging procedures will be given incorrect diagnoses. A further implication is that patients will be listed for and undergo surgical operations on tissues that are not related or the cause of their symptoms. It is unlikely a patient would agree to start insulin injections based on considerable inaccuracies in the diagnostic tests for diabetes, yet current clinical practice suggests that this may not be the case for many orthopaedic surgical procedures and musculoskeletal treatments.

4. Additional uncertainties associated with surgery

Success rates (good to excellent results) of up to 70-90% following SAD have been reported (Ellman and Kay, 1991, Spangehl et al. , 2002). Following surgery there is an extended period of reduced activity and graduated return to function that might take many months. Post-operative protocols typically dictate very slow and gentle movements in the early stages of rehabilitation, with the avoidance of active shoulder movement if the RC has been repaired. Following SAD, studies from Australia and the United Kingdom, have reported that non-manual workers take up to an average of 6 weeks and manual workers up to an average of 3 months to return to work with an avoidance of driving for up to 4 weeks (Charalambous et al. , 2010, McClelland et al. , 2005). A relative reduction in tissue loading (relative rest) is frequently recommended in the early stages of treating a tendinopathy (Cook, Rio, 2015, Lewis, 2010, Lewis, 2014). The relative rest and graduated rehabilitation imposed by the surgery may be the reason for improvement in symptoms and not the surgery itself (Lewis, 2011, 2015). This hypothesis needs to be tested in an appropriately designed investigation, but until it has, surgeons need be circumspect with their explanation of the intended benefits of SAD and RC repairs to those considering surgery. Two separate research investigations have suggested that the outcomes of knee surgical procedures for painful osteoarthritis of the knee and degenerative medial meniscus tears may be due to placebo (Moseley et al. , 2002, Sihvonen et al. , 2013). This may be an additional reason for success attributed to shoulder surgery and is another area of this condition requiring appropriate investigation, where one arm of the trial does not directly influence the glenohumeral joint. Furthermore, patients are frequently informed that removing the irritation caused by the acromion, repairing the damaged tendon tissue, and avoidance of an increase in the size of the RC tendon tear, are amongst the intended benefits of surgery. These precepts have also been challenged in investigations that suggest outcome may be related more to numbers of co-morbidities and level of education than tendon structural factors (Dunn, Kuhn, 2014).

5. Assessment and the Shoulder Symptom Modification Procedure

Assessment involves taking a detailed history and discussion with the patient, screening and on-going monitoring for potential red-flag presentations, functional/ disability questionnaires, assessment of impairment that may include; range of movement, strength, posterior capsule extensibility, neural tests, pain behaviour, etc. Increasing and decreasing load on the muscle tendon-unit may also help to support clinical hypotheses. Orthopaedic tests and imaging may support the clinical examination. However, as discussed the value of orthopaedic tests may be no more than symptom reproduction and clinical reasoning to implicate the structure(s) based on these tests has been challenged (Lewis, 2009b).

Narrative and systematic reviews have contested the extent to which a definitive structural diagnosis is achievable (Hegedus et al. , 2012, Hegedus and Lewis, 2015). In response to this, suggestions have been presented to use symptom modification (also known as treatment direction test / treatment classification tests) as a method to inform clinical management (Lewis, Hegedus, In Press, Lewis, 2009b, Lewis, McCreesh, 2015).

One such approach is the Shoulder Symptom Modification Procedure (SSMP) first described in 2009 (Lewis, 2009b). The SSMP systematically investigates the influence of thoracic posture, 3 planes of scapular posture (and combinations of scapular positioning), and humeral head position (using a battery of tests) on shoulder symptoms. SSMP assessment techniques found to reduce symptoms are then used to treat the symptoms. If the first three stages of the SSMP do not completely alleviate or reduce symptoms, then the final stage of the SSMP involves assessing the influence of manual procedures that may modulate shoulder symptoms and are primarily performed throughout the cervical, thoracic, and shoulder regions. The process has been presented and discussed in detail elsewhere (Lewis, Hegedus, In Press, Lewis, 2009b, Lewis, McCreesh, 2015). For the cervical and lumbar regions, there is limited evidence, that techniques found to improve symptoms within a session may be used to guide treatment selection and may contribute to predicting a between session change in symptoms (Hahne et al. , 2004, Tuttle, 2005). The SSMP is supported by anecdotal evidence and as such its implementation should be considered cautiously and is only one of many assessment options available to clinicians. If proven to be of clinical value the process needs to adapt and evolve to new and emerging information. Research is needed to establish the concepts reliability and to establish the component parts (if any) that can be used to inform patient management.

Figures 1 to 5 detail selected SSMP assessment procedures.

Figure 1 near here

Figure 2 near here

Figure 3 near here

Figure 4 near here

Figure 5 near here

The SSMP may influence the symptoms associated with RCRSP by; changing the RC muscle-tendon length tension relationships, producing variations in relationships of anatomical structures, neuromodulation and non-specific tissue based responses. If resolution of symptoms is not complete following the application of the SSMP then a structured and graduated exercise program aiming to target the RC is instigated. A model for the staged clinical management of RCRSP has been published previously (Lewis 2014). Figure 6 is based on this model.

Figure 6 near here

6. Exercise therapy

Although a structured exercise program is unequivocally the main intervention for RCRSP (Haahr and Andersen, 2006, Ketola, Lehtinen, 2013, Kukkonen et al. , 2014) consensus on dosage, frequency, method of delivery, acceptable pain tolerance, inter-exercise activity levels, and specific exercise inclusion has not been achieved. Systematic reviews investigating exercise for RCRSP have produced varied findings.

Desmeules et al. , (2003) reported limited evidence to support the efficacy of therapeutic exercise and manual therapy manual. Kromer et al. , (2009) reported equal effectiveness of physiotherapist-led exercises compared with surgery in the long term. Kuhn, (2009) concluded that; exercise had statistically and clinically significant effects on pain reduction and improving function, but not on range of motion or strength, and manual therapy may augment the effects of exercise. In this review home exercise programs were fund to be as beneficial as supervised exercises. Braun and Hanchard, (2010) reported limited support for manual therapy and exercise of short to medium term effectiveness, and highlighted methodological flaws and risk of bias in many of the included studies.

Kelly et al. , (2010) reported only limited evidence was found to support the use of exercise, whereas, Hanratty et al. , (2012) concluded that; strong evidence existed for exercise to decrease pain and improve function in the short-term, and moderate level evidence existed suggested that exercise resulted in short-term improvement in mental well-being and long-term improvement in function. They also concluded that synthesis of definitive exercise prescription to achieve these benefits was indeterminable due to poor reporting of protocols. Abdulla et al. , (2015) reported that; supervised and home based strengthening (and stretching) may lead to short term benefit in pain and disability, and that for persistent symptoms exercise leads to similar outcomes as surgery.

This differences in findings reported may relate to different; diagnostic categories, inclusion and exclusion criteria, quality assessment tools, and methods used within each review. Ideally treatment intervention would result in complete resolution of symptoms and in a Numbers Needed to Treat of 1 (Greenhalgh et al. , 2014, Sackett et al. , 2000), where everyone receiving an appropriate intervention reports a favourable outcome when compared to a control group. Unfortunately this is not the case. There are many possible reasons for this, including; incomplete knowledge on source and mechanism(s) of symptoms and inadequate and appropriate treatments to address these factors. Other factors include psychosocial influences, duration of symptoms, genetics, comorbidities, lifestyle issues and hormonal status. Inadequate and / or inappropriate provision of treatment will also influence outcome. One possible reason for suboptimal outcome is not stratifying intervention according to clinical presentation as has been suggested in other musculoskeletal conditions (O'Sullivan, 2005). As detailed in Figure 6, one method of stratifying management for RCRSP is to sub-categorise the clinical presentation into irritable, non-irritable and advanced. Overlap in management strategies occur between these sub-categories.

7. Management of rotator cuff related shoulder pain

Common to all clinical presentations is the need to engage with the individual experiencing the symptoms, allowing the person to voice their needs and concerns. Understanding and acknowledgement the impact of the problem demonstrates empathy. In addition, patients should be given the opportunity to discuss their understanding of the cause of the symptoms, how quickly they expect to recover, the treatments they may consider to be effective, and, their thoughts on the treatment the clinician recommends. Clinicians should provide information relating to cause, prognosis and expected outcome and avoid 'threatening' language such as 'acromion impinging and wearing away or tearing into the tendon'. Patients need to understand that the management of tendon related problems requires at least the same respect as afforded to the management of other musculoskeletal problems, such as fractures. A person with a fracture not as yet demonstrating clinical and radiological union involving the upper arm or forearm would be unable to perform certain activities, such as; serving in tennis, hammering nails into walls and would need to make certain compromises with respect to the fracture. Frequently tendon related problems are harder to treat and follow a more protracted course than fractures and the requirement to adhere to appropriate levels of activity is necessary. Managing a tendon related problem should not be seen as only treating a local problem and attention to wider issues, including lifestyle factors, are essential (Dean and Söderlund, 2015). Providing a local shoulder based treatment in isolation is an ineffective management strategy in the management of RCRSP and typically results in suboptimal outcomes. Clinicians and patients need to appreciate that many activities require that energy is transferred from the lower to upper limbs through the trunk and an inability to transfer energy from the lower limbs may result in increased demands on the shoulder (Kibler, 1995, Kibler and Chandler, 1995, Sciascia and Cromwell, 2012, Seroyer et al. , 2010), potentially leading to local overload and local symptoms. This is easy to appreciate and the clinician can facilitate this by asking the patient to describe how they would throw a ball, serve in tennis or perform some other similar activity. Although currently there is no definite method of identifying the impact, such as; movement restriction, pain, fatigue in the lower limbs and trunk has on the shoulder, clinicians should include exercise and appropriate management for these regions commensurate with the patient's level of function and functional requirements. Sensory-motor exercises appropriate for the patient's level of function may also enhance outcome.

Irritable RCRSP

This may occur in acute and chronic presentations and is commonly characterised by easily aggravated and prolonged (sometimes constant) shoulder pain once provoked, together with night pain. Limited research implicates subacromial bursal involvement in this presentation (Santavirta et al. , 1992). As with all presentations load management (relative rest) is important and the aim is to identify a level of activity that reduces the amount of pain experienced. Training using resistance exercise bands or other equipment, performed quickly, under high loads and repetitions, commonly aggravates this clinical presentation, and one potential reason for the equivocal findings reported by the systematic reviews, outlined previously, may relate to not considering the individual's response to exercise.

Anecdotal evidence suggests that isometric exercises, with the arm supported performed in the direction of pain, may help to control pain. Although there is some evidence to support this observation (Hoeger Bement et al. , 2008, Lemley et al. , 2014, Rio et al. , 2015), conclusive evidence for the shoulder is not available. The response to isometric exercises may be assessed across the spectrum of presentations (ie irritable, non-irritable and advanced). Additional anecdotal evidence suggests that the application of ice wraps may also be helpful in controlling pain. Exercise in the form of gentle loading, such as short lever flexion exercises may be well tolerated, as may shoulder flexion supported on a ball, which may be progressed as the patient is able (Figure 7). This and other examples of a motor control exercises should ideally not increase pain and when appropriate should incorporate lower limb weight transfer.

Pharmacological intervention may be required to control symptoms. All medicine is associated with risk, including; adverse reactions, side effects and interactions, and the risks must be considered together with the intended benefits. Non-steroidal anti-inflammatories have been associated with myocardial infarction and stroke, with the risk increasing even after several weeks of use. In addition, corticosteroids have been associated with deleterious effects on rotator cuff tissue (Dean et al. , 2014a, Dean et al. , 2014b). Although there is a worrying paucity of evidence to support injection therapy for the shoulder, studies that have compared analgesic only injections to corticosteroid and analgesic injections have reported comparable outcomes up to 6 months (Akgun et al. , 2004, Alvarez et al. , 2005) and due to the local and systemic risks associated with corticosteroids, analgesic only injections, although not without risk, could possibly be considered as first line injection management. One possible reason for this is that both glucocorticoids and local anaesthetics appear to be able to reduce tenocyte numbers (Carofino et al. , 2012, Scherb et al. , 2009). Tenocyte proliferation has been associated with tendinopathy (Scott, Backman, 2015, Screen, 2015) and one possibility is that injection therapy may contribute to restoration of tendon cellular homeostasis by reducing tenocyte numbers. This hypothesis requires appropriate scrutiny. Injection therapy may help reduce pain to permit exercise therapy to continue more effectively but may not confer long term benefit (Crawshaw et al. , 2010).

Non-irritable RCRSP

Non irritable RCRSP is characterised by pain (that may range from mild to severe) that increases with movement and no or minimal irritability. Pain and weakness is most commonly experienced in the direction of external rotation and elevation and the following relates to this presentation.

Non-irritable RCRSP may benefit from a graduated shoulder flexion program such as described in Figure 7 and progresses to short lever (ie elbow bent) shoulder flexion initially without, then with, increasing weights and resistances. Free weights may be used and another option is to secure resistance tubing under a door, using lower limb weight transference and flexing the shoulder within pain free ranges. As pain decreases, range can be progressed as can the resistance. One such exercise is a combination of the technique detailed in Figure 4, with resistance bands secured under the foot or a door and attached to the hand on the symptomatic side.

In addition to a graduated and progressive program performed in the direction of shoulder flexion, a concurrent graduated shoulder external rotation program should be introduced. Entry point into the program should be commensurate with the patient's physical ability and pain response. A comprehensive approach to exercise therapy for RCRSP has recently been published (Lewis, McCreesh, 2015). Examples of exercises used within a RC rehabilitation program are detailed in Table 2.

Clinicians should design treatment programs that include strengthening and endurance exercises. Strength programs are typically based on an assessment of 1 Repetition Maximum (1RM). One method of assessing this is to use a hand held dynamometer (Dollings et al. , 2012). If pain precludes a definitive assessment on the symptomatic side, the asymptomatic side can provide guidance as to the expected strength on the symptomatic side. Assessment in different shoulder joint positions is often more informative than standard arm by the side tests. Guidance on strength and endurance programs has been published (Jull et al. , 2015, McArdle et al. , 2014, mcGarber et al. , 2011).

One strategy to ensure that the tissues can tolerate the load imposed during the exercise program and the influence of any change can be assessed is to only introduce one change at a time and monitor its influence over a 24 hour period. There may be some benefit in developing an exercise program that delivers training in a range of postures and arm positions (even within one training session) to introduce variability in loading. Another strategy that may be considered, especially if the response to strengthening exercises has plateaued, is to permit a degree of pain during the exercise (Holmgren et al. , 2012). Pain that is tolerated by the patient in the order of 2 to 5 out of 10 as reported on an analogue scale of pain (where 10 is the worst imaginable pain) may be introduced to determine if this contributes to improvement. Pain should settle soon after the exercise and must not increase pain at night or pain experienced over 24 hours. Increases in pain should if possible be avoided during movement control exercises, such as Figure 7.

Advanced RCRSP

End stage or advanced RCRSP is characterised by massive and inoperable RC tears. These tears are frequently associated with substantial morbidity and represent a clinical challenge to physiotherapists. As these tears are generally unrepairable, surgeons may recommend joint replacement surgery (Harreld et al. , 2012). The findings of a randomised placebo controlled clinical trial (Ainsworth et al. , 2009) suggested that an exercise program specifically designed for this clinical presentation demonstrated significant benefit at 3 and 6 months. This program may be enhanced by SSMP techniques and exercises described in the irritable and non-irritable RCRPS stages exercises, including the exercises depicted in Figure 7.

Figure 7 near here

Although there are many reasons for suboptimal outcomes, people with RCRPS should derive considerable confidence from the research literature that they should achieve at least comparable results as they would if undergoing surgery for RCRSP (Haahr and Andersen, 2006, Haahr et al. , 2005, Ketola et al. , 2009, Ketola, Lehtinen, 2013), and, atraumatic partial thickness tears (Kukkonen, Joukainen, 2014). This extends to people diagnosed with atraumatic full thickness tears (Kuhn et al. , 2013) as well as those diagnosed with RCRSP who have previously failed non-surgical treatment (Hallgren et al. , 2014).

These studies suggest that patients with RCRSP managed with exercise therapy should expect equivalent outcomes to surgery. It is possible that the addition of whole of body exercises, manual therapy, life style management, screening of postural factors as identified during assessment procedures such as the SSMP and staged rehabilitation relevant to the patient's clinical presentation may further enhance outcomes. This hypothesis would require appropriate investigation. In addition, research is required to identify those that may not benefit from an exercise approach and require alternative management need to be identified.

8. Conclusion

Shoulder diagnosis is fraught with difficulty and assessment techniques such as the Shoulder Symptom Modification Procedure (Lewis, 2009b) may help direct management. Although no intervention can currently guarantee complete reduction in symptoms, both physiotherapists and people with RCRSP should derive confidence that an exercise based approach produces equivalent outcomes when compared to surgery for those diagnosed with subacromial impingement syndrome/ RC tendinopathy, and those with atraumatic partial and full thickness tears. There is also evidence that a graduated exercise program will benefit those who have failed an initial course of non-surgical treatment, and those with massive inoperable RC tears. Outcomes may be further enhanced if patients are categorised into clinical presentations and appropriate intervention is offered relevant to that stage. Addressing lifestyle factors may also contribute to improved outcomes as may whole of body exercise programs. The role of manual therapy is less clear and requires further research.

References

Abdulla SY, Southerst D, Cote P, Shearer HM, Sutton D, Randhawa K, et al. Is exercise effective for the management of subacromial impingement syndrome and other soft tissue injuries of the shoulder? A systematic review by the Ontario Protocol for Traffic Injury Management (OPTIMa) Collaboration. Man Ther. 2015;20:646-56.

Ainsworth R, Lewis JS, Conboy V. A prospective randomized placebo controlled clinical trial of a rehabilitation programme for patients with a diagnosis of massive rotator cuff tears of the shoulder. Shoulder & Elbow. 2009;1:55-60.

Akgun K, Birtane M, Akarirmak U. Is local subacromial corticosteroid injection beneficial in subacromial impingement syndrome? Clinical rheumatology. 2004;23:496-500.

Alvarez CM, Litchfield R, Jackowski D, Griffin S, Kirkley A. A prospective, double-blind, randomized clinical trial comparing subacromial injection of betamethasone and xylocaine to xylocaine alone in chronic rotator cuff tendinosis. The American journal of sports medicine. 2005;33:255-62.

Baumgarten KM, Gerlach D, Galatz LM, Teefey SA, Middleton WD, Ditsios K, et al. Cigarette smoking increases the risk for rotator cuff tears. Clinical orthopaedics and related research. 2010;468:1534-41.

Bey MJ, Song HK, Wehrli FW, Soslowsky LJ. Intratendinous strain fields of the intact supraspinatus tendon: the effect of glenohumeral joint position and tendon region. Journal of orthopaedic research : official publication of the Orthopaedic Research Society. 2002;20:869-74.

Bigliani LU, Morrison DS, April EW. The morphology of the acromion and its relationship to rotator cuff tears. Orthopaedic Transactions. 1986;10:228.

Bigliani LU, Ticker JB, Flatow EL, Soslowsky LJ, Mow VC. The relationship of acromial architecture to rotator cuff disease. Clinics in Sports Medicine. 1991;10:823-38.

Boettcher CA, Ginn KA, Cathers I. The 'empty can' and 'full can' tests do not selectively activate supraspinatus. Journal Science and Medicine in Sport. 2009;12:435-9.

Boettcher CE, Cathers I, Ginn KA. The role of shoulder muscles is task specific. Journal of science and medicine in sport / Sports Medicine Australia. 2010;13:651-6.

Braun C, Hanchard NCA. Manual therapy and exercise for impingement-related shoulder pain. Physical Therapy Reviews. 2010;15:62-83.

Carofino B, Chowaniec DM, McCarthy MB, Bradley JP, Delaronde S, Beitzel K, et al. Corticosteroids and local anesthetics decrease positive effects of platelet-rich plasma: an in vitro study on human tendon cells. Arthroscopy : the Journal of Arthroscopic & Related Surgery. 2012;28:711-9.

Carr AJ, Cooper CD, Campbell MK, Rees JL, Moser J, Beard DJ, et al. Clinical effectiveness and cost-effectiveness of open and arthroscopic rotator cuff repair [the UK Rotator Cuff Surgery (UKUFF) randomised trial]. Health Technol Assess. 2015;19:1-218.

Chambler A, Pitsillides A, Emery R. Acromial spur formation in patients with rotator cuff tears. Journal of shoulder and elbow surgery. 2003a;12:314-21.

Chambler AF, Bull AM, Reilly P, Amis AA, Emery RJ. Coracoacromial ligament tension in vivo. Journal of shoulder and elbow surgery / American Shoulder and Elbow Surgeons [et al]. 2003b;12:365-7.

Chang EY, Moses DA, Babb JS, Schweitzer ME. Shoulder impingement: objective 3D shape analysis of acromial morphologic features. Radiology. 2006;239:497-505.

Charalambous CP, Sahu A, Alvi F, Batra S, Gullett TK, Ravenscroft M. Return to work and driving following arthroscopic subacromial decompression and acromio-clavicular joint excision. Shoulder & Elbow. 2010;2:83-6.

Clark J, Sidles JA, Matsen FA. The relationship of the glenohumeral joint capsule to the rotator cuff. Clinical orthopaedics and related research. 1990:29-34.

Clark JM, Harryman DT, 2nd. Tendons, ligaments, and capsule of the rotator cuff. Gross and microscopic anatomy. The Journal of Bone and Joint Surgery. 1992;74:713-25.

Codman E. The Shoulder: Rupture of the supraspinatus tendon and other lesions in or about the subacromial bursa. Boston: Thomas Todd Company; 1934.

Colvin AC, Egorova N, Harrison AK, Moskowitz A, Flatow EL. National trends in rotator cuff repair. The Journal of Bone and Joint Surgery. 2012;94:227-33.

Connor PM, Banks DM, Tyson AB, Coumas JS, D'Alessandro DF. Magnetic resonance imaging of the asymptomatic shoulder of overhead athletes: a 5-year follow-up study. The American journal of sports medicine. 2003;31:724-7.

Cook J, Purdam CR. Is tendon pathology a continuum? A pathology model to explain the clinical presentation of load-induced tendinopathy. British Journal of Sports Medicine. 2009;43:409-16.

Cook JL, Rio E, Lewis JS. Managing tendinopathies. . In: Jull G, Moore A, Falla D, Lewis JS, McCarthy C, Sterling M, editors. Grieve's Modern Musculoskeletal Physiotherapy. 4th ed. London: Elsevier; 2015.

Couanis G, Breidahl W, Burnham S. The relationship between subacromial bursa thickness on ultrasound and shoulder pain in open water endurance swimmers over time. Journal of science and medicine in sport / Sports Medicine Australia. 2014.

Crawshaw DP, Helliwell PS, Hensor EM, Hay EM, Aldous SJ, Conaghan PG. Exercise therapy after corticosteroid injection for moderate to severe shoulder pain: large pragmatic randomised trial. BMJ. 2010;340:c3037.

Daghir AA, Sookur PA, Shah S, Watson M. Dynamic ultrasound of the subacromial-subdeltoid bursa in patients with shoulder impingement: a comparison with normal volunteers. Skeletal radiology. 2012;41:1047-53.

Dean BJ, Franklin SL, Murphy RJ, Javaid MK, Carr AJ. Glucocorticoids induce specific ion-channel-mediated toxicity in human rotator cuff tendon: a mechanism underpinning the ultimately deleterious effect of steroid injection in tendinopathy? Br J Sports Med. 2014a;48:1620-6.

Dean BJ, Lostis E, Oakley T, Rombach I, Morrey ME, Carr AJ. The risks and benefits of glucocorticoid treatment for tendinopathy: a systematic review of the effects of local glucocorticoid on tendon. Seminars in arthritis and rheumatism. 2014b;43:570-6.

Dean E, Söderlund A. Lifestyle factors and musculoskeletal pain. In: Jull G, Moore A, Falla D, Lewis JS, McCarthy C, Sterling M, editors. Grieve's Modern Musculoskeletal Physiotherapy. 4th ed. London: Elsevier; 2015.

Desmeules F, Cote CH, Fremont P. Therapeutic exercise and orthopedic manual therapy for impingement syndrome: a systematic review. Clinical journal of sport medicine : official journal of the Canadian Academy of Sport Medicine. 2003;13:176-82.

Dillman CJ, Fleisig GS, Andrews JR. Biomechanics of pitching with emphasis upon shoulder kinematics. The Journal of orthopaedic and sports physical therapy. 1993;18:402-8.

Dollings H, Sandford F, O'Conaire E, Lewis JS. Shoulder strength testing: the intra-and inter-tester reliability of routine clinical tests, using the PowerTrack II Commander. Shoulder & Elbow. 2012;4:131-40.

Dunn WR, Kuhn JE, Sanders R, An Q, Baumgarten KM, Bishop JY, et al. Symptoms of pain do not correlate with rotator cuff tear severity: a cross-sectional study of 393 patients with a symptomatic atraumatic full-thickness rotator cuff tear. The Journal of Bone and Joint Surgery. 2014;96:793-800.

Edelson JG, Taitz C. Anatomy of the coraco-acromial arch. Relation to degeneration of the acromion. The Journal of bone and joint surgery British volume. 1992;74:589-94.

Ellman H. Diagnosis and treatment of incomplete rotator cuff tears. Clinical orthopaedics and related research. 1990:64-74.

Ellman H, Kay SP. Arthroscopic subacromial decompression for chronic impingement. Two- to five-year results. The Journal of bone and joint surgery British volume. 1991;73:395-8.

Feltner MaD, J. Dynamic of the shoulder and elbow joints of the throwing arm during the baseball pitch. International Journal of Sports Biomechanics. 1986;5:420-50.

Fleisig GS, Barrentine SW, Zheng N, Escamilla RF, Andrews JR. Kinematic and kinetic comparison of baseball pitching among various levels of development. Journal of biomechanics. 1999;32:1371-5.

Frost P, Andersen JH, Lundorf E. Is supraspinatus pathology as defined by magnetic resonance imaging associated with clinical sign of shoulder impingement? Journal of shoulder and elbow surgery / American Shoulder and Elbow Surgeons [et al]. 1999;8:565-8.

Fukuda H, Mikasa M, Yamanaka K. Incomplete thickness rotator cuff tears diagnosed by subacromial bursography. Clinical orthopaedics and related research. 1987:51-8.

Gill TJ, McIrvin E, Kocher MS, Homa K, Mair SD, Hawkins RJ. The relative importance of acromial morphology and age with respect to rotator cuff pathology. Journal of shoulder and elbow surgery / American Shoulder and Elbow Surgeons [et al]. 2002;11:327-30.

Girish G, Lobo LG, Jacobson JA, Morag Y, Miller B, Jamadar DA. Ultrasound of the shoulder: asymptomatic findings in men. AJR American journal of roentgenology. 2011;197:W713-9.

Greenhalgh T, Howick J, Maskrey N. Evidence based medicine: a movement in crisis? BMJ. 2014;348:g3725.

Grimsby O, Gray J. Interrelation of the spine to the shoulder girdle. In: Donatelli R, editor. Physical Therapy of the Shoulder. 3 ed. New York: Churchill Livingstone; 1997. p. 95-129.

Haahr JP, Andersen JH. Exercises may be as efficient as subacromial decompression in patients with subacromial stage II impingement: 4-8-years' follow-up in a prospective, randomized study. Scand J Rheumatol. 2006;35:224-8.

Haahr JP, Ostergaard S, Dalsgaard J, Norup K, Frost P, Lausen S, et al. Exercises versus arthroscopic decompression in patients with subacromial impingement: a randomised, controlled study in 90 cases with a one year follow up. Annals of the rheumatic diseases. 2005;64:760-4.

Hahne AJ, Keating JL, Wilson SC. Do within-session changes in pain intensity and range of motion predict between-session changes in patients with low back pain? The Australian journal of physiotherapy. 2004;50:17-23.

Hallgren HC, Holmgren T, Oberg B, Johansson K, Adolfsson LE. A specific exercise strategy reduced the need for surgery in subacromial pain patients. Br J Sports Med. 2014;48:1431-6.

Hanratty CE, McVeigh JG, Kerr DP, Basford JR, Finch MB, Pendleton A, et al. The effectiveness of physiotherapy exercises in subacromial impingement syndrome: a systematic review and meta-analysis. Seminars in arthritis and rheumatism. 2012;42:297-316.

Harreld KL, Puskas BL, Frankle MA. Massive rotator cuff tears without arthropathy: when to consider reverse shoulder arthroplasty. Instructional course lectures. 2012;61:143-56.

Harvie P, Ostlere SJ, Teh J, McNally EG, Clipsham K, Burston BJ, et al. Genetic influences in the aetiology of tears of the rotator cuff. Sibling risk of a full-thickness tear. The Journal of bone and joint surgery British volume. 2004;86:696-700.

Hashimoto T, Nobuhara K, Hamada T. Pathologic evidence of degeneration as a primary cause of rotator cuff tear. Clinical orthopaedics and related research. 2003:111-20.

Hegedus EJ, Cook C, Lewis J, Wright A, Park JY. Combining orthopedic special tests to improve diagnosis of shoulder pathology. Physical therapy in sport : official journal of the Association of Chartered Physiotherapists in Sports Medicine. 2014.

Hegedus EJ, Goode AP, Cook CE, Michener L, Myer CA, Myer DM, et al. Which physical examination tests provide clinicians with the most value when examining the shoulder? Update of a systematic review with meta-analysis of individual tests. Br J Sports Med. 2012;46:964-78.

Hegedus EJ, Lewis JS. Shoulder Assessment. In: Jull G, Moore A, Falla D, Lewis JS, McCarthy C, Sterling M, editors. Grieve's Modern Musculoskeletal Physiotherapy 4th ed. London: Elsevier; 2015.

Henkus HE, de Witte PB, Nelissen RG, Brand R, van Arkel ER. Bursectomy compared with acromioplasty in the management of subacromial impingement syndrome: a prospective randomised study. The Journal of bone and joint surgery British volume. 2009;91:504-10.

Hoeger Bement M, Dicapo J, Rasiarmos R, Hunter S. Dose response of isometric contractions on pain perception in healthy adults. Medicine and science in sports and exercise. 2008;40:1880-9.

Holmgren T, Hallgren HB, Oberg B, Adolfsson L, Johansson K. Effect of specific exercise strategy on need for surgery in patients with subacromial impingement syndrome: randomised controlled study. Brit Med J. 2012;344.

Hyvonen P, Lohi S, Jalovaara P. Open acromioplasty does not prevent the progression of an impingement syndrome to a tear. Nine-year follow-up of 96 cases. The Journal of bone and joint surgery British volume. 1998;80:813-6.

Judge A, Murphy RJ, Maxwell R, Arden NK, Carr AJ. Temporal trends and geographical variation in the use of subacromial decompression and rotator cuff repair of the shoulder in England. The bone & joint journal. 2014;96-B:70-4.

Jull G, Moore A, Falla D, Lewis JS, McCarthy C, Sterling M, editors. Grieve's Modern Musculoskeletal Physiotherapy 4th ed. London: Elsevier; 2015.

Kelly SM, Wrightson PA, Meads CA. Clinical outcomes of exercise in the management of subacromial impingement syndrome: a systematic review. Clinical rehabilitation. 2010;24:99-109.

Ketola S, Lehtinen J, Arnala I, Nissinen M, Westenius H, Sintonen H, et al. Does arthroscopic acromioplasty provide any additional value in the treatment of shoulder impingement syndrome?: a two-year randomised controlled trial. The Journal of bone and joint surgery British volume. 2009;91:1326-34.

Ketola S, Lehtinen J, Rousi T, Nissinen M, Huhtala H, Konttinen YT, et al. No evidence of long-term benefits of arthroscopicacromioplasty in the treatment of shoulder impingement syndrome: Five-year results of a randomised controlled trial. Bone & joint research. 2013;2:132-9.

Kibler WB. Biomechanical analysis of the shoulder during tennis activities. Clinics in Sports Medicine. 1995;14:79-85.

Kibler WB, Chandler J. Baseball and Tennis. In: Griffin LY, editor. Rehabilitation of the Injured Knee. St Louis: Moseby; 1995.

Kromer TO, Tautenhahn UG, de Bie RA, Staal JB, Bastiaenen CH. Effects of physiotherapy in patients with shoulder impingement syndrome: a systematic review of the literature. Journal of rehabilitation medicine : official journal of the UEMS European Board of Physical and Rehabilitation Medicine. 2009;41:870-80.

Kuhn JE. Exercise in the treatment of rotator cuff impingement: a systematic review and a synthesized evidence-based rehabilitation protocol. Journal of shoulder and elbow surgery / American Shoulder and Elbow Surgeons [et al]. 2009;18:138-60.

Kuhn JE, Dunn WR, Sanders R, An Q, Baumgarten KM, Bishop JY, et al. Effectiveness of physical therapy in treating atraumatic full-thickness rotator cuff tears: a multicenter prospective cohort study. Journal of shoulder and elbow surgery / American Shoulder and Elbow Surgeons [et al]. 2013;22:1371-9.

Kukkonen J, Joukainen A, Lehtinen J, Mattila KT, Tuominen EK, Kauko T, et al. Treatment of non-traumatic rotator cuff tears: A randomised controlled trial with one-year clinical results. The bone & joint journal. 2014;96-B:75-81.

Lemley KJ, Drewek B, Hunter SK, Hoeger Bement MK. Pain relief after isometric exercise is not task-dependent in older men and women. Medicine and science in sports and exercise. 2014;46:185-91.

Lewis J, Hegedus E, Jones M. Shoulder pain: To operate or not to operate? . In: Jones M, Rivett D, editors. Clinical Reasoning in Musculoskeletal Practice. 2nd ed. Edinburgh: Churchill Livingstone / Elsevier; In Press.

Lewis J, McCreesh K, Roy J-S, Ginn K. Rotator Cuff Tendinopathy: Navigating the Diagnosis-Management Conundrum. Journal of Orthopaedic & Sports Physical Therapy. 2015;45:923-37.

Lewis JS. Rotator cuff tendinopathy. Br J Sports Med. 2009a;43:236-41.

Lewis JS. Rotator cuff tendinopathy/subacromial impingement syndrome: is it time for a new method of assessment? Br J Sports Med. 2009b;43:259-64.

Lewis JS. Rotator cuff tendinopathy: a model for the continuum of pathology and related management. Br J Sports Med. 2010;44:918-23.

Lewis JS. Subacromial impingement syndrome: A musculoskeletal condition or a clinical illusion? Physical Therapy Review. 2011;16:388-98.

Lewis JS. Management of rotator cuff tendinopathy. In Touch- Journal of the Organisation of Chartered Physiotherapists in Private Practice. 2014;149:12-7.

Lewis JS. Bloodletting for pneumonia, prolonged bed rest for low back pain, is subacromial decompression another clinical illusion? British Journal of Sports Medicine. 2015;49:280-1.

Lewis JS, Ginn K. Rotator cuff tendinopathy and subacromial pain syndrome. In: Jull G, Moore A, Falla D, Lewis JS, McCarthy C, Sterling M, editors. Grieve's Modern Musculoskeletal Physiotherapy 4th ed. London: Elsevier; 2015.

Magee D. Orthopedic Physical Assessment. 6 ed. Philadelphia: Elsevier; 2014.

Magnusson SP, Hansen M, Langberg H, Miller B, Haraldsson B, Westh EK, et al. The adaptability of tendon to loading differs in men and women. International journal of experimental pathology. 2007;88:237-40.

McArdle WD, Katch FI, Katch VL. Exercise Physiology: Nutrition, Energy, and Human Performance United States: Wolters Kluwer Health; 2014.

McClelland D, Paxinos A, Dodenhoff RM. Rate of return to work and driving following arthroscopic subacromial decompression. ANZ J Surg. 2005;75:747-9.

McCreesh K, Donnelly A, Lewis J. Immediate Response Of The Supraspinatus Tendon To Loading In Rotator Cuff Tendinopathy. . British Journal of Sports Medicine. 2014;48:A42-A3.

McCreesh K, Lewis J. Continuum model of tendon pathology - where are we now? International journal of experimental pathology. 2013;94:242-7.

McGarber CE, Blissmer B, Deschenes MR, Franklin BA, Lamonte MJ, Lee IM, et al. American College of Sports Medicine position stand. Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: guidance for prescribing exercise. Medicine and science in sports and exercise. 2011;43:1334-59.

Milgrom C, Schaffler M, Gilbert S, van Holsbeeck M. Rotator-cuff changes in asymptomatic adults. The effect of age, hand dominance and gender. The Journal of bone and joint surgery British volume. 1995;77:296-8.

Miniaci A, Mascia AT, Salonen DC, Becker EJ. Magnetic resonance imaging of the shoulder in asymptomatic professional baseball pitchers. The American journal of sports medicine. 2002;30:66-73.

Moseley JB, O'Malley K, Petersen NJ, Menke TJ, Brody BA, Kuykendall DH, et al. A controlled trial of arthroscopic surgery for osteoarthritis of the knee. The New England Journal of Medicine. 2002;347:81-8.

Mura N, O'Driscoll SW, Zobitz ME, Heers G, Jenkyn TR, Chou SM, et al. The effect of infraspinatus disruption on glenohumeral torque and superior migration of the humeral head: a biomechanical study. Journal of shoulder and elbow surgery / American Shoulder and Elbow Surgeons [et al]. 2003;12:179-84.

Nakajima T, Rokuuma N, Hamada K, Tomatsu T, Fukuda H. Histologic and biomechanical characteristics of the supraspinatus tendon: Reference to rotator cuff tearing. Journal of shoulder and elbow surgery / American Shoulder and Elbow Surgeons [et al]. 1994;3:79-87.

Neer CS. Anterior acromioplasty for the chronic impingement syndrome in the shoulder: a preliminary report. The Journal of Bone and Joint Surgery. 1972;54:41-50.

Neer CS. Impingement lesions. Clinical orthopaedics and related research. 1983;173:70-7.

O'Sullivan P. Diagnosis and classification of chronic low back pain disorders: maladaptive movement and motor control impairments as underlying mechanism. Man Ther. 2005;10:242-55.

Pappas AM, Zawacki RM, Sullivan TJ. Biomechanics of baseball pitching. A preliminary report. The American journal of sports medicine. 1985;13:216-22.

Passaretti D, Candela V, Venditto T, Giannicola G, Gumina S. Association between alcohol consumption and rotator cuff tear. Acta orthopaedica. 2015:1-4.

Payne LZ, Altchek DW, Craig EV, Warren RF. Arthroscopic treatment of partial rotator cuff tears in young athletes. A preliminary report. The American journal of sports medicine. 1997;25:299-305.

Reed D, Cathers I, Halaki M, Ginn K. Does supraspinatus initiate shoulder abduction? Journal of electromyography and kinesiology : official journal of the International Society of Electrophysiological Kinesiology. 2013;23:425-9.

Rio E, Kidgell D, Purdam C, Gaida J, Moseley GL, Pearce AJ, et al. Isometric exercise induces analgesia and reduces inhibition in patellar tendinopathy. Br J Sports Med. 2015;49:1277-83.

Sackett D, Straus S, Richardson W, Rosenberg W, Haynes R. Evidence-based medicine. How to teach and practice EBM. 2 ed. Edinburgh: Churchill Livingstone; 2000.

Santavirta S, Konttinen YT, Antti-Poika I, Nordstrom D. Inflammation of the subacromial bursa in chronic shoulder pain. Archives of orthopaedic and trauma surgery. 1992;111:336-40.

Scherb MB, Han SH, Courneya JP, Guyton GP, Schon LC. Effect of bupivacaine on cultured tenocytes. Orthopedics. 2009;32:26.

Sciascia A, Cromwell R. Kinetic chain rehabilitation: a theoretical framework. Rehabilitation research and practice. 2012; http://dx.doi.org/10.1155/2012/853037

Scott A, Backman L, Speed C. Tendinopathy-Update on Pathophysiology. The Journal of orthopaedic and sports physical therapy. 2015:1-39.

Screen H. Tendon and tendon pathology. In: Jull G, Moore A, Falla D, Lewis JS, McCarthy C, Sterling M, editors. Grieve's Modern Musculoskeletal Physiotherapy 4th ed. London: Elsevier; 2015.

Seitz AL, McClure PW, Finucane S, Boardman III ND, Michener LA. Mechanisms of rotator cuff tendinopathy: intrinsic, extrinsic, or both? Clinical biomechanics. 2011;26:1-12.

Seroyer ST, Nho SJ, Bach BR, Bush-Joseph CA, Nicholson GP, Romeo AA. The kinetic chain in overhand pitching: its potential role for performance enhancement and injury prevention. Sports Health. 2010;2:135-46.

Sher JS, Uribe JW, Posada A, Murphy BJ, Zlatkin MB. Abnormal findings on magnetic resonance images of asymptomatic shoulders. The Journal of Bone and Joint Surgery. 1995;77:10-5.

Sihvonen R, Paavola M, Malmivaara A, Itala A, Joukainen A, Nurmi H, et al. Arthroscopic partial meniscectomy versus sham surgery for a degenerative meniscal tear. The New England Journal of Medicine. 2013;369:2515-24.

Snow M, Cheong D, Funk L. Subacromial impingement: is there correlation between symptoms, arthroscopic findings and outcomes? Shoulder & Elbow. 2009;1:89-92.

Spangehl MJ, Hawkins RH, McCormack RG, Loomer RL. Arthroscopic versus open acromioplasty: a prospective, randomized, blinded study. Journal of shoulder and elbow surgery / American Shoulder and Elbow Surgeons [et al]. 2002;11:101-7.

Tamai M, Okajima S, Fushiki S, Hirasawa Y. Quantitative analysis of neural distribution in human coracoacromial ligaments. Clinical orthopaedics and related research. 2000:125-34.

Tuttle N. Do changes within a manual therapy treatment session predict between-session changes for patients with cervical spine pain? The Australian journal of physiotherapy. 2005;51:43-8.

Waddell G. The back pain revolution. 2nd ed. Edinburgh: Churchill Livingstone; 2004.

Wattanaprakornkul D, Cathers I, Halaki M, Ginn KA. The rotator cuff muscles have a direction specific recruitment pattern during shoulder flexion and extension exercises. Journal of science and medicine in sport / Sports Medicine Australia. 2011;14:376-82.

Worland R, Lee D, Orozco C, SozaRex F, Keenan J. Correlation of age, acromial morphology, and rotator cuff tear pathology diagnosed by ultrasound in asymptomatic patients. Journal-Southern Orthopaedic Association. 2003;12:23-6.