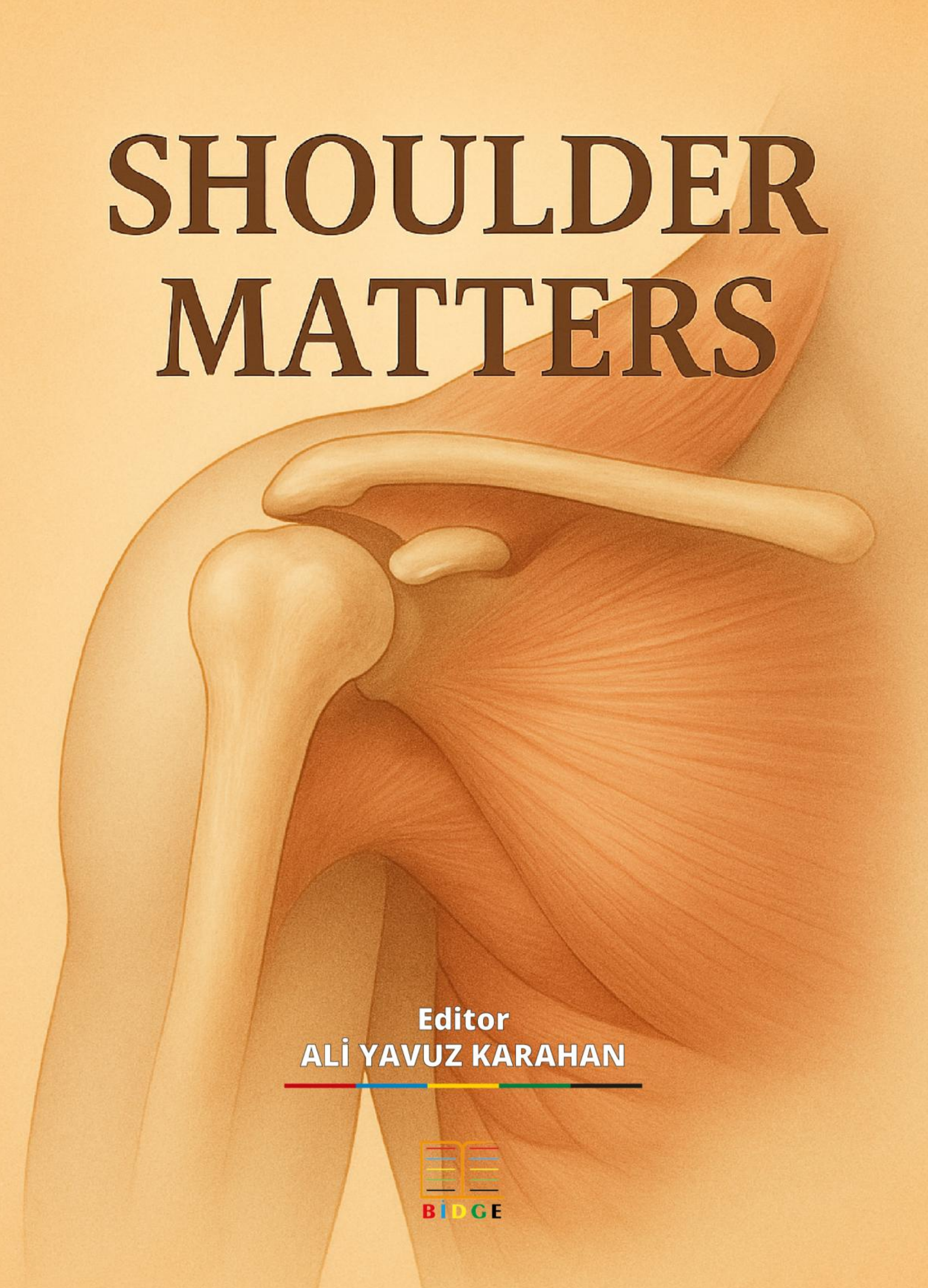

SHOULDER MATTERS

Editor

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BIDGE Publications

SHOULDER MATTERS

Editor: ASSOC. PROF. DR. ALI YAVUZ KARAHAN

ISBN: 978-625-372-650-8

Page Layout: Gözde YÜCEL

1st Edition:

Publication Date: 30.04.2025

BIDGE Publications,

Certificate No: 71374

www.bidgeyayinlari.com.tr - bidgeyayinlari@gmail.com

Krc Bilişim Ticaret ve Organizasyon Ltd. Şti.

Güzeltepe Mahallesi Abidin Daver Sokak Sefer Apartmanı No: 7/9 Çankaya / Ankara

CONTENTS

CLINICAL APPROACH TO SHOULDER PAIN AND DIFFERENTIAL DIAGNOSIS

ENDER SALBAŞ[1]

Introduction

Shoulder pain assessment is a frequent and occasionally challenging task in clinical practice. The shoulder joint's complex anatomical environment, famous for its immense mobility, is adapted to an extremely broad spectrum of functional activities (Warth & Millett, 2015: 5). Its unmatched mobility in three principal planes is partly responsible for causing diagnostic challenges in identifying the cause of the pain. Range of motion measurement is an important component of a physical examination. It is the role of the responsible clinician to ascertain if certain movements are both impaired and clinically relevant. This enables one to define static and dynamic contributors to a patient's pathologic condition. As it stands,

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a sound knowledge of basic principles and contemporary evidence on the assessment of shoulder range of motion is essential to conducting a precise and effective physical examination (Brian & Joseph, 2002: 47; Panayiotou Charalambous, 2019: 69; Warth & Millett, 2015: 5). The prognosis for relieving shoulder pain in patients is largely dependent upon making an accurate clinical diagnosis. Clinical evaluation should begin with a thorough history and careful physical examination, with special attention to the detection of any mechanical abnormalities that might affect the shoulder (Brian & Joseph, 2002: 47; Michael, Jesse & John, 2009: 145).

General Epidemiology and Clinical Significance

Chronic shoulder pain is a frequent complaint in day-to-day medical practice (Crookes et al., 2023: 753). The diagnosis and etiology of shoulder pathology are diverse, to a great extent based on the demographics of the patient(Hind et al., 2022: 5510). Neck and shoulder disorders have been extensively quoted in the literature as significant reasons for prolonged absence from work. In such cases, a multidisciplinary intervention, perhaps including physiotherapy, occupational therapy, and psychiatric intervention, is often recommended to improve patient care. Identification of patients who have incurred acute injury or present with 'red flag' symptoms is important to allow for early referral to specialist medical care. Referral to an orthopedic surgeon is recommended for patients who have persistent pain in the shoulder despite proper nonsurgical management. Shoulder pain and/or stiffness is a frequent complaint that can result from a wide range of pathological conditions (Crookes et al., 2023: 753; Hind et al., 2022: 5510).

Anatomical and Biomechanical Overview of the Shoulder Complex

The shoulder complex is a unique joint that has extensive movement in three planes, with some challenges being presented for clinical examination (Michael, Jesse & John, 2009: 145; Warth & Millett, 2015: 5, 2015: 39). Strength measurement is an essential component of examinations for the shoulder. Comprehensive examination of strength can give significant findings to support or negate an alleged condition in the differential diagnosis. The health care providers need to possess a background knowledge of the anatomy and function of the skeletal muscles surrounding the shoulder for them to carry out a meaningful strength examination. In addition, familiarity with the literature specific to shoulder strength examination is necessary for interpretation and management of shoulder pathology. The scapula, as a complex bony structure, plays a role in the maintenance of glenohumeral stability throughout the entire shoulder range of motion (Warth & Millett, 2015: 219, 2015: 39). Thus, scapular dynamics analysis would be included in the assessment of all patients to possibly prevent the development or onset of a number of shoulder pathologies, such as rotator cuff damage and glenohumeral instability. Clinical assessment of the shoulder typically continues in a systematic manner with observation, palpation, movement analysis, and some testing procedures (Gursoy, 2017: 57; Hind et al., 2022: 5510; Panayiotou Charalambous, 2019: 77). This includes examination of the patient and the shoulders, palpation over the scapular and shoulder areas, active and passive ranges of motion of the shoulder, and then checking individual muscle strength, and special tests based on suspected underlying pathology (Panayiotou Charalambous, 2019: 77). The glenohumeral joint examination is included in a more general shoulder examination, which necessitates careful evaluation of the whole shoulder (Warth & Millett, 2015: 109).

Shoulder Pain Classification: Acute, Subacute, and Chronic

Shoulder pain can be classified on the basis of onset and duration into three types: acute, subacute, and chronic. Although the time periods for the three types may vary in academic literature, such a classification is useful for making an initial diagnosis and investigation of potential causative conditions. Acute-onset shoulder pain is usually associated with an event or injury (Brian & Joseph, 2002: 47). Subacute pain is a period in which the initial inflammatory response might have resolved; however, symptoms continue. Shoulder chronic pain is characterized by the fact that it lasts typically longer than three months (Crookes et al., 2023: 753). Such a division is of clinical importance since the likelihood of certain conditions, e.g., serious injuries vs. degenerative disorders, may change with the course of symptomatology. A large number of patients in general practice consult with persistent shoulder pain

(Crookes et al., 2023: 753; Edwards, Counihan & Li, 2024: 53; Powell & Struyf, 2024: 59).

Mastery of Patient History Nuances

The initial and essential step in formulating a clinical diagnosis of shoulder pain is to take a thorough history of the patient's symptoms (Panayiotou Charalambous, 2019: 69). Best practice is a mix of open-ended questions, permitting patients to describe their difficulties, and targeted questions to obtain specific information that will not be offered but is of diagnostic value (Kevin, Michael & George, 2001: 75; Powell & Struyf, 2024: 59; Struyf, 2024: 51). A thorough history serves to limit the broad differential diagnosis and direct subsequent physical examinations.

Onset, duration, placement, and nature of pain: Identification of the onset, duration, site, and character of pain is of paramount importance in pain experience among patients. Medical practitioners must elucidate the onset of pain, either as acute, ongoing, insidious (abrupt), or associated with a recognizable defining incident (Brian & Joseph, 2002: 47; Hind et al., 2022: 5510). The duration of symptoms is important in the decision to diagnose as acute, subacute, or chronic. Determining the precise site of the discomfort (anterior, posterior, or superior) and whether it is radiating into the adjacent regions (including the neck, arm, regions below the elbow, and the deltoid insertion) can provide valuable diagnostic information. Furthermore, interrogation of the pain characteristics (i.e., dull, acute, aching, or lancinating) can differentiate a number of causes. Asking the patient specifically to delineate where the pain is can be helpful. The consideration of the spatial dimensions concerning pain is important (Brian & Joseph, 2002: 47; Hind et al., 2022: 5510; Powell & Struyf, 2024: 59).

Factors that exacerbate and mitigate pain: Determinants that exacerbate and mitigate pain: Determining particular activities or postures that enhance or reduce shoulder pain can provide fundamental understanding of the underlying pathology (Brian & Joseph, 2002: 47). Exacerbating factors might involve some arm positions, like activities done overhead, movements characterized by forward flexion, internal rotation, and cross-body adduction (particularly applicable with subcoracoid impingement), or variations occurring with varying times of day (Basat & Armangil, 2022: 77; Struyf, 2024: 71; Warth & Millett, 2015: 77). On the other hand, these symptoms are unlikely to be relieved by such stimuli as rest, specific arm positioning (such as the Saha position that reduces pain related to rotator cuff syndromes), or taking medications (Michael, Jesse & John, 2009: 145). Asking the patient to keep a symptom diary is a reliable way to assess such patterns and stimuli (Crookes et al., 2023: 753). For pain due to the rotator cuff, pain will most commonly follow with activities involving load-bearing, particularly abduction and external rotation of the shoulder (Struyf, 2024: 71).

An adequate history of any past trauma to the shoulder or adjacent regions is critical (Michael, Jesse & John, 2009: 145; Panayiotou Charalambous, 2019: 69). Clinicians must also examine the mechanism of injury, where feasible, encompassing falls, direct trauma, or acute forceful movements (Michael, Jesse & John, 2009: 145). Where there is suspected shoulder instability, the nature of the first injury must be determined, together with the degree of instability (subluxation or dislocation), reduction mechanism (spontaneous or manipulative), and the frequency of such occurrences (Michael, Jesse & John, 2009: 145). The fall onto an outstretched arm is a common occurrence that more commonly causes anterior shoulder dislocations, but these occurrences are infrequently associated with traumatic falls (Brian & Joseph, 2002: 47; Michael, Jesse & John, 2009: 145). One should also consider any acute traumatic injury associated with the sternoclavicular (SC) joint since these can cause anterior or posterior dislocations (Warth & Millett, 2015: 209).

Occupational and sports activities: An awareness of the patient's sporting and occupational activities is significant as these activities may initiate or exacerbate the shoulder pain (Basat & Armangil, 2022: 77; Gursoy, 2017: 57; Michael, Jesse & John, 2009: 145; Özbek & Demirtaş, 2022: 89). The clinicians should inquire about repetitive overhead activity, heavy lifting and throwing sport activity, or other activities involving severe stress to the shoulder complex (Özbek & Demirtaş, 2022: 89). Shoulder pain is a common symptom of athletes involved in overhead activities or throwing sports, and this condition can be associated with anterior instability, along with rotator cuff impingement (Warth & Millett, 2015: 109). Micro-movements and shear forces produced by certain occupational activities have the potential to produce degenerative changes of the sternoclavicular (SC) joint (Warth & Millett, 2015: 209). Assessment of activities of daily living, work demands, and career goals of the patient assists in planning an appropriate treatment plan according to their personal functional needs (Kevin, Michael & George, 2001: 75).

Systemic diseases, including rheumatic, neurologic, and cardiovascular disease, necessitate consideration of potential underlying systemic disease influencing the patient's shoulder pain (Gursoy, 2017: 57; Michael, Jesse & John, 2009: 145; Özbek & Demirtaş, 2022: 89). Cervical spine pathologic conditions can present as arm pain and neurologic symptoms radiating down the arm, potentially causing the patient to misattribute the location of the pathology to the shoulder (Michael, Jesse & John, 2009: 145; Struyf, 2024: 117; Warth & Millett, 2015: 241). Cervical spine screening is also included in examination of the shoulder (Brian & Joseph, 2002: 47; Michael, Jesse & John, 2009: 145; Struyf, 2024: 71). The doctor must take a history of rheumatological disease (e.g., arthritis), neurological disease (e.g., nerve entrapments), or cardiovascular disease that could refer pain to the region of the shoulder (Michael, Jesse & John, 2009: 145; Warth & Millett, 2015: 241). Surprisingly, an association of thyroid disease with adhesive capsulitis (frozen shoulder) has been reported (Edwards, Counihan & Li, 2024: 53). Shoulder dysfunction secondary to neurovascular disease, although difficult to diagnose, is a consideration (Warth & Millett, 2015: 241). Ruling out cervical origin of shoulder pain is a crucial aspect of differential diagnosis (Struyf, 2024: 71).

Previous treatments and their results: A thorough history of the patient should include a clear report of all past treatment provided for shoulder pain (Michael, Jesse & John, 2009: 145; Özbek & Demirtaş, 2022: 89). The history should be made up of conservative treatments, which may include rest, ice therapy, physical therapy, medication therapy (prescription and nonprescription), and injections (John, 2013: 23; Michael, Jesse & John, 2009: 145). It is necessary to particularly inquire about the intake of nutraceuticals, including glucosamine, chondroitin, shark cartilage, and methylsulfonylmethane (MSM), since some patients might not consider these products as drugs and therefore might leave them out of their list of medications. Given the lack of substantial scientific proof of the efficacy of a number of supplements, it remains necessary to document their use in the overall evaluation (Michael, Jesse & John, 2009: 145). It is important that clinicians examine any past surgery and its results (Özbek & Demirtaş, 2022: 89). An understanding of the nature and result of any prior treatment may provide valuable insight into the chronicity and reactivity of a patient's disorder.

Physical Examination

The shoulder physical examination assessment is done in a stepwise fashion, most frequently in the sequence "look/feel/move/special tests" (Hind et al., 2022: 5510; Panayiotou Charalambous, 2019: 77). The cervical spine, elbow, and other upper extremity joints must be tested because it is possible for these structures to refer pain to the shoulder or to have an influence on its function (Michael, Jesse & John, 2009: 145; Panayiotou Charalambous, 2019: 77; Struyf, 2024: 51).

Evaluation (postural evaluation, malformation, muscle wasting)

Physical examination starts with the thorough inspection of the patient's shoulder girdle and cervical spine (Kevin, Michael & George, 2001: 75; Michael, Jesse & John, 2009: 145; Panayiotou Charalambous, 2019: 77). The examiner must stand both posterior and anterior to the patient, scrutinizing carefully for symmetry, scars, muscle bulk, and deformities (Kevin, Michael & George, 2001: 75; Michael, Jesse & John, 2009: 145). Postural alignment has to be inspected from the anterior, posterior, and lateral aspects (Kevin, Michael & George, 2001: 75). Findings on observation may be the overall body habitus of the patient, any visible asymmetry between shoulders or differences in height or prominence of the clavicle or acromion (Kevin, Michael & George, 2001: 75).

Posture analysis is done by evaluating head, neck, and trunk position in relation to the shoulder girdle (Kevin, Michael & George, 2001: 75). Characteristics that were observed included forward head position, rounded shoulders, and increased thoracic kyphosis. One must observe resting scapular position for signs of winging (characteristics of medial prominence) or asymmetrical positioning on the thorax. Scapula position can be a factor in glenohumeral kinematics (Binkley, 2001: 132; Michael, Jesse & John, 2009: 145; Warth & Millett, 2015: 219).

The examiner should also evaluate for any palpable abnormalities, such as a step-off deformity at the acromioclavicular joint (separation) or bony prominences. Signs of muscular atrophy, particularly in the deltoid, supraspinatus, and infraspinatus muscles, should be noted as they can indicate chronic rotator cuff disease or nerve impairment. Scars from previous surgeries or trauma should be documented. One needs to observe the patient's capacity to move the affected limb and protective behaviors of the arm (Kevin, Michael & George, 2001: 75; Michael, Jesse & John, 2009: 145).

Palpation (mass, sensitivity, temperature)

Palpation involves the thorough exploration of structures around the shoulder girdle to identify tenderness, masses, temperature differences, crepitus, or deformity. Palpation should be carried out systematically, starting anteriorly, moving laterally, and ending posteriorly. The examiners should note the facial expressions of the patient since they might reflect pain localization (Hind et al., 2022: 5510; Panayiotou Charalambous, 2019: 77).

Anterior palpation was performed on the sternoclavicular (SC) joint, clavicle, acromioclavicular (AC) joint, and coracoid process (located just inferior to the distal third of the clavicle, where the short head of the biceps tendon is found). Tenderness or swelling over the acromioclavicular or sternoclavicular joints may point to underlying pathology at these points. Palpation over the clavicle may detect fractures or tenderness (Struyf, 2024: 107, 2024: 51; Warth & Millett, 2015: 209).

Lateral palpation, with the arm in external rotation, helps in the palpation of the lesser tubercle and bicipital groove containing the long head of the biceps tendon. Bicipital groove tenderness can point towards biceps tendinopathy. The greater tubercle can be palpated below the anterior border of the bony acromion with internal rotation. Local tenderness can refer to rotator cuff pathology, particularly the supraspinatus (Struyf, 2024: 107, 2024: 51; Warth & Millett, 2015: 209, 2015: 39).

Palpation of the posterior side enables evaluation of the rotator cuff muscles (supraspinatus, infraspinatus, and teres minor) above and below the scapular spine. The scapular borders and the associated musculature, such as the trapezius and rhomboids, are to be examined for tenderness, spasm, or trigger points (Hind et al., 2022: 5510).

Any palpable masses or regions of elevated temperature (reflecting inflammation) were noted. Crepitus, a grating or crackling sensation on movement, may reflect articular cartilage damage or tendon disease (Hind et al., 2022: 5510).

Range of Motion (Active and Passive) ROM assessment is an important component in the assessment of shoulder function. The shoulder joint has a great range of movements in three planes. It is important that the range of motion is assessed both actively and passively, where the patient moves the arm on their own and where the examiner assists in moving the patient's arm, respectively (Kevin, Michael & George, 2001: 75; Panayiotou Charalambous, 2019: 77; Struyf, 2024: 51; Warth & Millett, 2015: 5). Active range of motion (AROM) tests patients' willingness and ability to move their arms through planes. AROM restrictions could be caused by pain, muscle weakness, stiffness, or psychological factors (Kevin, Michael & George, 2001: 75). The ensuing movements need careful evaluation.

Flexion: Raising the arm in front of the head.

Extension: Posterior retraction of the arm.

Abduction: Lateral arm movement away from the body's midline.

Adduction: Movement of the arm toward the lateral surface of the body (across the midline)

External rotation: The externally rotated arm is flexed at 90° and held at the side.

Internal rotation: The arm is medially rotated with the elbow flexed at a 90° angle and positioned along the body (or, alternatively, extended behind the back).

Any restriction, pain on movement, or compensatory scapular motion (shoulder elevation) should be noted. Movement quality should be assessed for any abnormal scapulohumeral rhythm (Kevin, Michael & George, 2001: 75).

The examiner tested the patient with passive range of motion (PROM) when the patient was relaxed. PROM distinguishes between restriction due to muscle pain or weakness and that due to contracture or stiffness of the joint. An AROM that is greater than PROM is indicative of suppression of strength or pain. Limited PROM is mechanical limitation, i.e., capsular stiffness or osteoarthritis. The end-feel, or what the examiner feels when the point of motion stop is reached, is important to be carefully evaluated. Different end-feels can signify a multitude of pathological conditions (e.g., bone-on-bone, capsular tightness, springy block). The same movements that are tested under Active Range of Motion (AROM) are tested under Passive Range of Motion (PROM) (Kevin, Michael & George, 2001: 75; Warth & Millett, 2015: 5, 2015: 219) .

Identification of clinical significant movements is important due to the wide range of motion attributed to the shoulder.

Familiarity with concepts and research from the present relevant to the determination of shoulder range of motion is essential for properly performing an effective physical examination (Basat & Armangil, 2022: 77; Gursoy, 2017: 57; Kevin, Michael & George, 2001: 75; Özbek & Demirtaş, 2022: 89; Warth & Millett, 2015: 5, 2015: 219).

Special Tests (Rotator Cuff, Instability, Impingement)

Numerous special tests have been designed to assess specific shoulder pathologies, including rotator cuff tears, glenohumeral instability, and subacromial impingement. These tests often stress specific structures or reproduce symptoms to assist in the diagnosis (Basat & Armangil, 2022: 77; Gursoy, 2017: 57; Hind et al., 2022: 5510; Özbek & Demirtaş, 2022: 89).

Assessment Techniques of the Rotator Cuff:

Neer's Impingement Test: With the scapula fixed, the examiner passively flexed the patient's arm forward. Pain produced by this maneuver is a sign of subacromial impingement of the rotator cuff tendons, mainly the supraspinatus, on the anterior surface of the acromion (Crookes et al., 2023: 753; Gursoy, 2017: 57).

Hawkins-Kennedy Test is performed by forward flexing the patient's arm to 90 degrees with flexion of elbow to 90 degrees. Then the examiner internally rotated the shoulder of the patient passively. Pain on this test also indicates subacromial impingement (Crookes et al., 2023: 753; Warth & Millett, 2015: 39).

Painful Arc: The patient's pain on active abduction from about 60° to 120° is characteristic of subacromial impingement (Kevin, Michael & George, 2001: 75).

Jobe's test (Empty Can Test): The patient's arm is elevated to 90° in the scapular plane (about 30° anterior to the coronal plane) and internally rotated with the thumb pointed downwards (empty can position). The examiner presses downwards while the patient tries to resist. Pain or weakness indicates a probable tear or tendinopathy of the supraspinatus tendon (Kevin, Michael & George, 2001: 75; Warth & Millett, 2015: 39).

Apley Scratch Tests: A quantitative examination assesses a patient's Active Range of Motion (AROM) using coordinated physiological movement. Three different techniques are used involving the placement of the affected hand on the opposite shoulder, the occipital region, and the scapula. The initial movement entails flexion of the shoulder, horizontal adduction, and internal rotation. The second movement entails abduction and external rotation of the shoulder, while the third method entails extension, adduction, and internal rotation. These movements measure the distance of the thumb from anatomical landmarks like the C7 spinous process when in the back-of-the-head position. The test enables clinicians to compare with the contralateral side or to monitor progress with therapy. These composite movements are a rapid screening test, but any constraints detected should prompt a thorough examination of the individual movements to determine the cause of constraint (Kevin, Michael & George, 2001: 75).

Infraspinatus Test: The patient, with arm adducted and elbow flexed at 90°, attempts to externally rotate the arm against the resistance of the examiner. Pain or weakness indicates probable disease of the infraspinatus and/or teres minor muscles (Kevin, Michael & George, 2001: 75; Warth & Millett, 2015: 39).

Belly Press Test: Patient places hand on belly and attempts to press in using a straight wrist and an anterior elbow to the body. inability or weakness to maintain pressure without extending the shoulder (compensating with posterior deltoid) indicates subscapularis pathology (Kevin, Michael & George, 2001: 75; Özbek & Demirtaş, 2022: 89; Warth & Millett, 2015: 39).

Lift-off Test: The patient places the dorsal surface of their hands over the lumbar area. The patient then attempts to lift their hands off their back in the face of resistance being offered by the examiner. Failure to lift the hands or weakness signifies a subscapularis disorder (Özbek & Demirtaş, 2022: 89; Warth & Millett, 2015: 39).

Belly off Test: Same as belly press; however, if the patient does a belly press against any resistance, the examiner removes the patient's hand from his belly. Whether or not the patient can stand this force reflects subscapularis strength (Özbek & Demirtaş, 2022: 89).

External Rotation Lag Sign (ERLS): The arm is slowly abducted to 20° in the plane of the scapula and externally rotated maximally by the examiner, with the patient instructed to hold it. Inability to hold external rotation suggests a full-thickness tear of the infraspinatus and teres minor muscles (Warth & Millett, 2015: 39).

Internal Rotation Lag Sign (IRLS): The patient places his or her hand on the lumbar region, as in the lift-off position, and the examiner then slowly lifts it part of the way from the back. The patient is required to hold this position. Inability to maintain the internal rotation suggests the presence of a full-thickness subscapularis muscle tear (Warth & Millett, 2015: 39).

Tests for Glenohumeral Instability

Apprehension Test (Mnemonic: SLAPprehension): In supine position, the examiner abducts the arm to 90° and slowly externally rotates it and applies a light anterior force on the posterior humeral head. A test of the patient's apprehension or resistance is an indication of anterior instability (Struyf, 2024: 99; Warth & Millett, 2015: 139).

Relocation Test (Jobe Relocation Test): Following a positive anterior apprehension test, the examiner applies a posterior force to the anterior aspect of the humeral head. Reduction of apprehension or improvement in the range of external rotation signifies the presence of anterior instability, which is neutralized by reduction of the humeral head (Struyf, 2024: 99; Warth & Millett, 2015: 139).

Sulcus Sign: The examination is performed with traction force downwards on the elbow when the patient's arm is in a resting position at the side. Palpable or evident indentation (sulcus) below the acromion indicates inferior glenohumeral instability (Kevin, Michael & George, 2001: 75).

Load and Shift Test: The patient was seated while the examiner stabilized the clavicle and scapula with one hand, while also palpating the humeral head with the other hand. The humeral head was compressed into the glenoid (loaded) and then shifted anteriorly and posteriorly to determine the degree of translation. An excessive translation is indicative of instability (Kevin, Michael & George, 2001: 75).

Anterior and Posterior Drawer Tests: The patient is put in a supine position, and the arm is lifted to about 90 degrees of abduction. The scapula is stabilized by the examiner, and anterior and posterior forces are applied to the proximal humerus to examine the mobility of the glenohumeral joint. An abnormal translation signifies instability in the respective directions (Basat & Armangil, 2022: 77).

Clunk Test (The Jerk Test): This is utilized to assess posterior glenohumeral instability through axial stress on the humerus, with the arm in a flexed and internally rotated position, seeking a 'jerk' which is suggestive of humeral head subluxation. Although useful in physical examination, its diagnostic value is in question with various studies associating it more with posteroinferior labral tears. Test results should be taken into account by clinicians in conjunction with other clinical findings since a 'jerk' may be a sign of posterior instability but its absence does not rule it out (Basat & Armangil, 2022: 77; Warth & Millett, 2015: 139).

Biceps Tendon and Labral Tests:

Speed's Test: involves extending and supinating the patient's arm and resisting the forward flexion of the arm by the examiner when palpating the bicipital groove. Pain or tenderness in the anterior shoulder or within the bicipital groove signifies biceps tendinopathy or superior labral anterior-posterior (SLAP) lesion (Warth & Millett, 2015: 109).

O'Brien's Active Compression Test is done by positioning the patient's arm in 90° flexion and adducted 10-15° to the midline. Downward pressure is exerted with the forearm pronated (thumb down). The test is then repeated with the forearm in a supinated position (thumb up). Pain localized over the acromioclavicular (AC) joint that worsens with pronation and improves with supination is suggestive of a possible SLAP lesion, whereas pain localized over the AC joint in both positions may be an intrinsic AC joint disease (Warth & Millett, 2015: 109).

Yergason's Test: The bicipital groove is palpated as the examiner resists supination of the forearm and external rotation of the humerus when the patient has the elbow flexed to 90 degrees and the forearm is pronated. Bicipital groove pain indicates biceps tendinopathy(Warth & Millett, 2015: 109).

Evaluation of the Acromioclavicular Joint:

Cross-Body Adduction Test (Scarf Test): It asks the patient to adduct the affected arm voluntarily across the chest to the opposite shoulder. Pain, which is localized to the AC joint, indicates AC joint disease (Warth & Millett, 2015: 183).

AC Joint Shear Test: The doctor places hands on the anterior and posterior sides of the AC joint and compresses. Pain or crepitance indicates acromioclavicular joint pathology (Kevin, Michael & George, 2001: 75; Warth & Millett, 2015: 183).

Thoracic Outlet Syndrome Tests: These are tests used to evaluate compression of neurovascular structures at the thoracic outlet. Some examples are Adson's maneuver, Wright's test, and Roos test (Kevin, Michael & George, 2001: 75).

Scapular Dyskinesis Assessment: Although it is not a single "test," it is essential to watch scapular movement with elevation of the arm. Asymmetry of scapular motion, winging, or a disturbed scapulohumeral rhythm may signify scapular dyskinesis, which is linked with numerous shoulder diseases. Scapular Assistance Test and Scapular Retraction Test are special tests designed to examine the influence of manual scapular repositioning on pain and function (Kevin, Michael & George, 2001: 75; Warth & Millett, 2015: 219).

Neurovascular Assessment

The neurovascular examination evaluates the upper extremities' nerve and vascular integrity. The examination often begins with evaluation of the cervical spine, including inspection and range of motion testing, since cervical pathology may refer pain to the shoulder (Kelley, Kearns & Barry, 2024: 69; Panayiotou Charalambous, 2019: 77; Struyf, 2024: 51, 2024: 117; Warth & Millett, 2015: 241).

The neurological exam includes the assessment of sensory function (checking dermatomes for numbness or change in sensation), muscle strength (checking myotomes for weakness), and reflex response (biceps, triceps, and brachioradialis). Nerve compression special tests, such as Tinel's sign (tapping over a nerve to elicit paresthesia) at the elbow (ulnar nerve) or wrist (median nerve), may also be performed. An assessment of the symptoms pertaining to nerve entrapment syndromes, such as thoracic outlet syndrome and carpal tunnel syndrome, might be deemed necessary (Kelley, Kearns & Barry, 2024: 69; Panayiotou Charalambous, 2019: 77; Struyf, 2024: 51, 2024: 117; Warth & Millett, 2015: 241).

The vascular examination includes palpation of peripheral pulses, i.e., radial and ulnar pulses, and inspection of skin color and temperature to determine proper circulation. In instances where thoracic outlet syndrome is suspected, provocative maneuvers can be undertaken to test for changes in pulse characteristics or to elicit neurological symptoms (Warth & Millett, 2015: 241).

Differential Diagnosis of Shoulder Pain

Shoulder pain is a frequent clinical complaint, owing to the complex anatomy of the shoulder joint and its wide range of motion (Warth & Millett, 2015: 5). Evaluation of shoulder pain must be accomplished in a stepwise fashion to eliminate various potential underlying conditions (Crookes et al., 2023: 753; Hind et al., 2022: 5510). Careful history and physical examination are fundamental elements of this process, directing the requirement for additional diagnostic tests and the establishment of an adequate treatment plan (Brian & Joseph, 2002: 47; Hind et al., 2022: 5510; Kevin, Michael & George, 2001: 75; Özbek & Demirtaş, 2022: 89). Most patients come with pain, stiffness, decreased smooth motion, instability, neurological symptoms, or a mixture of these symptoms (Michael, Jesse & John, 2009: 145). Determining the chief complaint and knowing the chronological progression of symptoms are fundamental initial steps in maximizing the differential diagnosis (Brian & Joseph, 2002: 47; Kevin, Michael & George, 2001: 75; Özbek & Demirtaş, 2022: 89).

Rotator Cuff Tears and Tendinopathies

Rotator cuff disorders, such as tendinopathies and tears, are responsible for a large percentage of shoulder pain complaints (Brian & Joseph, 2002: 47; Struyf, 2024: 39). Patients typically present with complaints of pain on use of the arm at or above the level of the shoulder, referred to as impingement syndrome. Pain is occasionally localized to the anterolateral aspect of the shoulder and may radiate down the arm (Özbek & Demirtaş, 2022: 89). Limited motion of certain movements, particularly abduction and external rotation, is often observed, particularly with rotator cuff tears (Struyf, 2024: 71). A thorough patient history would also explore the onset of pain (acute as a result of injury or insidious in nature), exacerbating or alleviating factors for pain, along with any past shoulder problems (Kevin, Michael & George, 2001: 75; Özbek & Demirtaş, 2022: 89; Struyf, 2024: 71). Physical testing involves various tests, some of which are the Hawkins-Kennedy test, Jobe's (empty can) test for the evaluation of the supraspinatus, external rotation resistance test for infraspinatus, and the belly press test for the subscapularis (Crookes et al., 2023: 753; Özbek & Demirtaş, 2022: 89; Warth & Millett, 2015: 77). Their purpose is to reproduce patient pain and assess the strength of some rotator cuff musculature (Panayiotou Charalambous, 2019: 77). *Impingement syndrome* is a clinical syndrome related to varied etiologies of rotator cuff disease, with a mechanical blockade in the subacromial space present in only a small percentage. Chronic rotator cuff pathology may lead to a reduction of glenohumeral movement, as in adhesive capsulitis. In addition, rotator cuff pathology may be linked with acromioclavicular joint arthropathy and/or biceps tendonitis

(Aydıngöz, 2022: 101; Brian & Joseph, 2002: 47; Warth & Millett, 2015: 209).

Shoulder Instability and Labral Tears

Glenohumeral instability is a common cause of shoulder pain, presenting as a subjective feeling of looseness, instability, or frequent recurrence of dislocation. Pain is not present in all symptomatic patients; they will report only concerns about the joint stability. It may result from a traumatic acute event, either a direct blow or a fall, or it is atraumatic, often associated with a history of recurrent chronic overhead activities. The symptoms will often include apprehensions on certain arm positions, pain, and paresthesias. It is important to determine the frequency, ease, and voluntariness of dislocation episodes. The physical examination includes tests aimed at assessing glenohumeral joint laxity such as the apprehension test, the relocation test, and the sulcus sign test. Labral tears that are often seen with instability or repetitive overhead activities will provoke deep joint pain, either alone or accompanied by clicking, at times, and popping, at times. Focused tests such as O'Brien's test and biceps load tests will aid the assessment of labral pathology. Recurrent glenohumeral instability predisposes to secondary rotator cuff tendonitis or tearing (Brian & Joseph, 2002: 47; Michael, Jesse & John, 2009: 145; Panayiotou Charalambous, 2019: 77; Struyf, 2024: 51).

Adhesive Capsulitis (Frozen Shoulder)

Adhesive capsulitis, known as frozen shoulder, is caused by painful, worsening by time, limitation of both active and passive ROM's. Patients present with a slow progressive increase in pain, which then leads to a marked increase in stiffness that dramatically hinders their ability to perform activities of daily living. The condition usually runs through three recognizable phases: a pain-producing "freeze" stage followed by a rigid "frozen" stage, then a third stage of "thawing" where there is a slow improvement in joint ROM. Risk factors recognized for developing frozen shoulder are diabetes mellitus and thyroid abnormalities. The physical exam usually shows a total limitation of shoulder movement in various planes with external rotation being usually most restricted. Accessory movements of the glenohumeral joint are usually limited too. It is important to distinguish primary adhesive capsulitis from secondary causes of stiffness, which might stem from traumatic injury or operations, besides stiffness caused by disorders of the rotator cuff. Systemic illnesses as well as neoplastic disorders can mimic the presenting features of frozen shoulder (Kelley, Kearns & Barry, 2024: 69; Kevin, Michael & George, 2001: 75; Powell & Struyf, 2024: 59; Salamh, 2024: 223).

Osteoarthritis of the Shoulder

Glenohumeral osteoarthritis is the degeneration of shoulder cartilage characterized by pain and progressive loss of function. Pain is typically a deep, aching type that is exacerbated after exercise and is relieved during rest. Stiffness occurs mainly at the beginning of the day or after a period of prolonged immobilization. The physical findings consist of restriction of passive and active ranges of shoulder movement, often with crepitus on joint movement. Radiographic evidence, especially with the use of plain x-rays, secures the diagnosis through demonstration of joint space narrowing, osteophyte formation, and subchondral sclerosis. Chronic rotator cuff problems and joint instability are thought to cause the development of glenohumeral arthrosis (Aydıngöz, 2022: 101; Brian & Joseph, 2002: 47; Panayiotou Charalambous, 2019: 77).

Pathologies of the Acromioclavicular Joint

The acromioclavicular joint (ACJ) can be a subject to a variety of disorders, including osteoarthritis, sprains or separations, that cause characteristic shoulder pain. The pain is typically described as being localized to the ACJ worsening with cross-body adduction, overhead activities or sometimes during examination by palpation. In cases of ACJ sprain there usually is a reported history of a traumatic injury, often a fall onto the shoulder area. The physical examination for diagnosis requires inspection of the acromioclavicular joint for tenderness, swelling, or abnormal findings by palpation. Some provocative maneuvers, the cross-body adduction test and the acromioclavicular joint shear test are employed to provoke pain seen with ACJ pathology. Also, local anesthetic injection to the ACJ is a valuable tool to determine whether this joint is the pain-generating joint. ACJ arthropathy is often seen with rotator cuff disorders (Brian & Joseph, 2002: 47; Crookes et al., 2023: 753; Hind et al., 2022: 5510; Kevin, Michael & George, 2001: 75; Panayiotou Charalambous, 2019: 77; Struyf, 2024: 107, 2024: 71; Warth & Millett, 2015: 209).

Cervical Radiculopathy

Cervical nerve roots, if irritated or compressed, define this condition. This condition sends pain towards the shoulder. This condition radiates discomfort down the arm. Numbness might arise. Tingling might arise. Arm feebleness can occur; hand feebleness too, following a clear dermatomal map. Neck ache often leads prominently. Shoulder difficulties amplify with neck motion. Examination must assess neck movement scope. Examination must include pointed nerve-related checks. These checks test feeling. These checks evaluate power. These checks involve deep tendon reflexes. Spurling's test, a particular maneuver, could provoke radicular signals. Differentiating neck-origin shoulder soreness from essential shoulder maladies is vital (Kelley, Kearns & Barry, 2024: 69; Kevin, Michael & George, 2001: 75; Michael, Jesse & John, 2009: 145; Struyf, 2024: 117, 2024: 71; Warth & Millett, 2015: 241).

Neurological Etiologies (Brachial Plexus Lesions, Nerve Compressions)

Some different nerve troubles generate shoulder distress plus associated symptoms. The brachial plexus, when harmed or overstretched, brings hurt. It brings weakness. It brings sensory lack throughout the entire upper limb. Isolated nerve entrapments near the shoulder yield pain. They yield contained paralysis. Suprascapular nerve pinching affects certain muscles; axillary nerve pinching affects other muscles. A winging scapula can indicate long thoracic nerve impairment. This impairment weakens serratus anterior muscle action. A thorough nerve assessment is necessary. This assessment measures muscle might. This assessment probes sensation. This assessment reviews reflexes. Nerve conduction studies could prove beneficial. Electromyography could prove beneficial. These tests can confirm nerve participation. These tests can pinpoint the precise injury location (Crookes et al., 2023: 753; Hind et al., 2022: 5510; Struyf, 2024: 51; Warth & Millett, 2015: 241).

Rheumatological Disorders (Rheumatoid Arthritis, Psoriatic Arthritis)

Systemic inflammatory conditions such as rheumatoid arthritis can affect multiple joints. The shoulder area is one potential site. Patients often report discomfort and rigidity in both shoulders. Systemic inflammatory effects frequently appear alongside this. These include fatigue extended morning stiffness and arthritis elsewhere. Physical assessment might reveal warmth or motion pain. Both glenohumeral and acromioclavicular joints could show these inflammatory indicators. Passive shoulder movement may also be restricted. Specific lab tests aid diagnosis. Rheumatoid factor anti-CCP antibodies and markers like ESR CRP point toward rheumatoid arthritis (Brian & Joseph, 2002: 47; Kevin, Michael & George, 2001: 75; Kim, 2015: 115; Panayiotou Charalambous, 2019: 77).

Cardiovascular Etiologies (Myocardial Infarction, Aneurysm)

Shoulder pain can stem from cardiovascular issues though this is rare. Such causes merit consideration in the differential particularly for persons with known heart disease risks. Myocardial infarction sometimes manifests as referred ache. This pain travels to the left shoulder arm or jaw. Vascular problems like thoracic outlet syndrome compressing the subclavian artery are another source. Axillary artery thrombosis is yet another example. These conditions might produce shoulder distress plus arm discomfort skin color shifts or temperature alterations. A careful cardiovascular history and a thorough physical exam become necessary. They help rule out these dangerous disorders (Crookes et al., 2023: 753; Kevin, Michael & George, 2001: 75; Michael, Jesse & John, 2009: 145; Warth & Millett, 2015: 241).

Neoplasms (Osseous and Soft Tissue)

Shoulder area tumors affecting bone or soft tissues often cause intensifying pain. This discomfort persists even during rest frequently peaking at night. Additional clinical signs could include a non-mobile mass felt on palpation weight reduction or a prior cancer diagnosis. Tumors occasionally mimic different shoulder problems like adhesive capsulitis. Imaging is essential for identifying neoplastic disease. Conventional radiography MRI and sometimes scintigraphy permit detection and closer evaluation (Aydıngöz, 2022: 101; Hind et al., 2022: 5510; Kelley, Kearns & Barry, 2024: 69; Kevin, Michael & George, 2001: 75).

Infections (Septic Arthritis, Osteomyelitis)

Septic arthritis within the shoulder joint is an uncommon source of shoulder pain. Osteomyelitis in adjacent bone presents another infrequent yet serious cause. Presentation typically involves sudden harsh pain notably restricted movement swelling heat and redness around the joint. Systemic infection indicators often appear too. Fever chills general malaise are common alongside local symptoms. Certain people face higher infection likelihood. These include patients post-surgery intravenous drug users or those with immunity-weakening systemic conditions. Analyzing aspirated synovial fluid is key. This procedure accurately diagnoses septic arthritis (Kim, 2015: 115; Michael, Jesse & John, 2009: 145).

Additional Causes (Oncological pain, Tumor-associated radiating shoulder pain, Fibromyalgia, Referred pain)

Shoulder pain can result from atypical causes. Metastatic tumors within the bones can cause shoulder pain. In uncommonly encountered cases, tumors within the thoracic or cervical spine can cause pain in the shoulder as well. Fibromyalgia, a condition of widespread pain, might present as shoulder pain accompanied by generalized muscle pain, fatigue, and increasing pain at different trigger points. Also, pain can radiate from other anatomical structures, for example, diaphragm or gallbladder, as well. A detailed patient history and physical examination, within the overall clinical context, are necessary to distinguish these uncommon reasons (Brian & Joseph, 2002: 47; Crookes et al., 2023: 753; Michael, Jesse & John, 2009: 145).

Shoulder Pain in Specific Circumstances

Shoulder Pain in Athletes

Athletes, especially participants of sports that incorporate overhead motions or throwing events, subject their shoulders to significant amounts of stress, thus predisposing them to developing various pain-generating pathologies (Warth & Millett, 2015: 109). The development of pain in the shoulder among this group usually involves the intricate biomechanics involved in their respective sport, often resulting in overuse injury, instability, and impingement (John, 2013: 23; Warth & Millett, 2015: 109, 2015: 219). For the athlete presenting with shoulder pain, it is important to perform a thorough clinical assessment to identify the underlying pathology as well as to initiate proper therapeutic interventions (Panayiotou Charalambous, 2019: 77). This assessment involves a thorough medical history, a comprehensive physical examination, and, if necessary, the use of imaging modalities (Hind et al., 2022: 5510; Özbek & Demirtaş, 2022: 89).

The clinical history of a shoulder complaint in an athlete should entail a thorough review of the particular sport involved, training habits, and, where relevant, the mechanism of injury (Özbek & Demirtaş, 2022: 89). Questions should be asked regarding the onset, position, and nature of the pain, as well as any aggravating and relieving factors. Furthermore, an understanding of the impact of pain on the athlete's function and their prior experiences with treatment is also important. A known association between anterior instability and rotator cuff impingement, which contributes significantly to shoulder pain in overhead athletes, exists. Activities involving repetitive overhead motions can result in symptomatic internal shoulder impingement (Kevin, Michael & George, 2001: 75; Warth & Millett, 2015: 109, 2015: 39).

Athletes with shoulder pain are assessed using a specific series of observation, palpation, and movement tests. Observing the athlete's posture and faults was the first step. Shoulder and scapular palpation might reveal structural abnormalities and pain. Active and passive range of motion must be assessed to identify mobility limits and pain. Auxiliary joint mobility must be assessed. Rotator cuff, deltoids, and other shoulder girdle muscles must be assessed for strength. Specialized tests are then used to diagnose rotator cuff injuries, impingement syndromes, instability, and acromioclavicular joint issues. Jobe's (empty can) test is used to evaluate the supraspinatus, while external rotation under resistance evaluates the infraspinatus. Belly press tests subscapularis. The Hawkins-Kennedy test can detect subacromial impingement. O'Brien's exam assesses bicipital-labral abnormalities and acromioclavicular joint disease. Speed assesses bicipital-labral pathology (Crookes et al., 2023: 753; Kevin, Michael & George, 2001: 75; Panayiotou Charalambous, 2019: 77; Warth & Millett, 2015: 219).

Shoulder-pain athletes often have scapular dyskinesis. Proper shoulder kinematics and glenohumeral mobility depend on the scapula. External scapula stability improves rotator cuff contraction strength. In overhead athletes with scapular dyskinesis, supraspinatus and infraspinatus contraction forces increase with periscapular muscle balance rehabilitation. Thus, the physical exam must assess scapular mobility and regulation.

There are some conditions that are found in athletic populations. Since rotator cuff tendinopathy is prevalent, risk factors for it are being investigated. Suprascapular neuropathy may be found in athletes, particularly pitchers (Kelley, Kearns & Barry, 2024: 69; Warth & Millett, 2015: 241, 2015: 39). Neuropathy can weaken supraspinatus and infraspinatus muscles (Warth & Millett, 2015: 39). Suprascapular notch anatomy like a bifid superior transverse scapular ligament may lead to nerve entrapment (Warth

& Millett, 2015: 241, 2015: 219). Athletes with shoulder problems frequently have pain due to the long head of the biceps (LHB) tendon. The pathology of the LHB tendon must be evaluated in athletes with glenohumeral joint problems. Physical exams of the LHB tendon are challenging because of unclear findings, but it is essential to know the anatomy and biomechanics. Subluxation and dislocation of the LHB tendon can occur. Superior labral anterior-posterior (SLAP) lesions are frequent in overhead athletes and may lead to shoulder pain and dysfunction (Warth & Millett, 2015: 109).

Analysis of biomechanics is crucial to understanding shoulder injury within sports populations. Throwing kinematics, especially of the baseball pitcher, has been under great scrutiny. Fluctuations of biomechanics, such as stride length, stride angle, horizontal extension, trunk activation, acceleration, and follow-through, might cause shoulder pathologies. Isokinetic strength measurement is a powerful tool for determining muscle function as well as for detecting abnormalities among pain-symptomatic athletes (Kevin, Michael & George, 2001: 75). The measurement of bilateral strength differences, peak torque, and work as a percentage of body weight is beneficial for evaluation of functional impairment (John, 2013: 23; Warth & Millett, 2015: 109).

Treating shoulder pain in athletes demands specific strategies. A precise diagnosis guides this process. Initial care usually blends rest cryotherapy and analgesic medicine. Bodily rehabilitation follows often aided by injections or surgery if needed. Physical therapy aims to restore mobility. It works to improve strength optimize biomechanics too. Athlete rehabilitation programs focus on rotator cuff exercises. They also target periscapular muscles flexibility neuromuscular coordination. Correcting deep instability is vital for overhead sport participants. Refining pitching mechanics forms another key rehabilitation element (John, 2013: 23; Warth & Millett, 2015: 109).

Shoulder Pain in The Elderly

Shoulder pain frequently troubles older adults. Aging itself prompts degenerative shifts within the shoulder joint. Nearby tissues also change causing discomfort functional decline. Common shoulder problems in seniors include rotator cuff damage osteoarthritis. Adhesive capsulitis or frozen shoulder is another frequent issue. Thorough evaluation becomes necessary. It ensures correct diagnosis of shoulder pain causes in the elderly. This process helps tailor a suitable management strategy considering overall health functional requirements (John, 2013: 23; Panayiotou Charalambous, 2019: 69).

Clinical evaluation for an older patient with shoulder ache starts with details. Onset duration pain character matter greatly. Any related symptoms like stiffness muscle weakness need documentation. Assessing the pain's impact follows. How it affects daily activities overall independence is crucial. A detailed medical background must be gathered. This includes comorbidities like diabetes or thyroid disease. Such conditions link to higher rates of shoulder troubles like adhesive capsulitis. Note past interventions too. Pharmacologic treatments alternative therapies count. Asking about nutraceutical use like glucosamine chondroitin is particularly relevant. Patients often overlook these non-prescription substances (John, 2013: 23; Kevin, Michael & George, 2001: 75; Michael, Jesse & John, 2009: 145; Panayiotou Charalambous, 2019: 69).

The physical examination of the elderly patient with shoulder pain follows the same look-feel-move special test protocol for use on younger populations. However, some features may hold greater importance for this age group (Panayiotou Charalambous, 2019: 77; Warth & Millett, 2015: 77). The assessment for physical appearance may uncover changes within postural alignment, for example, severe kyphosis, which can influence shoulder mechanics (Kevin, Michael & George, 2001: 75). Palpation is important for detecting tenderness over certain tissues, for example, the acromio-clavicular joint if it is involved in osteoarthritis (Aydıngöz, 2022: 101; Warth & Millett, 2015: 183). The assessment of both active and passive ranges of movement must be included, as restrictions often result from degenerative changes or disorders such as adherent capsulitis. The character of movement, combined with the observation of compensation mechanisms, for example, shoulder elevation, must also be noted (John, 2013: 23; Kevin, Michael & George, 2001: 75). Manual muscle testing is of specific importance for the detection of muscle weakness, for example, resulting from rotator cuff injury or neurological disorders. Although special tests offer valuable information, their interpretation with the elderly must be treated cautiously due to this group's greater potential for pre-existing pathology (Kevin, Michael & George, 2001: 75).

Disorders of the rotator cuff are a significant source of shoulder pain among the aging population. Tearing caused by rotator cuff tendon degeneration is a frequent finding that results in pain, muscle weakness, and limited functionality. The clinical picture varies since not all cases of tearing of the rotator cuff are symptomatic (Aydıngöz, 2022: 101; Warth & Millett, 2015: 77). Adhesive capsulitis, often seen among the elderly, causes intense shoulder pain accompanied by marked stiffness of the shoulder joint. A course of development for adhesive capsulitis follows a pattern of a painful freezing stage, a stiff frozen stage, and a process of thawing indicating improved range of motion. Glenohumeral osteoarthritis, which involves degeneration of the shoulder joint's articular cartilage, is a cause of chronic pain and stiffness among elderly people. In addition, arthropathy of the acromioclavicular joint is a frequent cause of pain among elderly patients, resulting from degenerative changes (Crookes et al., 2023: 753; Warth & Millett, 2015: 183, 2015: 209).

Managing shoulder pain in older adults aims to lessen discomfort. It seeks to enhance functional ability preserve independence. Initial management stays conservative. This involves analgesics anti-inflammatory drugs plus bodily rehabilitation. Physical therapy works to restore shoulder movement range. It strengthens intact rotator cuff muscles other shoulder girdle stabilizers. Improving functional capability is another goal. Corticosteroid injections can sometimes reduce pain inflammation in specific cases. Surgery becomes an option for some conditions. Symptomatic full-thickness rotator cuff tears severe osteoarthritis qualify particularly in vigorous elders. Deciding on surgery however requires thorough review. The patient's general health function patient wishes all factor in (Crookes et al., 2023: 753; John, 2013: 23; Panayiotou Charalambous, 2019: 77).

Pediatric Shoulder Pain

Shoulder pain affects children less often than adults. Still it occurs for various causes. A detailed history and careful physical exam are key for children presenting shoulder pain. These steps help differentiate origins direct effective therapy. Considering the child's developmental stage activity level is necessary. Any past injury or overuse history matters too (Kevin, Michael & George, 2001: 75; Özbek & Demirtaş, 2022: 89; Panayiotou Charalambous, 2019: 77; Warth & Millett, 2015: 39).

The patient's medical history details the pain's onset location severity. It also notes related symptoms like stiffness weakness or joint noises. For small children caregivers or parents provide vital information. Their observations on the child's movement upper limb restrictions are useful. Note recent events as well. Any injuries falls sports participation recreational pursuits are relevant. Repetitive activities like swimming or throwing could lead to shoulder pain. This is common in physically active youngsters (Kevin, Michael & George, 2001: 75; Özbek & Demirtaş, 2022: 89; Panayiotou Charalambous, 2019: 77; Warth & Millett, 2015: 39).

The physical examination of children who present with shoulder pain must be adapted to their stage of development and their ability to cooperate. Inspection may demonstrate asymmetries, edema, or protective maneuvers related to the affected limb. Gentle palpation is necessary to determine areas of specific tenderness. Tests of active and passive ranges of motion are helpful in detecting restrictions or pain with movement. Muscle strength testing may be especially challenging in young children; however, an attempt should be made to carry out this test where possible. The use of special tests, where appropriate, must be done carefully, explaining the tests in a way that the child will understand.

The most common etiologies of shoulder pain among children and adolescents are fractures, dislocations, and strains and sprains like soft tissue injury which are sometimes associated with traumatic events (Panayiotou Charalambous, 2019: 77). Overuse injury may develop in young athletes who participate in activities involving repetitive overhead throwing, i.e., Little League shoulder (proximal humeral apophysitis). Inflammatory disorders, e.g., juvenile idiopathic arthritis, may also present as shoulder pain. Infections or neoplastic processes are rarely recognized as causative (Warth & Millett, 2015: 39).

Neuropraxia of the suprascapular nerve is commonly seen among young sportsmen but is more significant in adult populations. The anatomical features of the suprascapular notch and superior transverse scapular ligament, which show significant variation, can lead to nerve entrapment in young individuals (Warth & Millett, 2015: 241, 2015: 219).

Managing shoulder discomfort in children depends heavily on the root diagnosis. Fractures dislocations usually need immobilization. Soft tissue injuries often respond to RICE. This means rest ice compression elevation. A slow return to activity follows RICE. Overuse problems might demand rest periods. Modifying training techniques is also often required. Treat inflammatory conditions according to the specific rheumatological finding. Physical therapy can help restore motion strength function after injury. It also aids in handling certain disorders. Teaching kids' parents about good warm-up routines is vital. Explaining how to avoid undue or repeated shoulder stress is equally key (Crookes et al., 2023: 753; John, 2013: 23; Warth & Millett, 2015: 39).

Shoulder Pain in Pregnant Women

Shoulder pain can develop during pregnancy as a result of different physiological and biomechanical changes. The body hormonal changes of pregnancy can cause enhanced laxity of the ligaments, thus exposing pregnant women to joint instability and pain. Postural changes and the weight gain during pregnancy can put even more stress on the musculoskeletal system, especially on the shoulders. Also, fluid retention and compression syndromes can amplify pain generated within the upper limbs (Warth & Millett, 2015: 39).

The shoulder pain in the pregnant woman must also have a history of the onset, location, and nature of the pain, along with any associated symptoms, particularly whether there is numbness or paresthesias in the arm or hand. Attempts should also be made to elicit exacerbating and relieving activities. A complete obstetric history and details of the current gestation are essential (Kevin, Michael & George, 2001: 75; Warth & Millett, 2015: 39).

The physical examination should include assessment of posture, which can be affected by the growing uterus. Palpation of the shoulder area and surrounding tissues is important in locating areas of pain. Active and passive ranges of movement should be evaluated as a means of finding out if there is limitation or movement-induced pain. A neurological examination, involving assessment of sensory perception and reflexes, might be required if the patient complains of numbness or tingling sensations. Special tests should be conducted cautiously, considering the physiological changes that happen during pregnancy (Kevin, Michael & George, 2001: 75; Warth & Millett, 2015: 39).

Discomfort in the shoulder during pregnancy is often caused by postural problems, overuse of muscles, and nerve compression syndromes including thoracic outlet syndrome as well as carpal tunnel syndrome, which at times cause pain to radiate to the shoulder area. In addition, ligamentous laxity at a generalized level might cause a feeling of instability or pain within the shoulder joint (Kevin, Michael & George, 2001: 75; Warth & Millett, 2015: 39).

The management of shoulder pain during pregnancy is focused mainly on conservative measures aimed at alleviating symptoms rather than on employing potentially damaging treatments. Proper training in posture and adjustments to activities to reduce shoulder stress represent key elements of this strategy. Moderate exercise helps maintain flexibility. Gentle strengthening work offers advantages too. Use heat or cold packs to lessen discomfort. Doctors sometimes prescribe assistive devices. Posture braces serve as one example. Think carefully about medicines during pregnancy. Consult a healthcare provider first before using analgesics anti-inflammatories. Physical therapy offers direction. Therapists advise on suitable safe exercise plans pain relief methods. Most cases of shoulder pain related to pregnancy resolve postpartum, coinciding with a restoration of hormonal balance and a diminution of biomechanical stress (Crookes et al., 2023: 753; John, 2013: 23; Warth & Millett, 2015: 39).

Conclusion

Diagnosing shoulder pain demands grasping its many possible origins. A detailed medical history is step one. A meticulous physical exam guided by patient symptoms follows closely. Both steps are prerequisites before forming a differential diagnosis. Spotting telltale signs for various conditions is essential. These include rotator cuff injury instability adhesive capsulitis osteoarthritis acromioclavicular issues cervical radiculopathy neurological problems and rarer causes. Recognizing these indicators helps shape the differential diagnosis guides effective treatment. Clinicians merge clinical observations with fitting diagnostic tests. This pairing informs plans for specific actions like conservative care injections or surgery. The aims are pain reduction functional recovery. Evaluating shoulder pain requires special focus in some groups. Athletes older patients particularly warrant this distinct consideration.

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RESTORING SHOULDER FUNCTION: THE ROLE OF MANUAL THERAPY AND NEUROMUSCULAR CONTROL

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Introduction

Manual therapy works hand-in-hand with neuromuscular control training. Both are vital synergistic approaches for rehabilitating shoulder problems (McEvoy & Dommerholt 2011:351; McMahon & Donatelli 2003:405). Manual therapy uses skilled hand movements. These techniques address musculoskeletal issues. Neuromuscular control focuses differently. It aims to restore proper muscle firing coordination. This process ensures joint stability functional movement (Greenfield 2009:639; McMahon & Donatelli 2003:405). Together these methods form a core part of modern shoulder rehab. Their goals include speeding recovery after operations easing lasting pain improving overall shoulder wellness

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(Ellenbecker 2006:16; Kibler & Sciascia 2016:165; Kuhn Dickinson & Desir 2016:67; McEvoy & Dommerholt 2011:351). Good surgeon-therapist communication produces better results post-shoulder arthroplasty. A united rehabilitation plan is therefore necessary (Kuhn Dickinson & Desir 2016:67). Therapists must understand the exact surgical work done. This knowledge lets them provide correct rehab after procedures like Bankart repair (Di Giacomo et al. 2016:93).

Applications in Clinical Practice

Clinicians apply manual therapy neuromuscular control techniques widely for shoulder conditions. Uses include:

Rotator cuff issues (tears tendinopathies): Therapy lessens pain improves motion range. It rebuilds strength coordination. Rehab after rotator cuff replacement aims for functional recovery. Attention to tissue healing flexibility strength gain is required (Celik & Menek 2025; Ellenbecker 2006:16; Kibler & Sciascia 2016:165).

Adhesive capsulitis (frozen shoulder): Treatment reduces discomfort increases joint mobility. It restores functional arm use. Manual therapy like Movement with Mobilization (MWM) or Gong's Mobilization (GM) proves helpful. These methods correct posture problems ease capsular restriction (Amjad & Asghar 2025:4272; Malone & Hazle 2006:64).

Shoulder impingement syndrome: Therapy targets pain relief fixes biomechanical faults. It widens the subacromial space.

Impingement cases often show altered scapular muscle activity. This situation underlines the need for neuromuscular control exercises (Alatawi & Mohamed 2019; Ellenbecker 2006:16; Keirns & Whitman 2009:527).

Shoulder instability: Rehab improves dynamic steadiness via targeted muscle work proprioceptive drills. Post-arthroscopic Bankart repair therapists must restore useful stable motion. Fatigue-resistant scapular support enhanced rotator cuff power achieve this (Di Giacomo et al. 2016:93; Thatcher & Davies 2006:124).

Post-operative rehabilitation: Therapy aids recovery restores movement range. It boosts muscle performance after varied shoulder surgeries including arthroplasty. Protecting the subscapularis muscle is a chief concern. This applies particularly after anterior approach shoulder replacements (Di Giacomo et al. 2016:93; Ekstrom & Osborn 2003:435; Kuhn Dickinson & Desir 2016:67).

Chronic shoulder pain: A combined approach often works best. This might feature manual treatment exercises. The goals are pain reduction functional improvement (Go & Lee 2016:2422; McEvoy & Dommerholt 2011:351).

Manual therapy involves skillful hand applications. Joint mobilization manipulation soft tissue work muscle reeducation are examples (McMahon & Donatelli 2003:405). These methods aim to improve tissue stretch increase motion ease discomfort reduce soft tissue swelling. Manual therapy application considers if injuries are protective or nonprotective. This distinction guides the treatment path (Amjad & Asghar 2025:4272; McMahon & Donatelli 2003:405).

Neuromuscular control describes the body's ability coordinating muscle action. This coordination secures joints regulates movement maintains posture (Alatawi & Mohamed 2019; Di Giacomo et al. 2016:93; Greenfield 2009:639). It involves intricate links between nerve musculoskeletal systems. Proprioceptive input muscle power motor skill are components. Sound neuromuscular control is key for ideal shoulder mechanics both glenohumeral scapulothoracic. Rehabilitation often focuses on restoring scapular motion control. Stabilizing muscles around the shoulder joint is another priority (Alatawi & Mohamed 2019; Di Giacomo et al. 2016:93; Greenfield 2009:639).

2. Biomechanics and Functional Dynamics of the Shoulder Joint

Mechanism of Movement in the Shoulder Complex

The shoulder complex shows sophisticated biomechanical design. It permits wide motion via four joints working together. These are the glenohumeral (GH) scapulothoracic acromioclavicular (AC) sternoclavicular (SC) joints (Hoffman et al. 2009:627).

The GH joint is a ball-and-socket type. The humeral head meets the scapula's glenoid fossa here. This joint is the main site for flexion extension abduction adduction rotation (Di Giacomo et al. 2016:93; Hoffman et al. 2009:627). The scapulothoracic connection isn't a true synovial joint. It involves the scapula gliding over the back ribs. Muscles linking both structures allow this movement. This action is vital for full arm raising. It provides a solid base for GH mobility. The AC joint connects the scapula's acromion process to the clavicle. It allows scapular rotation winging tilting. These actions fine-tune glenoid fossa positioning. The SC joint links the clavicle sternum. It's the upper limb's only bony tie to the axial skeleton. This joint permits clavicle elevation depression protraction retraction rotation. All these movements influence scapular placement GH function consequently. The four joints work together smoothly. A muscle force-couple system drives this synchrony. Abnormal movement patterns can overload soft tissues (Di Giacomo et al. 2016:93; Hoffman et al. 2009:627).

Equilibrium of Stability and Mobility

The shoulder joint is known for impressive mobility. This allows many functional tasks (Davies et al. 2006:39). Such extensive motion however comes with inherent instability. This quality makes the shoulder prone to injury (Thatcher & Davies 2006:124). GH joint stability relies on a delicate balance. Static dynamic stabilizers interact constantly (Davies et al. 2006:39; Myers Wassinger & Lephart 2009:655). Static elements include the glenoid labrum. It deepens the glenoid socket increases humeral head contact. The capsuloligamentous complex is another static part. Its GH ligaments offer passive checks against too much humeral head shift. Negative pressure inside the joint also helps keep the humeral head seated (Bascharon & Manske 2011:411; Davies et al. 2006:39; Thatcher & Davies 2006:124). Dynamic stabilizers are the muscles around the shoulder. The rotator cuff group (supraspinatus infraspinatus teres minor subscapularis) is primary. The long head biceps tendon contributes too. These muscles actively pull the humeral head into the glenoid. They bolster stability throughout movement. Scapulothoracic muscles (levator scapulae trapezius rhomboids serratus anterior) are critical dynamic aids. They provide a dependable platform for GH movement. The sensorimotor system connects mechanical dynamic restraints (Davies et al. 2006:39; Hoffman et al. 2009:627; Myers Wassinger & Lephart 2009:655).

Anatomical Foundation of Neuromuscular Regulation

Proprioceptive nerve endings drive shoulder neuromuscular control. These mechanoreceptors sit in various joint structures. GH ligaments the joint capsule muscle-tendon units house them (Davies et al. 2006:39; Greenfield 2009:639; Hoffman et al. 2009:627). Golgi tendon organs are one receptor type. Found in tendons they sense muscle tension changes. Muscle spindles within muscle bellies detect length shifts rate of change. Pacinian corpuscles in GH ligaments sense joint acceleration deceleration. These nerve endings detect shoulder motion joint position. Shoulder movement triggers these receptors. They send signals via sensory nerves to the central nervous system (spinal cord brain). This input undergoes analysis.

The result is ongoing awareness of joint place (proprioception) movement (kinesthesia). Reflex arcs protect the shoulder from sudden instability. For instance attempted abrupt dislocation stretches the capsule ligaments. This stretch activates proprioceptors possibly triggering reflex rotator cuff contraction. This action counters the destabilizing push prevents dislocation. Unconscious processing of sensory data yields controlled movement dynamic joint stability. Effective neuromuscular control hinges on active joint proprioceptors (Davies et al. 2006:39; Greenfield 2009:639; Hoffman et al. 2009:627; Hunter-Giordand et al. 2009:569; Myers Wassinger & Lephart 2009:655).

3. Manual Therapy Methods

Manual therapy uses several hands-on methods. They aim to correct musculoskeletal problems improve function. Shoulder complex procedures fall into categories. Soft tissue mobilization joint work manipulation stretching proprioceptive actions are key types (McMahon & Donatelli 2003:405).

Soft Tissue Manipulation

Soft tissue mobilization covers diverse manual approaches. Massage myofascial release target muscles fascia other connective tissues (Kibler & Sciascia 2016:165; McMahon & Donatelli 2003:405). These applications can address muscles often linked to shoulder pain dysfunction. Pectoralis minor major subscapularis supraspinatus infraspinatus teres minor are examples. Techniques applied might include trigger point therapy (TPCR) massage myofascial manipulation (MFM). Trigger point compression release specifically targets myofascial trigger points. The spray stretch (S&S) technique perhaps using a topical skin coolant spray is another option. Additionally methods like soft-tissue mobilization deep friction massage could be considered. Modalities such as electroacupuncture laser therapy are sometimes added (Alatawi & Mohamed 2019; Go & Lee 2016:2422; Kibler & Sciascia 2016:165; McEvoy & Dommerholt 2011:351).

Therapists often use soft tissue mobilization improving motion range. It works by stretching connective tissues managing discomfort (Go & Lee 2016:2422). It helps ease pain post-surgery swelling. Restoring normal myofascial working in areas like upper trapezius levator scapulae subscapularis pectoralis minor is another goal (Di Giacomo et al. 2016:93; Keirns & Whitman 2009:527). These actions can support proper muscle firing sequences (Keirns & Whitman 2009:527). Combining TPCR massage MFM is suggested as a manual therapy foundation. Myofascial trigger points (MTrPs) can worsen shoulder discomfort dysfunction. Treating them is a vital part of soft tissue work. Techniques target the processes causing taut bands pain sensitization (McEvoy & Dommerholt 2011:351).

Articular Mobilization and Manipulation

Joint mobilization manipulation involves skilled passive shoulder joint movements. GH AC joints are specific targets

(McMahon & Donatelli 2003:405). Various manual therapy schools like Maitland's Kaltenborn's provide frameworks for these methods (Celik & Menek 2025; Keirns & Whitman 2009:527; McMahon & Donatelli 2003:405). Mobilization techniques use joint glides oscillations distractions. They improve joint mechanics (McMahon & Donatelli 2003:405). GH joint work might use posterior glides. These ease anterior capsule tightness boost flexion internal rotation. Inferior glides increase abduction. Distraction can lessen pain improve overall joint movement. Scapulothoracic mobilizations are also important. Superior inferior glides medial lateral glides help restore correct scapular motion (Alatawi & Mohamed 2019; Osar 2012:186).

Joint mobilization suits conditions like capsular tension restricted range (Ellenbecker 2006:16). It aims to normalize capsular relationships improve accessory joint play. Manual therapy including joint mobilization yields good results for shoulder issues. Mobilization with movement (MWM) is a distinct technique. The therapist applies a sustained glide. The patient performs an active movement simultaneously. This approach aims to fix joint positioning tracking faults (Amjad & Asghar 2025:4272; Celik & Menek 2025; Ellenbecker 2006:16).

Stretching and Proprioceptive Methods

Stretch treatments aim to increase extensibility of shoulder musculature, among them the latissimus dorsi, and the teres major.

Stretch treatments can incorporate static stretching, and more dynamic stretching, e.g., Proprioceptive Neuromuscular Facilitation (PNF). PNF treatments incorporate a combination of muscle contraction together with stretch for enhancing range of movement as well as neuromuscular control. Diagonal flexion together with concomitant horizontal adduction and external rotation is some of the PNF patterns for the shoulder. Other PNF treatments incorporate rhythmical initiation and antagonist reversal for enhancing scapular muscle control. Muscle energy techniques are a type of active stretching whereby the patient contracts a controlled isometric contraction against resistance for enhancing muscle length as well as joint movement (Crenshaw et al., 2009:775; McEvoy & Dommerholt, 2011:351; Uhl & Kibler, 2009:671; Wilk, Macrina & Reinold, 2009:545; Willmore, 2024:173).

Indications for Manual Therapy

Shoulder manual therapy is prescribed for a range of musculoskeletal disorders to alleviate pain, stiffness, as well as to improve functionality (Alatawi & Mohamed, 2019; Go & Lee, 2016:2422; McMahon & Donatelli, 2003:405). Refer to indications and contraindications on Table 1.

Table 1. *Indications and Contraindications for Manual Therapy*

Indications	Absolute Contraindications
Pain reduction	Fracture
Increased range of motion	Infection (local or systemic)
Improved tissue extensibility	Tumor (malignant) in the treatment area
Modulation of muscle tone	Joint instability (uncontrolled)
Improved joint mechanics	Open wounds or sutures in the treatment area
Decreased soft tissue swelling and inflammation	Signs of nerve root compression (severe)
Postural correction	Progressive neurological deficits
Management of myofascial pain	Cauda equina syndrome
Addressing capsular restrictions	Inflammatory arthritis (acute flare-up)
Rehabilitation following surgery	Vascular compromise
	Lack of a diagnosis

Clinicians must conduct a comprehensive evaluation to determine suitable individuals for manual treatment and to identify any contraindications. Treatment must consistently adhere to clinical reasoning, align with patient objectives, and remain within the therapist's professional scope of practice (McEvoy & Dommerholt, 2011:351).

4. Principles of Neuromuscular Regulation

Concepts of Proprioception and Kinesthesia

Neuromotor control relies on sensing joint position movement. We call this sense proprioception or kinesthesia

(Hoffman et al. 2009:627). Proprioception stems from sensory input via mechanoreceptors. It provides joint-position awareness. Knowing your arm's location with eyes shut shows proprioception working. Kinesthesia relates to managing joint movement. It covers direction range speed. Reaching smoothly for a cup without looking directly at your arm illustrates kinesthesia daily. Joint proprioceptors play a key part. They signal a stretch reflex if the shoulder capsule tightens. This action helps stop excess translation at movement limits (Davies et al. 2006:39; Hoffman et al. 2009:627; Hunter-Giordand et al. 2009:569).

Mechanisms of Motor Control in the Shoulder

Shoulder motor control uses feedforward feedback systems (Hoffman et al. 2009:627). Feedforward control happens beforehand. The brain readies muscles for action before movement starts. Shoulder-specific feedforward involves activating rotator cuff muscles first. This occurs before larger movers like the deltoid engage when throwing. This pre-firing helps steady the glenohumeral joint. Feedback control adjusts movement during action. It uses sensory information received mid-movement. For example walking on bumpy ground might make shoulder muscles adapt subtly. Sensory feedback from joints muscles guides these adjustments maintaining balance arm motion. Neuromuscular dynamic stability matters throughout the motion range. Many receptors help regulate joint movement constantly (Davies et al. 2006:39; Hoffman et al. 2009:627).

Pathophysiology of Neuromuscular Impairment

Injury or pain can greatly reduce shoulder proprioception motor control (Davies et al. 2006:39). After injury like anterior glenohumeral dislocation shoulder kinesthesia might suffer. Pain can weaken muscles alter firing patterns. Scapular stabilizers rotator cuff muscles often show these changes. This situation creates a damaging loop. Discomfort hinders muscle action leading to weakness less dynamic stability (Alatawi & Mohamed 2019; Keirns & Whitman 2009:527; Uhl & Kibler 2009:671). Poor muscle control places abnormal stress on joint parts. This stress can cause more instability pain. Weak proprioception might also lead to shoulder injuries. Dynamic stabilizers may fail controlling the joint properly if capsule laxity exists. Restoring proprioception kinesthesia is a primary rehab aim. It helps break this loop re-establish neuromuscular dynamic steadiness (Davies et al. 2006:39).

5. Manual Therapy and Neuromuscular Techniques in Shoulder Disorders

Rotator Cuff Disorders (Methods for Treating Tears and Tendonitis)

Rotator cuff disorders cover various problems. They affect muscles tendons around the glenohumeral joint. Tendonitis (inflammation) tears (partial full-thickness) are examples. Supraspinatus infraspinatus teres minor subscapularis muscles can be involved. Impingement falls into primary or secondary types (Ellenbecker 2006:16; Kibler & Sciascia 2016:165).

Rotator cuff diseases have intrinsic causes like tendon decay. Extrinsic factors like subacromial space compression also play roles. Biomechanical issues appear frequently. Altered scapular movement (scapular dyskinesis) incorrect humeral head placement are common. Rotator cuff scapular stabilizer weakness or imbalance can cause result from these issues. Therapists often see lower trapezius serratus anterior inhibition. Upper trapezius overactivation often occurs alongside this particularly in Shoulder Impingement Syndrome (SIS). Rotator cuff problems might mean less humeral head depression. This situation can functionally narrow the subacromial area (Alatawi & Mohamed 2019; Ellenbecker 2006:16; Falsone & Verstegen 2009:763; Keirns & Whitman 2009:527).

Manual therapy is central managing rotator cuff disorders. The acute phase goals are pain relief restoring normal capsule connections (Ellenbecker 2006:16). Gentle soft tissue work on the shoulder complex helps. This includes rotator cuff scapular muscles nearby tissues. Such work can ease discomfort improve tissue give. Passive joint movements auxiliary joint mobilizations (Maitland grades I II) might reduce pain too. These techniques are used in pain-free scenarios. Addressing related joint issues can help. Mobilizing or manipulating the thoracic spine might improve scapular position potentially activating the lower trapezius. In the subacute phase pain lessens. Focus shifts to regaining motion range addressing capsular limits. More forceful joint mobilizations (Maitland grades III IV) stretching techniques apply here. Mobilization with Movement

(MWM) can correct posture faults GH joint tracking problems. Therapists might use deep friction massage for soft tissue treatment (Alatawi & Mohamed 2019; Amjad & Asghar 2025:4272; Celik & Menek 2025; Ellenbecker 2006:16; Go & Lee 2016:2422; McMahon & Donatelli 2003:405).

Neuromuscular control exercises are critical during rehab. Initial steps involve submaximal rotator cuff scapular exercises (Ellenbecker 2006:16). Strengthening must target rotator cuff muscles (supraspinatus infraspinatus teres minor subscapularis). This work boosts dynamic stability. Strengthening scapular stabilizers is also key. Serratus anterior lower trapezius middle trapezius work restores good scapular movement. Exercise difficulty usually increases gradually. Isometric holds come first then concentric finally eccentric moves as pain allows. Proprioceptive drills like rhythmic stabilization in varied arm spots enhance joint position sense. Weight-bearing activities with controlled joint motion help too. Scapular awareness control exercises are important. Exercises move from simple restricted motions toward functional sport-specific actions. Closed kinetic chain work like wall push-ups push-up plus improves scapular stability shoulder muscle co-firing (Alatawi & Mohamed 2019; Ellenbecker 2006:16; Greenfield 2009:639).

Clinical Tips

- • Carefully assess correct any basic scapular dyskinesis (Ellenbecker 2006:16; Falsone & Verstegen 2009:763; Uhl & Kibler 2009:671).
- Consider the kinetic chain including core pelvis lower limbs. They affect shoulder function (Ellenbecker 2006:16; Falsone & Verstegen 2009:763; Uhl & Kibler 2009:671).
- Watch for impingement signs during exercises adjust activity promptly (Ellenbecker 2006:16).
- Educate patients on suitable posture movement patterns. This knowledge is valuable (Ellenbecker 2006:16).
- The "empty can" "full can" tests activate supraspinatus deltoid muscles differently (Reinold & Savidge 2009:589).

Adhesive Capsulitis (Frozen Shoulder) (Mobilization and Management Strategies)

Adhesive capsulitis also called frozen shoulder (FS) involves gradual pain onset. Limited active passive motion range characterises it. Adhesions within the glenohumeral joint capsule cause this limitation (Malone & Hazle 2006:64). Doctors often classify it as primary (idiopathic) or secondary due to other conditions. FS progresses through three clear stages: freezing frozen thawing (Amjad & Asghar 2025:4272; Malone & Hazle 2006:64).

The main biomechanical issue in FS is GH joint capsule contracture thickening. This results in marked stiffness. Pain can hinder muscle firing cause widespread active passive motion loss. This loss usually follows a capsular pattern (external rotation lost most then abduction then internal rotation). Altered scapulohumeral rhythm can arise. The body compensates for the reduced GH mobility (Alatawi & Mohamed 2019; Amjad & Asghar 2025:4272; Malone & Hazle 2006:64).

Manual therapy is basic to FS management particularly in frozen thawing stages (Amjad & Asghar 2025:4272). Techniques aim to restore joint flexibility ease discomfort. During the freezing stage gentle pain-relieving methods apply. Grade I II joint mobilizations soft tissue work are examples (Celik & Menek 2025). As FS moves to the frozen stage stronger mobilizations become appropriate. Grade III IV joint work Mulligan's MWM Gong's GM techniques might lessen capsular restrictions (Amjad & Asghar 2025:4272; Celik & Menek 2025; McMahon & Donatelli 2003:405). GH gliding after interscalene brachial plexus block is another reported method. Total End Range Time (TERT) principles can guide stretching methods improving passive motion (Malone & Hazle 2006:64; Struyf et al. 2024:139). Hydrodilatation can serve as an added treatment for shoulder adhesive capsulitis (Willmore 2024:173). In the thawing phase manual therapy works toward full motion range reducing any leftover stiffness (Amjad & Asghar 2025:4272).

Manual treatment eases stiffness. Neuromuscular control exercises help functional recovery lessen recurrence risk. Initially mild rotator cuff isometric exercises scapular stabilization work begin. These maintain muscle activity without worsening pain (Ellenbecker 2006:16). As motion range (ROM) improves therapists progress to active-assisted active ROM exercises. Strengthening rotator cuff scapular stabilizers is necessary improving dynamic stability normalizing scapulohumeral rhythm. Proprioceptive exercises like weight shifts closed kinetic chain tasks enhance joint awareness control as ROM increases. Neuromuscular exercises show good effects on pain active ROM in idiopathic frozen shoulder cases (Alatawi & Mohamed 2019; Amjad & Asghar 2025:4272; Ellenbecker 2006:16).

Clinical Tips

- Understand the patient's exact frozen shoulder stage. This directs treatment choices.
- Combine manual treatment with a structured home exercise plan stressing stretching ROM exercises.
- Educate patients about the condition's natural course exercise adherence importance. This understanding is key.
- Monitor pain levels carefully adjust manual therapy exercise intensity accordingly.
- Assess address the cervical thoracic spine. Problems there can impact shoulder mechanics.

Subacromial Impingement Syndrome

Subacromial Impingement Syndrome (SAIS) involves tendon compression usually supraspinatus. The subacromial bursa other soft tissues also get squeezed. This happens as they pass under the coracoacromial arch during arm lifting. SAIS classification includes primary secondary or internal impingement types (Alatawi & Mohamed 2019; Ellenbecker 2006:16; Wilk Macrina & Reinold 2009:545).

Biomechanical factors contributing to SAIS include acromion shape rotator cuff weakness. Joint laxity or stiffness muscular imbalances altered scapulothoracic movement also contribute (Alatawi & Mohamed 2019; Ellenbecker 2006:16). Scapular dyskinesis particularly reduced upward rotation links strongly to impingement (Greenfield 2009:639). Weak rotator cuff muscles especially supraspinatus might allow upward humeral head movement. This shift narrows the subacromial space (Wilk Macrina & Reinold 2009:545). Posterior capsule tightness can also change humeral head motion. Imbalances between upper lower trapezius serratus anterior muscles occur frequently (Alatawi & Mohamed 2019; Kibler 2006:94).

Manual therapy for SAIS aims to reduce discomfort improve motion range. It also works to fix underlying biomechanical faults (Alatawi & Mohamed 2019). In the acute phase gentle soft tissue work helps. Mobilizing rotator cuff deltoid periscapular muscles can lessen pain muscle guarding (Go & Lee 2016:2422; McMahon & Donatelli 2003:405). Passive GH joint mobilizations specifically inferior posterior glides improve humeral head position potentially widening subacromial space (Alatawi & Mohamed 2019). Mobilizing the thoracic spine rib cage can boost shoulder girdle function. As pain subsides more forceful mobilizations stretching activities begin. These target capsular limits especially the posterior capsule. Scapulothoracic joint mobilizations like superior/inferior medial/lateral glides restore ideal scapular movement. Manual treatment combined with supervised exercise therapy works well mitigating SAIS. It reduces discomfort improves shoulder muscle strength function (Alatawi & Mohamed 2019; Keirns & Whitman 2009:527).

Neuromuscular control exercises are key for long-term SAIS therapy. Strengthening exercises focus on restoring rotator cuff muscle balance strength. This ensures proper humeral head alignment (Ellenbecker 2006:16). Boosting scapular stabilizers (serratus anterior lower middle trapezius) is vital fixing scapular dyskinesis widening the subacromial space. Exercise follows the isometric-concentric-eccentric progression. Proprioceptive drills like weight-bearing tasks balance training enhance dynamic stability. Scapular retraction exercises can influence subacromial space width. Core stability work provides a solid base for shoulder movements. Scapular taping might supplement efforts improving correct scapular mechanics (Alatawi & Mohamed 2019; Di Giacomo Bellachioma &

Silvestri 2016:1; Ellenbecker 2006:16; Greenfield 2009:639; Thatcher & Davies 2006:124; Uhl & Kibler 2009:671).

Clinical Tips

- Identify correct any contributing factors like posture issues thoracic spine stiffness.
- Advise patients avoid aggravating activities maintain good shoulder mechanics during daily tasks.
- Watch scapular motion during exercises give feedback ensuring proper stabilizer activation.
- Use the kinetic chain approach for thorough rehabilitation.
- The scapular retraction test helps assess supraspinatus strength in people with shoulder injuries.

Shoulder Instability (anterior, posterior, multidirectional)

Shoulder instability means the humeral head moves too much on the glenoid fossa. This causes symptoms like pain clicking subluxation dislocation (Thatcher & Davies 2006:124). Classification depends on instability direction (anterior posterior multidirectional). Frequency (acute recurring chronic) cause (traumatic atraumatic) are other factors (Di Giacomo et al. 2016:93; Thatcher & Davies 2006:124).

Shoulder stability results from static stabilizers (ligaments labrum capsule) dynamic ones (rotator cuff periscapular muscles) working together. Damage to static parts like a Bankart lesion (front labral tear) often happens in traumatic anterior instability. Neuromuscular problems like weak or slow-firing rotator cuff scapular muscles cause dynamic instability. The inferior GH ligament is the main check against forward shift during 90° abduction instability. Poor proprioception kinesthesia can hinder dynamic stabilizers' ability responding well to joint loads. Multidirectional instability involves looseness in several directions. It often links to general ligament laxity neuromuscular control issues (Alatawi & Mohamed 2019; Di Giacomo et al. 2016:93).

Manual therapy for shoulder instability mainly targets pain relief related soft tissue limits. It does not directly fix the basic structural looseness (Bascharon & Manske 2011:411; Di Giacomo et al. 2016:93). Gentle soft tissue mobilization can ease discomfort muscle guarding (McMahon & Donatelli 2003:405). Therapists might use scapular mobilization improving scapular position function (Amjad & Asghar 2025:4272; Di Giacomo et al. 2016:93). In post-op rehab after stabilization surgery (e.g. Bankart repair) manual therapy starts gently. It focuses on keeping motion range protecting repaired tissues. As healing progresses therapists may integrate more advanced techniques easing stiffness improving tissue stretch (Di Giacomo et al. 2016:93).

Neuromuscular control exercises are central managing shoulder instability both non-surgically post-operatively.

Strengthening targets rotator cuff muscles. Subscapularis work helps anterior stability infraspinatus teres minor aid posterior stability. This improves dynamic joint compression control. Strengthening scapular stabilizers (serratus anterior trapezius rhomboids) is vital maintaining ideal scapulothoracic mechanics. It ensures a solid base for GH movement. Exercise starts with isometric holds in safe positions. It progresses to concentric eccentric work with increasing motion resistance. Proprioceptive exercises are very important. Closed kinetic chain tasks balance board work rhythmic stabilization drills in varied arm positions enhance joint awareness reflexive dynamic stabilizer firing. Ball tossing catching activities challenge dynamic stability (Bascharon & Manske 2011:411; Di Giacomo et al. 2016:93; McMahon & Donatelli 2003:405).

Clinical Tips

• Rehabilitation strategies must account for the particular type and orientation of instability.

• In the preliminary stages, a safeguarded range of motion is prioritized to prevent undue strain on the stabilizing structures.

• Monitor the abduction position during external rotation exercises, as it may impose stress on the anterior capsule post-Bankart surgery.

• Core stability is essential for establishing a secure foundation during upper extremity motions.

• Athletes participating in overhead throwing sports necessitate an extensive rehabilitation regimen that encompasses the complete kinetic chain.

Rehabilitation following trauma and surgery (e.g., SLAP repair, Bankart repair)

Posttraumatic rehabilitation is conducted following injuries such as fractures or dislocations, whereas postoperative rehabilitation is implemented after surgical procedures like SLAP (Superior Labrum Anterior Posterior) repair or Bankart repair for anterior instability (Di Giacomo, Bellachioma & Silvestri, 2016:1; Di Giacomo et al., 2016:93). The rehabilitation program is contingent upon the type and severity of the injury or surgical procedure.

Posttraumatic and postoperative disorders frequently encompass a confluence of tissue injury, discomfort, inflammation, restricted range of motion, and neuromuscular impairments (Di Giacomo et al., 2016:93; Kibler & Sciascia, 2016:165). A SLAP tear might compromise the stability of the biceps anchor, resulting in pain during overhead movements (Hunter-Giordand et al., 2009:569). The objective of Bankart surgery is to reestablish anterior stability; nevertheless, postoperative stiffness and weakening in the anterior shoulder musculature, such as the subscapularis, may arise (Di Giacomo et al., 2016:93). Fractures of the proximal humerus may result in considerable pain and limited mobility (Di Giacomo, Bellachioma & Silvestri, 2016:1). Post-traumatic or post-surgical immobilization may lead to muscular atrophy and diminished proprioception.

In the initial phases, manual therapy emphasizes the management of pain and edema with gentle soft tissue movement in the vicinity of the afflicted area, provided it does not jeopardize healing tissues or surgical repairs (Di Giacomo et al., 2016:93; Kibler & Sciascia, 2016:165).

Protected passive range of motion workouts are frequently commenced to avert stiffness. As recovery advances, manual therapy approaches seek to restore joint mobility and alleviate capsular limitations through modest to progressively intensive joint mobilizations. For example, after an arthroscopic release for a frozen shoulder, manual therapy is essential to preserve the acquired range of motion (Di Giacomo et al., 2016:93; Willmore, 2024:173).

Neuromuscular control exercises commence early in the rehabilitation phase, according to pain thresholds and tissue healing limitations (Di Giacomo et al., 2016:93; Kibler & Sciascia, 2016:165). Isometric workouts of the adjacent muscles facilitate muscular activation while minimizing stress on the healing tissues. As permitted by range of motion (ROM), active-assisted and active ROM exercises are advanced, succeeded by strengthening exercises aimed at the specific muscles impacted by the injury or surgical procedure (e.g., rotator cuff, deltoid, scapular stabilizers).

Proprioceptive exercises are incrementally used to enhance joint awareness and dynamic stability. Post-SLAP repair, exercises emphasizing biceps control and scapular stability are crucial. Exercise progression adheres to the isometric-concentric-eccentric concept, incrementally augmenting load and complexity as tolerated (Di Giacomo et al., 2016:93; Hunter-Giordand et al., 2009:569).

Clinical Tips

• Strict compliance with the surgeon's directives and precautions is essential in postoperative rehabilitation.

• Observe for indications of problems, including infection or nerve damage.

• Patient education regarding activity modification and the significance of compliance with the rehabilitation program is crucial.

• Pain should serve as a criterion for advancing workout regimens.

• A gradual reintegration into functional and sport-specific activities is a crucial final phase of recovery.

Therapeutic Interventions in Rheumatologic Disorders (e.g., rheumatoid arthritis, ankylosing spondylitis)

Rheumatological disorders, including rheumatoid arthritis (RA) and ankylosing spondylitis (AS), are chronic inflammatory syndromes that may impact the shoulder joint, resulting in discomfort, stiffness, and functional impairments (McEvoy &

Dommerholt, 2011:351). Rheumatoid arthritis (RA) is an autoimmune disorder predominantly impacting synovial joints, whereas ankylosing spondylitis (AS) is a chronic inflammatory condition largely affecting the spine and sacroiliac joints, though it may also involve peripheral joints.

In rheumatoid arthritis, inflammation of the synovial membrane may result in joint effusion, discomfort, and gradual joint deterioration, encompassing cartilage degradation and ligamentous laxity, which can induce instability. Muscle weakness in the shoulder region frequently occurs as a result of discomfort and disuse. In ankylosing spondylitis, inflammation and subsequent fusion of joints can result in stiffness and limited motion, impacting not only the spine but also potentially the shoulder girdle. Alterations in posture resulting from spinal involvement may also indirectly affect shoulder functionality. Pain and inflammation in both circumstances can hinder proprioception and motor function in the shoulder region (Keirns & Whitman, 2009:527; McEvoy & Dommerholt, 2011:351).

Manual treatment for individuals with rheumatological shoulder conditions emphasizes analgesia, preservation of joint mobility, and the resolution of soft tissue constraints (McEvoy & Dommerholt, 2011:351). Techniques are generally mild, particularly during phases of acute inflammation. Gentle soft tissue manipulation may alleviate muscle spasms and discomfort. Grade I and II joint mobilizations (Maitland) can be employed to preserve joint mobility and alleviate discomfort without aggravating inflammation. Mobilization of the thoracic spine may enhance overall posture in ankylosing spondylitis and indirectly influence shoulder mechanics. Aggressive procedures that may exacerbate inflammatory joints must be avoided (Celik & Menek, 2025; McEvoy & Dommerholt, 2011:351; McMahon & Donatelli, 2003:405).

Low-impact exercises and isometric contractions may be employed to sustain muscle activation while minimizing excessive joint stress. As inflammation diminishes, modest active-assisted and active range of motion exercises can aid in preserving or enhancing mobility. Strengthening exercises must focus on the rotator cuff and scapular stabilizer muscles to enhance joint support and dynamic stability. Proprioceptive exercises, including mild weight-bearing movements and balance training, can enhance joint awareness. Exercise regimens must be tailored to the individual and meticulously supervised by a therapist in conjunction with the patient and their rheumatologist (McEvoy & Dommerholt, 2011:351).

Clinical Tips

• Treatment must be synchronized with the patient's rheumatological care and should be attuned to exacerbations of their illness.

• Patient education regarding self-management tactics, encompassing pain management approaches and home exercise programs, is vital.

• Concentrate on preserving functional range of motion for everyday life tasks.

• Assess the influence of postural alterations associated with the rheumatological disease on shoulder mechanics.

• Aquatic therapy may serve as an advantageous exercise choice because to its buoyancy and less joint stress.

6. Clinical Implementation and Assessment

A thorough orthopedic physical therapy assessment is essential for shoulder rehabilitation (McEvoy & Dommerholt, 2011:351). Recognizing problematic movement patterns is the initial phase in the corrective approach (Osar, 2012:186). The fitness professional and therapist must become proficient in identifying indicators of dysfunctional patterns through visual observation and palpation. The fitness expert or therapist will assess the client's capacity for proximal stabilization during diaphragmatic breathing while simultaneously dissociating the extremities in their movements. A comprehensive sequential assessment that postulates specific deficits determines the suitable manual therapy approach. The clinical examination of the shoulder complex is essential for evaluation and include the assessment of pain, mobility, and impingement (Alatawi & Mohamed, 2019; Davies et al., 2006:39; McMahon & Donatelli, 2003:405; Osar, 2012:186).

Manual Assessments and Quantitative Evaluations

Multiple reasons may lead to scapular dyskinesis, and each potential component must be evaluated during the physical examination (Uhl & Kibler, 2009:671). Special tests encompass the Neer test, Hawkins-Kennedy test, Jobe test, and Gerber lift-off test (Alatawi & Mohamed, 2019; Ekstrom & Osborn, 2003:435). The belly-press test is utilized in the physical assessment of the subscapularis muscle and is contrasted with the lift-off test (Ekstrom & Osborn, 2003:435). Instruments like a goniometer are utilized to evaluate the active range of motion in the shoulder. Shoulder range of motion can be quantified in flexion, abduction, and external rotation with a goniometer (Alatawi & Mohamed, 2019). Although not expressly referenced in the sources, inclinometers and dynamometers may serve as additional measurement instruments for assessing range of motion and strength, respectively. The manual muscle test (MMT) can be employed to evaluate the strength of particular muscles surrounding the shoulder (Greenfield, 2009:639).

Functional testing involves assessing the client's capability to execute tasks such as elevating the arm overhead and reaching the back (Osar, 2012:186).

Formulating a Treatment Plan

The management of musculoskeletal pain with soft tissue techniques must be founded on a thorough assessment and the formulation of a treatment plan. The rehabilitation approach should primarily concentrate on promoting tissue healing and rectifying mechanical deficiencies (McEvoy & Dommerholt, 2011:351; Wilk, Macrina & Reinold, 2009:545).

Establishing objectives is an essential component of the therapeutic strategy. The primary objectives in rehabilitation may encompass alleviating discomfort to facilitate activity, resetting capsular connections, and commencing early submaximal resistance training for the rotator cuff and scapula (Ellenbecker, 2006:16), in addition to mitigating postoperative inflammation (Di Giacomo et al., 2016:93). Goals encompass alleviating discomfort, enhancing range of motion, rehabilitating the strength of the rotator cuff and scapular stabilizers (Ellenbecker, 2006:16), and ultimately resuming sports or daily activities (Alatawi & Mohamed, 2019). Treatment programs must encompass both short-term objectives targeting immediate symptom alleviation and functional enhancements, as well as long-term aspirations directed towards complete recovery and recurrence avoidance. The treatment approach must be tailored to meet the distinct deficits and requirements of each patient (Di Giacomo et al., 2016:93; Ellenbecker, 2006:16). The specific requirements of the patient and the essential principles of physiological tissue repair limits are consistently honored during rehabilitation (Uhl & Kibler, 2009:671).

Patient Instruction and Domestic Exercise Regimens

Delivering clear and comprehensible information to the patient regarding their condition and the treatment protocol is crucial for compliance and favorable results (McEvoy & Dommerholt, 2011:351). Participants in a rehabilitation program must be directed to perform self-correction and stabilizing activities (Alatawi & Mohamed, 2019). Effective instruction and monitoring of home exercises are essential elements of the rehabilitation process (Ellenbecker, 2006:16). Home exercise regimens may encompass self-correction and stability exercises for the scapula, shoulder depression during activities, rotator cuff muscle workouts, and pain-free range of motion exercises (Alatawi & Mohamed, 2019). Each activity must be meticulously organized on an individual basis.

7. Contemporary Methodologies and Investigations

Recent studies highlight the efficacy of manual therapy in treating diverse shoulder disorders. In the case of frozen shoulder (FS), Movement with Mobilization (MWM), frequently paired with electrotherapy such as ultrasound to facilitate the breakdown of thick collagen, has shown considerable advantages in alleviating pain and enhancing functional impairment and range of motion (ROM) (Amjad & Asghar, 2025:4272). Both MWM and Gong's Mobilization (GM) are deemed useful for frozen shoulder by addressing postural abnormalities of the humeral head. Research indicates that GM is more efficacious than alternative conservative therapies for FS. A systematic review and meta-analysis endorse MWM as an effective solution for FS (Amjad & Asghar, 2025:4272). Research indicates that in cases of rotator cuff injuries, the incorporation of both Mulligan and Maitland mobilization approaches alongside conventional workouts markedly enhances range of motion, functioning, and quality of life. The Mulligan group demonstrated superior enhancements in several areas relative to the Maitland group (Celik & Menek, 2025).

A randomized controlled trial for Shoulder Impingement Syndrome (SIS) comparing Kinesio Taping (KT) with Supervised Exercise Therapy (SET) and Manual Therapy (MT) with SET shown that both interventions resulted in considerable pain reduction and enhancements in function and range of motion (ROM). The KT with SET group had a greater proportion of change in pain, SPADI scores, and AROM in the short term (Alatawi & Mohamed, 2019; Go & Lee, 2016:2422). Manual therapy, encompassing soft-tissue mobilization and joint mobilization techniques, is frequently employed for shoulder impingement syndrome to enhance range of motion. A study including office workers experiencing shoulder pain revealed that manual treatment, encompassing soft-tissue mobilization, thoracic and cervical mobilization, and thoracic manipulation, resulted in more significant enhancements in pressure pain thresholds across many muscles than shoulder stability exercises.

A systematic review of systematic reviews regarding the cost-effectiveness of manual therapy for musculoskeletal disorders indicates that although certain reviews identified manual therapy as cost-effective for shoulder pain, the overall methodological quality and reporting were inconsistent, complicating definitive conclusions. The review emphasized that manual treatment is typically most efficacious when combined with therapeutic activity and patient education (Kirker et al., 2025:1).

Advancements in Neuromuscular Education Technology

The sources do not thoroughly elaborate on the application of specific technologies such as EMG biofeedback, robotic rehabilitation, or virtual reality in shoulder rehabilitation; however, they consistently highlight the fundamental principles of neuromuscular control and proprioception (Alatawi & Mohamed, 2019; Greenfield, 2009:639; Thatcher & Davies, 2006:124).

These technologies may improve neuromuscular retraining by offering real-time input, enabling accurate movement patterns, and generating immersive training settings. For instance, EMG biofeedback may enable patients to attain awareness and regulation of particular muscle activation patterns, whilst robotic technologies could facilitate movement guidance and evaluation. Virtual reality may provide effective and immersive rehabilitation experiences.

Incorporation of Multidisciplinary Therapeutic Strategies

Successful shoulder rehabilitation frequently requires a multidisciplinary strategy (Kuhn, Dickinson & Desir, 2016:67). Successful outcomes after shoulder arthroplasty, for example, rely on efficient communication between the surgeon and the therapist. Rehabilitation after arthroscopic Bankart reconstruction necessitates that therapists possess a comprehensive understanding of the surgical technique. Although the sources do not explicitly delineate the functions of occupational therapy, psychology, or direct physician collaboration beyond the surgical domain, the focus on thorough assessment, pain management, restoration of functional mobility, and consideration of the patient's overall well-being implies that a collaborative approach involving diverse healthcare professionals would enhance optimal patient-centered care (Davies et al., 2006:39; Di Giacomo et al., 2016:93; Ellenbecker, 2006:16; Kuhn, Dickinson & Desir, 2016:67; McEvoy & Dommerholt, 2011:351).

8. Conclusion

A comprehensive approach is essential in shoulder rehabilitation. It requires an examination of the interaction among pain, range of motion, strength, neuromuscular control, and functional capabilities. Comprehending the kinetic chain and the function of the scapula is essential for proficient administration. Rehabilitation should not concentrate exclusively on discrete impairments but should strive to restore cohesive movement patterns essential for daily activities and functional tasks (Davies et al., 2006:39; Di Giacomo et al., 2016:93; Ellenbecker, 2006:16; Kuhn, Dickinson & Desir, 2016:67; McEvoy & Dommerholt, 2011:351).

Practical Recommendations for Clinicians

• Perform a meticulous and exhaustive evaluation to ascertain all causes contributing to the patient's shoulder problem.

• Formulate personalized, evidence-informed treatment strategies that incorporate manual therapy methods, therapeutic exercises targeting the rotator cuff and scapular stabilizers, and neuromuscular control training.

• Employ evidence-based manual therapy modalities, including mobilizations (MWM, Maitland, Mulligan, GM) and soft tissue methods, customized to the particular ailment and recovery phase.

• Highlight neuromuscular retraining to enhance scapular kinematics, glenohumeral joint stability, and comprehensive motor control. Examine the application of proprioceptive neuromuscular facilitation (PNF) methodologies.

• Deliver thorough patient education concerning their disease, treatment regimen, and home exercise protocol to enhance self-management and compliance.

• Engage in good communication and collaboration with other healthcare professionals involved in the patient's care to achieve a coordinated and comprehensive approach.

Future Directions

Future paths in shoulder rehabilitation will likely prioritize tailored treatment strategies based on a comprehensive understanding of individual patient characteristics, biomechanics (Reinold & Savidge, 2009:589), and responses to therapies. Additional rigorous study is required to conclusively determine the long-term efficacy and cost-effectiveness of particular manual therapy modalities, as well as the ideal use of developing technologies for neuromuscular evaluation and training. Examining the potential influence of genetic variables and other biological indicators on predicting rehabilitation outcomes may inform future approaches in shoulder care.

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SHOULDER PROPRIOCEPTION, ISOKINETIC TRAINING AND ALTERNATIVE THERAPEUTIC APPROACHES

BİLAL UYSAL[1]

Introduction

The shoulder joint possesses the widest range of motion in the human body. It is of paramount importance as it permits the functional use of arm and hand movements, a crucial element of individual independence. This extensive mobility and functionality of the shoulder joint are provided by the shoulder complex, which comprises the glenohumeral joint, acromioclavicular joint, sternoclavicular joint, and the scapulothoracic articulation (which is not a true anatomical joint). The shoulder complex is formed by the humerus, scapula, clavicle, and sternum bones, the articulations between these bones, and the ligaments, muscles, and tendons that directly provide strength, function, and stability to these joints. All

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these structures work in a combined manner to execute the functions of the upper extremity, affording the limb a broad range of motion, functionality, and stability (DePalma & Johnson, 2003: 25; Ender, 2022: 59; Norris, 2004; Uğur & Öten, 2024: 21).

Proprioception

Proprioception is a concept first defined by Charles Sherrington in 1906 as the human body's "perception of joint movement and position in space without visual feedback" (Fox et al., 2024). It is defined as the ability to perceive the spatial position, movement, and applied force of the body's organs and joints; this mechanism constitutes one of the cornerstones of neuromuscular control (Proske & Gandevia, 2012: 1651). Proprioception is also described as afferent sensory information originating from the peripheral regions of the body, contributing to joint stability, postural control, and motor control (Fox et al., 2024).

Proprioception relies on mechanoreceptors, which act as transducers converting mechanical energy into electrical nerve impulses. Mechanoreceptors transmit proprioceptive stimuli to the central nervous system via afferent nerves (Vangsness et al., 1995: 180). Generally, proprioception consists of three submodalities: joint position sense, kinesthesia, and sense of force (Riemann & Lephart, 2002: 71; Zanca, Mattiello & Karduna, 2015: 903). Joint position sense is defined as the evaluation and interpretation of information regarding joint position and orientation; kinesthesia is the ability to identify joint movement; and sense of force is the ability to evaluate and interpret forces applied to or generated within a joint (Myers & Lephart, 2000: 351; Zanca, Mattiello & Karduna, 2015: 903).

Proprioception in the Shoulder

The interaction between shoulder function and proprioception is still not fully understood. A decrease in shoulder proprioception can both contribute to shoulder pathologies and result from the pathologies themselves (Fox et al., 2024).

Proprioceptive feedback systems greatly assist the shoulder joint in achieving its wide range of motion and functional independence. The complex anatomy of the glenohumeral joint, the dynamic stabilization provided by the rotator cuff muscles, and the ligamentous structures are the main elements shaping the proprioceptive sensitivity of the shoulder. These elements render the shoulder indispensable for stability, activities of daily living, and physical activities requiring high performance, such as sports or heavy labor (Han et al., 2016: 80).

Shoulder stability involves both passive and dynamic components. Passive structures include bone architecture, intra-articular negative pressure, capsuloligamentous structures, and the glenohumeral labrum. Dynamic structures encompass coordinated muscle contraction around the joint and modulation from the neuromuscular system. Effective proprioception arising from the interplay between these components enhances motor control and functional performance (Bak, Wiesler & Poehling, 2010: 249; Han et al., 2016: 80).

Increasing research interest in shoulder proprioception allows for a better understanding of this mechanism's effects on neuromuscular control and joint health, creating new opportunities for developing treatment approaches and improving patient outcomes (Han et al., 2016: 80).

Importance of Proprioception in the Shoulder

Proprioception, defined as the body's ability to perceive joint position, movement, and the force applied to muscles, occurs through the integration of afferent signals from peripheral mechanoreceptors by the central nervous system (Proske & Gandevia, 2012: 1651). This sensory mechanism is processed via specialized structures such as muscle spindles, Golgi tendon organs, and receptors in the joint capsule, forming the basis of neuromuscular control. In a structure like the shoulder joint, which has a wide range of motion and requires dynamic stability, proprioception provides both static position sense and coordination of kinetic movements. The complex biomechanics of the glenohumeral joint, in particular, reveal that proprioceptive feedback is indispensable for the functionality and stability of this joint (Han et al., 2016: 80). The role of proprioception in the shoulder is not limited to providing joint stability; it also optimizes neuromuscular coordination, reduces the risk of injury, and supports functional recovery (Riemann & Lephart, 2002: 71).

Proprioceptive Mechanisms in the Shoulder

Proprioception in the shoulder joint is shaped by the transmission of sensory information from muscles, tendons, ligaments, and the joint capsule to the central nervous system; this process occurs through the coordinated action of specialized mechanoreceptors (Proske & Gandevia, 2012: 1651). The shoulder's wide range of motion and dynamic stability are largely dependent on the effectiveness of these proprioceptive mechanisms. Among the anatomical structures of the glenohumeral joint, the primary sources of proprioception include muscle spindles, Golgi tendon organs, Ruffini and Pacini corpuscles in the joint capsule, and ligamentous receptors. These structures support neuromuscular control by sensing the shoulder's position, movement, and muscle tension (Han et al., 2016: 80).

The rotator cuff muscles are key components of the proprioceptive system in the shoulder. While stabilizing the joint, these muscles also sense changes in muscle length via muscle spindles, providing continuous information to the central nervous system through afferent pathways. Proske et al. stated that muscle spindles form the basis of proprioceptive sensitivity, especially during dynamic movements, while Golgi tendon organs monitor muscle tension, preventing overload (Proske & Gandevia, 2012:

1651). Han et al. emphasized that components of proprioception, such as joint position sense and kinesthesia, play a significant role in the motor control of the shoulder (Han et al., 2016: 80).

The joint capsule and ligaments also play an important role in the proprioceptive mechanisms of the shoulder. The glenohumeral joint capsule and ligaments detect changes in tension, complementing proprioceptive feedback, which contributes to the dynamic stability of the shoulder (Janwantanakul et al., 2001: 840). Numerous studies have demonstrated the presence of Ruffini and Pacini corpuscles, free nerve endings, and Golgi tendon organ mechanoreceptors within the capsuloligamentous structures of the shoulder joint (Gohlke et al., 1998: 510; Guanche et al., 1999: 615; Soifer et al., 1996: 182; Vangsness et al., 1995: 180). Han et al. showed that these receptors support joint position sense and function as a protective mechanism, particularly during extreme shoulder movements like excessive rotation or abduction. Ruffini corpuscles, being slowly adapting receptors, sense static changes in joint angle, whereas Pacini corpuscles respond to dynamic stimuli such as rapid movement and vibration. The presence of these receptors indicates that the shoulder capsule is not merely a passive structure but also functions as an active proprioceptive sensor (Han et al., 2016: 80).

The anatomical structures and proprioceptive mechanisms in the shoulder form an integrated network supporting the joint's functional capacity; understanding this network is critically important for the diagnosis and treatment of shoulder pathologies.

Studies Related to Proprioception in the Shoulder

Although changes in knee and ankle proprioception caused by musculoskeletal disorders have been studied extensively, current research on shoulder proprioception focuses on specific pathologies (Fabis et al., 2016: 123; Gajdosik & Bohannon, 1987: 1867). Shoulder proprioception has been investigated in conjunction with rotator cuff tears, glenohumeral joint instability, subacromial impingement syndrome, adhesive capsulitis (frozen shoulder), and glenohumeral arthritis (Cuomo, Birdzell & Zuckerman, 2005: 345; Fabis et al., 2016: 123; Gajdosik & Bohannon, 1987: 1867; Gumina et al., 2019: 229; Hetto et al., 2017: 577; Hung & Darling, 2012: 563; Kasten et al., 2009: 1641; Pötzl et al., 2004: 425; Rokito et al., 2010: 564; Sahin et al., 2017: 857; Walecka et al., 2020: 2691).

Proprioceptive impairment plays a significant role in the development and progression of shoulder pathologies. Proprioceptive deficits are frequently reported, particularly in cases of traumatic injuries, chronic instability, and conditions like rotator cuff tears (Gumina et al., 2019: 229; Hetto et al., 2017: 577; Hung & Darling, 2012: 563). A systematic review has shown that proprioceptive sensitivity decreases after rotator cuff injuries, and this deficit is detected in proprioception tests. These losses can impair neuromuscular control, leading to functional limitations and an increased risk of recurrent injury (Ager et al., 2017: 221).

The clinical importance of proprioception is also highlighted in common pathologies such as subacromial impingement syndrome (SAIS) of the shoulder. SAIS negatively affects the proprioceptive feedback capacity of the rotator cuff muscles and surrounding structures, potentially resulting in reduced range of motion and weakened muscle control (Sahin et al., 2017: 857). Han et al. emphasized that methods used for evaluating proprioception are critical in the diagnosis and treatment planning for such pathologies (Han et al., 2016: 80). Furthermore, it has been noted that proprioceptive deficits in patients with chronic shoulder pain may increase pain perception, creating a vicious cycle that hinders recovery (Fox et al., 2024). Fyhr et al. reported that proprioceptive impairments increase muscle fatigue associated with shoulder pain, deepening functional losses (Fyhr et al., 2015: 28).

Another dimension of proprioception's clinical application is in rehabilitation following invasive interventions such as shoulder arthroplasty or arthroscopic surgery. Fyhr et al. suggested that post-surgical proprioceptive losses can disrupt muscle activation patterns and that this can be corrected with proprioceptive rehabilitation (Fyhr et al., 2015: 28). The integration of proprioception into sport-specific rehabilitation programs enables athletes to return to their previous performance levels more quickly (Han et al., 2016: 80). A study by Stokes et al. demonstrated that rehabilitation efforts improved the patient's scapular position, strength, and overall function (Stokes, McCarthy & Frank, 2023: 393). These findings are similar to another study by Salles et al., which showed that an eight-week strength training program consisting of shoulder exercises improved athletes' neuromuscular control and shoulder joint position sense (Salles et al., 2015: 277). Another study by Jung et al. showed that a series of active shoulder exercises reduced shoulder subluxation and improved joint proprioception immediately following a stroke (Jung & Choi, 2019: 4849).

The clinical assessment of proprioception holds a significant place in diagnostic processes. Methods such as joint position sense tests, motion detection threshold measurements, and force reproduction tests are commonly used to determine the degree of proprioceptive loss (Han et al., 2016: 80). These tests offer an objective means of evaluating a patient's proprioceptive status during processes like shoulder instability assessment or postoperative rehabilitation. With recent technological advancements, innovative tools like 3D motion analysis and wearable sensors allow for more precise measurement of proprioception (Proske & Gandevia, 2012: 1651). Additionally, Ager et al. reported that these technologies have proven reliable in the multi-faceted evaluation of shoulder proprioception and support clinical decision-making processes (Ager et al., 2017: 221).

Future research holds the potential to elucidate the role of proprioception in the shoulder in greater detail. Technological advancements, particularly innovative tools like 3D motion analysis and wearable sensors, offer more precise data for the measurement and evaluation of proprioception (Proske & Gandevia, 2012: 1651). These technologies will provide significant opportunities for understanding the pathophysiological mechanisms of proprioceptive deficits and developing individualized treatment approaches (Ager et al., 2017: 221). Moreover, the relationship between proprioception, neuromuscular control, and pain modulation underscores the necessity of a multidisciplinary approach in the management of shoulder pathologies (Fyhr et al., 2015: 28).

In conclusion, the clinical importance of proprioception in the shoulder manifests across a wide spectrum, from the diagnosis of pathologies to rehabilitation strategies. Early diagnosis of proprioceptive deficits and targeted interventions hold a critical place in preserving shoulder function and improving patient outcomes (Ager et al., 2017: 221). Current technologies and exercise approaches have the potential to offer more effective solutions in this field, making proprioception an integral part of modern shoulder treatment.

Isokinetic Exercises in the Shoulder

Introduction

Isokinetic exercises are exercises that enable muscles to contract at a constant speed against controlled resistance. They are considered the exercises that maximally increase muscle strength, generating maximal contraction power at a constant speed throughout the entire range of joint motion. Isokinetic exercises were first developed in the late 1960s by James Perrine (Kocahan T, 2017: 77; Şahin, 2010: 386).

The term "isokinetic" is derived from the Greek words "iso" (same) and "kinetikos" (motion), signifying that muscle contraction occurs at a constant speed. This characteristic distinguishes isokinetic exercises from other types of exercise (isometric or isotonic). Isokinetic exercises are a type of exercise where muscles work at a constant angular velocity against variable resistance. This method allows muscles to generate maximum power throughout the range of motion and is typically performed using specialized isokinetic devices (e.g., Cybex, Biodex, or ISOMED) (Kocahan T, 2017: 77; Şahin, 2010: 386).

Isokinetic dynamometers enable muscle contraction at a constant speed throughout the joint's range of motion and allow for maximum torque production at every angle during contraction. Isokinetic strength is defined as the highest torque value a muscle can produce at a specific speed. An important feature of isokinetic dynamometers is that the speed of the moving segment does not exceed the predetermined constant value; this ensures that the speed remains constant regardless of how much the applied force increases. The individual performing the exercise on an isokinetic dynamometer does not encounter any additional resistance unless they attempt to exceed the device's set speed. This feature makes isokinetic dynamometers a safe and effective tool in the rehabilitation of patients with muscle and ligament injuries. Isokinetic dynamometers provide objective measurements of muscle strength, power, and endurance, making them increasingly common for assessing muscle performance (Kocahan T, 2017: 77; Şahin, 2010: 386).

Applications of Isokinetic Exercises (Morrissey, Harman & Johnson, 1995: 648; Şahin, 2010: 386)

1. Assessment: Evaluation of muscle strength is considered the primary function of these systems. This is achieved using data such as torque, work, and endurance, which provide information about the muscle's dynamic performance.

2. Rehabilitation: Isokinetic exercises are widely used to safely regain muscle strength after muscle and joint injuries (e.g., rotator cuff tears, knee ligament injuries). The risk of injury is low because the resistance adapts to the patient's capacity.

3. Sports Medicine: Used to detect muscle imbalances in athletes and optimize performance. These devices allow training at different and controlled speeds, making them suitable for sport-specific training.

4. Research: Isokinetic dynamometers are frequently used in research studies because they present dynamic muscle functions as measurable evaluations. They are preferred for collecting objective data in scientific studies on muscle biomechanics and neuromuscular adaptation.

Advantages of Isokinetic Exercises (Şahin, 2010: 386; Wilk, Arrigo & Davies, 2024: 374)

- **a.** Maximal muscle activation at every angle of movement
- **b.** Low risk of injury
- **c.** Objective and quantitative measurement of muscle performance

Disadvantages of Isokinetic Exercises (Şahin, 2010: 386; Wilk, Arrigo & Davies, 2024: 374)

- **a.** Requires patient motivation
- **b.** Needs specialized and expensive equipment and space
- **c.** Requires expert supervision and experienced personnel

Applications of Isokinetic Exercises in the Shoulder

The shoulder complex, with its wide range of motion and complex biomechanics, plays a critical role in both activities of daily living and athletic performance. However, these characteristics also make the shoulder joint susceptible to instability and injury. Conditions such as rotator cuff injuries, shoulder impingement syndrome, and instability can negatively impact individuals' quality of life by causing pain and functional limitations in the shoulder.

Isokinetic exercises offer the ability to measure and improve muscle strength and endurance by providing resistance at a constant speed. This method is considered an effective tool in shoulder rehabilitation and performance enhancement (Ellenbecker & Davies, 2000: 338). Isokinetic dynamometry is commonly used for the objective assessment of shoulder rotator muscle strength. Ellenbecker et al. stated that isokinetic testing is a valuable tool in shoulder rehabilitation for measuring muscle performance and guiding the treatment plan (Ellenbecker & Davies, 2000: 338). Missmann et al. reported that an isokinetic exercise program performed with a Baltimore Therapeutic Equipment (BTE) device resulted in significant improvements in shoulder abduction range of motion and scores on the Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire, used to assess functional status (Missmann et al., 2022).

Studies on the effect of isokinetic exercises in the treatment of subacromial impingement syndrome (SAIS) present conflicting results. Wang et al. reported that isokinetic exercises reduced pain and improved shoulder function in patients with SAIS (Wang et al., 2014: 744). However, a systematic review emphasized the lack of sufficient randomized controlled trials (RCTs) to determine the isolated effect of isokinetic exercises. Nevertheless, evidence is growing that eccentric isokinetic exercises increase strength and flexibility in the shoulder rotator muscles (Vetter et al., 2023: e0293439).

The role of isokinetic exercises in increasing shoulder strength in healthy individuals and athletes has also been investigated. Abdelraouf et al. found that shoulder muscle ratios (e.g., external/internal rotator ratio) measured by isokinetic tests in weightlifters were significantly lower compared to a control group (Abdelraouf et al., 2022). This suggests that isokinetic exercises may play a potential role in correcting muscle imbalances.

Studies support isokinetic exercises as a valuable method for shoulder rehabilitation and performance enhancement. Multi-planar movements, in particular, appear to be more effective as they provide a closer biomechanical match to activities of daily living (Missmann et al., 2022). However, isokinetic testing also has limitations, such as the inability of some patients (e.g., after rotator cuff repair) to reach the set speeds (Ellenbecker & Davies, 2000: 338).

Furthermore, more research is needed regarding the long-term effects and optimal protocols for isokinetic exercises. The lack of standardized treatment approaches for specific conditions like

SAIS makes it difficult to evaluate the effectiveness of isokinetic exercises. Future studies should focus on increasing the homogeneity of patient populations and examining the specificity of isokinetic data in different shoulder pathologies.

In conclusion, isokinetic exercises in the shoulder have the potential to measure muscle strength, support functional recovery, and enhance performance. While current evidence supports the integration of this method into rehabilitation programs, methodological limitations and heterogeneous results must be considered. Isokinetic dynamometry and exercises are powerful tools for optimizing shoulder health; however, individualized approaches and more RCTs are necessary to maximize their effectiveness.

Alternative Treatment Methods in Shoulder Pathologies

Common shoulder pathologies such as adhesive capsulitis (frozen shoulder), rotator cuff tendinopathies, and subacromial impingement syndrome are characterized by pain and functional loss in patients (Neviaser & Hannafin, 2010: 2346). To alleviate patients' complaints and regain joint function in shoulder lesions, conventional treatment methods including medical therapies, physical therapy applications, exercise, and surgical treatments are employed. Alongside these treatment methods, alternative treatment methods are also applied depending on the patient's condition, the type of lesion (e.g., rotator cuff tear, labral tear, shoulder instability, or subacromial impingement), and the severity of symptoms. These methods aim to reduce pain, restore function, and support healing.

Alternative Treatment Methods

1. Acupuncture

Acupuncture provides analgesic effects through neuromodulation and endogenous opioid release (Zhang et al., 2014: 482). When applied to the shoulder region, it has been hypothesized to reduce inflammation in conditions like subacromial bursitis and rotator cuff tendinopathies. A Cochrane review on acupuncture for shoulder pain examined nine studies but did not find significant results favoring acupuncture due to small sample sizes and low study quality (Green, Buchbinder & Hetrick, 2005: 53). However, a systematic review and meta-analysis evaluating acupuncture treatment in patients with adhesive capsulitis suggested that acupuncture may be safe and effective in the short and medium term for reducing shoulder pain, increasing joint range of motion, and restoring shoulder function. Yet, due to the very low level of evidence, they stated the need for higher quality and longer-term studies to strengthen the evidence base (Ben-Arie et al., 2020: 9790470).

2. Manipulation and Mobilization

Manipulation and mobilization constitute a treatment method involving the manual adjustment of the spine and joints. A randomized controlled trial examining the effectiveness of manipulation in patients with shoulder pain showed positive effects on pain and range of motion (Hains, 2002: 192). A systematic review evaluating manipulative therapies for shoulder pain and discomfort stated that there is moderate or Level B evidence for the use of manipulative therapies for shoulder complaints, dysfunction, disorders, and/or pain (Brantingham et al., 2011: 314; Hains, 2002: 192).

3. Phytotherapy

Herbal components such as curcumin (from Curcuma longa, turmeric) exhibit anti-inflammatory effects through cyclooxygenase-2 (COX-2) inhibition (Aggarwal et al., 2007: 1). Arnica (Arnica montana), when applied topically, provides relieving effects on edema and pain. Although the effects of curcumin on osteoarthritis have been confirmed in randomized studies, its efficacy in shoulder-specific pathologies is limited and requires support from clinical data (Daily, Yang & Park, 2016: 717).

4. PRP (Platelet-Rich Plasma) Therapy

Platelet-rich plasma, obtained from the patient's own blood, is injected into the site of lesions, particularly in shoulder pathologies like partial rotator cuff tears or chronic tendinitis, with the aim of accelerating the healing process. PRP therapy supports tissue repair through the growth factors contained within the platelet-rich plasma fluid. It is a highly popular alternative treatment method due to being non-surgical and natural. A systematic review and meta-analysis evaluating the effectiveness of PRP in rotator cuff tears shows that PRP treatment reduces pain and improves shoulder function, but indicates a need for more research regarding long-term effects. Generally, the results suggest that PRP treatment can positively influence clinical outcomes, but limited data and the poor methodological quality of studies prevent definitive conclusions (Chen et al., 2020: 2028; Jiang et al., 2023: 272).

5. Stem Cell Therapy

Stem cell therapy involves injecting mesenchymal stem cells, obtained from the patient's bone marrow or adipose tissue, into the damaged area, aiming to regenerate cartilage, tendon, or muscle tissue. It is a regenerative approach and holds promise as an alternative to surgery. Mesenchymal stem cells derived from sources like bone marrow and adipose tissue show promising effects in vitro by regulating tendon-related gene expression and modulating the microenvironment. Studies in animal models reveal that stem cell therapies reduce inflammation, support tissue remodeling, and increase the strength of the repaired tendon. Human trials, however, present limited and heterogeneous results; while some studies suggest that stem cell therapy reduces re-tear rates and provides functional improvement after surgery, randomized controlled trials report conflicting findings and highlight the need for more standardized research (Hooper et al., 2024: 3139).

6. Ozone Therapy

Ozone therapy is considered one of the non-surgical alternative treatment methods for managing shoulder lesions (e.g., rotator cuff tears, tendinitis, bursitis, and adhesive capsulitis). Ozone gas (O_3) is typically administered via intra-articular or peri-articular injection and provides anti-inflammatory effects by producing reactive oxygen species (ROS). This process supports the suppression of pro-inflammatory cytokines (IL-1β, TNF-α) and improvement of microcirculation, thereby aiming for pain reduction and functional recovery. Ozone therapy shows potential as an adjuvant option with its anti-inflammatory and analgesic effects in shoulder lesions. It may be particularly effective in pain management for inflammatory conditions like tendinitis and bursitis. However, current evidence is primarily based on pilot studies and observational data, and more evidence is required for it to be recommended as a standard treatment (Akkawi, 2020: e2020191).

Conclusion (Alternative Therapies)

Alternative treatment methods for shoulder lesions offer a wide range of options for patients seeking non-surgical solutions or alternatives to conventional treatments. However, the effectiveness of each treatment method depends on the individual situation, and scientific evidence for some methods is not yet fully conclusive. Higher quality randomized controlled clinical trials with longer follow-up periods are required to increase the level of evidence for alternative treatment methods.

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IMAGING THE SHOULDER: ESSENTIAL RADIOLOGICAL PERSPECTIVES

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1. Introduction

Shoulder discomfort is a common musculoskeletal complaint. People present with it in many clinical settings often leading to diagnostic imaging (Aydıngöz 2022:101; Leung & Griffith 2019:3; Nwawka Kothary & Miller 2019:67; Prakash et al. 2024:102384). The shoulder ranks high among frequent sites for musculoskeletal trouble (Leung & Griffith 2019:3; Nwawka Kothary & Miller 2019:67; Prakash et al. 2024:102384). Shoulder discomfort stems from diverse conditions. These problems affect bone soft-tissue parts alike (Nwawka Kothary & Miller 2019:67; Zlatkin 2002:117). Common causes include rotator cuff issues like tendinopathy tears. Impingement syndromes glenohumeral

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instability labral tears adhesive capsulitis fractures dislocations arthropathies are also frequent. Nerve entrapments tumors although rare can also cause shoulder pain (Dirim 2017:25; Eajazi Bredella & Torriani 2019:321; Nwawka Kothary & Miller 2019:67; Walker Minn & Murphey 2019:269; Zlatkin 2002:117).

Pinpointing the underlying pathology is key for good patient care. Knowing the cause of shoulder discomfort guides treatment selection. Options might range from conservative care to surgical steps. A definite diagnosis helps provide an accurate outlook. It also aids tracking disease progress treatment success. Radiology plays a vital part in the diagnostic workup. It offers important views into the shoulder complex's structural sometimes functional state (Aydıngöz 2022:101; Dirim 2017:25; Prakash et al. 2024:102384).

Several imaging methods help assess the shoulder. Each technique has unique strengths weaknesses (Aydıngöz 2022:101; Dirim 2017:25; Hobbs & Morrison 2011:24). Direct radiography or plain films are usually the first imaging step. This is especially true in acute trauma providing key details on fractures dislocations bone irregularities (Dirim 2017:25; Hobbs & Morrison 2011:24). Ultrasonography (US) uses high-frequency sound. It creates real-time soft tissue images. US proves very useful evaluating the rotator cuff biceps tendon bursae. It also assists guiding interventions (Diep et al. 2024; Yemin & Adler 2019:55). Computed tomography (CT) uses X-rays computer processing. It generates cross-section pictures excelling at detailed fracture assessment. CT clarifies fracture complexity displacement helps evaluate glenoid bone loss plan arthritis surgery (Leung & Griffith 2019:3). Magnetic resonance imaging (MRI) employs powerful magnets radio waves. It yields high-definition multiplanar images showing soft tissues exceptionally well. MRI is often preferred evaluating many shoulder problems tendons ligaments muscles labrum hidden fractures included (Prakash et al. 2024:102384). Other methods like arthrography exist too. Usually done with CT or MRI arthrography involves injecting contrast material into the joint. This step enhances views of joint structures problems particularly labral capsular damage (Hsu Afifi & Isaac 2024:1264; Palmer 2002:277).

Shoulder radiography matters across several medical fields. Many specialties handle patients with shoulder conditions (Blake Hochman & Edelman 2002:1; Hobbs & Morrison 2011:24). Orthopedic surgeons depend on imaging. They use it detecting fractures dislocations rotator cuff tears labral damage. Imaging supports preoperative planning for instability arthritis trauma cases (Aydıngöz 2022:101; Yamada & McKinnis 2020:513). Rheumatologists use imaging assessing inflammatory joint diseases like rheumatoid arthritis. They also evaluate conditions such as calcific tendinitis adhesive capsulitis (Huang & Schweitzer 2019:211; Prakash et al. 2024:102384; Tamai et al. 2024:365). Physiatrists employ imaging finding muscle tendon issues nerve entrapments. It informs rehab plans after injury surgery (Eajazi

Bredella & Torriani 2019:321). Solid understanding of shoulder radiology imaging is fundamental for relevant healthcare workers. This knowledge lets them use these diagnostic aids effectively helping patients (Blake Hochman & Edelman 2002:1).

2. Anatomy of the Shoulder and Radiological Correlation

Understanding the shoulder girdle's detailed anatomy is key. This knowledge permits accurate reading of shoulder x-rays imaging studies. The shoulder girdle is a complex zone. It contains bones joints muscles ligaments the joint capsule bursae. All these parts work together giving the upper limb its impressive motion range (Dirim 2017:25; Yu 2019:191).

2.1. Fundamental Anatomical Components of the Shoulder

The shoulder's bony frame uses three main bones. These are the humerus scapula clavicle. The humerus is the upper arm's long bone. Its near end includes the humeral head. This head joins the scapula's glenoid fossa (Yamada & McKinnis 2020:513). Below the head's articular cartilage sits the anatomical neck. Next come the greater lesser tuberosities. The intertubercular (bicipital) groove separates them. The narrow part below the tuberosities is the surgical neck. Fractures often happen here (Yamada & McKinnis 2020:513). The scapula or shoulder blade is a flat triangle-shaped bone. It lies on the back thorax (Yamada & McKinnis 2020:513). Key scapular features include the spine. This structure runs backward ending sideways as the acromion process. The coracoid process juts forward from the scapula's upper edge. The glenoid fossa is a shallow dish on the scapula's side edge. It meets the humeral head forming the glenohumeral joint. The clavicle or collarbone is a long thin bone. It connects near the body center to the sternum (sternoclavicular joint). Outwardly it links to the scapula's acromion process (acromioclavicular joint) (L. S. Beltran Tafur & Bencardino 2019:147; Diep et al. 2024).

Multiple joints allow shoulder complex movement stability. The glenohumeral joint is a ball-and-socket synovial type. It acts as the shoulder's main joint. Stability challenges arise here. The large humeral head meets the relatively small glenoid fossa. Nearby soft tissue structures help manage this inherent looseness (Dirim 2017:25; Yamada & McKinnis 2020:513; Yemin & Adler 2019:55; Zlatkin Hoffman & Needell 2002:85). The acromioclavicular (AC) joint is a synovial joint. It sits between the clavicle's far end the scapula's acromion. The sternoclavicular (SC) joint is another synovial junction. It connects the clavicle's inner end to the sternum's manubrium the first rib cartilage. The scapulothoracic connection isn't a true synovial joint. It represents the working link between the scapula's front surface the back chest wall. Muscles allow this link letting the scapula glide on the thorax. This glide greatly boosts shoulder motion range. Standard x-rays often show the AC joint poorly. Special views like the Zanca view become necessary (Dirim 2017:25; Yamada & McKinnis 2020:513; Yemin & Adler 2019:55; Zlatkin Hoffman & Needell 2002:85).

Muscles around the shoulder joint are vital for function. The rotator cuff includes four muscles their tendons. They wrap the glenohumeral joint providing support allowing broad motion (Chang & Chung 2019:87; Yemin & Adler 2019:55). These muscles are supraspinatus infraspinatus teres minor subscapularis. The supraspinatus mainly handles abduction. It works especially in the first 15-20° of arm lifting. The infraspinatus teres minor act as the arm's external rotators. The subscapularis is the arm's main internal rotator. The deltoid muscle lies over the rotator cuff. It's the prime mover for abduction beyond the supraspinatus's initial work. Other muscles like pectoralis major latissimus dorsi biceps brachii also help shoulder movement stability (L. S. Beltran et al. 2019:127; Chang & Chung 2019:87; Yemin & Adler 2019:55; Zlatkin 2002:117).

The glenohumeral joint's stability gets help. An intricate system of ligaments the joint capsule provides this support. The glenohumeral joint capsule is a loose fibrous pouch. It encloses the joint (Zlatkin Hoffman & Needell 2002:85). The glenohumeral ligaments (superior middle inferior) are thickened parts of the front joint capsule. They grant static stability particularly at different motion ranges. The coracohumeral ligament runs from the coracoid process to the humerus's tuberosities. It boosts stability especially during external rotation (Tamai et al. 2024:365). The glenoid labrum is a fibrocartilage rim. It attaches to the glenoid fossa's edge deepens the socket. This structure increases glenohumeral joint stability.

Numerous bursae sit around the shoulder joint. These fluid-filled sacs reduce friction between moving parts. The subacromial-subdeltoid bursa lies between the acromion deltoid muscle above the rotator cuff tendons below. It's often a site for inflammation pain. The subscapularis bursa sits between the subscapularis tendon scapular neck. It often connects to the glenohumeral joint. The subcoracoid bursa lies between the subscapularis tendon the combined coracobrachialis short head biceps tendon (Dirim 2017:25; Leung & Griffith 2019:3; Zlatkin Hoffman & Needell 2002:85).

2.2 Anatomical Landmarks in Radiologic Images

Identifying anatomical features on different imaging types is key. Accurate interpretation depends on this skill. Bony landmarks show up best on direct x-rays (Dirim 2017:25). Anteroposterior views in varied rotations (neutral internal external) help assess many structures. The humeral head greater lesser tuberosities anatomic surgical necks glenoid fossa acromion coracoid process scapular spine clavicle are visible (Dirim 2017:25; Yamada & McKinnis 2020:513). Acromion shape (types I II III) might relate to rotator cuff impingement. Lateral outlet x-rays help evaluate this shape (Hobbs & Morrison 2011:24). The greater tuberosity shows clearly on AP external rotation views. The lesser tuberosity appears better on internal rotation views (Leung & Griffith 2019:3). The coracoid process usually appears on AP oblique (scapular Y) views. These views also help spot anterior posterior shoulder dislocations (Leung

& Griffith 2019:3). Fractures of these bony parts are readily seen on radiographs. X-rays clearly show calcifications in tendons bursae like in calcific tendinitis (Hobbs & Morrison 2011:24; Leung & Griffith 2019:3).

Ultrasound (US) allows real-time viewing of soft tissue parts (Yemin & Adler 2019:55). One can directly see rotator cuff tendons the biceps tendon deltoid muscle superficial bursae (e.g. subacromial-subdeltoid bursa). Tendons look like fibrous bright structures. Muscles show a darker background with bright connective tissue strands. Fluid collections in bursae tendon sheaths appear readily. They show as dark or black areas. Ultrasound helps with dynamic checks guiding procedures (Hobbs & Morrison 2011:24; Yamada & McKinnis 2020:513; Yemin & Adler 2019:55).

Magnetic resonance imaging (MRI) gives superior soft tissue contrast. It permits detailed looks at muscles tendons ligaments cartilage bone marrow. Different pulse sequences (like T1-weighted T2-weighted fat-saturated) highlight distinct tissue characteristics. Rotator cuff muscles tendons appear clearly defined. The biceps tendon within the bicipital groove is also well seen. Glenoid labrum glenohumeral ligaments assessment is possible. Injecting contrast into the joint (MR arthrography MRA) especially helps this. MRI detects subtle soft tissue problems. Tendinopathy tears bursitis synovitis are examples. Bony features show clearly too helping find fractures bone marrow swelling neoplasms. Axial sagittal coronal planes are commonly used. They provide varied viewpoints for shoulder anatomy assessment (Dirim 2017:25; Hobbs & Morrison 2011:24; Jensen & Rockwood 2009:177).

Computed tomography (CT) excels assessing bony structures. It provides detailed cross-section images of humerus scapula clavicle. Fractures dislocations bone lesions appear sharply defined. CT arthrography involves injecting iodinated contrast into the joint. This technique gives excellent views of the glenoid labrum articular cartilage. CT shows soft tissues less well than MRI. But it proves useful in certain situations like complex fractures or when MRI cannot be done (Dirim 2017:25; Nwawka Kothary & Miller 2019:67).

2.3 Functional Anatomy and Clinical Correlations

The shoulder's anatomical parts interact intricately. This interplay dictates its wide motion range. Rotator cuff muscles are central to glenohumeral joint movement. They enable abduction (supraspinatus deltoid) external rotation (infraspinatus teres minor) internal rotation (subscapularis). Rotator cuff tendon tears often cause shoulder pain weakness. They limit active motion particularly abduction rotation. A supraspinatus tendon tear usually brings pain weakness when lifting the arm. Rotator cuff health is vital. It keeps the humeral head centered in the glenoid fossa during arm motion (Chang & Chung 2019:87; Zlatkin 2002:117).

The glenohumeral joint capsule ligaments provide static stability. This support matters most at movement extremes. Injuries here like labral tears ligament looseness (seen in GH instability) cause problems. Pain clicking a sense the shoulder might "pop out" can result. These issues may limit overhead work movements needing external rotation abduction. An anterior inferior labrum tear (Bankart lesion) often follows forward shoulder dislocation. It can lead to repeated instability particularly with the arm raised abducted externally rotated (L. S. Beltran Tafur & Bencardino 2019:147; Chang & Chung 2019:87; Zlatkin Hoffman & Needell 2002:85).

The biceps tendon starts at the supraglenoid tubercle. It runs through the bicipital groove helps with shoulder flexion forearm supination (Zlatkin Hoffman & Needell 2002:85). Biceps tendon problems like tendinitis tears cause anterior shoulder pain. Resisted elbow bending supination can worsen this pain. The long head biceps tendon sheath connects with the GH joint. Fluid in this sheath might be a non-specific finding. Or it could point to disease within the joint (Hsu Afifi & Isaac 2024:1264; Leung & Griffith 2019:3).

The subacromial-subdeltoid bursa allows smooth rotator cuff tendon gliding. This occurs under the acromion deltoid during arm elevation. Bursitis or inflammation here causes significant pain. Overhead activities movements pressing the bursa (like internal rotation adduction) often trigger it (Hsu Afifi & Isaac 2024:1264; Leung & Griffith 2019:3).

Solid grasp of shoulder structure how it appears on imaging is fundamental. Precise identification of shoulder pathology relies on it. Radiologists clinicians use the link between anatomy imaging features. This helps them find the root causes of shoulder discomfort functional limits. Understanding this relationship informs effective treatment plans (Aydıngöz 2022:101).

3. Imaging Modalities

Diagnostic imaging strongly supports clinical checks for upper limb problems. Thorough knowledge of imaging options is necessary. This helps select the best most cost-effective test for a specific clinical need. Shoulder problems commonly involve several imaging types. Each type has its own pluses minuses uses typical findings (Hobbs & Morrison 2011:24).

3.1 Direct Radiography (X-Ray)

Fundamental Assessment: Direct radiography is a basic starting point imaging shoulder issues (Aydıngöz 2022:101; Dirim 2017:25; Hobbs & Morrison 2011:24; Magneli et al. 2024:319). A standard shoulder x-ray series usually includes several views. This ensures good visibility of bone structures GH AC joints (Aydıngöz 2022:101). Common x-ray views typically include an anteroposterior (AP) shot in neutral rotation. An AP oblique view an axillary view a lateral scapula view (scapular Y) are also standard (Aydıngöz 2022:101; Dirim 2017:25). Extra specialized x-ray pictures might be needed. AP views in internal external rotation the Grashey view (AP shot patient turned 45° toward affected side) the Garth view Stryker notch view are examples. Clinical suspicion guides their use (Aydıngöz 2022:101; Dirim 2017:25). Internal external rotation AP views reveal the greater humeral tubercle's middle superior aspects. They allow measuring infraspinatus supraspinatus tendon insertion sites. The head-on scapular Y view depicts humeral head glenoid fossa relations. Axillary views show these relations the GH joint well. Arm abduction difficulty after trauma might require adjusted axillary views like the Velpeau view. The Grashey view highlights the GH joint supraspinatus insertion critical shoulder angle (CSA). CSA links to osteoarthritis rotator cuff disease. Viewing the AC joint sometimes requires special methods. Techniques with limited exposure or a headward beam tilt (Zanca view) avoid over-penetration. Suspected scapular fracture needs AP scapulolateral views for proper assessment. A straightforward scapular spine labeling technique helps technologists get true scapulolateral shots (Aydıngöz 2022:101; Jensen & Rockwood 2009:177; Yamada & McKinnis 2020:513).

Plain film radiography is usually the first imaging choice for acute shoulder discomfort. This holds particularly for suspected trauma fracture dislocation. X-rays are key for initial checks of GH dislocation AC joint injury humerus scapula clavicle fractures. For acute trauma x-rays serve as the first step ruling out fracture dislocation (Eajazi Bredella & Torriani 2019:321). X-rays also begin the imaging workup for clinically suspected impingement (Hobbs & Morrison 2011:24).

Direct radiography mainly assesses bone structure integrity. It shows fracture presence type displacement (Dirim 2017:25; Eajazi Bredella & Torriani 2019:321). It helps evaluate joint spaces like GH AC joints. Narrowing might suggest osteoarthritis (Hobbs & Morrison 2011:24). X-rays clearly depict soft tissue calcifications seen in calcific tendinitis bursitis (Dirim 2017:25; Hobbs & Morrison 2011:24; Hsu Afifi & Isaac 2024:1264). Certain x-ray findings can indirectly point to soft tissue problems. A high-riding humeral head might hint at a chronic rotator cuff tear for example. Bone growths on the greater tuberosity subacromial spurs suggest impingement. An os acromiale an unfused bone center linked to cuff impingement shows on x-ray. For possible nerve entrapment x-rays rule out bony causes. Examples include complete bone blockage or near-blockage of the suprascapular notch (Stryker notch view). Identifying bony notch variations (suprascapular notch view) is also possible (Eajazi Bredella & Torriani 2019:321).

Key advantages of direct radiography include low-cost quick performance wide availability. This non-invasive method works well as an initial screen for bone joint issues (Eajazi Bredella & Torriani 2019:321; Hobbs & Morrison 2011:24).

Disadvantages: A main drawback of radiography is poor soft tissue detail. Tendons ligaments muscles labrum doesn’t show well. Radiography also uses ionizing radiation though standard shoulder series doses are usually low. Subtle hidden fractures bone marrow problems thorough soft tissue disease checks require more advanced imaging (Dirim 2017:25).

3.2 Ultrasonography (US)

Advantages of Dynamic Imaging: Ultrasonography offers a clear plus real-time viewing. This allows dynamic checks of the shoulder during motion provocative tests (Aydıngöz 2022: 101; Hobbs & Morrison 2011: 24; Hsu Afifi & Isaac 2024: 1264; Yemin & Adler 2019: 55). This ability proves particularly helpful assessing problems like impingement syndromes. It lets doctors see the subacromial bursa rotator cuff tendons move during specific arm maneuvers (Hobbs & Morrison 2011: 24). Dynamic ultrasound can reveal issues static images might miss (Yemin & Adler 2019: 55). Clinicians can track the humeral head's movement relative to the acromion during abduction. This real-time monitoring helps check for subacromial impingement (Chang & Chung 2019: 87).

Shoulder ultrasonography mainly looks at surface soft tissue parts. These include rotator cuff tendons (supraspinatus infraspinatus subscapularis teres minor). The biceps tendon (long short heads) bursae (especially subacromial-subdeltoid) joint fluid collections are also checked (Aydıngöz 2022: 101; Chang & Chung 2019: 87; Dirim 2017: 25; Yemin & Adler 2019: 55). US can spot rotator cuff tears tendinopathy tendon calcifications (Aydıngöz 2022: 101; Dirim 2017: 25; Yemin & Adler 2019: 55). Biceps tendon issues like tenosynovitis subluxation rupture show up clearly (Aydıngöz 2022: 101). Ultrasonography effectively spots fluid buildup in the subacromial-subdeltoid bursa indicating bursitis. Joint fluid can be seen too though viewing inside-joint structures like the glenoid labrum ligaments is limited (Aydıngöz 2022: 101). Color power Doppler imaging adds value during checks. It helps spot increased blood flow (hyperemia). This finding might relate to symptomatic tendinopathy inflammation healing stages (Yemin & Adler 2019: 55). Ultrasound can also gauge rotator cuff muscle wasting (Hobbs & Morrison 2011: 24).

Ultrasonography uses no radiation is cost-effective portable. This makes it readily available in many medical settings (Hobbs & Morrison 2011: 24; Nwawka Kothary & Miller 2019: 67). The real-time dynamic check ability is a major benefit. It helps link imaging findings directly with patient symptoms physical exam results (Yemin & Adler 2019: 55). US can guide shoulder procedures like injections aspirations. Additionally, some research suggests shoulder ultrasound's diagnostic accuracy for rotator cuff damage rivals traditional MRI. However, this accuracy heavily depends on the operator's skill (Yemin & Adler 2019: 55).

A key downside of shoulder ultrasonography is operator dependence. Diagnostic accuracy relies strongly on the sonographer's experience skill (Yemin & Adler 2019: 55). Ultrasound's ability penetrating deep viewing bone deep joint parts is limited. Glenoid labrum glenohumeral ligaments articular cartilage are examples (Aydıngöz 2022: 101; Yemin & Adler 2019: 55). Overlying bone air can block views of certain structures. Ultrasound is also generally less adept than MRI finding hidden fractures bone marrow issues complex soft tissue problems (Dirim 2017: 25). Checking nerve entrapment syndromes proves difficult. Consistently showing muscle swelling seeing nerves clearly along their full path is challenging. Metal artifacts from prior surgeries can hinder image quality too (Yemin & Adler 2019: 55).

3.3 Magnetic Resonance Imaging (MRI)

MRI stands as the main tool for advanced shoulder musculoskeletal imaging. Its exceptional power showing soft tissue structures with high contrast resolution drives this status. Unlike x-ray CT MRI uses no ionizing radiation. It relies instead on the magnetic behavior of hydrogen protons within the body (Blake Hochman & Edelman 2002: 1).

MRI skillfully depicts numerous soft tissues in around the shoulder joint. It gives vital information for diagnosing many conditions. Various pulse sequences tap into tissues' unique relaxation traits. This process creates contrast highlighting specific anatomical parts clinical states (Blake Hochman & Edelman 2002: 1; Hobbs & Morrison 2011: 24). Applying these sequences smartly across different planes allows thorough checks. Axial coronal sagittal views often angled to match specific anatomy permit detailed study of muscles tendons ligaments capsules labra cartilage bone marrow (Aydıngöz 2022: 101; Blake Hochman & Edelman 2002: 1; Hobbs & Morrison 2011: 24).

MRI's main strength is superior soft tissue contrast. This allows detailed viewing of the shoulder joint's complex anatomy nearby tissues. MRI also involves no radiation making it attractive for children patients needing repeat scans. Its multiplanar imaging ability permits comprehensive checks across several anatomical views. This improves pathology detection characterization (Aydıngöz 2022: 101; Blake Hochman & Edelman 2002: 1; Hobbs & Morrison 2011: 24).

Disadvantages: Despite its strengths MRI has limits. This imaging method costs more compared to x-ray ultrasound (Yemin & Adler 2019: 55). Scan times are longer potentially troubling patients who cannot lie still. Movement artifacts can result degrading image quality (Hobbs & Morrison 2011: 24; Soldatos Shah & Chhabra 2024: 418). People with claustrophobia might feel intense discomfort inside the MRI scanner's tight space sometimes needing sedation. MRI use requires caution for individuals with certain metal implants. Pacemakers some surgical hardware metallic foreign objects pose potential safety risks. They can also create metal susceptibility artifacts obscuring nearby anatomy. Open MRI scanners are available but often use weaker magnetic fields. This lower field strength can result in poorer image quality (Hobbs & Morrison 2011: 24).

3.4 Computed Tomography (CT)

Computed Tomography (CT) uses X-rays computer analysis. It creates cross-section body images (Leung & Griffith 2019: 3). MRI shows soft tissue better. But CT excels giving detailed views of bone structure (Aydıngöz 2022: 101).

Bone Structure Analysis: CT is the go-to method checking skeletal problems thoroughly in the shoulder (Aydıngöz 2022: 101; Yamada & McKinnis 2020: 513). Its high spatial resolution allows close checks of cortical trabecular bone. CT proves particularly useful in certain clinical settings. These include complex fractures bone tumors evaluating prostheses measuring glenoid bone loss. Pre-surgery planning for severe glenohumeral arthritis fracture healing checks three-dimensional reconstructions also benefit (L. S. Beltran et al. 2019: 127; L. S. Beltran Tafur & Bencardino 2019: 147; Dirim 2017: 25; Hobbs & Morrison 2011: 24; Leung & Griffith 2019: 3).

CT offers several pluses assessing the shoulder. It is a fast imaging method. Picture taking times are much shorter than MRI's. This technique gives superior bony structure detail making it preferred for fracture checks other bone issues. CT is usually more available less expensive than MRI (Hobbs & Morrison 2011: 24; Leung & Griffith 2019: 3).

Disadvantages: CT's main downside is using ionizing radiation. This is a notable concern for younger patients situations where radiation-free methods give needed diagnostic answers. Additionally CT shows poorer soft tissue contrast than MRI. This limits its use checking tendons ligaments muscles labrum unless enhanced. Adding intra-articular contrast in CT arthrography improves these views (Hobbs & Morrison 2011: 24; Leung & Griffith 2019: 3; Prakash et al. 2024: 102384).

3.5 Arthrography

Arthrography involves injecting contrast material directly into a joint space. This radiography technique enhances views of inside-joint structures. Historically doctors used conventional x-rays after contrast injection assessing joint problems. But better cross-section imaging methods have largely taken over shoulder assessments. Magnetic resonance arthrography (MRA) computed tomography arthrography (CTA) are chief among these replacements (Aydıngöz 2022: 101; Palmer 2002: 277). MR arthrography usefully builds on standard MRI. It involves injecting contrast agent into the joint usually a weakened gadolinium-based liquid (Yamada & McKinnis 2020: 513). Putting contrast in the joint space expands it clarifies inside-joint parts. This greatly boosts detection of subtle problems like labral tears capsular issues (Yamada & McKinnis 2020: 513). MR arthrography finds common use checking suspected glenohumeral instability SLAP lesions rotator cuff injuries. It helps particularly with partial-thickness tears connecting to the joint surface. Doctors may perform the injection using fluoroscopy ultrasound CT guidance. Sometimes they use anatomical landmarks without direct imaging help. Taking scans in the ABduction External Rotation (ABER) position during MRA stresses the anterior capsulolabral complex. This stress improves finding lesions linked to anterior instability like Bankart tears (Yamada & McKinnis 2020: 513).

Traditionally arthrography allowed viewing anatomical parts hard to see on standard x-rays. Rotator cuff labrum joint capsule are examples. It could show full-thickness rotator cuff damage via contrast leaking into the subacromial-subdeltoid bursa (Palmer 2002: 277).

Disadvantages: Conventional arthrography is invasive requires joint puncture. This carries infection discomfort risks (Zlatkin 2002: 117). Its ability showing soft tissue details falls short compared to MRI ultrasound (Dirim 2017: 25). The images obtained were mostly two-dimensional limiting checks of complex 3D anatomy disease. Sources show MRA is now preferred for intra-articular contrast soft tissue checks (Palmer 2002: 277; Yamada & McKinnis 2020: 513).

Indications: Though less common now traditional arthrography might still apply sometimes. Specific situations include when MRI is not possible (e.g. patients with certain metal implants). It might also serve when a basic check of joint connection substantial rotator cuff damage is needed. Historically doctors used it assessing rotator cuff injuries labral tears adhesive capsulitis (Palmer 2002: 277).

Key Findings: Arthrography might show contrast leaking outside the joint capsule indicating rotator cuff tears. It could outline labral tears with the contrast agent show capsular problems in adhesive capsulitis (Palmer 2002: 277).

3.6 Positron Emission Tomography/Computed Tomography

Positron Emission Tomography/Computed Tomography (PET/CT) is a combined imaging method. It merges PET's functional information CT's anatomical detail (Hobbs & Morrison 2011: 24). The process involves injecting a radiopharmaceutical tracer intravenously. Metabolically active cells absorb this tracer. PET detects radiation the tracer emits. CT provides a clear anatomical map of areas showing high metabolic activity.

PET/CT proves highly sensitive finding spots of increased metabolic activity. This activity might indicate cancer processes (tumor spread) or infection. The CT part helps pinpoint these findings accurately within specific shoulder anatomy (Hobbs & Morrison 2011: 24).

Disadvantages: PET/CT involves ionizing radiation exposure. Its spatial resolution for soft tissues is lower compared to MRI. It is relatively expensive not typically used for common musculoskeletal shoulder complaints (Hobbs & Morrison 2011: 24; Prakash et al. 2024: 102384).

Indications: Main reasons for PET/CT in the shoulder area include checking suspected confirmed tumor spread to bone soft tissues. This method can also spot infection sites particularly when other imaging is unclear. Evaluating infection spread is another use (Hobbs & Morrison 2011: 24).

Key Findings: High tracer uptake on PET scans combined with structural issues on CT might point towards metastatic lesions active infection in the shoulder girdle (Hobbs & Morrison 2011: 24).

3.7 Scintigraphy

Scintigraphy or bone scanning is a nuclear medicine technique. It checks bone metabolism (Hobbs & Morrison 2011: 24). The procedure requires injecting a small amount of radioactive tracer intravenously. Bone tissue with increased metabolic activity takes up this tracer specifically. A gamma camera detects the tracer's distribution creating a functional skeleton image.

Bone scintigraphy is remarkably sensitive detecting bone metabolism changes. Various conditions cause these changes including stress fractures bone cancers. It can survey the whole skeleton helping find multiple distant lesions (Hobbs & Morrison 2011: 24).

Disadvantages: Scintigraphy gives poorer anatomical detail than x-ray CT MRI. Increased tracer uptake doesn't point to one specific problem. It can happen with fractures cancers infections arthritis many other bone conditions. Correlation with other imaging clinical findings is often needed (Hobbs & Morrison 2011: 24; Prakash et al. 2024: 102384).

Indications: Regarding shoulder checks bone scintigraphy might be requested evaluating suspected stress fractures. Detecting staging primary bone tumors assessing bone infection (osteomyelitis) checking avascular necrosis (AVN) of the humeral head are other uses (Hobbs & Morrison 2011: 24; Magneli et al. 2024: 319).

Key Findings: Increased tracer uptake (hot spots) in the shoulder area signals heightened bone metabolism. This might indicate stress fracture cancer infection other bone pathology. Linking findings with clinical history physical exam other imaging results is key for accurate reading (Hobbs & Morrison 2011: 24).

__Table 1:__ Shoulder Imaging Modality Selection

Clinical Scenario / Suspected Condition	**Primary Imaging Modality(ies)**	**Secondary / Adjunct Imaging Modality(ies)**	**Key Advantages**	**Key Disadvantages**
Preliminary evaluation of shoulder pain, particularly following trauma.	**Radiography**		Initial, cost-effective screening for fractures, dislocations, and osseous abnormalities. Can show calcific tendinosis and AC joint OA.	Restricted soft tissue delineation
Rotator cuff pathology (tears, tendinopathy)	**MRI, Ultrasound**	MR Arthrography (MRA)	MRI: Excellent soft tissue contrast, multiplanar imaging, detailed assessment of tendons, muscles, labrum, and bone marrow. Ultrasound: Cost-effective, real-time dynamic assessment, evaluation of superficial structures.	MRI: More expensive, longer acquisition time, contraindications (e.g., some metallic implants). Ultrasound: Operator-dependent, limited penetration for deep structures, suboptimal evaluation of bony structures.
Labral tears and glenohumeral instability	**MRI, MR Arthrography (MRA)**	CT Arthrography (CTA)	MRA: Distends joint space, enhances visualization of labrum, ligaments, and capsule, superior for detecting nondisplaced tears. MRI: Can show associated bone marrow edema and soft tissue injuries.	MRA/CTA: Invasive, requires intra-articular contrast injection. MRI may miss subtle labral tears compared to MRA.

Shoulder fractures and dislocations (complex or requiring surgical planning)	**CT**	Radiography, MRI (for associated soft tissue injuries)	Excellent depiction of bony anatomy, fracture patterns, and glenoid bone loss, useful for preoperative planning. 3D reconstructions can aid in visualization.	Ionizing radiation, limited soft tissue contrast.
Shoulder impingement syndrome	**Radiography**, **MRI**, **Ultrasound**		Radiography: May show subacromial spurs, high-riding humeral head, AC joint OA. MRI/Ultrasound: Evaluate rotator cuff tendons, subacromial-subdeltoid bursa for inflammation or tears, dynamic ultrasound can assess for impingement.	Radiography provides indirect signs. MRI/Ultrasound findings in asymptomatic individuals can complicate interpretation.
Adhesive capsulitis (frozen shoulder)	**MRI** (primarily for ruling out other pathology)	Radiography (may be normal or show subtle osteopenia)	MRI: Can show capsular thickening, increased T2 signal in joint capsule in early stages. Primarily used to exclude other causes of pain and stiffness.	MRI findings may not always correlate perfectly with clinical stages.
Bone tumors and metastases	**Radiography** (initial), **MRI**, **PET/CT**, **Scintigraphy**	CT (for bony detail and staging)	Radiography: Initial detection of bone lesions. MRI: Excellent for local staging, soft tissue extension, and marrow involvement. PET/CT/Scintigraphy: Detection of metabolically active	PET/CT/Scintigraphy: Lower anatomical detail and specificity compared to MRI.

			lesions and distant metastases.	
Shoulder infection (septic arthritis, osteomyelitis)	**MRI** (preferred), **Radiography**, **Scintigraphy**, **PET/CT**	Ultrasound (for guided aspiration of joint effusion)	MRI: Superior for detecting joint effusion, synovial thickening, bone marrow edema, and soft tissue involvement. Scintigraphy/PET/CT: Sensitive for increased metabolic activity suggestive of infection.	Radiography may be normal in early stages. Scintigraphy/PET/CT: Lower anatomical detail.
Nerve entrapments (e.g., suprascapular neuropathy)	**MRI**	Radiography (to rule out osseous causes), Ultrasound (for dynamic assessment)	MRI: Can visualize nerve thickening, edema, and denervation changes in muscles.	May not directly visualize the nerve compression in all cases.
Shoulder arthropathies (osteoarthritis, rheumatoid arthritis)	**Radiography**, **MRI**	CT (for detailed bony changes in advanced OA)	Radiography: Shows joint space narrowing, osteophytes, subchondral sclerosis and cysts. MRI: Evaluates cartilage, synovium, effusion, and associated soft tissue abnormalities.	Radiography may not show early cartilage changes or soft tissue involvement.
Pediatric shoulder disorders	**Radiography**, **MRI**, **Ultrasound**		Radiography: Initial assessment for fractures and developmental abnormalities. MRI: Evaluation of soft tissues, bone marrow, and growth plates	Interpretation in pediatrics requires understanding of skeletal maturation. Ultrasound has limited penetration.

			without ionizing radiation. Ultrasound: Real-time assessment, cost-effective for certain conditions.	
Postoperative shoulder evaluation	**MRI, MR Arthrography (MRA)**	Radiography (for hardware assessment)	MRI/MRA: Assessment of healing, recurrent tears, complications, and new pathology. MRA can help differentiate scar tissue from retears.	Interpretation can be challenging due to surgical changes and artifacts.

Table 1 serves as general reference. The exact imaging plan needs tailoring though. Customization considers the individual patient clinical picture requires discussion with a radiologist (Aydıngöz 2022: 101).

4. Radiological Observations in Shoulder Disorders

4.1 Traumatic Lesions

Direct radiography should be the first imaging step for shoulder trauma patients. It helps rule out fracture dislocation (Dirim 2017: 25).

4.2 Fractures

Shoulder girdle fractures usually involve the clavicle scapula humerus. X-rays generally suffice for diagnosis. Computed tomography (CT) however excels showing fracture details completely particularly with 3D views (Yu 2019: 191).

- ***Clavicle Fractures:*** Checking clavicle injuries often uses an anteroposterior view. Caudal cephalic tilt views might supplement this clarifying fracture shape displacement (Jensen & Rockwood 2009: 177).

- ***Scapula Fractures:*** X-ray is vital for initial checks of scapula fractures (Dirim 2017: 25). Different views can show specific scapula areas. A simple way getting a true scapulolateral image involves drawing a skin line along the scapular spine. Aim the x-ray beam perpendicular to this line place the cassette parallel to it. CT scanning often follows giving better detail on scapular fractures especially those involving the glenoid fossa (Jensen & Rockwood 2009: 177; Yu 2019: 191).

- ***Humerus Fractures:*** Proximal humerus fractures happen often especially in older adults sometimes after falls (Yu 2019: 191).

  - ***Classification:*** Doctors might classify proximal humerus fractures using systems like Neer's. This system groups fractures by the number of shifted parts (anatomic neck surgical neck greater tuberosity lesser tuberosity) (J. Beltran & Bencardino 2002: 225; Yamada & McKinnis 2020: 513).

  - ***Radiological Findings:*** X-ray checks must include anteroposterior (AP) views. Neutral internal external rotation views are needed plus an axillary or scapular Y view (Dirim 2017: 25)

4.3 Dislocations

Shoulder dislocations usually involve glenohumeral acromioclavicular joints (Yu 2019: 191). X-ray checks are key for diagnosis classification (Dirim 2017: 25).

- ***Glenohumeral Dislocations:*** These are the most common major joint dislocations (J. Beltran & Bencardino 2002: 225).

  - ***Anterior Dislocation:*** This type is most frequent. The humeral head moves forward relative to the glenoid fossa. AP axillary x-ray views show this shift (Jensen & Rockwood 2009: 177). An AP image with external rotation might show the humeral head sitting beside the glenoid. A Hill-Sachs lesion often links to anterior dislocation. This lesion is a compression fracture on the humeral head's back-outer part. Internal rotation AP views or the Stryker notch view show it best. An osseous Bankart lesion involves an anterior-inferior glenoid rim fracture. The apical oblique x-ray shows this fracture more clearly (Jensen & Rockwood 2009: 177).

  - ***Posterior Dislocation:*** This type is rare. The humeral head sits behind the glenoid fossa seen on axillary or scapular Y views. The AP view might show fixed internal rotation a widened GH joint space. Reverse Hill-Sachs lesions can appear on the humeral head's front-inner part (Jensen & Rockwood 2009: 177).

- ***Inferior Dislocation:*** Often called luxatio erecta this rare type presents distinctively. The arm holds fixed in abduction. The humeral head sits below the glenoid fossa on x-ray (Jensen & Rockwood 2009: 177).

- ***Acromioclavicular (AC) Dislocations:*** These injuries involve AC joint coracoclavicular ligament disruption. X-ray checks include AP shoulder views. Often targeted AC joint views supplement these using less exposure or a headward tilt (Zanca view). This technique improves joint visibility. Findings range from minor sprains to complete separation. Significant upward clavicle shifts relative to the acromion marks severe cases (Jensen & Rockwood 2009: 177).

4.4 Rotator Cuff Tears

Rotator cuff problems including tendinopathy tears are a common source of shoulder pain (Chang & Chung 2019: 87).

- ***Imaging Modality:*** *Magnetic resonance imaging (MRI) ultrasound (US)* are the main imaging tools assessing rotator cuff tears. MRI usually gets preference for complete rotator cuff tendon checks. It shows tear location size severity assesses related soft tissue bone issues too. Ultrasound offers a valuable alternative especially for surface tears dynamic checks (Yemin & Adler 2019: 55).

- ***Location, Size, and Shape of the Tear:*** Imaging reports should specify the affected tendon(s) (supraspinatus infraspinatus subscapularis teres minor). They detail the tear's exact spot (e.g. articular-sided bursal-sided intratendinous) its measurements in different planes. Tear shape can vary too (e.g. crescent U L) (Chang & Chung 2019: 87).

- ***Extent of Tear:***

    - ***Full-Thickness Tears:*** These tears go completely through the tendon. They often show as a tendon gap. Fluid signal fills this gap on fluid-sensitive MRI shots (like T2-weighted fat-suppressed). The torn tendon ends might pull back (Zlatkin 2002: 117).

    - ***Partial-Thickness Tears:*** These tears involve only part of the tendon thickness. Doctors classify them by location (articular bursal intratendinous) percentage of thickness involved. High signal within the tendon on MRI without a full gap might mean a partial tear tendinosis. MR arthrography helps tell between high signal a partial tear connecting to the joint or bursa surface (Zlatkin 2002: 117; Zlatkin Hoffman & Needell 2002: 85).

- ***Retraction and Muscle Atrophy:*** In long-standing rotator cuff tears the torn tendon ends might retract. Classification often notes retraction distance. MRI assesses muscle wasting fatty changes in rotator cuff muscles particularly supraspinatus infraspinatus. These findings offer important prognostic clues (Zlatkin 2002: 117).

Note: *Connect radiological interpretation always with the patient's clinical story physical exam findings. Findings like fluid in the subacromial-subdeltoid bursa high intratendinous signal on MRI need careful assessment. They sometimes appear in people without symptoms* (Ibounig et al. 2024: 1184; Leung & Griffith 2019: 3; Zlatkin 2002: 117).

Degenerative Diseases

- ***Osteoarthritis and Glenohumeral Degeneration:*** Shoulder radiological checks including x-ray advanced imaging might show clear signs of glenohumeral osteoarthritis. Findings include joint space narrowing typically in the GH joint's upper part. Osteophytes or bone spurs often appear around the humeral head glenoid edge. Subchondral sclerosis increased bone density below cartilage is a frequent finding. Subchondral cysts fluid-filled bone cavities might also exist (Hobbs & Morrison 2011: 24).

- ***Subacromial Impingement Syndrome:*** X-rays often serve as the first method checking suspected subacromial impingement clinically. The outlet view x-ray helps check acromion shape. While sources don't explicitly label acromion types 1 2 or 3 shape changes link to impingement. Subacromial spurs bony points on the acromion's lower surface are one example. X-rays might also show subacromial space narrowing the area between acromion humeral head. An upwardly shifted humeral head might appear possibly adding to narrowing. An os acromiale an unfused bone center at the front acromion strongly links to cuff impingement shows on x-rays. X-rays might hint at rotator cuff problems via secondary signs. But MRI is preferred directly spotting rotator cuff tendonitis tears. Ultrasound also serves this purpose (Hobbs & Morrison 2011: 24).

4.6 Inflammatory and Rheumatologic Conditions

- ***Rheumatoid Arthritis:*** MRI is a key tool checking shoulder involvement in various joint diseases including rheumatoid arthritis. Radiological signs in shoulder RA might show joint erosions often at articular surface edges. Synovitis synovial membrane inflammation appears on MRI as thickened synovium effusion often enhanced by contrast. Effusion fluid buildup within the joint is a typical finding (Prakash et al. 2024: 102384).

- ***Frozen Shoulder (Adhesive Capsulitis):*** MRI findings in frozen shoulder get more recognition now. Non-contrast MRI might show T2 high signal in the joint capsule more often in early stages. MRI also reveals axillary capsule thickening especially in stages 1 2. Fluid around the long biceps head subcoracoid fat wiping out coracohumeral ligament thickening are common MRI signs. But their link to specific stages isn't always definite. Though rare as a main sign severe adhesive capsulitis might show some joint space narrowing due to capsule tightening (Huang & Schweitzer 2019: 211; Tamai et al. 2024: 365).

4.7 Neoplastic and Cystic Lesions

- ***Benign and Malignant Tumors:*** Check shoulder tumors using cross-section imaging preferably MRI. This determines local spread anatomical compartment involvement. Musculoskeletal cancer staging considers histologic grade local spread metastasis. Biopsy paths surgical removals need compartmental anatomy understanding. Bone cancers like osteolytic sclerotic lesions show differently on x-ray. X-rays show osteochondromas as bony bumps from the bone surface often near growth plates. Chondrosarcomas malignant cartilage tumors might show distinctive calcification patterns within cartilage matrix on x-ray CT MRI. MRI is needed assessing soft tissue reach. Shoulder metastases from distant primary cancers might look like lytic blastic spots on x-ray CT scans MRI (Walker Minn & Murphey 2019: 269).

- ***Ganglion Cysts, Paralabral Cysts:*** Shoulder ganglion cysts are fluid-filled sacs from joint capsule tendon sheaths. MRI shows well-defined cystic spots bright signal on fluid-sensitive shots. Paralabral cysts are ganglion cysts related to labral tears. Synovial fluid leaks through a labral tear forming a cyst near the labrum. MRI arthrography can show paralabral cysts labral problems well. These cysts often arise near the glenoid labrum might press nearby structures causing pain nerve issues. Cysts in the lesser tuberosity might connect to shoulder arthroscopy subscapularis supraspinatus long head biceps tendon problems (Chang & Chung 2019: 87; Zlatkin 2002: 117).

4.8 Neuropathic and Vascular Abnormalities

- ***Nerve Entrapments:*** Nerve entrapment syndromes cause shoulder pain sometimes though uncommonly. They are getting more recognition. MRI helps diagnose shoulder nerve entrapments. It images nerve paths detects possible compression sources like tumors ganglion cysts. Suprascapular nerve entrapment can happen at the suprascapular notch spinoglenoid notch. MRI might show denervation evidence in supraspinatus and/or infraspinatus muscles. High T2 signal intensity muscle wasting are signs. Ultrasound can view nerves spot potential entrapment compression areas (Eajazi Bredella & Torriani 2019: 321).

- *Aneurysms and thromboses:* Vascular problems rarely cause shoulder discomfort. But doctors should consider them in specific clinical situations. The provided text doesn't detail this. Yet imaging like magnetic resonance angiography (MRA) conventional angiography might check for aneurysms (abnormal blood vessel widening) thromboses (vessel blood clots) if needed clinically. Doppler ultrasound can serve for initial checks of blood flow (Hobbs & Morrison 2011: 24; Yemin & Adler 2019: 55).

Note: Always evaluate the radiological results mentioned above alongside the patient's clinical story physical exam. Correlating with other imaging types surgical findings when available is vital for correct diagnosis therapy.

5. Prevalent Clinical Situations and Imaging Approaches

This section outlines common clinical pictures linked to shoulder discomfort checks. It suggests suitable first follow-up imaging methods. The imaging choice should follow a thorough clinical check including patient history physical exam findings (Aydıngöz 2022: 101).

5.1 Initial Imaging for Acute Shoulder Pain

- ***History of Trauma:*** Image patients having acute shoulder pain trauma using direct radiography first. X-rays can quickly cheaply rule out fractures dislocations. Usual x-ray views include neutral oblique axillary lateral scapula shots. The Stryker or suprascapular notch view might help depending on suspected injury type. 3D CT imaging adds useful detail in complex shoulder trauma (Dirim 2017: 25; Leung & Griffith 2019: 3; Yu 2019: 191).

- ***No Trauma, Suspected Rotator Cuff Tear:*** Acute shoulder discomfort without trauma history but suggesting rotator cuff tear might need different imaging. Sometimes ultrasound (US) matches MRI's sensitivity specificity assessing shoulder problems (Yemin & Adler 2019: 55). US offers good value quick scans real-time dynamic checks. The sonographer's expertise however dictates shoulder ultrasound's diagnostic accuracy. MRI is a powerful tool checking soft tissue bone structures used widely for shoulder issues. Recent MRI technology upgrades shortened scan times improved image quality. Ultrasound or MRI might be the main imaging tool depending on local skill availability for non-traumatic acute shoulder pain likely involving rotator cuff damage (Mirowitz & Shih 2002: 27).

5.2 Diagnostic Algorithm in Chronic Shoulder Pain

The diagnostic path for chronic shoulder pain needs a personalized plan. Clinical presentation guides this plan. A strict flowchart doesn't always fit yet these points help guide imaging choices:

- ***History and Physical Examination as the Cornerstone:*** The clinical assessment should drive imaging selection. Specific diagnostic questions arise from this check. Factors like pain location type motion limits specific exam findings help narrow the differential diagnosis guide imaging (Aydıngöz 2022: 101; Eajazi Bredella & Torriani 2019: 321; Hobbs & Morrison 2011: 24).

- ***Radiography as a Potential First Step:*** For many chronic shoulder discomfort cases standard x-rays can be a smart starting point. This applies particularly to older adults situations where degenerative changes seem likely. X-rays show problems like glenohumeral osteoarthritis (joint space narrowing osteophytes subchondral sclerosis cysts). They reveal subacromial spurs suggesting impingement calcific tendinosis too. They also help exclude bony causes for nerve entrapment check for GH subluxation osteoarthritis (Dirim 2017: 25).

- ***Advanced Imaging for Soft Tissue and Complex Pathology:*** Advanced imaging becomes necessary when soft tissue problems seem very likely clinically (e.g. rotator cuff tears labral tears nerve entrapments). It's also needed when x-rays don't give clear answers. Ultrasound (US) Magnetic Resonance Imaging (MRI) are the usual choices (Hobbs & Morrison 2011: 24).

- **MRI** gives superior views of soft tissues. Rotator cuff labrum biceps tendon joint capsule are included. MRI helps greatly assessing rotator cuff tears (full partial-thickness). It also aids checking labral tears (especially with MR arthrography) rotator interval lesions nerve issues internal joint problems (Beltran Tafur & Bencardino 2019: 147; Zlatkin Hoffman & Needell 2002: 85).

- **Ultrasound** provides a valuable accessible alternative. It works especially well checking surface tissues like rotator cuff tendons subacromial-subdeltoid bursa biceps tendon. Dynamic checks during provocative movements offer a unique ultrasound benefit (Hobbs & Morrison 2011: 24; Yemin & Adler 2019: 55).

- ***Computed Tomography (CT) for Specific Indications:*** Shoulder CT mainly serves diagnosing categorizing acute fractures. Quantifying glenoid bone loss evaluating severe GH arthritis before surgery monitoring fracture healing assessing shoulder hardware are other uses. CT might help when bony issues are the main concern for nerve damage. CT arthrography checks rotator cuff tendon tears labral disease offering an alternative when MRI is not possible (Chang & Chung 2019: 87; Eajazi Bredella & Torriani 2019: 321).

- ***MR Arthrography for Intra-articular Pathology:*** Direct MR arthrography injects contrast agent into the joint. It's often seen as the best standard checking labral capsular injuries. It can help distinguish high intratendinous signal from a rotator cuff tear connecting to the joint surface. Imaging guidance (ultrasound fluoroscopy) is typical for the injection. But puncture using anatomical landmarks might work in some cases (Oca Pernas & Fernandez Canton 2025: 17).

5.3 Postoperative Evaluation and Monitoring of Complications

- ***In Patients with Prosthesis:*** After shoulder replacement direct x-ray is the main imaging tool for routine checks. X-rays check prosthesis position spot loosening at the bone-prosthesis interface assess for nearby fractures. Comparing with older x-rays is vital finding subtle changes over time (Hobbs & Morrison 2011: 24; Leung & Griffith 2019: 3).

- ***After Rotator Cuff Repair:*** Magnetic Resonance Imaging (MRI) MR arthrography are preferred checking healing spotting retears post-repair. An MRI views the repaired tendon checks continuity signal within it spots retear signs like a fluid-filled tendon gap. MR arthrography might offer better sensitivity finding minor partial-thickness retears. It shows contrast communication with the tear. Post-op MRI timing depends on clinical factors surgeon preference. MRI helps find other post-surgery problems too like infection adhesive capsulitis impingement (Zlatkin 2002: 249).

6. Essential Factors in Analyzing Diagnostic Imaging

Interpreting shoulder imaging needs several things. Knowledge of normal anatomy common variations likely artifacts matters. Connecting imaging findings clinical data helps form a differential diagnosis. Multidisciplinary shoulder care involves radiologists. Their readings should show this team approach (Blake Hochman & Edelman 2002: 1).

6.1 Standard Variations and Artifacts

In the interpretation of shoulder pictures, it is essential to differentiate normal anatomical changes from actual pathology (Mirowitz & Shih, 2002: 27). The presence of an os acromiale, an unfused ossification center of the acromion, is a prevalent finding that may be linked to subacromial impingement but should not be confused with a fracture or other pathologies (Hobbs & Morrison, 2011: 24). The *supratubercular* ridge of the humerus is a typical osseous protrusion that may occasionally be misconstrued (Mirowitz & Shih, 2002: 27).

MRI artifacts can look like pathology. The "magic angle" effect happens when collagen fibers like in tendons sit at 55 degrees to the main magnetic field. This angle might raise signal intensity on short echo time (TE) scans. It can resemble tendinosis a partial tear. Understanding the location (often supraspinatus tendon near insertion) signal features helps avoid this error. Checking other sequences aids this too. Rotator cuff signal intensity can also change when the arm rotates during MRI (Hsu Afifi & Isaac 2024: 1264; Meraj & Bencardino 2019: 23; Zlatkin Hoffman & Needell 2002: 85).

6.2 Differential Diagnosis of Pathologic Findings

Many shoulder conditions show overlapping imaging signs. This overlap demands a careful differential diagnosis. Telling rotator cuff tendonitis from a partial-thickness rotator cuff tear on MRI proves tricky sometimes (Zlatkin 2002: 117). Both might show increased intratendinous signal (Zlatkin Hoffman & Needell 2002: 85). Some partial tears however show fluid signal on fluid-sensitive scans like T2-weighted fat-suppressed. This fluid extends to the articular bursal surface or within the tendon substance unlike typical tendinitis. MR arthrography distinguishes these conditions well showing intra-articular contrast mixing with a tear. Fluid in the subdeltoid bursa often relates to rotator cuff disease. But it also occurs with primary bursitis other inflammatory states. The radiologist therefore must weigh all imaging findings clinical context giving the most probable diagnosis (Palmer 2002: 277; Zlatkin Hoffman & Needell 2002: 85).

6.3 The Function of the Radiologist in a Multidisciplinary Framework

The radiologist's job extends past image reading. Report comments should connect imaging results with the referring doctor's clinical picture. Understanding the patient's symptoms physical exam medical history is necessary. Mismatches between clinical suspicion imaging results might signal need for more study different diagnoses (Jensen & Rockwood 2009: 177).

Furthermore radiologists should participate actively in team-based patient management. Good communication teamwork with specialists improves patient outcomes. Orthopedists physiatrists rheumatologists are key partners. This teamwork might involve direct talks about complex cases joining multidisciplinary team meetings. Or it could mean clarifying imaging results guiding therapy decisions. The radiologist's skill reading shoulder images adds vital data to the overall clinical picture improving patient care consequently (Aydıngöz 2022: 101).

7. Contemporary Advancements and Prospective Outlooks

Shoulder radiology keeps evolving. Technology breakthroughs better grasp of musculoskeletal problems drive this progress. Recent progress future possibilities promise better diagnostic accuracy smoother workflows ultimately better patient results.

7.1 Artificial Intelligence and Radiological Analysis

Artificial intelligence (AI), including machine learning deep learning increasingly enters medical imaging (Lee et al. 2024: 102:166). These systems can automatically check huge datasets of medical images like x-rays MRI scans. They accurately spot patterns find lesions (Lee et al. 2024: 102:166; Magneli et al. 2024: 319). Deep learning algorithms show promising results classifying glenohumeral osteoarthritis (GHOA) avascular necrosis (AVN) on plain x-rays. AI algorithms are also under development validation finding various shoulder problems on MRI. Rotator cuff tears labral lesions are examples. Radiologists remain responsible for image interpretation now. Yet AI tools can act as helpful assistants potentially boosting diagnostic accuracy efficiency. They might flag concerning findings help with image checks. The quick integration of AI deep learning into medicine will likely have deep transformative effects on healthcare particularly diagnostics (Lee et al. 2024: 102:166; Magneli et al. 2024: 319; Vosshenrich et al. 2025: e241351).

7.2 Advanced Imaging Techniques

Substantial advancements are occurring in sophisticated imaging methodologies for the shoulder. Three-dimensional (3D) reconstruction with computed tomography (CT) and MRI data enhances the view of intricate osseous and soft tissue structures, facilitating the evaluation of fractures, instability, and other disorders (Leung & Griffith, 2019: 3). 3D isotropic MRI demonstrates advantages above conventional 2D MRI, perhaps enhancing the identification of labral lesions (Soldatos, Shah & Chhabra, 2024: 418). Functional MRI approaches, although not yet commonly utilized in standard shoulder imaging, provide the ability to elucidate muscle activation and biomechanics, which may be crucial in comprehending intricate shoulder diseases and rehabilitation responses (Cordes et al., 2024: 955). The advancement of novel contrast agents for MRI and CT arthrography may improve the depiction of intra-articular structures and subtle diseases (Palmer, 2002: 277). Moreover, enhancements in MRI acquisition methodologies, including parallel imaging augmented by deep learning, are resulting in expedited scanning durations while preserving robust diagnostic efficacy (Vosshenrich et al., 2025: e241351).7.3 Contemplations on Clinical Practice

The amalgamation of AI and sophisticated imaging methodologies is set to effectuate substantial transformations in clinical practice. Accelerated and precise diagnosis can result in more prompt and suitable therapies (Lee et al., 2024: 102:166). AI-assisted analysis has the potential to alleviate the workload of radiologists and decrease diagnostic inaccuracies. Enhanced vision by 3D reconstruction and functional imaging may facilitate superior treatment planning, especially for surgical procedures. Moreover, enhanced diagnostic information can improve prognosis prediction and therapy response monitoring. These developments highlight the transforming function of shoulder radiology in delivering more sophisticated and clinically pertinent information for the management of shoulder problems (Lee et al., 2024: 102:166).

8. Conclusion

Shoulder radiology and imaging are essential instruments in assessing shoulder discomfort and dysfunction, providing vital information regarding various osseous and soft tissue diseases. The judicious choice and analysis of imaging modalities are crucial for precise diagnosis and efficient clinical management (Aydıngöz, 2022: 101; Blake, Hochman & Edelman, 2002: 1; Hsu, Afifi & Isaac, 2024: 1264).

Practical Application of Shoulder Radiology

The selection of imaging modalities must be informed by the clinical presentation and the presumed underlying pathology (Knight, Powell & Johnson, 2024: 144).

- **Radiography** is the principal imaging technique for the preliminary assessment of shoulder pain, especially in the examination of fractures, dislocations, and significant arthritic alterations (Magneli et al., 2024: 319; Yamada & McKinnis, 2020: 513).

- **Ultrasound** is an economical and easily obtainable method for assessing rotator cuff tendons, bursae, and certain superficial soft tissue irregularities. Its dynamic capabilities are especially beneficial for evaluating impingement and directing treatments. Nonetheless, its precision is contingent upon the operator (Hsu, Afifi & Isaac, 2024: 1264; Yemin & Adler, 2019: 55).

- **Computed Tomography (CT)** is essential for the thorough evaluation of osseous structures, especially in cases of trauma, intricate fractures, and the assessment of glenoid version in instances of instability. CT arthrography, employing intra-articular contrast, offers superior visibility of labral tears and articular cartilage (Knight, Powell & Johnson, 2024: 144; Leung & Griffith, 2019: 3; Yamada & McKinnis, 2020: 513).

- **Magnetic Resonance Imaging (MRI)** is the preferred method for thorough assessment of soft tissues, encompassing the rotator cuff, labrum, ligaments, and cartilage. It provides superior tissue contrast and multiplanar imaging functionalities. **MR arthrography**, with intra-articular contrast, significantly improves the identification of minor labral tears, partial-thickness rotator cuff tears, and capsular anomalies (Beltran, Tafur & Bencardino, 2019: 147;

Blake, Hochman & Edelman, 2002: 1; Palmer, 2002: 277; Prakash et al., 2024: 102384).

Recommendations and Protocols for Medical Practitioners

- ***Clinical correlation is key*****:** Always interpret imaging results in connection to the patient's history, physical examination, and clinical symptoms (Blake, Hochman & Edelman, 2002: 1).

- ***Start with the basics*****:** Radiographs frequently represent the initial and most suitable approach in numerous shoulder assessments (Magneli et al., 2024: 319; Yamada & McKinnis, 2020: 513).

- ***Consider ultrasound for dynamic assessment and guided procedures*****:** Ultrasound provides real-time imaging, facilitating the assessment of tendon mobility and the direction of injections (Nwawka, Kothary & Miller, 2019: 67; Yemin & Adler, 2019: 55).

- ***MRI for soft tissue detail*****:** Employ MRI when a comprehensive examination of the rotator cuff, labrum, or other soft tissues is necessary. Evaluate MR arthrography for potential modest intra-articular disease.

- ***CT for bony detail and complex trauma*****:** CT is essential for evaluating fractures and osseous irregularities in cases of complicated trauma (Leung & Griffith, 2019: 3; Yamada & McKinnis, 2020: 513).

- ***Stay informed*:** Stay updated on developments in AI and imaging methodologies, as these will persist in influencing the future of shoulder radiology (Lee et al., 2024: 102:166; Magneli et al., 2024: 319).
- ***Communicate effectively*:** Sustain transparent dialogue with radiologists and other experts to guarantee cohesive and optimal patient care (Blake, Hochman & Edelman, 2002: 1).

By following these guidelines and utilizing the advantages of each imaging modalities, clinicians can effectively employ shoulder radiology to attain precise diagnoses and inform suitable therapy regimens for their patients.

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CURRENT APPROACHES TO COMMON SHOULDER PROBLEMS IN ATHLETES

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Introduction

The shoulder is one of the most complex and versatile joints in the human body, enabling a wide range of movements that are essential for a variety of sporting activities. The shoulder's unique anatomy allows for exceptional mobility and strength, from the overhead serve of a tennis player to the powerful throws of a baseball pitcher. However, it is this very complexity and mobility that makes the shoulder particularly susceptible to injury. This is especially true for athletes who subject the shoulder to repetitive stress, high impact and extreme ranges of motion. Shoulder problems, which often cause significant pain, functional limitations and time away from sport, are among the most common musculoskeletal conditions in

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athletes. These injuries can result from acute trauma, such as a fall or collision, or from chronic overuse, which gradually wears down the structures of the joint. Shoulder problems are more common in activities with repetitive overhead movements, such as swimming, baseball and tennis (Warth & Millett, 2015:109).

Shoulder injuries are common among athletes, particularly those involved in repetitive overhead or high-impact activities. Common conditions include rotator cuff inflammation and tearing, often due to overuse or trauma, and shoulder impingement syndrome, where the rotator cuff tendons or bursa become pinched underneath the socket (Edelson, G., & Teitz, C. 2000). Labral tears, such as superior labrum anterior to posterior (SLAP) tears, are common in overhead athletes, while shoulder instability and dislocation are common in contact sports (Conway, J. E. 2001). Injuries to the acromioclavicular (AC) joint, such as sprains or dislocations, often result from direct trauma, and biceps tendinitis results from inflammation of the biceps tendon due to repetitive stress (Warth & Millett, 2015:109). Other conditions include adhesive capsulitis (frozen shoulder), characterized by stiffness and pain; glenohumeral osteoarthritis, caused by cartilage degeneration; and multidirectional instability (MDI), seen in athletes with hypermobile joints (Warth & Millett, 2015:109). Thoracic outlet syndrome (TOS) can cause nerve or vessel compression, while scapular dyskinesis is an abnormal movement of the shoulder blade that contributes to other shoulder problems. Fractures of the clavicle, humerus or scapula are common in contact sports, and bursitis occurs when the bursa becomes inflamed due to repetitive friction (Pires, E. D., & Camargo, P. R. 2018). Finally, internal impingement, often seen in overhead athletes, is a pinching of the rotator cuff and labrum during throwing motion (Edelson, G., & Teitz, C. 2000). Understanding these conditions is essential for effective prevention, diagnosis and treatment in athletes. For effective prevention, diagnosis and treatment, it is important to understand the common shoulder problems faced by athletes (Warth & Millett, 2015:109). The aim of this chapter is to provide a comprehensive overview of the most common shoulder injuries in the athletic population, including rotator cuff tendinitis, labral tears, shoulder impingement syndrome and shoulder instability. Underlying mechanisms, clinical manifestations and current evidence-based approaches to management and rehabilitation are reviewed (Edelson, G., & Teitz, C. 2000).

Clinical Importance

Several attempts have been made to identify risk factors and optimal management, and it is widely accepted that these athletes are at significant risk of shoulder injury. Sporting movements in these activities are highly skilled and require maximum coordination, synchronising and neuromuscular adaptation (Brown, K. E., & Stickler, L. 2011). Shoulder joint is an important link in the kinetic chain, perfectly transferring the large force generated by the lower limb and trunk to the hand joint which completes the movement, and also changing the direction of the movement. Shoulder injuries can result from the instant transfer of large amounts of kinetic energy, from the progressive accumulation of low energy transfer over time, or from a combination of both mechanisms. Athletes involved in overhead sports perform a large number of rapid and extreme movements in all joints, particularly the shoulder joint, during training and competition, exposing them to repetitive microtrauma over and above major trauma. In such athletes, cumulative microtrauma, micro-instability and associated internal impingement, labral lesions and rotator sheath tendinosis are seen due to extreme and very high impact movements (Warth & Millett, 2015:109). The clinical management of these sports injuries is of interest to a wide audience within the sports medicine profession, including physiotherapists, sports medicine specialists and orthopedic surgeons with an interest in the diagnosis, prevention and treatment of such injuries. This chapter therefore summarizes and evaluates the evidence for the diagnosis, prevention and treatment of common shoulder injuries in sport.

Frank Jobe and others developed the "micro-instability" theory (1979) that anterior instability is the result of repeated stretching of the anterior capsular ligaments due to repeated arm flexion (Jobe, F. J., Stark, H., & Lombardo, S.J. 1986). The results of capsular tightening have been mediocre, although success with capsular ligament retention has been reported in 68% of cases. On the other hand, by publishing a series of 17 arthroscopies performed on athletes with pain at the cocking phase of throwing but no associated instability, Walch et al. developed the theory of isolated posterosuperior impingement (Edelson, G., & Teitz, C. 2000). They explained this symptomatology by a repeated mechanical impingement between the greater tubercle and the posterosuperior glenoid rim at 90% abduction, maximum external rotation and extension, causing partial tears of the posterosuperior rotator cuff and the facing glenoid labrum (Walch, G., Boileau, P., Noel, E., & Donell, S. T. 1992). In 1995, Kibler et al. introduced the concept of a kinetic chain that encompasses all the parts of the body that are involved in the throwing action, including the whipping motion that is developed by the shoulder muscles in the tennis game (Kibler, W. B. 2006). They proposed that the role of the arm is to deliver the stored energy and that the shoulder acts as a regulator to ensure the appropriate transfer of speed and energy (Kibler, W. B. 2006). Good alignment of the glenoid and humerus allows for maximum muscle efficiency, maximum compression of the glenoid and humerus, and frees up the rotational movements of the shoulder that act like a catapult when throwing. To prevent injury and increase efficiency, Kibler et al. emphasize the need to strengthen the entire muscular chain (Kibler, W. B. 2006). The proximal part of the shoulder joint has a much greater mass than the distal part of the arm and has a much greater influence on the force generated. It is therefore essential that the proximal part remains stable and remains stable during all activities so that the distal part can move smoothly (Warth & Millett, 2015:109). The primary function of the scapula is to provide a stable articular surface for the rapidly rotating humerus and to maintain the glenohumeral (GH) joint in an optimal position, protecting the labrum and reducing capsular tension. For example, reduced acromial elevation due to impaired scapular movement can cause subacromial impingement, or impairment of the length-contraction relationship of muscles in this region can impair performance and cause muscles to contract more for the same force, leading to overuse (Edelson, G., & Teitz, C. 2000). The shoulder joint is an important joint where flexibility and strength must always be in balance. It must be flexible enough to allow maximum external rotation of the arm before the throw, but stable enough to prevent injury and subluxation. A group of authorities have dubbed this combination of flexibility and stability the 'thrower's paradox'. An antero-inferior capsular laxity or retroversion of the humeral head is indicated by an increased range of motion in external rotation and abduction of the shoulder. A difference of 12-15 degrees between each side can result from retroversion, but greater differences can result from capsular and posterior rotator sheath contractures. Reduced flexibility in the M. latissimus dorsi, M. trapezius, M. subscapularis and M. pectoralis muscles leads to anterior displacement of the humeral head, resulting in decreased internal rotation of the shoulder (Burkhart, S. S. (2006). This can lead to decreased performance and increased shoulder-related injuries. So, this chapter aims to provide a comprehensive overview of common shoulder injuries in sportsmen and women, such as rotator cuff inflammation, labral tear, shoulder impingement syndrome and shoulder instability (Edelson, G., & Teitz, C. 2000). It reviews the basic mechanisms, clinical presentation and current evidence-based approaches to management and rehabilitation.

Shoulder Instability and Shoulder Laxity in Athletes

Shoulder instability refers to the inability of the shoulder joint to maintain its normal anatomical alignment, resulting in partial (subluxation) or complete dislocation. It is a common problem among athletes, particularly those involved in contact sports or activities that require repetitive overhead movements. Shoulder instability can result from a variety of causes, including acute trauma, such as a dislocated shoulder from a tackle in football or rugby, or repetitive overhead movements common in sports such as throwing, swimming or tennis (Warth & Millett, 2015:109). In addition, ligament laxity or a genetic predisposition, such as Ehlers-Danlos syndrome, can contribute to instability, as can muscle imbalances or poor shoulder blade control. Athletes with shoulder instability often experience pain, especially during overhead activities or after a dislocation, along with a feeling of the shoulder "slipping out" or "giving way". Recurrent dislocations or subluxations are common, accompanied by reduced range of motion and strength. Many people also report anxiety or fear when performing certain movements, such as throwing or reaching overhead, because of the instability (Kevin, Michael & George, 2001:75).

Types of shoulder instability

- Traumatic instability: Caused by a specific injury, such as a fall, collision or violent overhead movement. This often results in a Bankart lesion (torn labrum) or a Hill-Sachs lesion (bone defect in the head of the humerus).

- Atraumatic instability: Occurs without specific injury, often due to inherent ligamentous laxity or repetitive microtrauma. This is more common in athletes with hypermobile joints.

- Multidirectional instability (MDI): A subtype of atraumatic instability in which the shoulder is unstable in multiple directions (anterior, posterior and inferior). It is often associated with generalized ligamentous laxity.

The diagnosis of shoulder instability involves a clinical examination using tests such as the apprehension test, relocation test and sulcus sign to assess the degree of instability. Imaging techniques such as x-rays, MRI or MR arthrography are also used to detect structural abnormalities such as labral tears or bone defects. Treatment of shoulder instability can be divided into non-surgical and surgical approaches. Non-surgical management typically includes physiotherapy to strengthen the rotator cuff, scapular stabilizers and dynamic stabilizers, activity modification to avoid aggravating movements, and bracing or taping for temporary support during sport (Burkhart, S. S., Morgan, C. D., & Kibler, W. B. 2003). In cases of recurrent dislocation or significant structural damage, surgical treatment (e.g., Bankart repair) may be required, followed by a comprehensive rehabilitation programme to restore function and prevent recurrence (Kibler, W. B. 2006).

Clinical examination using tests such as the sulcus sign to assess inferior shoulder instability and the Beighton score to assess general joint hypermobility are used to diagnose generalized joint laxity, particularly in the context of shoulder instability. Imaging, such as x-rays or MRI, may be used to rule out structural abnormalities, although this is not always necessary (Kibler, W. B. 2006). Treatment focuses on proprioceptive training to improve joint awareness and control during movement, as well as strengthening exercises targeting the rotator cuff, scapular stabilizers and dynamic stabilizers to compensate for ligamentous laxity (Özbek & Demirtaş, 2022:89). Modification of activity is recommended to avoid worsening of symptoms, and bracing or taping may be used to provide additional support during high-risk activities. Comprehensive treatment, including physiotherapy and patient education, should be considered for long-term stability and function. For accurate diagnosis and effective treatment, it is important to understand the difference between shoulder instability and shoulder laxity (Kibler, W. B. 2006). These terms refer to different concepts, although they are often used interchangeably. A detailed explanation of how they differ from each other is given in Table 1 below.

Table 1.Key Differences shoulder instability and shoulder laxity

Aspect	***Shoulder Laxity***	***Shoulder Instability***
Definition	○ Physiological looseness of the joint	• Pathological inability to maintain alignment
Symptoms	○ Usually, asymptomatic	• Pain, subluxation, dislocation, apprehension
Causes	○ Congenital, developmental, nontraumatic	• Traumatic, atraumatic, multidirectional
Clinical Tests	○ Beighton score, sulcus sign (may be positive)	• Apprehension, relocation, load and shift tests
Imaging Findings	○ Normal	• Structural damage (e.g., Bankart lesion)
Management	○ Strengthening, proprioception, activity mod	• PT, bracing, or surgery if severe
Prognosis	○ Excellent if asymptomatic	• Depends on cause and treatment

Glenohumeral Internal Rotation Deficit (GIRD) in Athletes

Glenohumeral Internal Rotation Deficit (GIRD), characterized by a significant loss of internal rotation (IR) range of motion in the dominant shoulder compared to the non-dominant side, is a common condition in overhead athletes such as baseball pitchers, tennis players, swimmers and volleyball players (Burkhart, S. S. 2006). This deficit, thought to be an adaptive response to the repetitive overhead movements required in these sports, is often accompanied by a compensatory increase in external rotation (ER) (Kibler, W. B. 2006). The underlying mechanism is a tightening of the posterior structures of the shoulder, including the posterior capsule, posterior rotator cuff (infraspinatus and teres minor) and shoulder girdle, and humeral retroversion (a bony adaptation in which the humerus turns back). These changes alter the biomechanics of the shoulder, altering the glenohumeral rotation arc and possibly leading to increased stress on anterior structures such as the labrum and biceps tendon. Over time, this imbalance may predispose athletes to injuries such as labral tears, rotator cuff tendinopathies, impingement syndromes and even superior labral anterior posterior (SLAP) lesions (Conway, J. E. 2001). Clinically, GIRD is diagnosed when the loss of internal rotation is greater than 20 degrees compared to the contralateral shoulder, or when the total range of motion (ER + IR) is significantly reduced (Burkhart, S. S. (2006). Management focuses on restoring normal shoulder motion through targeted interventions such as posterior capsule stretching (eg, sleeper's stretching, cross body stretching), strengthening exercises for the rotator cuff and shoulder girdle stabilizers (eg, external rotation, shoulder blade withdrawal), and proprioceptive training to improve neuromuscular control (Panayiotou Charalambous, 2019:77). In addition, addressing the mechanics of the throwing or overhead motion and incorporating recovery strategies (e.g., rest, ice, and soft tissue mobilization) are essential to prevent recurrence. Early detection and intervention are critical as untreated GIRD can be a chronic shoulder dysfunction and a limitation to athletic performance. Athletes can maintain optimal shoulder health and performance through regular monitoring of shoulder range of motion and strength, and sport-specific conditioning programs (Panayiotou Charalambous, 2019:77).

Scapular Dyskinesis in Athletes

Scapular dyskinesis is a condition commonly seen in athletes, particularly those involved in overhead or throwing sports such as baseball, tennis, swimming and volleyball, characterized by abnormal movement or positioning of the scapula (shoulder blade) during shoulder motion (Pires, E. D., & Camargo, P. R. 2018). By providing a stable base for rotator cuff activation and facilitating optimal glenohumeral joint mechanics, the scapula plays a critical role in shoulder function. Impaired scapular motion can lead to altered shoulder biomechanics, increased stress on surrounding structures and increased risk of injury (Pires, E. D., & Camargo, P. R. 2018).

Causes and contributing factors: Muscle imbalance, weakness or inhibition of key scapular stabilizing muscles such as serratus anterior, lower trapezius and rhomboids (Veeger, H. E. J., & Van Der Helm, F. C. T. 2007). Over-activity or tightness of the upper trapezius, levator scapulae or pectoral muscles, which can change shoulder blade positioning. Athletes who play overhead often suffer from dyskinesia due to repetitive strain on the shoulder complex, leading to fatigue or overuse of the shoulder muscles (Özbek & Demirtaş, 2022:89). Also, poor posturing, forward head posturing or rounded shoulders (common in athletes and non-athletes alike) can contribute to abnormal scapular positioning, such as scapular protraction or anterior tilt. Normal scapular mechanics may be disrupted by previous shoulder injuries such as rotator cuff tears, labral tears or AC joint sprains. Since the scapula relies on the thorax for proper movement, limited mobility of the thoracic spine can restrict scapular movement (Burkhart, S. S., Morgan, C. D., & Kibler, W. B. 2003)..

Types of scapular dyskinesis: Based on the abnormalities observed during shoulder movement, scapular dyskinesis is often classified into three main types:

Type I (Inferior Scapular Angle Protrusion): Often due to tightness of the pectoralis minor or weakness of the lower trapezius, the inferior scapular angle protrudes posteriorly.

Type II (medial border prominence): Typically caused by weakness in the serratus anterior or rhomboids, the entire medial border of the scapula protrudes posteriorly.

Type III (Superior border prominence): The superior border of the scapula is elevated, often as a result of over-activity of the upper trapezius and levator scapulae muscles.

The diagnosis of scapular dyskinesia begins with a thorough medical history. This includes identifying any recent shoulder trauma, repetitive overhead activities, or previous injuries that may predispose to the condition (Özbek & Demirtaş, 2022:89). A physical examination will focus on observing the movement of the scapula during active arm movements, especially during activities that mimic functional tasks (e.g., reaching overhead) (Pires, E. D., & Camargo, P. R. 2018). Specific tests, such as the scapular assistance test (in which a doctor assists the scapula during shoulder movements to see if this reduces pain or improves range of motion) and the scapular reposition test, can help to confirm the dysfunction. Imaging techniques such as x-rays, MRI or CT scans are not usually used to diagnose scapular dyskinesia (Panayiotou Charalambous, 2019:77). However, they may be used to rule out underlying structural causes such as rotator cuff tears or glenohumeral instability. Electromyography (EMG) may sometimes be used for research purposes or in more complex cases to assess the function of the scapular muscles (Kibler, W. B. 2006). The diagnosis will be based on the clinical findings and the management will be based on the underlying causes such as muscle weakness, joint instabilities and neurological problems (Panayiotou Charalambous, 2019:77).

To prevent further injury and optimize performance, the treatment of scapular dyskinesia in athletes focuses on improving scapular stability, strength and proper movement patterns. The treatment approach should be comprehensive and tailored to the specific demands of the sport, as scapular dyskinesia often results from repetitive overhead movements common in athletes such as swimmers, baseball pitchers, tennis players and weightlifters (Kevin, Michael & George, 2001:75).

- Physical therapy: A structured rehabilitation programme is the cornerstone of treatment. The athlete's posture, shoulder mechanics and muscle function will be assessed by a physiotherapist. Rehabilitation typically includes exercises designed to improve the strength and endurance of the stabilizing muscles of the scapula, in particular the lower trapezius, the serratus anterior and the rhomboids. During upper extremity movements, these muscles are critical for maintaining proper scapular alignment and function. Scapular retraction exercises, wall slides, resisting scapular depressions and scapular flexion are common interventions (Kibler, W. B. 2006).

- Neuromuscular training: Exercises that focus on proprioception and neuromuscular re-education are key because scapular dyskinesia is often associated with poor neuromuscular control. Proper scapular movement patterns can be restored by training the athlete to activate the right muscles at the right time. This may include the use of techniques such as scapular rhythm training (coordination of scapular and humeral movement) or the incorporation of dynamic exercises such as push-ups, planks and stability ball rolls to promote scapular control during functional movements (DePalma, M. J., & Johnson, E. W. 2003).

- Stretching and soft tissue mobilization: Muscle tightness around the shoulder, such as the pectoralis, upper trapezius, and levator scapulae, often contributes to changes in shoulder mechanics. Stretch and soft tissue techniques, such as myofascial release or trigger point therapy, may reduce muscle tension and improve the flexibility of structures that interfere with normal shoulder motion.

- Kinesiology Taping: To provide sensory feedback, support the muscles and facilitate better shoulder blade positioning during activity, some athletes benefit from kinesiology tape applied to the shoulder and scapula. It's not a long-term solution. However, it can be effective in the short term to improve posture and function during training or competition (DePalma, M. J., & Johnson, E. W. 2003).

- Sport specific training: Sport-specific exercises should be incorporated once an athlete shows improvement in basic shoulder control. This involves incorporating rehab exercises into movements that simulate the athlete's specific sport movements. For example, throwing, swimming or overhead lifting. Training should emphasize efficient scapulohumeral rhythm. This will prevent re-injury.

- Progressive weight bearing and return to sport: Once the athlete has regained strength and glenohumeral control, there is a gradual return to sport. To ensure the athlete doesn't rush back into full activity and risk aggravating the condition, a graduated return to play protocol is essential. Progressive loading is a gradual increase in the intensity and volume of sport-specific exercises, with close monitoring of any signs of pain or abnormal movement patterns.

- Injury prevention: After treatment, ongoing preventive exercises should be part of the athlete's routine. The risk of recurrence can be reduced through regular strength training, postural correction and dynamic warm-ups. In some cases, the incorporation of a shoulder or shoulder blade stability programme into the athlete's off-season conditioning can be beneficial in the prevention of further problems.

In rare or severe cases, additional interventions such as corticosteroid injections or even surgery may be considered if scapular dyskinesia is associated with structural abnormalities such as rotator cuff tears or scapulothoracic bursitis. However, a non-surgical approach with comprehensive rehabilitation strategies will benefit most athletes (Burkhart, S. S., Morgan, C. D., & Kibler, W. B. 2003).

Impingement Syndrome in Athletes

This syndrome is very prevalent among athletes, especially for overhead sports like swimming, tennis, baseball and weightlifting. Impingement is a mechanical conflict between the rotator cuff ligaments and the socket (part of the shoulder blade), causing pain, inflammation and sometimes injury. In time, repeated friction can lead to inflammation of the tendons, bursitis and damage to the shoulder (Lombardo, S. J., et al., 1977). The shoulder joint is a ball and socket type of joint that allows for a wide range of motion. The rotator cuff, a group of four muscles, helps keep the shoulder stable and allows for motion. Impingement syndrome occurs when there is a narrowing of the space between the acromion and the rotator cuff, resulting in compression and irritation of the soft tissues (Özbek & Demirtaş, 2022:89). It is caused by compression of the rotator cuff tendons or the subacromial bursa (a sac filled with fluid that cushions the rotator cuff tendons) against the acromial or coracoacromial ligaments. This can cause the tendons and bursa to become inflamed, thickened or even torn. The narrowing of the subacromial space can be the result of anatomical variations - the shape of the acromion can be different from person to person (type I, II or III). Type III, which has a hooked shape, is more likely to lead to impingement due to the reduced space available for the rotator cuff. Also, tendinopathy, which is swelling and thickening of the rotator cuff tendons, and overuse can result from repetitive overhead movements (Edelson, G., & Teitz, C. 2000). Weakness or dysfunction of the rotator cuff and scapular stabilizers can have an effect on shoulder mechanics and contribute to impingement due to muscle imbalances. Traumatic shoulder injuries can alter shoulder alignment and predispose to impingement, such as fractures or dislocations (Panayiotou Charalambous, 2019:77).

Due to the repetitive nature of overhead movements and high-impact activities, athletes are particularly at risk (DePalma, M. J., & Johnson, E. W. 2003). The most important risk factors are

- Age: Degenerative changes in the rotator cuff tendons are more likely to occur in athletes over the age of 35.

- Repetitive overhead activities: Repeated overhead arm movements in sports such as swimming, tennis, baseball and volleyball increase the risk of impingement.

- Poor posture: By narrowing the subacromial space, rounded shoulders or forward head posture can increase the risk of impingement.

- Muscle imbalances: Shoulder mechanics can be affected by weakness in the rotator cuff or scapular stabilizers, and tightness in the pectoralis major and upper traps.

- Previous shoulder injury: Prior dislocation or tear may predispose the shoulder to impingement due to biomechanical changes or scarring.

There are two main categories of impingement that occur:

- Primary impingement (intrinsic impingement): This is caused by structural problems within the shoulder. These include anatomical abnormalities (e.g. hooked acromion) or degenerative changes in the rotator cuff tendons (Kibler, W. B. 2006).

- Secondary impingement (extrinsic impingement): Caused by abnormal biomechanics resulting in altered shoulder mechanics and increased compression on the rotator cuff, such as muscle imbalances, poor posture or scapular dyskinesis.

Athletes with impingement syndrome often experience pain, typically in the front or side of the shoulder. The pain can get worse with overhead movements and can radiate down the arm or neck. They may also experience weakness, making it difficult to lift the arm overhead or perform sport-specific tasks (Kvıtne, R. S., & Jobe, F. W. 1993). They may also have limited range of motion, with flexion or abduction beyond 90 degrees causing pain or restriction. In some cases, bursitis can cause swelling, and lying on the affected side can make the pain worse, especially during sleep. Friction between the joints can also cause a grinding or popping sensation, known as crepitus, when the arm is moved (Edelson, G., & Teitz, C. 2000).

The diagnostic evaluation for impingement syndrome begins with a thorough history and physical examination. The clinician will ask about the athlete's sports activities, the onset of symptoms, and the nature of the pain (Edelson, G., & Teitz, C. 2000). The clinician will assess range of motion and strength, and perform specific tests such as Neer's test (passive forward bending of the arm to induce pain), Hawkins and Kennedy's test (raising the arm to 90 degrees and internal rotation to assess pain), emptying can test (to assess supraspinatus muscle strength), and abduction test (moving the arm across the body to assess acromioclavicular joint involvement) (Burkhart, S. S. 2006). Imaging studies may also be used to confirm the diagnosis, including X-rays to detect bone abnormalities such as a hooked acromion, MRI for detailed soft tissue assessment, and ultrasound for a cost-effective assessment of inflammation or tears (Lombardo, S. J., et al., 1977).

Unless structural damage, such as a rotator cuff tear, is identified, treatment and management of impingement syndrome usually begins with a conservative approach. Non-surgical treatments include rest and activity modification to avoid aggravation of symptoms, especially with overhead movements, as well as ice therapy to reduce inflammation and swelling after exercise (Veeger, H. E. J., & Van Der Helm, F. C. T. 2007). Non-steroidal anti-inflammatory drugs (NSAIDs) such as ibuprofen can help manage pain and inflammation, while physiotherapy focuses on stretching tight muscles, strengthening the rotator cuff and shoulder blade stabilizers, and correcting posture to restore proper shoulder mechanics (Burkhart, S. S., Morgan, C. D., & Kibler, W. B. 2003). In cases of significant pain or inflammation, corticosteroid injections into the subacromial space may provide temporary relief. Surgical options to relieve impingement, such as arthroscopic subacromial decompression, rotator cuff repair or acromioplasty to reshape a hooked acromion, may be considered if conservative measures fail (Lombardo, S. J., et al., 1977).

The prognosis for impingement syndrome is generally favorable with appropriate treatment, especially if it is caught early. Most athletes will return to full activity after a course of physiotherapy, with resolution of pain and improvement in shoulder function. However, if left untreated or if there is severe structural damage, long-term problems such as chronic pain or rotator cuff tears may develop, requiring surgical intervention (Kevin, Michael & George, 2001:75).

Preventing impingement syndrome in athletes involves several key strategies to minimize the risk of injury. Ensuring proper technique during sport-specific movements, particularly those involving overhead movements, is essential to avoid overloading the shoulder. Strengthening and conditioning programmes should focus on the rotator cuff, scapular stabilizers and core muscles to improve shoulder stability. Regular stretching, particularly of the posterior capsule and surrounding muscles, can improve flexibility and reduce tension (Edelson, G., & Teitz, C. 2000). Adequate rest and recovery between intense overhead activities is essential to prevent overuse injuries. In addition, maintaining good posture can help reduce the likelihood of developing impingement syndrome, both during sports and daily activities, especially for athletes who tend to have rounded shoulders or repetitive movements (Kevin, Michael & George, 2001:75).

Impingement syndrome is a common and potentially debilitating condition for athletes, especially those involved in overhead or repetitive sports (Burkhart, S. S. 2006). Early diagnosis, appropriate rehabilitation and a comprehensive approach to management can help athletes make a full recovery and prevent long-term complications. Understanding the causes, risk factors and treatment options can help clinicians tailor effective rehabilitation programmes to ensure a successful return to sport (Kibler, W. B. 2006).

Superior Labral Anteroposterior (SLAP) Lesions in Athletes

A common cause of shoulder pain and dysfunction, especially in athletes who engage in overhead or repetitive shoulder activities, are superior labral anteroposterior (SLAP) lesions. The term "SLAP" refers to a superior labral injury in which the labrum is torn from anterior to posterior (Conway, J. E. 2001). The labrum is a ring of fibrous cartilage that surrounds the glenoid cavity of the shoulder blade, provides stability to the shoulder joint, and serves as the attachment site for the long head of the bicep's tendon. SLAP lesions can significantly impact an athlete's performance, resulting in pain, instability, and decreased shoulder function. Risk factors for a SLAP lesion include the following Involvement in overhead sports, poor shoulder mechanics, muscular imbalances, prior shoulder injuries, and glenohumeral instability. So, the injury can result from a single traumatic event, such as a fall on an outstretched arm, or from repeated microtrauma over time (Conway, J. E. 2001).

For the development of SLAP lesions, several mechanisms have been proposed:

Compressive force: A fall on an outstretched arm can cause the head of the humerus to be compressed against the superior labrum, resulting in a tear.

Traction force: The biceps tendon and attached labrum can be avulsed by a sudden pull on the arm, such as when trying to catch a heavy object.

Peel-Back Mechanism: In overhead athletes, the biceps tendon can "peel back" the superior labrum from the glenoid as a result of extreme external rotation and abduction of the shoulder.

Repetitive overhead motion: Repeated overhead activities can cause cumulative microtrauma. Over time, this can lead to a SLAP lesion.

Shoulder pain, especially during overhead activities, is typical in athletes with SLAP lesions. The pain is often described as deep in the shoulder and may be associated with a catching, popping, or grinding sensation. Other common symptoms include: decreased shoulder range of motion, weakness, especially during overhead activities, also, feel unsteady or loose in the shoulder, pain when doing certain activities such as reaching overhead or behind the back (Veeger, H. E. J., & Van Der Helm, F. C. T. 2007).

During physical examination, several tests can be used to evaluate for a SLAP lesion, although no single test is definitive. Commonly used tests include;

O'Brien's active compression test: The patient's arm is flexed forward to 90 degrees, adducted 10-15 degrees, and internally rotated. The examiner applies a downward force while the patient resists. A SLAP lesion is suspected if pain with resistance decreases as the arm is externally rotated.

Speed's Test: With the elbow extended and the forearm supinated, the patient's arm is flexed forward to 90 degrees. While the patient resists, the examiner applies a downward force. Pain with resistance suggests a SLAP lesion or biceps tendon pathology.

Crank test: The examiner applies an axial force while rotating the humerus with the patient's arm abducted to 160 degrees. Pain or clicking suggests a SLAP lesion.

After physical examination to confirm the diagnosis of a SLAP lesion and to assess the extent of the injury, imaging studies are essential. MRI is the gold standard for imaging SLAP injuries (Kvıtne, R. S., & Jobe, F. W. 1993). It provides detailed images of the labrum, the biceps tendon, and the structures surrounding the labrum. An MRI arthrogram, in which contrast material is injected into the joint, can improve detection of labral tears. Computed tomography (CT) arthrography can also be used when MRI is contraindicated or unavailable. It can help evaluate for associated glenoid bone loss and provides detailed images of the bony structures. Ultrasound is less commonly used in the diagnosis of SLAP lesions, but can be helpful in the assessment of the bicep's tendon and dynamic function of the shoulder (Conway, J. E. 2001).

SLAP treatment in sports patients is based on several factors, including type and severity, symptoms, and functional goals. Treatment options range from non-operative management to operative intervention.

For Type I and some Type II SLAP lesions, especially in non-competitive athletes or those with minimal symptoms, non-surgical management is usually the first line of treatment. Activity modification and avoidance of activities that aggravate symptoms, especially overhead movements. A structured rehabilitation program that focuses on strengthening the rotator cuff, scapular stabilizers, and core muscles is often beneficial. It may also include stretching exercises to improve shoulder range of motion. Nonsteroidal anti-inflammatory drugs (NSAIDs) may be prescribed to reduce pain and inflammation. To reduce inflammation and pain, a corticosteroid injection into the glenohumeral joint may be considered in some cases (Kvıtne, R. S., & Jobe, F. W. 1993).

Surgery is often considered for athletes with type II, III, and IV SLAP lesions, especially if symptoms persist despite nonoperative management or if they are highly competitive and require a quick return to sport. The goal of surgery is to repair the torn labrum and restore normal shoulder anatomy. Arthroscopic surgery is the most common approach to treating SLAP injuries. The surgeon uses small incisions and a camera to visualize the shoulder joint. The labrum is repaired with sutures and anchors. The biceps tendon may also be addressed, either by repair or by tenodesis (reattaching the tendon to the humerus). In some cases, particularly in older athletes or those with significant biceps tendon pathology, a biceps tenodesis may be performed. In this procedure, the biceps tendon is detached from the labrum and reattached to the humerus. This procedure can reduce pain and improve function in selected patients.

Rehabilitation following a SLAP lesion, whether surgical or non-surgical, is critical to restoring shoulder function and returning the athlete to sport (DePalma, M. J., & Johnson, E. W. 2003). The rehabilitation process is typically divided into several phases:

- Phase 1: Acute Phase (0-6 weeks):

The goal of the acute phase is to reduce pain and inflammation, protect healing tissue, and restore passive range of motion. Activities during this phase may include;

Rest and immobilization: The shoulder may be immobilized in a sling for a short period of time, especially after surgery.

Pain management: NSAIDs and ice may be used to treat pain and inflammation.

Gentle range of motion exercises: Passive and active range of motion exercises are used to prevent stiffness and maintain joint mobility (Veeger, H. E. J., & Van Der Helm, F. C. T. 2007).

- Phase 2: Intermediate (6-12 weeks):

The Intermediate Phase focuses on regaining active range of motion, improving strength, and addressing any muscle imbalances. Activities during this phase may include;

Strengthening exercises: Gradual introduction of strengthening exercises for the rotator cuff, scapular stabilizers, and core muscles.

Proprioceptive training: Exercises to improve shoulder proprioception and neuromuscular control.

Stretching: Continued use of stretching exercises to improve flexibility and range of motion.

- Phase 3: Advanced Strength Phase (12-16 weeks):

The Advanced Strengthening Phase focuses on improving strength, power, and endurance with a gradual return to sport-specific activities. Activities during this phase may include;

Plyometric exercises: Introduction of plyometric exercises for the improvement of power and explosiveness.

Sport-specific drills: Gradually reintroduce sport-specific drills and activities, focusing on proper mechanics and technique.

Functional Training: Exercises focused on improving functional strength and endurance that mimic the demands of the athlete's sport.

- Phase 4: Return to Sport Phase (16+ Weeks)

The final phase of rehabilitation focuses on a safe and gradual return to sport. The athlete should have full range of motion, strength, and functional ability before returning to competition. Activities during this phase may include:

Gradual Return to Sport: A gradual return to full participation in sport, with close monitoring for any signs of pain or dysfunction.

Maintenance Program: Continued strength and conditioning to maintain shoulder health and prevent re-injury.

In athletes, especially those who engage in overhead or repetitive shoulder activities, SLAP lesions are a significant cause of shoulder pain and dysfunction. An understanding of the anatomy, etiology, and classification of SLAP lesions is essential for accurate diagnosis and effective treatment. Both non-operative and operative management options are available (DePalma, M. J., & Johnson, E. W. 2003). The choice of treatment depends on the type and severity of the lesion, the athlete's symptoms, and his or her functional goals. Rehabilitation, with a focus on strength, flexibility, and proper mechanics, plays a critical role in restoring shoulder function and returning the athlete to sport. Athletes can reduce the likelihood of developing a SLAP lesion and maintain optimal shoulder health by implementing prevention strategies and addressing risk factors (Kvıtne, R. S., & Jobe, F. W. 1993).

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HYDROTHERAPY AND BALNEOTHERAPY IN SHOULDER PATHOLOGIES

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Introduction

The shoulder joint is one of the most mobile and complex structures in the human body, enabling a wide range of motion essential for daily activities, sports, and occupational tasks (Miniato, Anand, & Varacallo, 2023). However, this mobility comes at the cost of stability, making the shoulder susceptible to a variety of injuries and degenerative conditions (Veeger & van der Helm, 2007). Shoulder pathologies, such as rotator cuff tears, adhesive capsulitis (frozen shoulder), shoulder impingement syndrome, osteoarthritis, and post-surgical conditions, are common causes of pain, disability, and reduced quality of life. Pain and disability due to shoulder pathologies are frequently seen in clinics. Therefore, pain and

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disability due to shoulder pathologies are an important problem in the general population and are one of the most common musculoskeletal problems after low neck and back pain (Aguilar García et al., 2024). Effective management of these conditions requires a multidisciplinary approach, and both hydrotherapy and balneotherapy have emerged as valuable therapeutic modalities (Aguilar García et al., 2024).

The use of water for medical purposes is probably as old as humanity itself. Hydrotherapy, also known as aquatic therapy, involves the use of water for pain relief, rehabilitation, and overall well-being. It leverages the physical properties of water, such as buoyancy, viscosity, hydrostatic pressure, and temperature, to create a therapeutic environment (Becker, 2009; Patil et al., 2024). In addition to hydrotherapy, balneotherapy involves the therapeutic use of mineral-rich waters and thermal baths in particular. In fact, balneotherapy includes applications and methods that use thermomineral waters, muds and natural gases from natural sources for therapeutic purposes. One of the most commonly used methods in balneotherapy is bathing with thermal mineral water (Bender et al., 2005; Gálvez, Torres-Piles, & Ortega-Rincón, 2018). Both hydrotherapy and balneotherapy offer unique benefits for individuals with a wide range of conditions. Hydrotherapy is particularly effective for pain relief, muscle strengthening, and rehabilitation, while balneotherapy excels in reducing inflammation, improving skin health, and promoting relaxation. Together, these modalities provide a comprehensive approach to healing and well-being, making them valuable tools in both clinical and wellness settings (Protano et al., 2024). This section explores the principles, physiological effects, clinical applications, and evidence-based research supporting the use of hydrotherapy and balneotherapy in shoulder rehabilitation.

Anatomy and Biomechanics of the Shoulder

The shoulder joint, or glenohumeral joint, is a ball-and-socket joint that allows for a wide range of motion, including flexion, extension, abduction, adduction, and rotation. The stability of the shoulder is maintained by a combination of static stabilizers (e.g., ligaments and joint capsule) and dynamic stabilizers (e.g., the rotator cuff muscles). The rotator cuff, comprising the supraspinatus, infraspinatus, teres minor, and subscapularis muscles, plays a critical role in stabilizing the humeral head within the glenoid cavity (Miniato et al., 2023).

Shoulder problems are caused by overuse, excessive movement and excessive strain. The shoulder's multi-directional movement capacity and anatomical structure make it susceptible to injuries and degenerative conditions (Armfield et al., 2003; Lucas et al., 2022). Common shoulder pathologies include:

Rotator Cuff Tears: Partial or complete tears of the rotator cuff tendons, often caused by trauma, repetitive overhead activities, or age-related degeneration. Rotator cuff tears can lead to significant pain, weakness, and functional impairment (Varacallo et al., 2024).

Adhesive Capsulitis (Frozen Shoulder): Characterized by pain, stiffness, and limited range of motion due to inflammation and thickening of the joint capsule. This condition often progresses through three stages: freezing, frozen, and thawing (Angelo, Taqi, & Fabiano, 2023).

Shoulder Impingement Syndrome: Occurs when the rotator cuff tendons are compressed during shoulder movements, leading to pain and inflammation. This condition is commonly seen in individuals who perform repetitive overhead activities (Horowitz & Aibinder, 2023).

Osteoarthritis: Degenerative changes in the shoulder joint, resulting in pain, stiffness, and reduced function. Osteoarthritis is more common in older adults and those with a history of shoulder injuries (Chillemi & Franceschini, 2013).

Post-Surgical Conditions: Patients recovering from shoulder surgeries, such as rotator cuff repair or shoulder arthroplasty, often experience pain and limited mobility during rehabilitation. Effective post-surgical rehabilitation is crucial for restoring function and preventing complications (Koorevaar et al., 2017).

These conditions, which are common among shoulder diseases, can significantly affect many of the patients' abilities to perform daily activities, participate in sports and social activities, or maintain their professional productivity. Traditional rehabilitation methods, such as physical therapy, medications, and surgical interventions, are often complemented by hydrotherapy and balneotherapy to enhance outcomes. Their beneficial effects may increase treatment success and effectiveness.

Physiological Principles of Hydrotherapy

Hydrotherapy uses the physical properties of water to create a therapeutic environment that promotes health, healing, and rehabilitation. Understanding the physiological principles underlying hydrotherapy is important to effectively utilize its therapeutic benefits. These principles include buoyancy, viscosity, hydrostatic pressure, and the thermal properties (temperature) of water. The key principles of hydrotherapy include:

Buoyancy: The upward force exerted by a submerged or floating body by a fluid is called the buoyancy force. When the weight of the floating body is equal to the weight of the displaced liquid, and the centers of buoyancy and gravity are in the same vertical line, the body is held in a stable equilibrium (Torres-Ronda & Schelling I Del Alcázar, 2014). Water's buoyant force reduces the effective weight of the body, decreasing the load on joints and muscles. This is particularly beneficial for patients with shoulder pathologies, as it allows for pain-free movement and early mobilization (Becker, 2009). For example, a patient with a rotator cuff tear can perform shoulder abduction exercises in water with significantly less pain compared to land-based exercises.

Viscosity: Viscosity is a measure of the resistance of a fluid to deformation under surface tension. In other words, it can be defined as the internal friction exhibited by the fluid against the flow. Water provides resistance to movement, which can be used to streng then muscles without the need for weights or resistance bands (Patil et al., 2024). The resistance is proportional to the speed of movement, allowing for controlled and progressive exercises (Geytenbeek, 2002). This property is particularly useful for strengthening the rotator cuff muscles in a low-impact environment.

Hydrostatic Pressure: The pressure exerted by water or another liquid on an object in it is called hydrostatic pressure. Hydrostatic pressure varies depending on factors such as the depth of the liquid, its density, and gravity. The deeper the immersion, the greater the pressure exerted on the body. The pressure exerted by water on the body helps reduce swelling and improve circulation, which can aid in the healing process (Chu et al., 2004; Patil et al., 2024). This is especially beneficial for post-surgical patients who may experience edema and inflammation. Hydrostatic pressure also provides a form of compression that can contribute to proprioception and promote joint stability. In addition, evenly distributing the pressure around the body can reduce pain and discomfort and make it easier for patients to exercise.

Thermal properties: The thermal properties of water play an important role in hydrotherapy. The thermal effect mechanism of hydrotherapy refers to the physiological and biochemical responses that occur in the body when it is exposed to water at different temperatures. These mechanisms vary depending on whether warm or cold water is used, and they play a key role in the therapeutic benefits of hydrotherapy. Warm water (typically between 33°C and 36°C) promotes muscle relaxation, reduces pain, and increases blood flow to the affected area (Becker, 2009). The thermal effects of water can help alleviate muscle spasms and improve tissue elasticity, making it easier for patients to perform stretching and range-of-motion exercises.

These principles make hydrotherapy an effective and versatile tool for addressing pain, improving range of motion, and enhancing muscle strength in patients with shoulder pathologies.

Physiological Principles of Balneotherapy

Balneotherapy is a form of therapy that involves bathing in mineral-rich waters, thermal springs, or muds for therapeutic purposes. It has been used for centuries to treat various health conditions and promote overall well-being. The principles of balneotherapy are based on the unique properties of the water and its interactions with the body. It causes local and general physiological effects on the organism both through physical mechanisms and the chemical properties of the agent (Gálvez, Torres-Piles, & Ortega-

Rincón, 2018). The therapeutic effects of balneotherapy are attributed to the combination of thermal, mechanical, and chemical factors. In many studies, it has been shown that the physical thermal effects of thermomineral waters cause changes in metabolic and enzymatic activity, vascular, neuromuscular, analgesic and viscoelastic properties of tissues. They have also been shown to have anti-inflammatory, chondroprotective and immunological effects, which can also be attributed to their chemical composition (Cozzi et al., 2018; Forestier, Erol-Forestier, & Francon, 2017; Gálvez, Torres-Piles, & Ortega-Rincón, 2018; Gálvez, Torres-Piles, & Ortega, 2018; Morer et al., 2017; Ortega et al., 2017). Despite the increasing evidence, it is difficult to analyze the specific effects of each mechanism and each chemical component separately. Each thermomineral water and mud in the world has its own physical properties and chemical composition. Although its physical effects are relatively well known, its chemical and biological effects are not fully known due to the difficulties in defining and evaluating them (Fioravanti et al., 2011; Tenti et al., 2014).

Thermal Effects: Thermal and cold applications are applications performed for therapeutic purposes, with the aim of having a systematic or local effect on various body parts, depending on the temperature changes in the tissue. Heat transfer can be simply classified into 3 categories: conduction, convection and radiation. Heat transfer to the body in water occurs mainly through convection and conduction. In traditional cure, the general application time varies between 20 and 30 minutes, and the application temperature for thermal water baths varies between 34 and 39 °C (Odabasi & Turan, 2022). Thermal water promotes vasodilation, increases blood flow, suppresses inflammation, increases systemic concentrations of serotonin and β-endorphin, and promotes muscle relaxation, which may help reduce pain and stiffness (Fioravanti et al., 2011). The thermal properties of balneotherapy are particularly beneficial for patients with chronic shoulder pain such as osteoarthritis or adhesive capsulitis (Gálvez, Torres-Piles, & Ortega, 2018; Özkuk & Ateş, 2020; Şen, Karagülle, & Erkorkmaz, 2010).

Mechanical Effects: The buoyancy and hydrostatic pressure of water reduce joint loading and improve circulation, similar to hydrotherapy. These mechanical effects can help alleviate pain and improve mobility in patients with shoulder pathologies (Matsumoto, 2018; Yoshioka et al., 2019).

Chemical Effects: In vitro and in vivo studies have shown that some water-soluble minerals can penetrate human skin and appear to be the key mechanism responsible for the improvement in some clinical outcomes in balneotherapy. Therefore, it appears that the beneficial effects are not only due to mechanical and thermal effects but also to chemical factors (Cheleschi, Gallo, & Tenti, 2020). The minerals in balneotherapy waters, such as sulfur, magnesium, and calcium, have anti-inflammatory and analgesic properties that can enhance the therapeutic effects (Karagülle & Karagülle, 2004).

For example, sulfur-rich waters have been shown to reduce inflammation and promote tissue healing in patients with chronic shoulder conditions.

Although the most evaluated and known mechanism of action of balneotherapy applications is the thermal effect due to the high application temperature, it is thought that it may have a type of systemic effect that cannot be attributed to the thermal effect alone, and that its chemical and biological components may also play a role in these effects by passing through the skin barrier, so the mechanism of action is probably due to a more complex synergistic combination. Balneotherapy is usually used in conjunction with other treatments such as physical therapy and exercise to maximize its benefits. The combination of thermal, mechanical and chemical effects makes balneotherapy an effective method for managing shoulder pathologies.

Physiological Effects of Hydrotherapy and Balneotherapy

The therapeutic effects of hydrotherapy and balneotherapy are based on their ability to affect the physiological processes of the body. All the effects mentioned above create a therapeutic effect. These effects provide the expected effects and benefits in the clinic. The main effects are:

Pain Relief: During balneotherapy and hydrotherapy, sensorimotor hyperstimulation due to hydrostatic pressure, viscosity and water temperature applied to the body or extremity blocks nociceptors while increasing the triggering of thermal receptors and mechanoreceptors, which leads to a decrease in pain (Mooventhan & Nivethitha, 2014). In addition, immersion helps to improve the nutrition of tissues and removing cytokines involved in inflammatory processes by increasing blood flow in the tissues (Rivas Neira et al., 2024). As a result, thermal water helps to relax muscles and reduce pain by reducing muscle spasms. In addition, the buoyancy of water reduces the load on the joint surface, relieving pain during movement. For example, patients with adhesive capsulitis often experience significant pain relief after hydrotherapy sessions, allowing them to perform exercises that would be too painful on land.

Improved Range of Motion: The supportive environment of water allows patients to perform movements that may be difficult or painful on land. During hydrotherapy and balneotherapy, it facilitates passive or active range of motion exercises by reducing tension on the musculo-tendon structures. This reduced stress on the muscles and tendons has the potential to improve the healing process by allowing the affected shoulder to be engaged earlier without compromising long-term tendon integrity (Brady et al., 2008). In other words, the reduction of stress on the muscles and tendons during therapy allows the affected shoulder to return to motion earlier, thus preserving long-term tendon integrity without affecting the healing process (Lädermann et al., 2024). Hydrotherapy can help patients regain shoulder mobility more quickly than land-based therapy alone.

Muscle Strengthening: The resistance provided by water enables patients to perform strengthening exercises in a low-impact environment. This is essential for rebuilding strength in the rotator cuff and surrounding muscles (Geytenbeek, 2002). Patients with rotator cuff pathology often present to clinics with weakness and loss of motion in various movements. It has been reported that weakness of more than 50% compared to the contralateral side in shoulder abduction at 10° abduction is indicative of a large or massive rotator cuff tear (Lädermann et al., 2024; McCabe, Nicholas et al., 2005). For example, water-based resistance exercises can help patients with rotator cuff tears regain strength without exacerbating their symptoms.

Reduced Swelling and Inflammation: Hydrotherapy and balneotherapy, the use of water for therapeutic purposes, can help reduce swelling and inflammation through several mechanisms. Immersing the affected area in thermal water causes blood vessels to dilate, improving blood flow to the area. This improved circulation helps carry oxygen and nutrients to the tissues, promoting healing and reducing inflammation. It also helps suppress inflammation in the immune response produced by thermal applications (Cheleschi et al., 2020). It can also stimulate blood circulation by alternating between thermal and cold water. Thermal water dilates blood vessels, while cold water constricts them. This pumping action helps clear inflammatory byproducts and reduce swelling. Applying cold water or ice packs to the swollen area constricts blood vessels, reducing blood flow and fluid leakage into the tissues. This helps reduce swelling and inflammation. The hydrostatic pressure of the water can help reduce swelling by encouraging the movement of excess fluid out of the tissues and back into the circulatory system. Aquatic exercises or massages can stimulate the lymphatic system through the tissues. Improved lymph flow can help reduce swelling and inflammation. This is particularly beneficial for post-surgical patients who may experience significant swelling after shoulder surgery (Mooventhan & Nivethitha, 2014).

Improved Proprioception and Balance: Hydrotherapy and balneotherapy can significantly improve proprioception and balance through a variety of mechanisms (Jain, Shinde, Jain, & Shinde, 2025; Li, Xiang, Li, & Zhao, 2024). The buoyancy of the water supports the body, reduces stress on the joints, and allows for safer, more controlled movements. The resistance exerted by the water helps strengthen the muscles responsible for balance and coordination. Additionally, the fluid nature of the water creates an unstable environment. During underwater movement, the body is forced to constantly adjust and balance itself, improving proprioceptive awareness and balance. The tactile sensation of the water on the skin provides additional sensory input that increases the brain's awareness of body position and movement. As a result, the body's balance and proprioception in the water improves, which can improve overall joint stability (Becker, 2009).

Clinical Applications of Hydrotherapy and Balneotherapy in Shoulder Pathologies

Hydrotherapy and balneotherapy are used in various stages of rehabilitation for shoulder pathologies, from acute injury management to post-surgical recovery and chronic condition management.

Acute Phase: In the early stages of injury or post-surgery, hydrotherapy and balneotherapy can be very beneficial in the acute phase because it provides a controlled, low-impact environment that promotes healing, reduces pain, and prevents complications. The warmth of the water causes vasodilation, improving blood flow to the injured area, which helps deliver oxygen and nutrients for tissue repair, and helps relax muscles, reduce muscle spasm, and relieve pain. Cold hydrotherapy can also be used to reduce acute inflammation and pain. The hydrostatic pressure of the water helps reduce swelling by encouraging fluid movement from the tissues to the lymphatic system. The buoyancy of the water reduces the weight-bearing load on joints and tissues, allowing early movement without increasing pain or risking further injury.

Rehabilitation Phase: The rehabilitation phase of hydrotherapy and balneotherapy for shoulder pathologies focuses on restoring mobility, strength and function while reducing pain and inflammation. In other words, the waves and buoyancy of the water support the body's weight, reducing stress on the joints and the intensity of perceived pain (Yázigi et al., 2013). In addition, the temperature and water pressure of the thermal water relax the muscles, reduce stress, reduce muscle stiffness and facilitate movement (Barker et al., 2014; Song & Oh, 2022; Yázigi et al., 2013). As a result, it improves pain, mobility and function while minimizing joint stress, making these treatments ideal for chronic and post-operative shoulder conditions.

The types of exercises commonly used during hydrotherapy are passive and active range of motion exercises, active assisted and resistance exercises, strengthening exercises using water resistance, stretching and flexibility exercises.

In hydrotherapy, special equipment and tools designed to increase the resistance of water, improve range of motion or support exercises are used. The choice of equipment varies according to the patient's condition and the rehabilitation phase. For example, buoyancy supports are preferred in the acute phase, and resistance-creating tools are preferred in the advanced phases. Commonly used equipment and tools are summarized below.

1. Swimming Equipment

Swimming Belt: Keeps the body on the surface of the water in deep water exercises.

Swimming Bar (Noodle): Provides support in arm and leg movements, used in flexibility exercises.

Swimming Devices (Arm/Leg Rings): Facilitates movement by reducing joint load.

2. Resistance-Increasing Equipment

Water Gloves: Increases water resistance by expanding the hand surface and is used for strengthening purposes.

Paddles: Used to increase resistance in shoulder and arm exercises.

Water dumbbells: Made of EVA foam, they provide resistance due to the buoyancy forces in water. The natural resistance of water, combined with water weights, provides low-impact exercise.

Resistance Bands: Fixed by the poolside and resistant pulling movements are performed.

3. Functional and Sport-Specific Equipment

Aqua Bike: Lower/upper extremity endurance exercises are performed.

Aqua Jogger Belt: Provides balance for deep water running.

Sports Equipment: Water-resistant tennis rackets, golf clubs (sport-specific rehabilitation).

4. Mobility and Balance Devices

Water Step Boards: Very effective in balance and proprioception exercises.

Floating Platforms: Used for core stabilization exercises.

5. Therapeutic Aids

Underwater Treadmill: Facilitates easier movement for people with mobility difficulties.

Whirlpool: Used for local heat and hydromassage.

Hydrotherapy Protocol for Chronic Shoulder Pathologies

When designing a rehabilitation program for shoulder patients, it is important to consider many factors (Barrett et al., 2018; Littlewood et al., 2012; McEvoy, O'Sullivan, & Bron, 2011; Thein & Brody, 2000). Many factors such as the type of pathology, time of onset of symptoms, severity of pain, movement restrictions, and concomitant pathologies (Bankart lesion, Hill Sachs lesion, reverse Hill Sachs lesion, etc.) should be considered in planning the rehabilitation program.

Taking into account the tissue healing process, it can be divided into 4 phases;

Phase 1: Acute/Protective phase (Weeks 0–6)

Phase 2: Intermediate phase (Weeks 6–12)

Phase 3: Strengthening phase (Weeks 12–18)

Phase 4: Return-to-Activity Phase or Functional Training phase (Weeks 18+)

Phase 1: Acute/Protective phase (Weeks 0–6)

The acute/preventive phase of shoulder rehabilitation (Weeks 0-6) focuses on protecting healing tissues, reducing pain and inflammation, and preventing secondary complications (e.g., stiffness, restriction, muscle atrophy). Water is particularly beneficial in this phase because its buoyancy and resistance properties reduce joint loading and allow gentle movements.

Goals for Phase 1:

- Reduce Pain and Control Inflammatory Processes
- The thermal effects of water (usually 30-34°C) are used to relax muscles and reduce pain. Its physicochemical effects also help reduce swelling and edema.
- Protect Healing Tissues and Prevent New Damage
- Buoyancy supports the limb, reducing the gravitational load on the shoulder. Allows movement without excessive stress to healing structures. Prevents overstrain in postoperative repairs, rotator cuff injuries, or acute injuries.
- Maintaining Passive and Active Supported Range of Motion
- Controlled mobilization can be achieved with pendulum movements (Codman exercises) in the water. Supported flexion,

abduction and external rotation can be performed using buoyancy aids (e.g. buoys for support).

- Preventing Muscle Atrophy and Providing Neuromuscular Activation
- Atrophy of muscle groups in the region can be prevented with in-water isometric muscle exercises (e.g. rotator cuff, scapula stabilizers). Scapula retraction/protraction exercises can be performed to maintain scapulothoracic mobility.
- Minimize Joint Stiffness and Adhesion Formation
- Slow, controlled movements in the water help reduce the risk of developing capsular contracture (especially important after immobilization).

Advantages of Hydrotherapy in Phase 1

- Increase in Painless Movement Ability: Thanks to the buoyancy of the water, minimal load is placed on the shoulder joint, providing painless movement in the early period.
- Early joint range of motion gain: Thanks to the gravity-free environment, joint range of motion can be safely increased with passive and active assisted movements.
- Edema and Inflammation Control: Thanks to hydrostatic pressure, post-operative/acute injury edema control becomes easier.

- Muscle Activation: Minimal muscle contractions are provided with water resistance, preventing atrophy in the early period.
- Psychological Benefit: Patients gain motivation by being able to perform movements in water that they cannot perform in a terrestrial environment.

Sample of Phase 1 Exercises with Hydrotherapy

- Pendulum Movements in Water: Provides painless movement by reducing the effect of gravity.
- Wall Walking: Shoulder flexion/abduction movements are performed with the help of fingers on the pool wall.
- Passive/Active Supported Range of Motion exercises with floating dumbbells or noodles
- Assisted Scapular Mobilization
- Underwater Scapula Squeeze and Retraction exercises: To strengthen and increase the flexibility of the muscles responsible for pulling the shoulder blades together. These exercises improve upper back strength and shoulder stability by working muscles such as the rhomboids and middle trapezius.
- Isometric Resistance: Water resistance is applied to the arm to activate the shoulder muscles.

Precautions

- Avoid forced stretching or aggressive ROM.

- Monitor for pain exacerbation.
- Post-surgical cases (e.g., rotator cuff repair) must follow protocol restrictions (e.g., no active ROM in certain directions).

Phase 2: Intermediate Phase (Weeks 6–12)

The Intermediate Phase of shoulder rehabilitation targets the transition from preservation to regaining mobility, strength, and dynamic stability. This phase is critical for patients recovering from rotator cuff repairs, frozen shoulder, labral repairs, or other shoulder pathologies.

Goals of Phase 2

- Restore Full Passive and Active Range of Motion (ROM): Efforts are made to achieve painless ROM in flexion, abduction, external/internal rotation.
- Minimize Residual Pain and Stiffness
- Improve Rotator Cuff and Scapular Muscle Strength: Strengthening the muscles that support the shoulder helps stabilize the shoulder joint and scapula. As a result, functional stabilization helps improve function, reduce pain, and provide greater recovery and protection for patients.
- Development of Dynamic Stability and Proprioception: Scapulothoracic and scapulohumeral rhythm is attempted to be restored.

- Preparation for daily activities by gradually increasing functional load: Controlled transition to overhead movements is made.

Advantages of Hydrotherapy in Phase 2

- Joint Protective Environment: Thanks to the buoyancy of the water, the load on the shoulder is reduced, and painless movement is provided.
- Early Functional Movements and preservation and increase of tissue flexibility: Weight transfer exercises that cannot be done on land (e.g. push-ups by the pool) can be done safely. Stretches done in water prevent post-surgical adhesions.
- Natural and Adjustable Resistance: The resistance of the water, which changes according to the speed of movement, develops muscle strength in a balanced way.
- Edema and Pain Control: Hydrostatic pressure reduces edema, water temperature relaxes muscle spasm.
- Dynamic Stability Training: Movements in water develop balance and proprioception.

Sample of Phase 2 Exercises with Hydrotherapy

- Mobility and Flexibility Exercises
    - Active Assisted ROM: Lifting the arm up with a float rod or buoyant dumbbells and external rotation with a pool noodle for gentle resistance.

    - Capsular Stretches
- Strengthening
    - Rotator Cuff Activities: External/internal rotation with water paddles or resistance jets.
    - "Scaption" (45° abduction) with buoyant weights.
    - Resisted internal rotation with paddles or gloves.
- Scapula Stabilization:
    - Rowing motions against water resistance.
    - Protraction/retraction with pool wall pushes.
- Dynamic Stability
    - Pool Wall Balance Drills: Plank position with hands on the wall and feet on the floor.
    - Proprioception: Eyes closed, feeling the arm position in the water.
    - Closed-Kinetic Chain Exercises: Weight shifts on pool wall (hands submerged, mini-squats).
    - Plyometrics: Gentle water-based ball toss/catch (chest pass).
- Functional Transition Exercises
    - Simulate daily tasks (e.g., weight carrying, reaching, lifting light objects underwater).

- Ball Throwing-Catching
- Gradual introduction of overhead motions

Precautions

- Rotator Cuff Repairs: Heavy resistance should be avoided for up to 12+ weeks (tendon healing time).
- Frozen Shoulder: Stretching can be done at the pain limit, but aggressive approaches should be avoided if there is acute inflammation or if the pain flares up.
- The end of ROM should be controlled while performing rotation movements.

Phase 3: Strengthening phase (Weeks 12–18)

The strengthening phase of shoulder rehabilitation is a period focused on restoring full functional strength, dynamic stability, and preparing for return to daily living and occupational activities. This phase is critical for patients recovering from rotator cuff repairs, shoulder instability, labral tears, frozen shoulder, or post-surgical cases.

Goals of Phase 3

- Maximize Strength and Power Development: Moderate intensity to high intensity resistance training (e.g. weights, bands). Muscle strength exercises such as the rotor cuff, deltoid and scapular stabilizers (trapezius, serratus anterior, rhomboids) are performed to increase muscle strength, and eccentric strengthening exercises (especially in tendinopathies) are performed to increase tendon endurance.

- Improve Muscle Endurance: Higher repetition loads are increased for endurance in functional and athletic activities.
- Improve Neuromuscular Control and Dynamic Balance: Plyometric exercises (e.g. ball throwing and catching) and proprioception exercises (e.g. balance board, closed kinetic chain exercises) are performed for strength and coordination.
- Regain Full Functional Mobility: Dynamic flexibility exercises are performed to maintain scapulohumeral rhythm.
- Sport/Activity Specific Preparation: Weight transfers and multiplanar movements (PNF diagonal patterns) simulating the sport/work environment are performed.
- Prevent Re-Injury: Biomechanical deficiencies are attempted to be corrected (e.g. scapular dyskinesia)

Advantages of Hydrotherapy in Phase 3

- Low Joint Stress: Thanks to the buoyancy of the water, there is no overload on the shoulder joint.
- Multi-Directional Resistance: Water provides natural resistance according to the direction of movement.

- Proprioception Development: Balance and stabilization can be worked on in water.
- Painless Mobility: Ideal especially for post-surgery or chronic pain patients.

Sample of Phase 3 Exercises with Hydrotherapy

- Resistance-Based Strengthening:
  - Shoulder Abduction/Adduction: The arm is opened to the sides and raised and lowered with equipment.
  - External/Internal Rotation: The elbow is bent 90°, the forearm is rotated outward/inward against water resistance.
  - Shoulder Press: The dumbbells in the water are pressed overhead with controlled eccentric lowering.
- Plyometric and Strength Training: Water Plyometrics: Explosive push/pull movements (e.g., clapping hands underwater) and water ball throwing movements are performed.
- Dynamic Stabilization: While standing on the balance board, drawing circles with resistance in the water with the arms, pushing (protraction) and pulling (retraction) movements of the kickboard under water are performed.
- Closed Kinetic Chain Exercises: Push-ups are performed with the hands on the edge of the pool with the help of buoyancy, and

stepping to the edge of the pool while lifting the arms above the head (Step-Up + Arm Lift) movements are performed.

- Functional Movement Patterns: Freestyle or backstroke swimming without straining with resistance equipment and "chopping" or "lifting" movements (Diagonal PNF Patterns) are done with paddles underwater for body coordination.
- Endurance Training: Forward/backward walking is done with arms submerged in water and abducted up to 90°.

Precautions

- To avoid overloading, the size of the water dumbbells/paddles should be increased gradually.
- During the exercises, proper scapulohumeral rhythm should be provided and correct movement should be made during the application of resistive exercises.
- Pain and fatigue levels should be controlled.
- Excessive and strenuous movements at the overhead level should be avoided.

Phase 4: Return-to-Activity Phase or Functional Training phase (Weeks 18+)

This phase of hydrotherapy for shoulder pathologies usually begins around Week 18. The primary goals of this phase are to restore full function, improve sport or activity specific performance, and safely return to daily activities or athletic participation.

Goals of Stage 4:

- Achieving Full Functional Range of Motion: The aim is to achieve painless, unrestricted shoulder mobility in all planes.
- Developing Dynamic Stability and Proprioception: Work is done to increase dynamic stability and improve joint position sense with functional movement patterns (e.g. overhead reaches, cross movements).
- Regaining Functional Movements Specific to Sports/Work: The speed, strength and resistance of movements are gradually increased by simulating sports or work-related movements (e.g. swimming strokes, throwing movements, lifting mechanics) in an underwater environment.
- Developing Strength and Endurance: Plyometric exercises and aquatic running or resisted swimming workouts are performed to develop strength and endurance. Strengthening the shoulder complex (rotator cuff, scapular stabilizers, deltoids) to a level close to pre-injury levels using gradual resistance in the water.
- Dynamic Balance and Trunk Integration: Balance and coordination are improved by including trunk and lower body participation during shoulder exercises.

Advantages of Hydrotherapy in Phase 4

- Provides low impact high efficient strength and endurance training opportunity.
- For sports specific conditioning thanks to the natural resistance of water in all directions, conditions similar to life/sports environment are created.
- The movement and resistance of water contribute to the development of dynamic balance and proprioception.
- Creates a safer environment for plyometric training.
- Patients work without fear of movement with the supportive effect of water and ease the transition to land-based activity.

Sample of Phase 3 Exercises with Hydrotherapy

- Functional Strength Training
    - Resisted Shoulder Press (Aqua dumbbells)
    - Rotator Cuff Strengthening (Resistance bands/paddles)
    - Rowing Movements (Paddles or hand webs)
- Dynamic Balance and Control
    - One-Arm Ball Handling Exercises (Catch/Throw Against Water Movement)
    - Plank + Shoulder Abduction (On Foam Board)
- Sport Specific Training
    - Freestyle/Backstroke Swimming Exercises

    - Slow Motion Ball Throws (Underwater Throw Drills)
- Strength and Plyometric Training
    - Plyo Push-Up (From Pool Wall)
    - Resisted Jumps (Shoulder Height Against Water Resistance)
- Core-Linked Movements
    - Water Woodchops (Diagonal Resistance Pulls)
    - Lunge + Shoulder Rotation (Combined Stability Work with Dumbbells)

Precautions

Observe the precautions in phase 3.

Evidence-Based Research on Hydrotherapy and Balneotherapy in Shoulder Pathologies

Several studies have demonstrated the efficacy of hydrotherapy and balneotherapy in the management of shoulder pathologies. However, shoulder disorders are quite heterogeneous and many pathologies can coexist, which causes both different treatments and difficulties in standardizing treatments. In a recent meta-analysis, it was reported that the most common shoulder disorder in the shoulder disorders treated with hydrotherapy was rotator cuff repair, followed by studies on shoulder pain (shoulder pain, injury, pathology, rotator cuff injury, myofascial pain, and breast cancer-related shoulder pain), shoulder fracture, rotator cuff tear, frozen shoulder, and shoulder arthroplasty (Capdevila-Pons, Pla-Campas, & Gironès, 2023; Murray, Kennedy et al., 2025). As a result, the methodological quality of studies on these diseases varies.

Hydrotherapy for rotator cuff disorders can be very effective during early rehabilitation to reduce joint stress and assist with shoulder mobilization in patients experiencing pain, anxiety, or dysfunctional muscle activation (Speer, Cavanaugh, Warren, Day, & Wickiewicz, 1993). Despite these advantages, evidence regarding the benefits of hydrotherapy for rotator cuff problems is limited. Most studies use hydrotherapy as an adjunct to standard land-based rehabilitation (Speer et al., 1993). Shoulder recovery has been shown to be accelerated by using hydrotherapy rather than land-based therapy (Brady et al., 2008; Cikes et al., 2023). Hydrotherapy has been reported to be particularly effective for patients who have been immobilized for a longer period of time (Sarver et al., 2008). In other words, hydrotherapy is a method that provides superior results in the short-term follow-up compared to land-based therapy in patients who start physiotherapy later (Lädermann et al., 2024).

Early hydrotherapy after rotator cuff repair may allow rapid improvement in the range of motion of the glenohumeral joint. In addition, the water environment appears to be safe in terms of suture integrity. Thus, it has been reported that it may help reduce secondary postoperative complications such as subacromial adhesions and glenohumeral capsule contracture and stiffness (Brady et al., 2008; Burmaster, Eckenrode, & Stiebel, 2016; Capdevila-Pons et al., 2023; Cikes et al., 2023; DasSarma, Mallick, & Bhattacharyya, 2010; Thein & Brody, 2000). It has also been reported that it is better and safer to start early rehabilitation exercises in water as the buoyancy of water reduces workload and can help reduce tensile stress and protect repaired tendons (Castillo-Lozano, Cuesta-Vargas, & Gabel, 2014; Ezell & Malcarney, 2021; Pabian, Rothschild, & Schwartzberg, 2011). Additionally, active functional work in water can be performed at earlier stages than land-based exercises (Brady et al., 2008; Thein & Brody, 2000).

There are very limited studies on the effectiveness of balneotherapy in rotator cuff diseases. It has been reported that it provides an additional contribution to land-based physical therapy applications (Chary-Valckenaere et al., 2018; Koç, Kurt, Koçak, Erdem, & Konar, 2020; Şen et al., 2010). Hydrotherapy has been reported to be an effective therapeutic approach to improve pain and functional status in individuals with shoulder pain and dysfunction (Srinivasan, Srinivasan, & Senthil Kumar, 2024). In studies conducted in the treatment of chronic shoulder pain, it has been determined that balneotherapy increases the effectiveness of physical therapy (Chary-Valckenaere et al., 2018; Özkuk & Ateş, 2020; Tefner et al., 2015). Hydrotherapy has been found to be effective in reducing pain and increasing range of movement in patients with frozen shoulders (Huss, 2014; Thein & Brody, 2000).

Conclusion

Hydrotherapy and balneotherapy are effective treatment options in the management of shoulder pathologies. Their physical-chemical and thermal properties provide a safe and effective environment for pain relief, rehabilitation and functional recovery. These methods help overcome the difficulties in the treatment and rehabilitation processes of shoulder pathologies by reducing joint load, promoting muscle relaxation and allowing controlled exercise. Hydrotherapy and balneotherapy can significantly increase patients' mobility, muscle strength and quality of life.

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REHABILITATION PROTOCOLS AFTER ROTATOR CUFF REPAIR FROM PATHOLOGY TO RECOVERY

SEZİN SOLUM[1]

Introduction

Shoulder pain is a common musculoskeletal issue that can lead to considerable functional disability. Shoulder discomfort is the third most prevalent musculoskeletal condition in clinical practice (Urwin et al., 1998: 654), with epidemiological research indicating that it affects 7-10% of the general population (Pope et al., 1996: 1139). The majority of shoulder discomfort arises from periarticular structures, with rotator cuff disorders being the primary cause, accounting for over 65% of cases in certain populations (Veccio et al., 1995: 441).

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Rotator Cuff Pathologies

The rotator cuff, an essential anatomical and functional unit consisting of the supraspinatus, infraspinatus, teres minor, and subscapularis muscles, is vital for the dynamic stabilization of the shoulder joint (DePalma, 1963: 1510). These muscles jointly provide glenohumeral rotation and elevation. The supraspinatus mostly initiates abduction and aids in rotation (Halder et al., 2001: 210). The infraspinatus and teres minor form the posterior cuff, acting as primary external rotators and applying an inferior compressive stress on the humeral head within the glenoid fossa, thus reducing the risk of subacromial impingement. The subscapularis muscle provides anterior stability, plays a crucial role in internal rotation, and assists in joint compression (Sgroi & Clienti, 2018: 88). Optimal rotator cuff function guarantees glenohumeral joint stability while preserving mobility; in contrast, damage to any of these tissues often leads to dysfunction. Rotator cuff pathologies are the predominant source of shoulder pain (Boykin et al., 2010: 6), potentially resulting in muscular weakening, altered shoulder kinematics, and instability (Lin, Weintraub & Aragaki, 2008: 628).

Rotator cuff disorders include rotator cuff tendinitis, subacromial impingement syndrome, and rotator cuff tears. Tears are acknowledged as sources of pain, functional limits affecting daily activities, and impairment (Bennell et al., 2007: 86; Smith et al., 2000: 400). Symptomatic rotator cuff tears are predicted to impact

4-32% of the population, with prevalence showing a distinct association with age (Boykin et al., 2010: 6). About 30% of those aged over 60 are impacted, a figure that doubles by the age of 80 (Yamaguchi et al., 2006: 1700). Principal risk factors for rotator cuff tears encompass senior age, use of the dominant arm, and a history of trauma (Yamamoto, Takagishi & Osawa, 2006: 118).

Various variables contribute to the etiology of rotator cuff illness, classified into intrinsic and extrinsic components. Intrinsic aspects relate to the individual and tendon biology, encompassing age-related deterioration, possible genetic predisposition, tendon microstructure, and vascularity. Extrinsic variables encompass external impacts, including acute trauma, chronic overuse, poor biomechanics, distinct acromial morphologies, and postural abnormalities. Moreover, smoking has been identified as a factor affecting the onset of rotator cuff diseases and the results of postoperative recovery (Galatz et al., 2006: 2031; Mallon et al., 2004: 129).

Neer (1983: 72) proposed a categorization scheme for rotator cuff disorders comprising three successive stages:

Stage 1 (Edema and bleeding): Defined by edema and bleeding in the supraspinatus tendon and subacromial bursa. This phase is commonly seen in individuals under 25 years of age, frequently linked to sports or professions that require repetitive overhead movements.

Stage 2 (Fibrosis and Tendinitis): Characterized by fibrosis and hypertrophy of the supraspinatus tendon and subacromial bursa. This stage, often manifesting between the ages of 25 and 40 but conceivable at any age, may signify irreversible changes necessitating modifications in activity.

Stage 3 (Bone Lesions and Tendon Rupture): Characterized by partial or complete rotator cuff tears, often accompanied by concomitant biceps tendon injuries and osteoarthritic alterations affecting the acromion and greater tuberosity. This stage is primarily noticed in adults aged above 40 years.

Symptoms

Pain and weakness are the primary symptoms linked to rotator cuff disorders. Patients frequently report these symptoms during shoulder flexion, internal rotation, and external rotation procedures (Osborne et al., 2016: 85). Subacromial impingement syndrome often manifests as pain localized to the anterior shoulder, which is aggravated by overhead exercises. Pain from rotator cuff injuries typically manifests laterally, indicating common involvement of the supraspinatus tendon (Lansdown & Feeley, 2012: 74). Nocturnal pain is a defining feature of rotator cuff injuries; patients often describe challenges in attaining a comfortable sleeping posture or heightened pain when resting supine (Lansdown & Feeley, 2012: 74). Substantial tears can markedly hinder overhead arm control, resulting in notable weakness and challenges with dynamic shoulder movements.

Clinical Findings

The physical examination may indicate atrophy of the rotator cuff muscles upon inspection. Evaluating scapular kinematics is essential, as effective shoulder movement is significantly dependent on scapular stability and coordinated motion (Lansdown & Feeley, 2012: 75). Tenderness following examination at the Codman point, located on the lateral surface of the proximal humerus, is a prevalent indicator of rotator cuff disease. Assessing both passive and active range of motion (ROM) is crucial in patients exhibiting shoulder discomfort. The existence of complete passive range of motion alongside restricted active range of motion may suggest a full-thickness rotator cuff tear (Lansdown & Feeley, 2012: 75). Manual muscle testing of the rotator cuff components is essential for detecting strength deficiencies, with particular assessments such as the Jobe test examining the integrity of the supraspinatus tendon (Jobe & Jobe, 1983: 120).

The Neer and Hawkins impingement tests are commonly employed provocative techniques that exhibit notable sensitivity and specificity in identifying impingement (Park et al., 2005: 1447; Hawkins & Kennedy, 1980: 153). A study indicated that the Neer test had a sensitivity of 75% and a specificity of 48% for partial rotator cuff injuries (Park et al., 2005: 1447). In patients with a positive Neer test (pain reproduction), a diagnostic subacromial injection of 3-5 mL of 1% lidocaine may be administered; a pain decrease of at least 50% post-injection strongly indicates a subacromial source of the pain (Neer, 1983: 72).

Imaging

Radiography is advised as the primary imaging technique when rotator cuff pathology is anticipated (Lansdown & Feeley, 2012: 77). While plain radiographs do not directly see the rotator cuff tendons, they are important in identifying alternative structural causes of shoulder pain and in detecting osseous alterations associated with advanced rotator cuff diseases. The interaction among the humeral head, glenoid, and acromion can be evaluated. Substantial rotator cuff injuries can cause superior migration of the humeral head, leading to a reduced acromiohumeral interval. An interval of less than 6 mm strongly indicates a significant or massive tear (Weiner & Macnab, 1970: 526). In chronic cases advancing to rotator cuff arthropathy, radiographic findings may reveal degenerative alterations in the acromion and humeral head (Wall et al., 2007: 1478).

Magnetic Resonance Imaging (MRI) and Ultrasonography (USG) are the most efficacious techniques for direct viewing and evaluation of the rotator cuff. MRI offers superior soft tissue contrast, facilitating comprehensive assessment of joint cartilage, labrum, tendons, muscles, and the subacromial bursa. It can evaluate essential prognostic indicators including tear retraction, muscle atrophy, and fatty infiltration, which are critical in assessing surgical candidacy (Oğuz, 2015: 915). Ultrasound is proficient in differentiating between partial and full-thickness rips and can quantify tear dimensions; nonetheless, its precision is significantly reliant on the operator (Oğuz, 2015: 915).

Conservative Treatment

Management solutions for rotator cuff disorders include both conservative and surgical methods. Conservative therapy is frequently successful, especially for partial rips in older patients or those affecting the non-dominant arm, with data endorsing its efficacy in partial-thickness tears (Mantone, Burkhead & Noonan, 2000: 300). Preliminary conservative approaches generally entail activity restriction and the administration of non-steroidal anti-inflammatory medications (NSAIDs) (McConville & Iannotti, 1999: 39). Patients are instructed to refrain from exacerbating overhead activities, and NSAIDs may effectively manage inflammation and related pain (Oğuz, 2015: 915). Subacromial corticosteroid injections may be regarded as an adjunctive treatment (Lansdown & Feeley, 2012: 80), however their use is typically discouraged within 4-6 weeks post-acute injury (Oğuz, 2015).

Exercise therapy constitutes a fundamental aspect of conservative treatment. The initial phase emphasizes the restoration of shoulder range of motion and flexibility, alongside educating the patient on safe shoulder mechanics to avert additional rotator cuff irritation (Lansdown & Feeley, 2012: 80). Incorporate stretching activities that target the posterior capsule, typically incorporating adduction and internal rotation, as well as pendulum exercises. Pendulum exercises promote supraspinatus relaxation while enabling gentle abduction (Mantone, Burkhead & Noonan, 2000: 300). Upon attaining sufficient range of motion, a progressive strengthening regimen focusing on the internal and external rotators, deltoid, and scapular stabilizers should be implemented to guarantee balanced strength throughout the shoulder girdle (Lansdown & Feeley, 2012: 80). An organized fitness program, usually lasting 6 weeks, is frequently advised (Oğuz, 2015: 915).

Surgical Intervention

Surgical intervention is warranted when conservative therapy methods do not yield sufficient symptom relief, with ongoing pain serving as the principal justification for surgery (Oğuz, 2015: 917). Acute traumatic injuries resulting in substantial functional impairment, especially in younger, active individuals, or instances of concurrent biceps tendon rupture—which heightens the likelihood of rotator cuff arthropathy—may necessitate surgical intervention (Lansdown & Feeley, 2012: 81). The primary objectives of surgery are to alleviate subacromial impingement, excise non-viable tissue, and physically reconstruct the torn rotator cuff tendon(s) (Oğuz, 2015: 917).

Codman first delineated rotator cuff surgery in 1911, employing an open method (Ghodadra et al., 2009: 82). Traditional open repair has mostly been replaced by newer techniques because to potential disadvantages, including considerable postoperative pain, extended immobilization needs, and the danger of deltoid muscle impairment (Ghodadra et al., 2009: 82; Hawkins, Misamore & Hobeika, 1985: 1352). Nevertheless, open repair may still be favored for addressing substantial, chronic injuries marked by inferior tendon quality and significant soft tissue adhesions (Osborne et al., 2016: 88). Mini-open rotator cuff repair, utilizing a deltoid-sparing technique to reduce muscular damage, has shown positive results in most patients (Morse et al., 2008: 1827; Ji et al., 2015: 121). At present, arthroscopic rotator cuff repair is the predominant surgical procedure employed. The benefits encompass diminished deltoid injury risks, reduced infection rates, less postoperative joint stiffness, and maybe expedited recovery of range of motion (Lansdown & Feeley, 2012: 81; Moen & Levine, 2012: 170).

Postoperative retear rates demonstrate significant heterogeneity in the literature, with reported ranging from 13% to 94% across several studies (Miller et al., 2011: 2068; Cole et al., 2007: 582; Sugaya as al., 2005: 1312; Galatz et al., 2004: 220). The peak risk time for retear transpires between 3- and 6-months post-surgery, highlighting the imperative to safeguard the repair site from substantial mechanical stress during this crucial healing phase (Ahmad, Haber & Bokor, 2015: 229; Kim et al., 2014: 2610).

Rehabilitation Following Rotator Cuff Surgery

The principal aims of rehabilitation following rotator cuff surgery are to safeguard the integrity of the healing repair, avert the onset of postoperative joint stiffness, and reduce concomitant muscle atrophy (Nikolaidou, Migkou & Karampalis, 2017: 155; Jackins, 2004: 673; Bruzga & Sleer, 1999: 790). Rehabilitation programs are generally organized according to the biological stages of tendon healing: inflammation (0-14 days), proliferation (approximately 2-4 weeks), and remodeling (approximately 4-12/16 weeks), integrating graduated exercise regimens and activity advancement (Conti et al., 2009: 56; Thigpen et al., 2016: 522). Creating an effective rehabilitation program necessitates the evaluation of multiple factors affecting recovery, including patient age, pre-injury activity level, symptom duration (Hawkins, Misamore & Hobeika, 1985: 1352; Bjorkenheim et al., 1988: 150), tear characteristics (size, location, number of tendons involved) (Illyes & Kiss, 2007: 628), tissue quality, extent of muscle atrophy or fatty infiltration (Demirors et al., 2009: 533; Gerber et al., 2007: 693; Gladstone et al., 2007: 725), and the particular surgical technique utilized (Killian et al., 2012: 233; Thomopoulos, Williams & Soslowsky, 2003: 110.

Postoperative joint stiffness due to immobilization is a prevalent issue, irrespective of the surgical technique employed (Nikolaidou, Migkou & Karampalis, 2017: 155). Animal studies indicate that immobility diminishes stress at the repair site, which may augment collagen synthesis, enhance collagen organization, and elevate tissue elasticity relative to early motion protocols (Thomopoulos, Williams & Soslowsky, 2003: 110). As a result, numerous clinicians recommend a duration of 4-6 weeks of immobilization (Millett et al., 2006: 604). Some advocates propose commencing early passive range of motion exercises to perhaps mitigate the development of subacromial scar tissue, a recognized factor in postoperative stiffness (Peltz et al., 2009: 2426).

The ideal arm position during the immobilization phase is still a matter of contention. An abduction sling is often advised (Nikolaidou, Migkou & Karampalis, 2017: 156). Research indicates that stabilizing the arm at roughly 30° of abduction and in neutral rotation for the first 4-6 weeks may enhance vascularity at the treatment site and reduce strain on the repaired tendon (Rathbun & Macnab, 1970: 547).

Cryotherapy may be utilized in the early postoperative phase to diminish discomfort, decrease swelling, relieve muscular spasms, and regulate the inflammatory response (Nikolaidou, Migkou & Karampalis, 2017: 156). Its use is frequently advised during the initial 10-14 days post-surgery (Speer, Warren & Horowitz, 1996: 65).

Rehabilitation is often organized into four separate phases, each with defined goals. The primary objective is to safeguard the surgical repair during the initial postoperative phase while gradually enabling a return to pre-surgical activity levels (Sonnabend & Watson, 2002: 214; Delbrouck et al., 2002: 208; Kibler, McMullen & Uhl, 2001: 530; Kibler, 2003: 842; Browning & Desai, 2004: 817; Huberty et al., 2009: 886).

Table 1: *Goals of Rehabilitation Phases*

Phase	Aim
Phase 1	Mitigate joint rigidity resulting from postoperative adhesions
Phase 2	Enhance joint range of motion without scapular compensation
Phase 3	Reinstate strength and physiological scapulohumeral rhythm
Phase 4	Attain the requisite strength and functionality for occupational and athletic endeavors

Source: Conti et al. (2009). Post-operative rehabilitation after surgical repair of the rotator cuff. Musculoskeletal Surg, 93, 55-63. Doi: 10.1007/s12306-009-0003-9

Rehabilitation Phases

Phase 1 (Weeks 0-4/6)

This initial phase lasts from the immediate postoperative period to 4-6 weeks. The main objectives are to reduce stress on the repaired tendon(s) and avert stiffness caused by adhesion formation by meticulously regulated passive range of motion exercises (Conti et al., 2009: 58). In the absence of explicit directives from the surgeon, patients with full-thickness tears generally employ an abduction sling for 6 weeks, however those with minor tears may utilize it for 4 weeks (Nikolaidou, Migkou & Karampalis, 2017: 157; Conti et al., 2009: 59). The sling is typically removed 3-4 times a day to do passive abduction, flexion, and external rotation exercises within a pain-free range. External rotation is frequently restricted to 0° (neutral) following the surgery of the subscapularis tendon (Conti et al., 2009: 59). Pendulum exercises, executed with the trunk flexed at roughly 30°, are frequently included.

Thorough patient education concerning activity limitations is essential at this stage. Activities to avoid encompass lifting large things, pushing, tugging, significant shoulder extension, reaching behind the torso, strong stretching, or abrupt, uncontrolled motions (Austin et al., 2013: 8).

Transition requirements from Phase 1 to Phase 2 generally encompass (Nikolaidou, Migkou & Karampalis, 2017: 157):

- Painless passive movement within the permitted range
- Attainment of a minimum of 125° of passive forward flexion
- Attainment of a minimum of 75° of passive internal and external rotation in the scapular plane (as allowed and authorized)
- Attainment of a minimum of 90° of passive glenohumeral abduction.

Phase 2 (Weeks 6-12)

This phase typically extends from week 6 to week 12 following surgery. By the sixth week, tendon repair generally allows for the commencement of low-load active motion (Conti et al., 2009: 59). The application of low-level muscular stresses is believed to improve tendon tensile strength and facilitate optimal collagen matrix architecture (Long et al., 2010: 233). The principal objectives of this phase are to preserve the attained passive range of motion (ROM), initiate active-assisted range of motion (AAROM), commence enhancement of neuromuscular control and fundamental strength, and persist in reducing discomfort and inflammation (Nikolaidou, Migkou & Karampalis, 2017: 158). AAROM activities, including stick-assisted internal/external rotation and flexion supported by the contralateral hand while in a supine posture, are introduced (Nikolaidou, Migkou & Karampalis, 2017: 158). Ball sliding exercises on a table or wall may also prove advantageous. Gentle open-chain exercises designed to improve strength and proprioception may begin between weeks 5 and 7, typically initiating with the affected limb elevated to 90° in a supine posture while executing short circular movements (Nikolaidou, Migkou & Karampalis, 2017: 158). Submaximal isometric workouts for internal and external rotation are generally incorporated.

Transition requirements from Phase 2 to Phase 3 typically encompass (Nikolaidou, Migkou & Karampalis, 2017: 158):

- Attainment of complete active range of motion (or near-complete, constrained by symptoms).
- Lack of notable scapular dyskinesis during vigorous motions.

Phase 3 (Weeks 12-16)

This phase marks the commencement of intensified strengthening, generally starting 10-12 weeks post-surgery, when histological remodeling is adequately progressed and the repaired tendon can withstand greater stresses (Conti et al., 2009: 60). The goals encompass attaining pain-free full passive range of motion, augmenting neuromuscular control, and improving muscle strength and endurance. Achieving sufficient range of motion is essential for safely advancing to this phase. Stretching and strengthening exercises progress, frequently integrating elastic resistance activities to enhance endurance. Suggested exercises encompass resisted external rotation, internal rotation, forward flexion, and rowing variations, typically executed with a towel roll positioned between the elbow and the torso to ensure correct biomechanics (Nikolaidou, Migkou & Karampalis, 2017: 158). Exercises focusing on scapular stabilizers and closed kinetic chain activities, essential for progressive functional recovery, are also highlighted (Conti et al., 2009: 60).

Transition requirements from Phase 3 to Phase 4 typically encompass (Nikolaidou, Migkou & Karampalis, 2017: 158):

- Unimpeded execution of the majority of daily activities without discomfort.
- Capacity to endure all strengthening workouts in the program without substantial pain induction.

Phase 4 (Weeks 16-24)

This phase, generally beginning at week 16 and lasting up to 6 months postoperatively, functions as an enhanced strengthening stage, perpetuating the advancement began in Phase 3. The emphasis is on gradually enhancing the restored rotator cuff and adjacent muscles to fulfill increased functional requirements. Exercises such as external rotation at 45° of abduction with elastic tension especially engage the infraspinatus and teres minor, whereas exercises at 90° of abduction focus on strengthening the supraspinatus (Nikolaidou, Migkou & Karampalis, 2017: 159). Plyometric workouts for the upper extremities may be implemented to improve neuromuscular control and proprioception. The ongoing enhancement of the serratus anterior and additional scapular stabilizers is essential.

The criteria for assessing preparedness to resume normal activities and sports engagement typically encompass (Nikolaidou, Migkou & Karampalis, 2017: 159):

- Attainment of symmetrical range of motion and strength in relation to the contralateral, unaffected limb.

- Exhibition of typical, physiological scapulothoracic kinematics during functional activities.

- No discomfort experienced at rest or during pertinent activities

Conclusion

Surgical surgery is required for rotator cuff disorders that do not respond to thorough conservative treatment. A systematic, criterion-driven postoperative rehabilitation program is essential for safeguarding the surgical repair, enhancing functional recovery, and aiding the patient's reintegration into daily, vocational, and recreational activities. Rehabilitation programs must be tailored to individual patients, taking into account specific circumstances and activity requirements, while constantly following biomechanical principles that safeguard the integrity of the surgical repair during recovery.

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