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Weight-lifting Injuries: A Review of Imaging and Biomechanics

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Abstract

Weight lifting, although offering substantial health benefits such as improved bone density, muscle strength, and cardiovascular fitness, poses significant injury risks. In this article, we review common weight-lifting injuries associated with specific activities of Olympic lifts, bench press, deadlift, and squat, as well as general weight-lifting injuries.

Keywords
- weight lifting
- sports injuries
- Olympic lifts
- biomechanics

In the past decade, the popularity of weight lifting has risen sharply, with participation rates increasing by 37% between 2011 and 2021.[1] Contemporary weight lifting encompasses Olympic-style lifting (such as the snatch and the clean and jerk), compound movements (squat, bench press, deadlift), and isolation exercises (bicep curls, tricep extensions, etc.). However, training is not without risk. Recent epidemiological data indicate an injury rate of 2.4 to 3.3 injuries per 1,000 hours of training, and imaging plays a crucial role in diagnosis and management.[2]

Olympic Lift-Related Injuries

The clean and jerk and the snatch are the two maneuvers in Olympic weight lifting. The clean and jerk consists of two distinct phases: the clean, where the barbell is lifted from the ground to the front rack position across the shoulders and chest, followed by the jerk, where the athlete jerks the bar from the shoulders to an overhead position. The snatch requires lifting the barbell from the ground to overhead in a single smooth motion, with control demonstrated by holding the barbell steady overhead for 3 seconds.[3] Both lifts involve rapid ankle plantar flexion, knee extension, and hip extension. During these movements, athletes regularly handle weights exceeding twice their body weight.[4]

The overhead catch position in Olympic lifts generates stress on the shoulder. During the catch phase, the glenohumeral joint experiences forces from the weight, combined with sudden shoulder flexion, abduction, and external rotation.[4] This mechanism may produce injury patterns that overlap with the overhead throwing athlete. Labral injuries are most likely to occur during the turnover phase of the snatch and clean because this phase places traction forces on the labrum. It twists the labrum, causing a so-called peel-back mechanism of injury or traction. The same mechanism in concert with the needed repetitive use of shrugging a flexed shoulder can lead to tendinitis and tears of the long head of the biceps tendon[4] (►**Fig. 1**).

Superior labral injuries in Olympic lifters can show distinctive posterosuperior patterns with associated bone marrow edema in the posterior glenoid, contrasting with the anterosuperior patterns typically seen in throwing athletes.[5] Dynamic magnetic resonance imaging studies have revealed momentary subluxation events during the rapid transition from the pull to catch phase, resulting in characteristic chondral injury patterns along the posterosuperior glenoid rim. These findings appear in 38% of competitive lifters and demonstrate a strong correlation with years of training experience.[6]

The shoulder abduction and external rotation required to push the bar overhead puts stress on the supraspinatus and infraspinatus muscles and tendons that adapt with chronic thickening,[7] but these tendons can also be acutely injured. The overhead motion decreases the subacromial space that can lead to supraspinatus tendinosis and tears. The infraspinatus tendon and muscle, acting as the primary external rotator, is subject to forces during the jerk phase that may also result in tears and tendinosis.[4]

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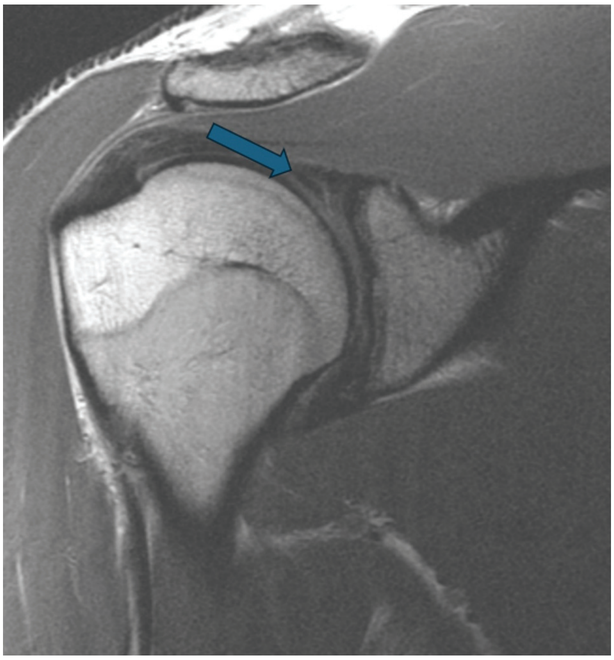

Fig. 1 Tear through the superior labrum. A 24-year-old male Olympic weight lifter. Coronal proton-density-weighted image of the shoulder shows a linear high signal cleft within the superior labrum (arrow) compatible with a nondisplaced tear.

Elbow dislocations frequently occur in Olympic-style weight lifters during the jerk phase as the barbell is lifted overhead. The valgus and posterior forces applied in this position can lead to a posterior elbow dislocation or result in acute and chronic strains of the ulnar collateral ligament.[8]

The clean and jerk shares lower extremity injury patterns with other exercises that require deep hip flexion and explosive extension (as further detailed in the deadlift and squat section). Associated with explosive hip extension, injuries to the hip flexors are common.[9,10] This injury often occurs during the clean phase when the lifter transitions from a deep squat position to an upright position. The rapid hip extension required to lift the barbell can lead to excessive strain on the hip flexors, resulting in muscle strains and tears.

More unique to the clean and jerk is the risk of anterior cruciate ligament (ACL) injury. Improper knee alignment and excessive forward lean during the dip phase of the jerk can increase the likelihood of ACL sprains and tears.[11]

Bench Press Injuries

The bench press represents a fundamental upper-body exercise in weight-lifting programs. Bench pressing is a compound movement primarily targeting the pectoral muscles, anterior deltoids, and triceps. It involves pushing a barbell or dumbbells away from the chest while lying supine on a bench. The weight starts overhead and is lowered to the chest and then pushed back to the starting position. During the lowering phase, the pectoralis major and anterior deltoids primarily act to decelerate the weight, placing an eccentric load on these muscles.[12] Because of the positioning of the elbows posterior to the trunk, stress and traction is also placed on the distal clavicle. The rotator cuff and labrum help stabilize the glenohumeral joint.[13]

Arguably the most dreaded complication of bench pressing is a pectoralis major tear. Once thought to be uncommon, the prevalence of pectoralis major tears is increasing.[14] Approximately 48% of pectoralis major tears occurred during weight lifting, although it can also occur during other sporting activities such as waterskiing, football, wrestling, parallel bar dips, ice hockey, and windsurfing.[15,16] The pectoralis major is a fan-shaped muscle with a small clavicular head and large sternocostal head that both insert onto the proximal humerus. Injuries to the pectoralis major most often occur during the eccentric lowering phase of the lift. Tears of the pectoralis major may be associated with periosteal stripping or hematoma and may be incomplete in one head or complete involving both heads. The tears typically occur at specific locations: at the muscle origin or muscle belly, at or in between the myotendinous junction and tendinous insertion, and bony avulsion of the humerus.[17] Treatment varies based on the location of the tear with muscle belly or muscle origin tears more amenable to conservative management (►**Fig. 2**).

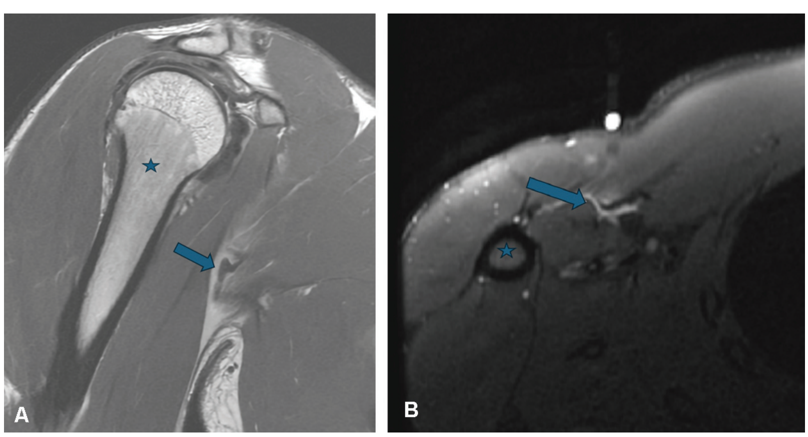

Fig. 2 Tear of the pectoralis major tendon. A 29-year-old man with injury sustained during the bench press. (**A**) Oblique coronal proton-density-weighted and (**B**) axial inversion recovery images through the pectoralis and humerus (star) show a complete tear through the pectoralis tendon with retracted tendon fibers to the deltopectoral groove (arrow) and surrounding soft tissue edema.

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A less commonly described injury involves the pectoralis minor. Overuse insertional tendinosis of the pectoralis minor has been termed *bench presser's shoulder* when symptomatic. The often forgotten pectoralis minor is a thin muscle deep to the pectoralis major, originating from the third through fifth ribs, and inserts on the coracoid process. Its function is to tilt the scapula inferiorly and anteriorly.[18]

The rotator cuff, like in many lifts, is also susceptible to injury during bench pressing. During the bench press, the shoulder muscles must shift between concentric and eccentric contractions to stabilize, lift, and lower the barbell. During the exercise, the rotator cuff is in a vulnerable position as the shoulder is positioned in abduction and external rotation that increases subacromial impingement and increases the load transmitted to the rotator cuff.[19,20] Repeated stress on the glenohumeral joint can also lead to labral tears (often posterior) and labrocapsular dysfunction.[8]

Clavicular stress and subsequent distal clavicular osteolysis (DCO) can also be related to bench pressing. It was previously reported that up to 97% of people with DCO have a history of bench pressing.[21] During horizontal adduction, as the arm comes closer to the body, the distal clavicle is compressed against the acromion and released during the concentric phase. Over time, this repetitive cycle of compression and release, especially under load, can lead to microtrauma at the distal clavicle, resulting in DCO[8] (►**Fig. 3**).

Less common but documented injuries that occur with bench pressing are anterior shoulder dislocation, clavicular fracture, distal radial fracture, scaphoid fracture, and triceps tendon tendinosis/rupture, with the fractures attributed to direct blows by the weight.[22]

Deadlift Injuries

The deadlift, considered a test of full-body strength, requires coordinated activation of multiple muscle groups to lift a loaded barbell from the floor to hip level while maintaining proper spinal alignment. The two predominant versions of the lift are the conventional deadlift, with feet hip-width apart, and the sumo deadlift, with a wider stance and greater emphasis on hip abduction.[23] Although popular, deadlifting poses risks for several musculoskeletal injuries, especially with improper form or excessive loading.

The deadlift involves sequential joint actions and corresponding muscle activation patterns through its range of motion. Initial movement from the floor requires knee extension while maintaining thoracic stability, with the barbell tracking vertically along the shins. As the barbell ascends past knee level, hip extension becomes the primary movement pattern, placing significant demands on the posterior chain musculature (largely the hamstrings, gluteus maximus, and erector spinae).[24,25] Terminal lockout requires coordinated hip and knee extension to achieve full erection. Electromyographic analysis demonstrated phase-specific muscle activation, with initial quadriceps dominance transitioning to posterior chain engagement through completion of the movement.[26]

The lumbar spine is commonly injured when performing a deadlift. It must bear the load to maintain spinal alignment under the weight. Excessive forward flexion of the spine can lead to increased forces in the lower lumbar spine with the most shearing and compressive forces acting on L4–L5 and L5–S1.[27–29] This strain can lead to acute disk herniations. The erector spinae muscles, part of the posterior chain, also bears increased forces during the deadlift that can lead to strain/injury[27] (►**Fig. 4**).

The hip joint plays a critical role in the deadlift because it acts as the hinge during the lift. The repetitive loading of the hip extensors, combined with rapid flexion-extension movements, can increase the risk of hip impingement, especially femoroacetabular impingement. It is characterized by abnormal bony contact between the femoral head and acetabulum throughout the normal range of motion and was observed in lifters experiencing groin pain and reduced hip range of motion.[30] Hamstring injuries are also prevalent during deadlifting. The hamstrings function as both hip extensors and knee flexors, making them particularly vulnerable to injury during barbell ascent. Eccentric loading can lead to proximal hamstring tendinosis, tears, and avulsions.[31]

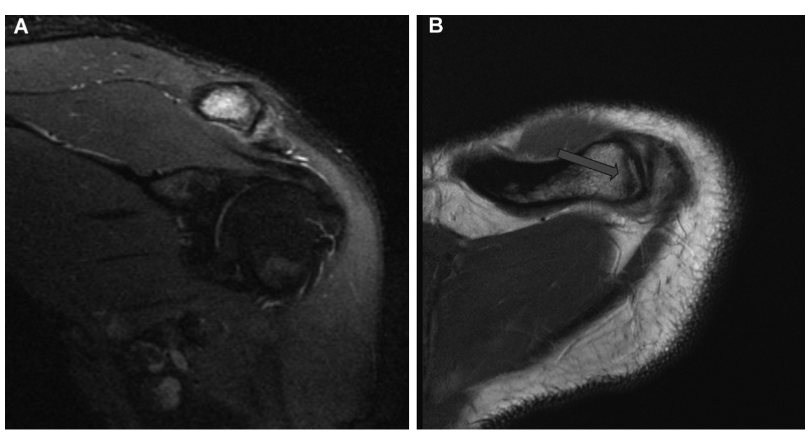

Fig. 3 Distal clavicular osteolysis. A 26-year-old male weight lifter with chronic pain. (**A**) Coronal inversion recovery and (**B**) axial proton-density-weighted images show intense bone marrow edema in the distal clavicle with surrounding soft tissue edema. A hypointense subchondral fracture line is evident (B, arrow).

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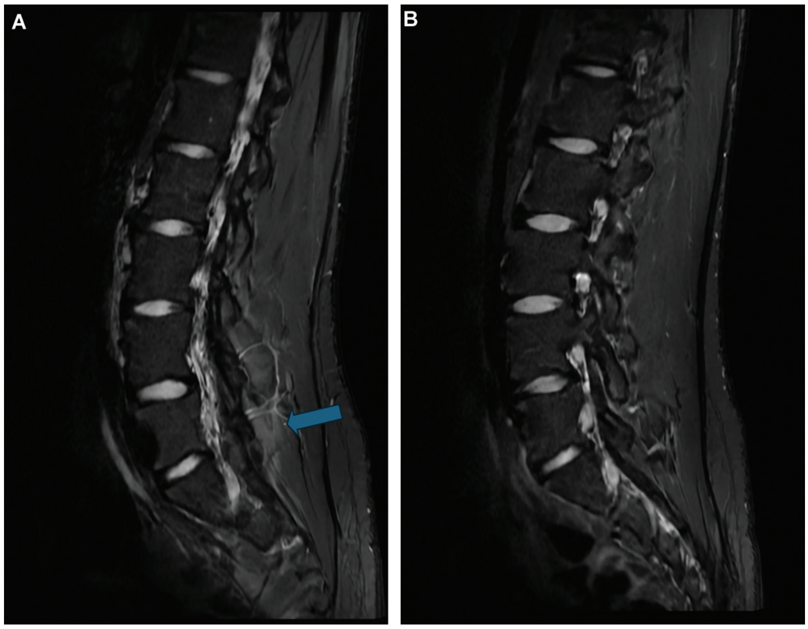

Fig. 4 Erector spinae muscle strain. A 17-year-old adolescent with asymmetric back pain after deadlifting. (**A**) Sagittal inversion recovery image of the low back shows edema within the right erector spinae group (arrow). (**B**) The included contralateral side is without signal abnormality.

The hip adductors also play a vital role during the deadlift movement. During the ascent at higher knee flexion intervals (61–90 degrees), there is increased activation of the adductor magnus as the ischial fibers of the adductor magnus act as a hip extensor. During descent as the weight decelerates, the adductors group (adductor longus, adductor magnus, and gracilis) help stabilize the hip.[32] Repetitive load and inflexibility can lead to strains of the adductor muscle group.[33]

The mixed-grip deadlift variation is used to decrease rotation of the barbell while lifting; one hand is pronated and the other supinated (as opposed to the double-pronated "overhand" grip). The supinated "underhand" arm is at risk for biceps tendon tears or ruptures. The biceps tendon is susceptible to strain as it resists the weight of the barbell, particularly at the distal attachment near the elbow. Heavy loads, coupled with elbow flexion during the eccentric phase, significantly increase the risk of distal biceps tendon rupture (►**Fig. 5**).

Squat Injuries

The squat is a compound exercise performed by positioning a barbell across the trapezius muscles while executing synchronized hip and knee flexion during the eccentric phase. The descent continues until the femurs achieve parallel orientation to the ground. The concentric phase is initiated through coordinated activation of the posterior chain musculature (hamstrings and gluteal complex) and the quadriceps muscle group, driving extension against resistance.[10] Proper biomechanical alignment is fundamental to injury

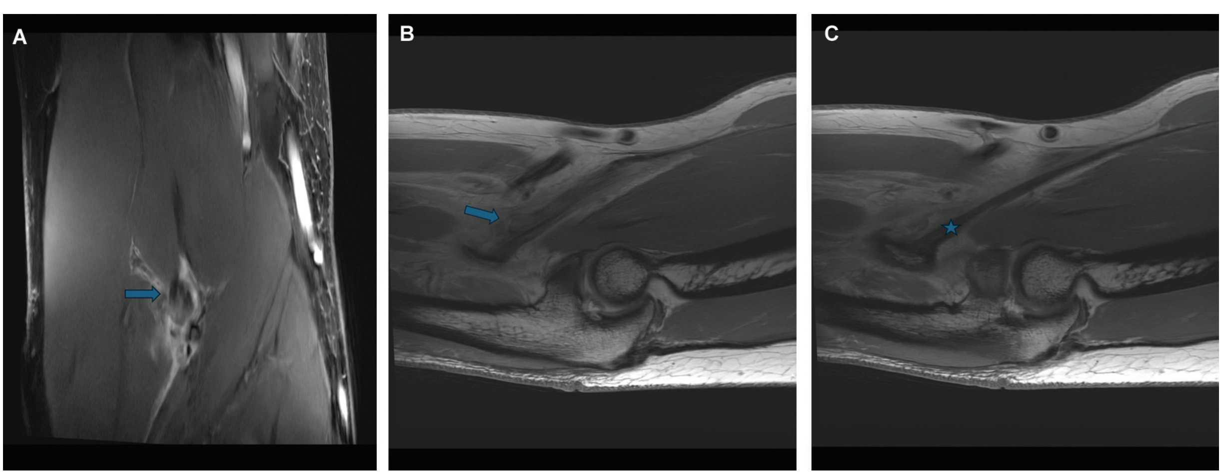

Fig. 5 Distal biceps avulsion. A 39-year-old man with acute pain weight-lifting injury. (**A, C**) Sagittal proton-density and (**B**) coronal inversion recovery weighted images of the elbow. Note a full-thickness tear through the distal biceps short head insertion with retracted tendon stump and soft tissue edema (A, B, arrow). (C) The long head was noted to be intact, maintaining a separate insertion (star).

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prevention across all resistance exercises, but the squat's characteristic heavy axial loading pattern and complex movement pattern leaves the lifter susceptible to injury.[34]

The knee is subject to substantial forces while squatting, and injuries to the knee are common.[35] Injury to the quadriceps and patellar tendons (tendinosis/tear) can be precipitated by the supraphysiologic loading under deep flexion during the squat, with increased susceptibility noted in individuals presenting with preceding tendinopathy or increased body mass index.[36] During the squat, excessive hip medial rotation increases patella cartilage stress that may lead to chondral wear.[35]

Meniscal injuries can often occur with movements that require deep knee flexion, such as squatting.[37] High compressive forces experienced during deep squats and rapid changes in loading can lead to tears in the meniscus, especially in individuals with preexisting degenerative changes.[38]

During the ascent phase of the squat, significant stress is placed on the gluteal tendons that serve as primary hip extensors; however, like the deadlift, significant stress is also placed on the adductor muscle group. Although the primary function of the adductor muscles is to bring the legs together, they (particularly the adductor magnus) also assist in hip extension, depending on the degree of hip flexion.[39] The adductor magnus has a significant role in extending the hip joint when the hip is in a deep flexed position, such as during the ascent phase of a squat.[40] The degree of hip medial rotation augments the stress seen on the adductor group.[35] Either the gluteal muscles or the adductors can experience muscle strains/tears during the squat ascent (►**Fig. 6**).

The lumbar spine encounters substantial mechanical demands during squatting movements, with significant compressive and shear forces acting on the vertebral bodies, intervertebral disks, and associated paraspinal soft tissues. The form and technique a lifter uses can greatly impact the risk of injury. Like deadlifts, intervertebral disk herniation is a prevalent injury associated with squatting, particularly when performed with improper technique or excessive load. The combination of axial loading and lumbar flexion during squats can elevate intradiskal pressure, leading to herniation.[27] The intervertebral disk is at greater risk when compressive forces are combined with bending or twisting motions that can occur with improper squatting technique.[41]

Shear forces not only act on the spine and disks but on the intertwined muscles and ligaments. The erector spinae muscle group and multifidus aid in stabilizing the spine throughout the movement.[42] Excessive spinal flexion in concert with load can strain these muscles. Weakness of these muscles was shown to exacerbate back pain and increase the risk of more serious injury.[43] The structural integrity of the lumbar spine is also maintained by an intricate network of ligamentous tissues, with the anterior and posterior longitudinal ligaments serving as primary stabilizing elements. These ligamentous structures become vulnerable to mechanical compromise when subjected to excessive torsional or flexion moments during squatting.[44]

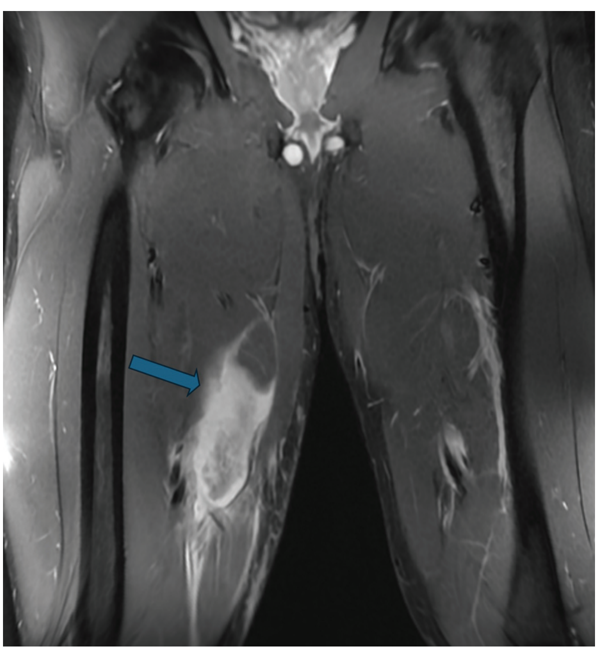

Fig. 6 Adductor longus tear. A 24-year-old man with acute injury during a squat. Coronal inversion recovery images of the thigh show a high-grade distal adductor brevis muscle-tendon junction tear (arrow) with associated hematoma.

General Weight-lifting Injuries

Beyond the specific injuries associated with major lifts, weight lifters can experience a wide range of injuries across various exercises and movement patterns. Hand and wrist injuries are particularly common across various lifting disciplines. Repetitive gripping under load can lead to finger flexor tendinosis and carpal tunnel syndrome, with studies reporting a 15% prevalence of carpal tunnel symptoms in regular weight lifters.[45] The hook grip technique, commonly used in Olympic lifting, may result in chronic metacarpophalangeal joint capsular injuries and thumb pain.

Chronic overuse syndromes, encompassing the spectrum of tendonitis and enthesopathy, represent another significant category of injuries related to weight lifting. Enthesopathy at tendon insertion points was documented across multiple muscle groups, particularly in lifters with high training volumes.[18]

Muscle strains, bony stress reactions, and fractures can occur in weight lifters due to repetitive loading or acute trauma. Stress reactions can even affect the ribs, particularly in movements involving significant thoracic loading such as the bench press or the clean and jerk.[46–48] Stress fractures of the pars interarticularis can develop from repeated spinal extension and flexion under load. Acute fractures, although less common, typically result from direct trauma or equipment accidents, with scaphoid and metacarpal fractures the most prevalent in upper extremity injuries.[49,50]

The subacromial-subdeltoid bursa can be irritated by weight-lifting movements. Bursitis can develop from repetitive overhead movements or improper technique across multiple lifting patterns. This condition can be exacerbated

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by altered scapular mechanics and poor thoracic mobility, common adaptations in weight lifters.[51]

Systemic complications rarely arise from intensive weight-lifting regimens. Exercise-induced rhabdomyolysis, although uncommon, presents a serious risk, particularly during periods of increased training intensity or following extended breaks.[52] Compression neuropathies can affect regular weight lifters gradually due to repetitive pressure on peripheral nerves during various lifting movements. Median nerve entrapment, ulnar neuropathy, radial neuropathy, medial pectoral nerve injury, and musculocutaneous nerve injury have all been described.[53,54] Additionally, pre-existing conditions such as osteoarthritis may be exacerbated by regular heavy loading.[55]

Conclusion

As weight-lifting participation continues to rise in popularity, imaging plays an increasingly vital role in evaluating injuries. Understanding the biomechanics of various lifts helps radiologists identify associated injuries.

Conflict of Interest
None declared.

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