

Rehabilitation in Overhead Athletes With Thoracic Outlet Syndrome



Lindsey Colbert, D.P.T., Chelsea Harrison, P.T.A., and
Clayton Nuelle, M.D., F.A.A.O.S., F.A.O.A.

Abstract: Thoracic outlet syndrome (TOS) is a clinical diagnosis resulting from the impingement of neurovascular structures between the clavicle and first rib. Effective prevention and nonoperative treatment in high-performance athletes with TOS are not well documented. The objective of reporting this case was to discuss the symptom progression, relevant clinical findings, and rehabilitation of an overhead athlete with diagnosed neurogenic TOS. Numerous rehabilitative techniques may be used to treat an athlete with TOS, with an emphasis on restoring full shoulder mobility, motor control, and normalized scapular mechanics in a throwing athlete, as well as improving functional thoracic range of motion. Modalities such as neuromuscular electrical stimulation and targeted muscle exercises are incorporated in the process. In the case presented, a collegiate-level throwing athlete returned to full participation at her previous level of play within 18 weeks of rehabilitation initiation. This report details the clinical findings and treatment options available to address pathology in an overhead athlete with a diagnosis of TOS. The clinical case example shows techniques that may help guide the clinician in establishing effective nonoperative or postoperative treatments for TOS. **Level of Evidence:** Level V, expert opinion.

Thoracic outlet syndrome (TOS) is a clinical diagnosis resulting from the impingement of neurovascular structures between the clavicle and first rib.¹ Although the reported incidence is only 3 to 80 in 1,000, TOS can be highly debilitating when it occurs. This condition, although rare, is becoming more recognized in individuals who perform repetitive tasks, including those who participate in overhead sports such as baseball, softball, volleyball, and swimming.²⁻⁶ Symptoms typically include pain, numbness,

paresthesia, and weakness through the upper extremity. These symptoms are often intermittent in athletes, which leads to difficulty in early recognition and diagnosis. Over time, symptoms through the thorax and shoulder gradually progress to include numbness, heaviness, and fatigue through the involved arm with exertion. There are 3 types of TOS: neurogenic TOS (nTOS), venous TOS, and arterial TOS, with the most common type being nTOS.

Overuse injuries in overhead sports are typically the product of multiple factors such as excessive repetitive strain, poor conditioning, high work-to-rest ratios, and long-term playing time. Elite-level players show greater efficiency than amateur players with transferring energy from the lower body through the arm to throw. Up to 20% less electromagnetic activity is seen in elite players' shoulders than in amateur players' shoulders, showing their ability to perform at a high level without as much exertion.⁷ The ability of elite players to transfer energy through the kinetic chain is supported by their physical maturity and a well-designed strength and conditioning program, which is often lacking at the youth and high school levels. Poorly controlled hypermobility often seen in adolescent female athletes, combined with insufficient conditioning, may place amateur players at a higher risk of injury.⁸⁻¹¹

From Mizzou Therapy Services, University of Missouri Health Care, Columbia, Missouri, U.S.A.

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Address correspondence to Lindsey Colbert, D.P.T., Mizzou Therapy Services, University of Missouri Health Care, 1100 Virginia Ave, Columbia, MO 65212, U.S.A. E-mail: Colbertl@umsystem.edu

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Compression of the neurovascular structures between the clavicle and first rib occurs under circumstances equitable to a perfect storm. The throwing motion begins at the ground, with up to 50% of the total force in a pitch deriving from the lower body.¹² Poor motor control and/or joint restriction in the spine results in a dissipation of this energy as it transfers to the arm. To maintain the velocity and power while throwing or hitting, the thorax, shoulder, and arm are required to make up for this deficit. Cervical, thoracic, and scapular instability has been documented in patients with a diagnosis of TOS.¹³⁻¹⁵ Stiffness of the scalene muscles has been shown to increase with throwing, which produces a superior force on the first rib.¹⁶ This rib elevates in the absence of a stabilizing inferior counterforce of the serratus anterior. When these conditions occur in a player with an overall depressed scapulothoracic joint and a downwardly sloped clavicle, the neurovascular structures running through the infraclavicular space may be compressed.

The clinical profile of an overhead athlete at risk of the development of TOS is not as well understood as that in other conditions specific to this population. Clinical findings such as range-of-motion (ROM) changes, fatigue, abnormal throwing mechanics, lumbopelvic complex weakness, and motor control deficits have been correlated with a higher injury risk in a thrower's shoulder and elbow.¹⁷ However, owing to the inconsistent nature of the symptoms leading up to the diagnosis of TOS, the warning signs of its development are not well documented. The most commonly reported findings specific to patients with a diagnosis of TOS include excessive resting tension in the scalene and/or pectoralis muscles, abnormal scapular position and posture, and early fatigue in the upper extremity with resisted motions.^{2,4,5,18-20} The subsequent rehabilitative techniques necessary to improve symptoms are aimed at addressing each of these specific deficits and abnormalities. The purpose of this review was to discuss the symptom progression, relevant clinical findings, and recommended rehabilitation of an overhead athlete with TOS, with a case example of a collegiate player with a diagnosis of nTOS.

Case Description

A 21-year-old, right hand—dominant, National Collegiate Athletic Association Division I softball player presented with right shoulder pain and instability, elbow pain, and intermittent hand swelling with throwing. The patient played left field for her collegiate softball team, throwing right-handed and batting left-handed (leading with the right arm).

The patient had undergone a right scalenectomy and first-rib resection for TOS 1 year prior and underwent an uneventful rehabilitation course, but when returning to play as an outfielder, she reported limiting pain in

the right posterosuperior shoulder with throwing. Intermittent, mild right hand swelling then returned with throwing that summer. She presented for outpatient physical therapy in the fall of her junior year with complaints of the shoulder feeling “abnormal” with full-speed throws and continued hand tingling and swelling with prolonged play.

TOS Clinical Evaluation and Examination

Clinical examination of overhead athletes with a diagnosis of TOS includes an initial ROM and strength examination, in addition to assessment of overall resting posture and muscle tone. Resting scapular position has not been shown to correlate with pathology, nor does it indicate the presence of poor movement patterns.²¹ Furthermore, most overhead athletes with a diagnosis of TOS initially report symptoms with exertion, rather than at rest. Therefore, although resting scapular depression may be commonly noted in patients with a diagnosis of TOS, it is a small clinical piece of the puzzle and may not necessarily predict pathology. Resting muscle tone through the scalenes, upper trapezius, and pectoralis major and minor also receives similar attention in the assessment of this population. However, these structures commonly show neurologic tone as a compensatory mechanism to stabilize the glenohumeral and scapulothoracic joints in patients with many upper-extremity conditions, including impingement syndrome, rotator cuff tendinosis, neck pain, clavicular fractures, and acromioclavicular joint separations.

Passive ROM measurements of the bilateral shoulders were taken with the patient placed in the supine

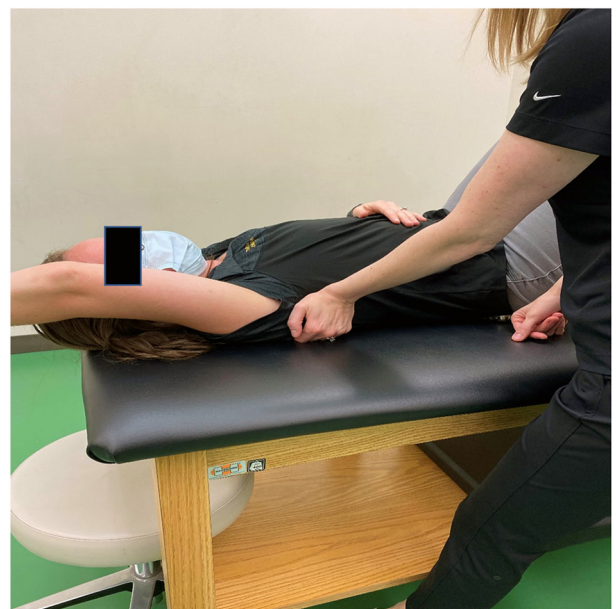


Fig 1. Manual stabilization of lateral border of scapula for passive range-of-motion measurements.

Table 1. Improvements in PROM Over 18 Weeks of Physical Therapy

Scapular Plane	Degrees of Range of Motion at Evaluation	Degrees of Range of Motion at 18 Week Re-evaluation
Passive Flexion	154	180
Passive Horizontal Abd	21	44
Passive External Rotation	105	124
Passive Internal Rotation	53	61

hook-lying position (supine, knees flexed, feet resting on a plinth) and a pillow placed under the head (no further lateral than the ear). Passive shoulder flexion (PSFlx) and passive shoulder horizontal adduction were measured using a standard goniometer with the lateral border of the scapula manually stabilized (Fig 1). Passive shoulder external rotation and passive shoulder internal rotation (PSIR) were measured at 90° of shoulder abduction with the humerus elevated approximately 10° off the table; manual stabilization of the coracoid process and spine of the scapula was performed during measurement of PSIR for standardization.²² The measurements were repeated on the nondominant shoulder for comparison at each time point (Table 1). Taking precise measurements of the patient's ROM in both the affected shoulder and unaffected shoulder allows the clinician to monitor changes and progress during the treatment process.

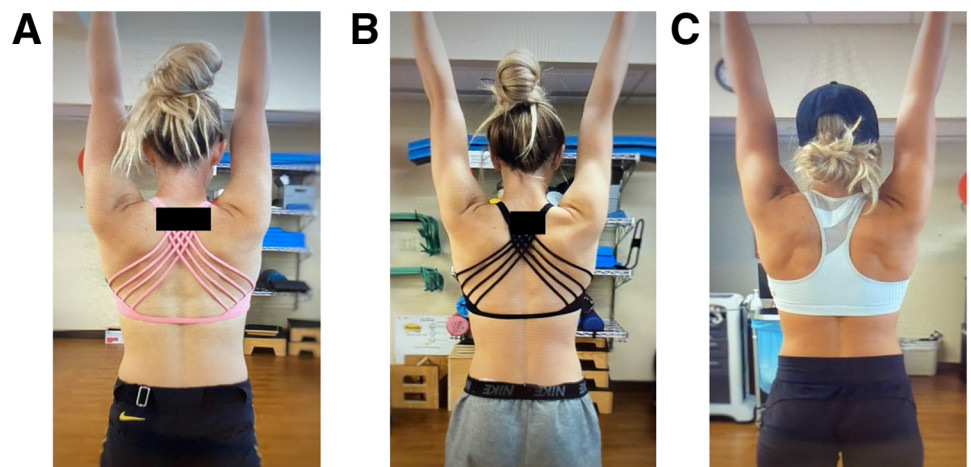
Active scapulothoracic mechanics were analyzed using 2-dimensional marker-less video analysis during bilateral active shoulder flexion (ASFlx) and active shoulder abduction with the patient standing. Videos were used to assess scapular movement, limb symmetry, upper-quadrant muscle recruitment, and eccentric scapular control compared with the contralateral limb. The resting scapular position was noted during evaluation; however, more concern was placed on the active

scapulothoracic mechanics during gravity-resisted ASFlx and active shoulder abduction (Fig 2).

Static positioning of the thoracic spine is not significantly different between populations with and without TOS.¹⁴ However, the available active ROM observed within a total arc of motion (combined flexion and extension) is significantly less in patients with TOS. Assessment of the quantity of thoracic extension has been described using an inclinometer, the Ott sign, and ultrasound. Approximately 13° to 15° of active thoracic extension is required to achieve full upper-extremity elevation.²³ For this case study, assessment of the quality of thoracic extension was performed with video analysis and palpation of T5 to T9 during ASFlx by the primary therapist. However, it is recommended to use an objective measure, such as the Ott sign, to objectively measure progress in most patients.

Strength testing was conducted using a handheld dynamometer for 9 planes of movement (Fig 3). Three trials were averaged for each plane of movement and compared bilaterally. Shoulder flexion, shoulder abduction, shoulder external rotation, and shoulder internal rotation were all tested at 0° of shoulder abduction. The scapular muscles including the lower trapezius, middle trapezius, and rhomboid were tested with the extremity positioned in alignment with the respective muscle fibers in the prone position; the upper trapezius was tested in the sitting position; and the serratus anterior was tested in the supine position. These results were used to assess the patient's readiness to begin a throwing program, and thus, testing was conducted at 10 weeks and 18 weeks. The patient was required to achieve at least 90% strength in all planes of the dominant limb as compared with the nondominant limb prior to beginning a throwing program.

Palpation of the affected limb was performed in adjunct to the aforementioned assessments. The characteristics of shoulder and scapular muscle tension,

**Fig 2.** Scapular and thoracic positioning with active shoulder flexion in patient's sophomore year (A), junior year (B), and senior year (C) of college.

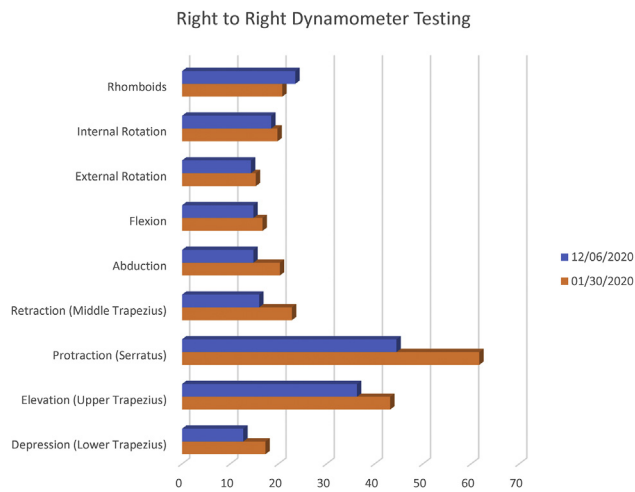


Fig 3. Progress of dynamometer testing on re-evaluation dates of treatment.

scapulothoracic joint mobility, glenohumeral joint mobility, passive mobility of the thoracic spine, and palpation of neuromuscular recruitment during active shoulder ROM were noted and compared with the nondominant limb. Resting tension was compared in anti-gravity and gravity-resisted positions and then correlated to observations during functional movements to determine which structures showed true muscular restriction versus neurologic tone.

TOS Rehabilitation Methods

First-line nonoperative care for TOS typically includes rest, physical therapy, anti-inflammatory medication, and anticoagulant medication. Currently, there is no consensus on the best physical therapy interventions that lead to a successful nonoperative or postoperative outcome, particularly returning an overhead athlete to high-performance play. Rehabilitation specialists are reliant on their clinical expertise to treat this condition and prevent further injury. Many rehabilitation protocols (nonoperative and postoperative) recommend interventions targeting scalene and pectoralis muscle tension, posture, and scapular mobility, with caution against resistance and strength training.^{1,24,25} This treatment plan has so far only been shown to be effective in treating 27% to 34% of patients with a diagnosis of nTOS.^{3,24} One prospective study showed that approximately 60% of nTOS cases did not experience a meaningful reduction in their symptoms and disability scores with physical therapy alone and therefore went on to require surgery. Return to play after first-rib resection and scalenectomy has been reported in up to 70% of players, with half of these returning to play within 1 year.¹⁷ However, owing to the dynamic nature of this condition's development, physical therapy interventions that target resting posture and muscle tone alone are likely not enough to

return an overhead athlete to his or her previous level of participation.

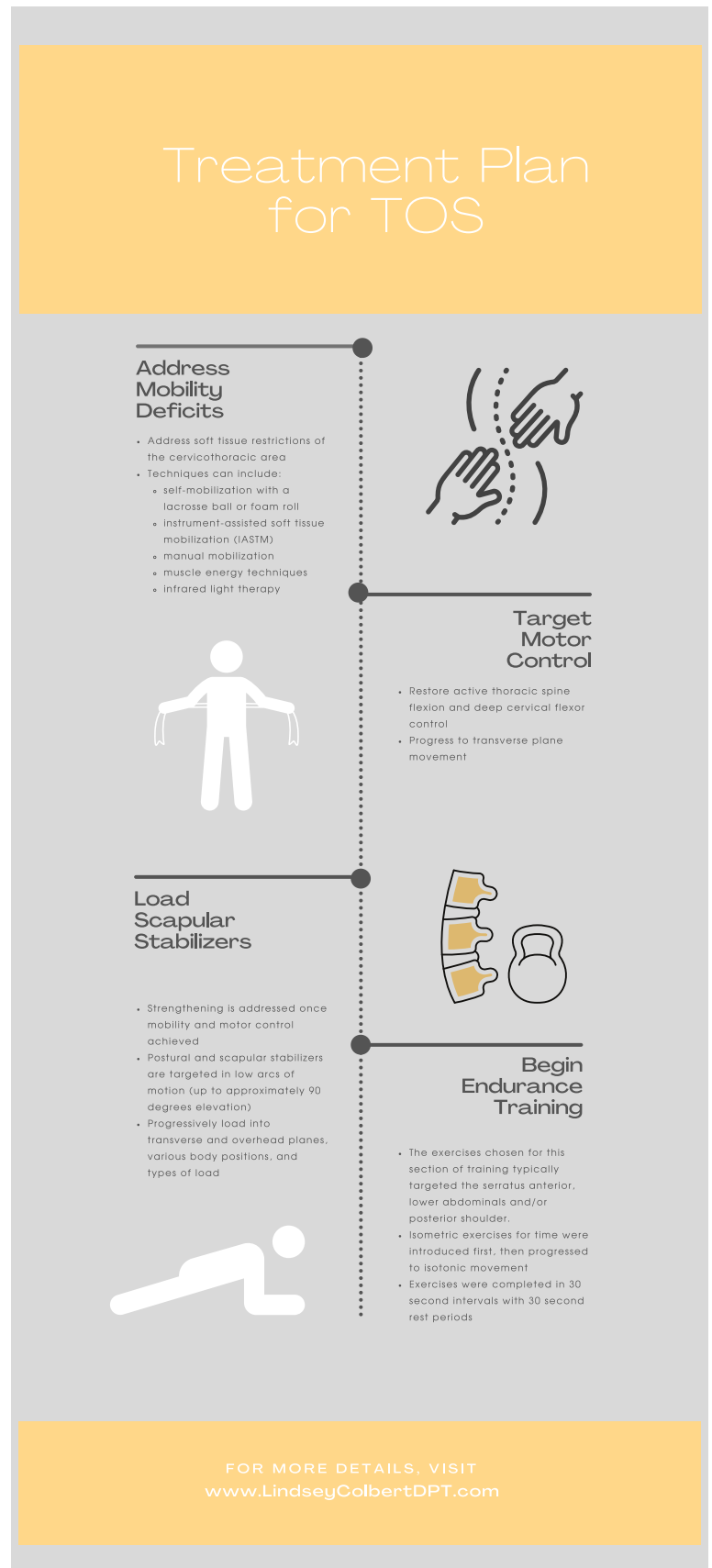
In this case example, each therapy session consistently followed a sequential model of initial mobility, then motor control, and finally progressive loading. Interventions to restore full mobility in the spine and dominant arm were emphasized first to allow the affected tissues to be trained within their full capacity. Progression criteria for advancement to loading were a minimum of 80% of PSFlx, passive shoulder horizontal adduction, and PSIR within each treatment session. After progression criteria were met, motor control exercises were performed to restore appropriate recruitment and timing of the affected tissues. Progressive loading of the spine and shoulder girdle were then applied to promote greater capacity of these tissues to exert and withstand strain.

The mobility of the soft tissues surrounding the cervicothoracic spine was addressed first, including the thoracic paraspinal muscles, as well as the pectoralis major, pectoralis minor, latissimus dorsi, teres major, subscapularis, and upper trapezius (Fig 4). Soft-tissue mobilization techniques included self-mobilization with a lacrosse ball or foam roll, instrument-assisted soft-tissue mobilization, manual mobilization, muscle energy techniques, and infrared light therapy. Manual techniques were expected to provide a short-term reduction in soft-tissue restriction. The resultant decrease in muscle tone is best maintained by improving the motor control of support structures, thus minimizing the need for neurologic compensation.

Once the mobility criteria were achieved, exercises targeting motor control of the thoracic spine, cervical spine, and shoulder were performed. Early emphasis on restoring active thoracic spine flexion and deep cervical flexor control is vital. The exercises used included supine scapular retraction in a T with cervical flexion, supine scaption (i.e., scapular-plane elevation) with a TheraBand and cervical flexion, and sequential spinal flexion-extension using external weight (Fig 5). Thereafter, sagittal-plane exercises progressed to transverse-plane movement, including half-kneeling thoracic rotation with a band or half-kneeling windmills. As spinal alignment and mobility normalized, these motor control exercises were progressed to emphasize the scapular stabilizers and rotator cuff. Neuromuscular electrical stimulation was applied initially to the infraspinatus and serratus anterior with selection of the exercises that elicited the highest electromagnetic activity within the arc of motion that the patient was able to perform.²⁶

Progressive loading to the scapular stabilizers and shoulder was performed next in the patient's treatment session. Strengthening was conducted in circuits of 3 exercises to keep the patient motivated and for time efficiency; exercises within a circuit varied in

Fig 4. Infographic with treatment recommendations for thoracic outlet syndrome (TOS).



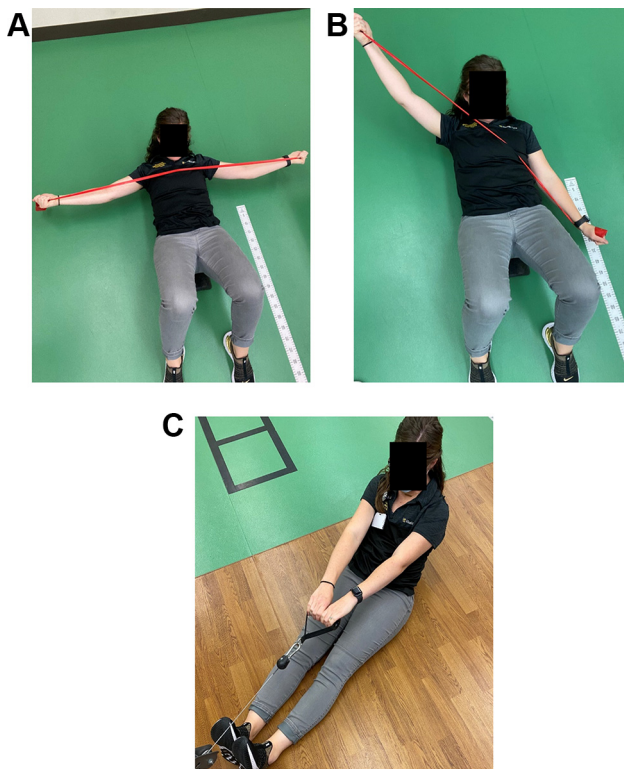


Fig 5. (A) Supine scapular retraction in T with cervical flexion. (B) Supine scaption (i.e., scapular-plane elevation) with TheraBand and cervical flexion. (C) Active thoracic flexion.

movement type and muscle group emphasized. Exercise selection was also based on evidence of moderate to high electromagnetic activity with minimal compensation. The postural and scapular stabilizers were targeted in low arcs of motion (up to approximately 90° of elevation) and then progressively loaded into the transverse and overhead planes, various body positions, and types of load. The muscle groups emphasized throughout the treatment sessions included the serratus anterior, lower and middle trapezius, posterior rotator cuff, deep cervical flexors of the neck, and lower abdominal core stabilizers.

As patient tolerance for loading improved, endurance training was then gradually introduced. The exercises chosen for this section of training typically targeted the serratus anterior, lower abdominals, and/or posterior shoulder. Isometric exercises were included in 30-second intervals with 30-second rest periods, which eventually progressed to isotonic movement. Examples of these exercises are up-and-down planks, ball flips, and reverse plank walking.

From evaluation to 18 weeks, the patient showed restoration of full mobility, strength, and scapular mechanics appropriate for the dominant arm of an overhand thrower. The resting scapular position typically

seen in the dominant arm of an overhand thrower includes a mild degree of protraction, anterior tilt, and upward rotation.²⁷ The patient's soft-tissue pliability was fully restored based on the minimal palpable resting tone in the tissues and ability to achieve full passive shoulder ROM in all planes. Approximately 75% of the patient's active thoracic extension was restored during active shoulder elevation. Additionally, appropriate muscular recruitment of the scapular stabilizers was noted during weighted and unweighted active elevation of the arms (shoulder flexion and shoulder abduction).

At 18 weeks from evaluation, the patient began a throwing program and returned to full participation. She was able to achieve full velocity and accuracy in her throws from left field but required arm care after competitive play for post-activity fatigue and soreness. Overall, this National Collegiate Athletic Association Division I softball player with a diagnosis of nTOS was able to return to her previous level of play without radicular symptoms, hand swelling, or cervical or anterior shoulder symptoms within 4 to 5 months using this rehabilitation model (Fig 2).

Discussion

A growing body of evidence supports the concept that overuse and chronic shoulder conditions that carry over from youth and high school leagues have the potential to impact athletes at the collegiate level.²⁸⁻³⁰ The American Sports Medicine Institute reports that year-round throwing, playing while fatigued, playing for multiple teams, and poor overall conditioning correlate with the development of compensation and higher injury rates in overhand throwers. TOS is among the conditions reported in this population owing to the repetitive nature of their overhead strain, as in the case presented in this article. Although muscular tightening, relative loss of ROM, and weakening of the arm decelerators are anticipated over a season owing to fatigue, too much compensation in certain areas can increase an athlete's risk of injury.³¹⁻³³ In this review, we have described the case of an overhead thrower with TOS and the rehabilitative techniques used to improve the symptoms associated with TOS.

A unique clinical characteristic observed in patients with TOS is a loss of functional thoracic ROM. It is suspected that poor postural stabilization, motor control, and conditioning contribute to this limitation in spinal mobility, particularly in patients with no structural abnormalities. Limited active thoracic flexion results in a loss of the convex-to-concave relation between the scapula and thorax. The convex surface of the thorax allows for an appropriate length-tension relation of the muscles stabilizing the scapula to the

thorax, including the serratus anterior, trapezius, and rhomboid. Relative extension, or flattening, of the thoracic curve does not allow the concave surface of the scapula to fully contact the surface of the thorax, thus altering the length-tension relation in these muscles. These circumstances, combined with posterior shoulder and scapular fatigue, can result in the development of relative depression, protraction, and downward rotation of the dominant scapula, as well as downward slope of the clavicle, in a patient. This position lengthens the upper trapezius, scalenes, sternocleidomastoid, and rhomboid, which can be triggered to provide support owing to the lack of sufficient support from the scapular stabilizers. The shift in length-tension ratios among the scapular stabilizers then leads to the pectoralis major becoming hyperactive with pushing and elevation movements, contributing to a loss of shoulder flexion and internal rotation. The inability of the shoulder to functionally move the scapulothoracic and glenohumeral joints away from these resting postures results in inadequate clearance of the neurovascular tissues and compression of the infraclavicular space. Therefore, it is beneficial to assess a patient's thoracic spine mobility using an objective measure such as the Ott sign or an inclinometer and then treat it by a proximal-to-distal method. In the absence of an objective measurement to assess the thoracic spine's functional ROM, a loss of bilateral PSFlx and PSIR can be indicative of altered mechanics.

In the literature, the resting tone of the scalenes, sternocleidomastoid, and upper trapezius is commonly described as a limiting factor for patients with nTOS. These structures are likely showing increased neuromuscular tone to compensate for a lack of stabilization from the spine and scapula. Thus, treatment should emphasize gaining functional curvature of the spine and motor control of the scapular stabilizers, such as the serratus anterior. Inclusion of specific cervical stabilization exercises to improve the motor control, strength, and endurance of the deep flexors of the neck is also recommended when treating the proximal portion of an overhead athlete's kinetic chain. This can be achieved using biofeedback or neuromuscular control drills in a rehabilitative setting or using cues for appropriate cervical alignment while athletes are lifting with their teams. Ultimately, these treatments should be attempted first, before seeking surgical intervention. Although first-rib resection and scalenectomy have been shown to effectively decompress the infraclavicular space, the compensatory patterns that resulted in neurovascular compression remain after surgery and may negatively impact an athlete's ability to return to his or her previous level of play.

Conclusions

This report details the clinical findings and treatment options available to address pathology in an overhead athlete with a diagnosis of TOS. The clinical case example shows techniques that may help guide the clinician in establishing effective nonoperative or postoperative treatments for TOS.

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