ABSTRACT

Background. Thoracic Outlet Syndrome (TOS) involves compression of the brachial plexus, subclavian artery and vein. Many studies discuss efficacy of surgery and few discuss conservative treatment. It is unknown what specific forms of conservative treatment are best.

Objective. Describe conservative management for TOS using unique exercises.

Case Description. A collegiate football player reported numbness/tingling down his right arm after a right brachial plexus stretch injury. Seven months later, he was diagnosed with recurrent cervical traction neuropraxia. Two months later, he reported bilateral symptoms and was diagnosed with functional TOS. The athlete began shoulder strengthening (deltoid, middle trapezius, rhomboids, pectoralis major, latissimus dorsi, biceps, upper trapezius and rotator cuff) and stretching (pectoralis, scalene and upper trapezius) which failed to resolve his symptoms after four weeks. Surgical resection of bilateral first ribs and quitting football was recommended by four physicians. Unique therapeutic exercises developed by the Postural Restoration Institute™ were used to optimize respiration/posture via muscle activation and inhibition. After six weeks, the athlete was asymptomatic and returned to football but still experienced paresthesia with contact. Additional exercises were prescribed and remaining symptoms were abolished.

Outcomes. The Northwick Park Neck Pain Questionnaire was 55.5% at initial and 0% at four weeks and discharge.

Discussion. Athlete did not demonstrate relief of symptoms from shoulder stretching and strengthening. Intervention designed to optimize respiration/posture by repositioning the pelvis/trunk via specific muscle inhibition and activation resulted in abolishing the athlete's symptoms. Management that aims to optimize respiration via muscle inhibition, activation, and repositioning warrants further research.

Key words: thoracic outlet syndrome, postural restoration, respiration

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We would like to thank the Postural Restoration Institute™ for their creative development of the specific therapeutic exercises that were prescribed for the patient in this case report.

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INTRODUCTION
Thoracic outlet syndrome (TOS), also known as neurovascular compression syndrome, consists of a group of distinct disorders that affect the nerves or vascular structures between the base of the neck and axilla. Specifically, these disorders result from positional compression of the subclavian artery or vein, and the brachial plexus nerves in a variety of locations including the cervical spine (from cervical rib), scalene interval, infraclavicular space or under the pectoralis minor tendon. The brachial plexus is divided into an upper plexus (median nerve distribution) and a lower plexus (ulnar nerve distribution). Upper plexus compression was initially described by Swank and Simeone with symptoms secondary to C5, C6, and C7 nerve root compression. Sensory changes will primarily occur in the first three fingers, and associated muscle weakness or pain in the anterior chest, triceps, deltoids, and parascapular muscles, as well as down the outer forearm to the extensor muscles. Lower plexus irritation involves C8 and T1 nerve root compression. Sensory changes primarily occur in the fourth and fifth fingers, with muscle weakness or pain from the rhomboid and the scapular muscles to the posterior axilla, down the ulnar distribution of the forearm, involving the elbow, wrist flexors, and the intrinsic muscles of the hand.

Thoracic outlet syndrome disorders are complex, poorly defined, and a diagnosis of exclusion that can cover a wide range of ailments each producing various signs and symptoms arising from the upper extremity and the chest, neck, and head. An accurate diagnosis of TOS requires a thorough history and physical examination. Several tests exist that may be used to assist in diagnosing TOS, including nerve conduction velocity (NCV), electromyography (EMG), radiographs, computed tomography (CT) scan, and magnetic resonance imaging (MRI). Authors have attempted to study the thoracic outlet region by CT scan or MRI. One of the limitations is that the compromise of the neurovascular bundle is often positional and intermittent. In neurogenic TOS, electrophysiological testing is often entirely normal. EMG can sometimes detect neurogenic C8/T1 signs.

Thoracic outlet syndrome can be a result of postural alterations, hypertrophic muscles, muscle imbalances, an elevated first rib, presence of a cervical rib, and macrotrauma such as automobile accidents. These syndromes have been categorized into anatomical and functional TOS. Anatomical TOS includes congenital anomalies or traumatic osseous and soft tissue injury. Functional TOS includes postural adaptations as a result of work or sport participation, respiratory changes, and psychological conditions.

The literature suggests that a variety of methods have been traditionally used to manage TOS. Conservative interventions focus on pain control, edema control, verbal posture education and ergonomics, relaxation, stretching, strengthening, and nerve gliding exercises. Additional interventions include moist heat, massage, acupuncture, cervical traction, manual joint mobilization, first rib mobilization, braces, and aerobic exercises. Exercises to manage TOS may focus on stretching the levator scapulae, lower trapezius, scalenes, and pectoralis muscles and strengthening the cervical extensors, scapular adductors, and shoulder retractor muscles. Additionally, cervical traction, isometric exercises (cervical spine and shoulder girdle), and manual joint mobilization (cervical-thoracic spine, sternoclavicular joint, acromioclavicular joint and costovertebral joint) has been described in the literature.

Any of the described methods have been advocated to alter posture in some way. Authors of a recent literature review for TOS conclude that although conservative treatment may reduce symptoms and improve function, it is not known if this approach is significantly better than no treatment or placebo. The most commonly recommended interventions are strengthening and stretching of the shoulder girdle musculature. However, little agreement exists on which muscles need strengthening and which ones need lengthening. These types of exercises do not detail how they address functional TOS as a result of respiratory alterations and they do not aim to inhibit muscle.

Postural Restoration is a holistic posture based approach to patient management that considers the influence of dysfunctional respiration on posture and utilizes therapeutic exercises that activate or inhibit specific muscles and manual trunk techniques as needed in order to achieve optimal respiration and posture. Postural Restoration also recognizes patterns of postural asymmetries (similar to Kendall’s right handed pattern) that are believed to be present in most people to varying degrees. Clinicians who use Postural Restoration, therefore, often target intervention to correct the asymmetrical pattern. This pattern is consistent with the pre-existent vertebral rotation in
“normal” individuals. The postural restoration methodology has been used to manage patients with sciatica and low back pain, asthma, anterior knee pain, and trochanteric bursitis. This approach has appeared to be successful in managing athletes with iliotibial band syndrome, and patients with chronic pain and knee pain, however, the evidence for these three conditions remains anecdotal. To date, no case studies describing the use of Postural Restoration for a patient with TOS have been published. The purpose of this case is to describe management of a collegiate football player with bilateral functional TOS who was first managed with traditional therapeutic exercises and then with unique Postural Restoration therapeutic exercises to address his faulty posture and suboptimal respiration.

CASE DESCRIPTION

The athlete was a 22-year-old male collegiate football player (tight end). Social history included living with three other football players in an apartment with parents living an hour away. Other than his current condition, his general health including physical, psychological, and social function was excellent. Athlete denied use of alcohol, tobacco, or any drugs. He had an unremarkable medical and family history. The chief complaint for this football player included sustaining a right brachial plexus injury during the fall football season. Approximately seven months later, the athlete suffered multiple brachial plexus injuries to his right neck during spring football practice. Cervical spine radiographs were taken and he was seen by the team orthopedic surgeon. Radiographs revealed mild-moderate posterior osteophyte formation at C6-C7 greater than C5-C6 with elevation of the ribs. The physician diagnosed the athlete with cervical traction neurapraxia and prescribed Ibuprofen and Vicodin.

Due to the athlete’s signs and symptoms progressively becoming worsened, he altered his posture to favor the involved side. This compensation in his posture potentially led to the left side becoming involved. He then began developing radicular pain down his left arm and into his hand. Now his signs and symptoms consisted of bilateral numbness, tingling, and weakness into his hands (median nerve distribution), achy pain in shoulders, and a shooting sensation down both arms, pain at Erb’s point, tenderness to palpation over anterior chest and neck muscles, and tenderness and pain between his right scapula and vertebral column at the level of T4. These findings were consistent with someone who has sustained an upper plexus compression injury.

Postural observation revealed bilateral: hypertrophic/over-developed latissimus dorsi, pectoralis, upper trapezius and bicep muscles, anterior rib flares (ribs are in a position of external rotation/elevation which is a combined position of chest expansion with pump handle and bucket handle motions), increased lumbar lordosis (over-active paraspinal muscles), left pelvic forward rotation, forward head posture, and over-active neck musculature. He reported that he was unable to sleep on either side and had to sleep prone with his face buried in his hands. The athlete had several positive tests including Adson’s, Allen’s, Military Brace and Roos.

Two months later he was sent for a cervical spine MRI, a bilateral brachial plexus MRI, a nerve conduction velocity test, and an EMG. The cervical spine MRI was normal. The bilateral brachial plexus MRI revealed muscular hypertrophy in the neck and shoulders. All other structures appeared normal. The nerve conduction velocity test and EMG studies revealed ulnar nerve compression at the elbow on the right. The test results were negative on the left. It was interesting to note that the athlete did not have any neurological symptoms in the ulnar distribution of his hand. An orthopaedic surgeon diagnosed him with bilateral functional TOS. The physician recommended that he should discontinue playing football. Multiple physicians advised him to consider having surgery for resection of both first ribs as a last resort. The athlete decided to take a conservative approach to see if he could benefit from non-surgical management. He was managed by three different clinicians over the course of care and seen daily in the athletic training room. See Table 1 for dosage of interventions.

Intervention – Clinician 1

The first clinician focused on traditional recommended interventions, primarily guided by information on a website for TOS including stretching and strengthening exercises. Specific interventions (done twice a day, seven days a week) consisted of: moist heat for fifteen minutes (over the neck and both shoulders in sitting to prepare for stretching), self stretching exercises (three repetitions x 30 seconds) for bilateral neck, shoulder, and chest muscles (scalenes, upper trapezius, pectoralis major muscles), verbal postural education (to keep head and shoulders back, and chin and chest up) and shoulder strengthening using

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tubing for the rotator cuff (internal and external rotation muscles), deltoid, pectoralis major, latissimus dorsi, supraspinatus, biceps, and upper trapezius muscles. All stretches were performed three times for 30 seconds each, the exercises were done in three sets of fifteen each, and all treatment was done twice a day everyday for four weeks. With this type of conservative treatment the athlete did not see much improvement and continued to progressively get worse after each lifting and conditioning session. After a month of conservative treatment, the athlete began to contemplate having surgery and ending his football career. Because the athlete was not making progress, clinician one asked another clinician to take over his case.

**Intervention – Clinician 2**

During weeks 5-11, this new clinician changed the focus of treatment by addressing the athlete’s specific impairments of faulty posture via activation and inhibition of specific muscles to change position of bones and soft tissue rather than through verbal education alone. Faulty posture noted via visual observation included: over-developed latissimus dorsi, pectoralis, biceps, and upper trapezius muscles, over-active anterior neck muscles, increased lumbar lordosis (anterior pelvic tilt with left forward rotation), elevated ribs, downwardly rotated scapula, and forward head posture. Exercises and manual therapy techniques developed by the Postural Restoration Institute™ were utilized to optimize posture of the trunk/scapula and pelvis via activation, inhibition, and lengthening of specific muscles.

The initial exercises were prescribed in order to restore a normal pelvic and rib cage position (from left pelvic anterior tilt/forward rotation and elevated, externally rotated ribs toward neutral) by doing a 90/90 hip shift with hemibridge and balloon (Figure 1). The exercise activated left hamstring muscles which facilitate left hip extension (posterior pelvic tilt). Forced exhalation into the balloon should activate transversus thoracis (triangularis sterni), internal and external intercostals, and abdominal oblique muscles which facilitate depression/internal rotation of the ribs and inhibition of paraspinal
muscles (lumbar flexion). Additionally, via the back pressure of the balloon, opening of the right apical chest wall is facilitated upon inhalation without using neck or paraspinal muscles. Depression of the ribs was thought to allow for a more optimal rest position of the scapula and, thereby, an optimal infraclavicular space to minimize the opportunity for compromise of the subclavius artery, vein, and brachial plexus nerves. This exercise was done twice daily with two sets of 15 repetitions.

The second exercise was also designed to address the athlete’s faulty postural position. A sternal positional Swiss ball release was prescribed to reposition the head over the shoulder girdles and inhibit the anterior neck muscles, to decrease forward head posture and lengthen the bilateral pectoralis major muscles. This was done twice daily for five repetitions and held for five breaths (Figure 2). Manual techniques consisted of four techniques: left anterior interior chain (L AIC), superior T4, subclavius stretch (right and left), and infraclavicular pump with opposition. These techniques were done to assist with the postural correction goals for repositioning of the pelvis and trunk including soft tissue and bones. These were done for five breaths, each twice daily.

After six weeks of Postural Restoration techniques, the athlete was completely asymptomatic, and he was cleared to return to football. Upon returning to football, the athlete realized that all of his symptoms would come back once he made contact. During the entire football season, the athlete continued doing his Postural Restoration exercises. He did not practice during the week and played on Saturdays. Although he was much improved, his body did not remain symptom-free in a contact situation when he played football, so additional intervention seemed warranted.

**Intervention – Clinician 3**

After the season, the athlete made an out-of-state trip to see the physical therapist who developed the Postural Restoration techniques to discuss further recommendations. Postural observation revealed bilateral over-developed upper trapezius, pectoralis, biceps, and latissimus muscles, and under-developed right lower trapezius and bilateral triceps muscles (right > left), with anterior rib flares (left > right), bilateral abnormal scapular resting position (abduction, retraction, elevation and downward rotation) (Figure 3), and increased lumbar lordosis. Horizontal shoulder abduction was measured in supine at 15 degrees bilaterally. Hand held spirometry revealed an average of 5300cc upon forced exhalation. The therapist noted that this value was 1000cc over the reported norm for his age and sex, and, therefore, interpreted the results to indicate hyperinflation. When the therapist applied manual pressure over the athlete’s left ribs for depression and had him exhale again into the spirometer, his numbers decreased.

The therapist prescribed additional exercises to further progress the athlete’s existing program in order to achieve optimal respiration and postural position of his pelvis/trunk and scapula that would carryover during football. These exercises allowed him to practice and play everyday. Key goals for the exercises were to train the athlete to be able to keep his ribs down during breathing and, at the same time, open his apical chest wall without using his neck or paraspinal muscles to inhale, and get bilateral scapulae to depress/upwardly rotate and protract. In order to achieve scapular protraction, the exercises targeted bringing his ribs back on the scapula (rather than the scapula forward on the ribs) and knees forward (to help keep ribs down and spine flexed). Eight exercises were prescribed by the physical therapist including 1. seated resisted serratus punch with left hamstring muscles, 2. standing resisted bilateral serratus press through, 3. standing serratus squat, 4. paraspinals release with left hamstrings, 5. two point stance on the left and right sides, 6. all four belly lift reach, 7. long sitting press downs and 8. latissimus dorsi hang with low trap activation (Figures 4-11). This high number of exercises was prescribed in a single visit because the
Figure 4. Seated resisted serratus punch with left hamstrings

Figure 5. Standing resisted bilateral serratus press through

Figure 6. Standing serratus squat

Figure 7. Paraspinals release with left hamstrings

Figure 8. Two-point stance exercise
The patient traveled by airplane to the out-of-state appointment.

These exercises focused on neuromuscular re-education to alter or reposition the pelvis, ribs, and scapula to prevent compression of the brachial plexus nerves. After the athlete performed several repetitions of exercise one, the therapist rechecked his breathing (by visual observation of the athlete in supine), and noted that his upper trapezius muscle tone had noticeably decreased and he seemed to be breathing only with his diaphragm. The athlete was aware of his altered breathing and he noted that he was almost short of breath when not compensating with accessory respiratory muscles. The therapist then rechecked his horizontal shoulder abduction and it was 45 degrees, bilaterally. The therapist interpreted this increase in passive range of motion to be reflective of a decrease in tone/activity of the pectoralis and biceps musculature. A squat position was added to the second exercise to help train the quadriceps muscles since the therapist perceived the athlete using his paraspinal muscles more than his quadriceps muscles to run and push forward. After exercise number three, postural observation of the shoulder girdles revealed normal bilateral scapular rest position. This resting scapular portion was interpreted as the athlete having his ribs down (relatively depressed/externally rotated position) compared to his initial position of rib flares (anterior rib elevation/external rotation). This positioning allowed the athlete’s scapula to rest on the ribs and no longer required the scapula to be held up by upper trapezius muscles.

The athlete was instructed to work on the first three exercises until five repetitions of each could be performed easily before progressing to the exercises in Figures 7-11. With the exercise in Figure 7, it was noted that the athlete’s right upper extremity was weaker than the left. The exercise required lifting his right leg up to force his right upper extremity to work harder. The athlete was encouraged to achieve balance and work on the exercise until it was as easy to do lifting his right leg as it was lifting his left leg. The exercise in Figure 8 was designed to teach the athlete to learn how to move his thorax on his scapulas. The exercises were instructed to be done on both the right and left sides but with different breathing instructions during certain phases of movement for each side to facilitate more air flow into the right chest wall rather than the left.

After several repetitions of each exercise were performed, the hand-held spirometer was used again and his values dropped to 4300cc. This was the reported norm for a 22-year-old male. The therapist attributed the drop in air exhaled into the spirometer as a result of taking away his compensatory strategies of using upper trapezius and paraspinal muscles and putting his ribs and diaphragm in a better position so the diaphragm could be better used as the primary muscle of respiration. When the ribs are elevated and externally rotated, the diaphragm was more linear/flat and less surface area of the diaphragm was available for a dome or zone of apposition (ZOA). The ZOA (area of the diaphragm from the most cephalad portion of the dome to the inferior attachments on the sternum and ribs) is impor-
tant for optimal respiration and when it is decreased, the diaphragm functions more as a postural stabilizing muscle rather than as a primary muscle of respiration. The diaphragm is also important for exercise tolerance and decreasing shortness of breath. At the end of the session, the therapist perceived that the athlete had a good prognosis and would be able to play football without eliciting his symptoms when he made contact. He was additionally instructed to do his exercises before going to sleep (to avoid a dry mouth, tense neck, and upper extremity numbness) and to do them immediately before any weight lifting and to avoid any upper trapezius or latissimus muscle strengthening. A comparison of the muscles targeted for activation, lengthening, and inhibition for the traditional versus the Postural Restoration phases of rehabilitation for this athlete are presented in Tables 2-4. These charts highlight what the clinician’s intended goals were as it related to activating, lengthening, and inhibiting specific muscles during the rehabilitation of the athlete.

OUTCOME
The Northwick Park Neck Pain Questionnaire (NPNPQ) was used for the initial examination, after his initial course of traditional conservative intervention (four weeks), and after his second course of conservative intervention (10 weeks). This questionnaire was developed at Northwick Park Hospital in Middlesex England in order to measure neck pain and the consequent patient disability. The parameters consist of nine areas: 1. neck pain intensity, 2. neck pain and sleeping, 3. pins and needles or numbness in the arms at night, 4. duration of symptoms, 5. carrying, 6. reading and watching television, 7. working and housework, 8. social activities, and 9. driving. Each category has a scoring of 0-4 with (0) being no pain and (4) being the worst pain. The minimum score is 0 and a maximum score is 36. The NPNPQ percentage = (neck pain score) / 36 x 100%. The percentage range is from 0 to 100%, where the higher the percentage the greater the disability. The results of the initial NPNPQ were 55.5%. His NPNPQ was redone at four weeks and did not change, remaining at 55.5%. At 10 weeks, his NPNPQ dropped to 0% representing a 100% improvement in function. The minimal clinically meaningful difference is 5% on the NPNPQ.

DISCUSSION
Thoracic outlet syndrome is often difficult to diagnose and manage. Traditional management has focused on upper body musculature to improve posture via stretching and strengthening of shoulder girdle muscles even though different perspectives exist on which muscles need to be stretched versus which muscles need to be strengthened. Several conservative management strategies have been studied and seem to be effective at reducing symptoms and facilitating return to work in the majority of subjects; however it is not known what type of conservative treatment is best. Types of treatment which have been described in the

Table 2: Comparison of muscles that were targeted with exercise prescription in the two phases of rehabilitation for the athlete with thoracic outlet syndrome.

<table>
<thead>
<tr>
<th>Muscles Activated</th>
<th>Traditional Exercises</th>
<th>Postural Restoration Exercises</th>
</tr>
</thead>
<tbody>
<tr>
<td>Serratus Anterior</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Lower Trapezius</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Triceps</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Middle Trapezius</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Rhomboids</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Hamstrings</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Abdominals</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Triangularis Sterno</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Intercostals</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Pectorals</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Deltoïds</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Latissimus Dorsi</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Rotator Cuff</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Biceps</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

Table 3: Comparison of muscle inhibition that were targeted with exercise prescription in the two phases of rehabilitation for the athlete with thoracic outlet syndrome.

<table>
<thead>
<tr>
<th>Muscle Inhibition</th>
<th>Traditional Exercises</th>
<th>Postural Restoration Exercises</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper Trapezius</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Pectoralis</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Biceps Brachii</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Pneumogalis</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Anterior Neck</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>
literature include upper trapezius muscle activation (shoulder elevation) followed by relaxation; a strapping device for shoulder elevation and shoulder girdle exercises; stretching for upper trapezius and levator scapulae muscles; chin retraction and strengthening of lower scapular stabilizers; aerobic conditioning; active mobilization of the cervical spine; stretching of the upper trapezius, pectoralis minor, and scalenes muscles; strengthening of the scapular stabilizers; shoulder girdle massage; strengthening of shoulder adduction (pectoralis major and latissimus muscles); shoulder extension (posterior deltoid and triceps muscles); cervical spine isometrics; and manual traction. None of these types of interventions focus on muscle inhibition or specifically correcting respiratory alterations, as was used with this patient.

In this case, two different conservative approaches were used by the treating clinicians to manage the athlete. During the first approach, the clinician prescribed traditional shoulder girdle stretching and strengthening exercises, however the athlete did not show improvement after this course of treatment. For the second approach, the clinicians included non-manual exercises and manual techniques developed by the Postural Restoration Institute\textsuperscript{40} to optimize breathing and posture of the pelvis, ribs, and scapula via activation and inhibition of specific muscles.

The nine Postural Restoration Institute (PRI) exercises prescribed for this athlete with bilateral TOS, would potentially be beneficial to other patients/athletes with faulty posture, faulty respiration, and over-developed musculature. The 90/90 hip shift exercise (Figure 1) could be used for any patient with an anterior pelvic tilt, elevated ribs, over-active paraspinal muscles, weak abdominal muscles, over-active neck muscles, or long hamstring muscles. Because the exercise puts the pelvis into a posterior pelvic tilt and the ribs into depression, the technique discourages the paraspinal and neck muscles from firing (inhibits) and assists with shortening hamstrings via hamstring muscle contraction. In a published case study, this exercise was used to manage a female with sciatica and low back pain.\textsuperscript{8}

The sternopositional swiss ball stretch (Figure 2) could be used for any patient with weak gluteus maximus muscles, over-active or short pectoralis musculature, or acquired forward head posture. This exercise is designed to activate the gluteal muscles in a sagittal plane against gravity, to lengthen the pectoral muscles, and to some extent the latissimus muscles, and bring the head out of a forward head position. The seated resisted serratus punch with left hamstrings (Figure 4) could be used to manage any patient/athlete with elevated ribs, over-developed paraspinal muscles, excessive lumbar lordosis, and weak serratus anterior muscles. The exercise is designed to help depress the ribs, discourage activation of the paraspinal muscles via lumbar flexion, and may be especially helpful to individuals who run since the exercise mimics a closed kinetic chain position in one lower extremity while the contralateral upper extremity is in a forward swing position.

The standing resisted bilateral serratus press through (Figure 5) may be beneficial for patients/athletes who need lumbar flexion training (to inhibit over-active paraspinal muscles), scapular depression (to oppose over-active upper trapezius muscles and accessory respiratory breathing), and inhibition of over-active/developed pectoral muscles. With the exercise done in the squat position it would also be beneficial for strengthening quadriceps muscles. The standing serratus squat (Figure 6) could be used for any patient needing activation of serratus anterior and low trapezius muscles for proper scapular position and dynamics without allowing excessive lumbar lordosis and over-activation of latissimus muscles to occur. This exercise is designed to train an individual to breathe with the ribs down, pelvis back, spine flexed, latissimus muscles elongated, and quadriceps muscles firing. The paraspinals release with left hamstrings (Figure 7) may be beneficial for any patient/athlete who needs to strengthen one or both upper extremities (lower trapezius, rhomboids, and triceps muscles) in a closed kinetic chain position with the lumbar spine in a flexed position (rather than an anteriorly tilted position). This particular position would discourage over-
activation of the patient/athlete’s paraspinal muscles and encourage ribs to depress and abdominal muscles to work in a shortened (rather than lengthened) position.

The two-point stance exercise (Figure 8) could be prescribed for any higher level patient/client needing to activate/strengthen core musculature, lower trapezius, rhomboids and serratus anterior muscles and needing to lengthen pectoral muscles and expand their apical chest wall. The all four belly lift reach (Figure 9) may be beneficial for a higher level patient/athlete to progress from the seated resisted serratus punch (Figure 4) because the exercise is similar (when they reach toward the floor) but in a four point/quadruped position. The exercise likely requires more abdominal muscle activation, because the position requires the abdominal muscles to work/activate against gravity. Lastly, the lat hang with low trap (Figure 11) could be prescribed for any patient/client who has the strength and shoulder range of motion to do the exercise with proper form that may benefit from latissimus lengthening and lower trapezius muscle activation. The exercise is thought to be beneficial for patients who need to lengthen their latissimus muscles while maintaining a posterior tilted pelvic position (rather than a pelvic anteriorly tilted and excessively lumbar lordotic position). The exercise is designed to activate/strengthen the lower trapezius muscles too, which would oppose over-active/developed upper trapezius muscles.

For the football player in this case study, rather than clinicians two and three focusing on stretching the upper trapezius, levator scapulae, scalene, and pectoralis muscles, the focus was on inhibiting these muscles. Rather than focusing on strengthening (rotator cuff, biceps, deltoids, pectoralis, latissimus, and upper trapezius muscles) the focus was on identifying the muscles the patient was using to breathe with (upper trapezius, paraspinal, and anterior neck muscles), and the concomitant position the body was in (rib elevation/external rotation, lumbar lordosis, scapular elevation, retraction, and downward rotation) and what muscles were over-developed (upper trapezius, pectoral, and latissimus muscles). Specific exercise prescription was then recommended by the therapist to alter the athlete’s postural position and muscle activation patterns to optimize respiration.

Although mobilization of the first rib has been discussed in the literature, altering the position of multiple ribs via activation of hamstring muscles has not been presented in the literature. Activation of the hamstring muscles puts the pelvis in a posterior pelvic tilt helping the abdominal muscles obtain an optimal position/length to facilitate spinal flexion and to inhibit the paraspinal muscles to prevent lumbar extension (lordosis). Serratus anterior muscle activation to reposition the ribs posteriorly rather than to move the scapula forward (protraction) has also not been discussed in the literature. Triceps muscle activation to inhibit biceps muscle and reposition the scapula in a relatively abducted position is another novel concept. The Postural Restoration techniques resulted in remarkable outcomes: the athlete was able to avoid surgery, return to full symptom-free football even during contact, and improved his function by 100% based on the NPNPQ.

Further research is needed to help guide clinicians toward effective interventions for patients with TOS. Case studies may be a good choice to establish efficacy of conservative management for TOS because of the variation in impairments that patients have that may contribute to TOS. A case study may be written in the near future by the author after having success treating three other patients who also have had TOS but other impairments as well. Further research is also warranted to explore the benefits of therapeutic exercises to inhibit muscles rather than to stretch them and to optimize respiration via specific muscle repositioning techniques.

CONCLUSION

Postural Restoration management of a collegiate football player with bilateral TOS using exercises (developed by the PRI) designed to optimize respiration/posture by repositioning the pelvis/trunk via specific muscle inhibition and activation resulted in abolishing the athlete’s symptoms and allowed him to participate in football without further complications. Management that aims to optimize respiration via muscle inhibition, activation, and repositioning warrants further research.

REFERENCES


ABSTRACT

Background. Conflicting reports of range of motion (ROM) findings exist related to shoulder instability. Knowledge of range of motion findings among individuals with shoulder subluxation may aid in diagnosis and facilitate appropriate management.

Purpose. The purpose of this study was to compare passive rotation ROM and determine if a symptom-provoking activity alters ROM between patients with shoulder subluxations and healthy controls.

Methods. Seventeen symptomatic patients with shoulder subluxations and 14 healthy controls between the ages of 18 and 35 years were recruited. Lateral and medial rotation ROM measures were taken using a universal goniometer. Symptoms were assessed using a 10cm visual analog scale (VAS). Each group performed a symptom-provoking activity, and VAS and ROM measures were repeated.

Results. A two-factor analysis of variance with repeated measures on pre/post activity demonstrated lower medial rotation measures for the instability group, but no differences for lateral rotation or total range (p<0.05). A “warm-up” effect was noted, with greater ROM found in each group post activity, with a greater increase noted among controls. Analysis of the ratio of lateral rotation to medial rotation ROM found a significantly greater ratio in the instability group. VAS pain scores were greater in the instability group.

Conclusion. Shoulder subluxation is not necessarily associated with increased rotation ROM, therefore total ROM findings should not be used to screen for instability. Imbalances in rotation ROM may be associated with symptomatic shoulder instability and may have implications for treatment.

Key Words: atraumatic, instability, multidirectional

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INTRODUCTION

Shoulder instabilities are classified based on the presence or absence of trauma, chronicity, volition, direction, and degree of instability. Grading schemes have been developed to quantify degree of shoulder instability. Shoulder subluxation is also known in the literature as subtle shoulder instability, occult shoulder instability, and minor shoulder instability. The American Academy of Orthopaedic Surgeons broadly categorizes shoulder instability into two groups: Atraumatic, Multidirectional, Bilateral, Rehabilitation, and Inferior capsular shift (AMBRI) and Traumatic, Unidirectional, Bankart, Surgery (TUBS). These groupings are useful to help guide management. Not all shoulder instabilities fit clearly into these classifications. Shoulder subluxation is characterized by excessive translation of the head of the humerus on the glenoid surface and may involve hyperelasticity of the joint capsule and attenuation of the glenohumeral ligaments. Other authors suggest that tears of the glenoid labrum, loss of joint cohesion and compromise of supporting musculature may also be involved.

Symptoms reported with instability include: apprehension with certain movements, a sensation of “slipping out,” pain with overhead movements, catching, clunking, Dead Arm Syndrome, weakness, and loss of proprioception. Physical findings noted include: full or excessive range of motion (ROM), loose end feel, decreased lateral rotation ROM, positive apprehension sign, and resisted movements that are often strong and pain free. Jobe and Pink have associated shoulder instability with generalized multi-joint laxity. Diagnosis of shoulder subluxation, in the absence of trauma, is made through clinical history and physical exam including instability tests such as the Load and Shift and the Relocation tests. No gold standard of investigation exists for identifying this condition.

Congenital hypermobility has been implicated in the etiology of shoulder instability. Many authors have related instability dysfunction of the shoulder to overhead athletic activity. Shoulder instability may often go undiagnosed due to a poverty of physical findings on examination. Differential diagnosis between instability and subacromial impingement is reportedly one of the most difficult in the shoulder region. Normative data on shoulder ROM measures active rather than passive ROM, does not report the assessment protocol, or measures ROM in very specific populations. No significant difference is noted between left- or right-sided ROM measures in studies on asymptomatic controls.

Conservative treatment of patients with shoulder instability may differ drastically from treatment of other shoulder conditions. Improper rehabilitation may perpetuate or exacerbate shoulder symptoms. Physical examination techniques to assess for shoulder instability can be difficult to perform and require significant experience to interpret correctly. The problems associated with diagnosis and the significant disability created by shoulder instability demonstrate the need for reliable clinical assessment tools to help identify this condition. Inter-rater reliability for passive lateral rotation “end-feel” has been demonstrated with a variety of shoulder pathologies. Conflicting reports of ROM findings associated with shoulder instability raise the question of the efficacy of ROM findings in diagnosis. Range of motion may be altered by the presence of pain or other symptoms and this may obscure the relevance in examination findings. Passive rotation ROM assessment is a much less challenging evaluation procedure than stability testing the shoulder. A relationship between passive shoulder rotation ROM and subluxation may allow findings of ROM assessments to be used to guide further assessment/investigation in the direction of instability testing.

The purpose of the study was twofold: i) to determine if patients with shoulder subluxation have abnormal passive rotation ROM and ii) to assess if a symptom-provoking shoulder activity will alter ROM measures.

Our main null hypothesis was that no significant difference between passive range of motion measures would be found i) in symptomatic patients with shoulder subluxation and a group of healthy controls and ii) between pre and post symptom-provoking activity. Our main null hypothesis was that no significant difference between passive range of motion measures would be found i) in symptomatic patients with shoulder subluxation and a group of healthy controls and ii) between pre and post symptom-provoking activity. Secondly, whether differences existed between the two groups and post symptom-provoking activity in VAS of pain/discomfort was tested.

METHODS

Thirty-one outpatient clients at the QEII Health Science Centre, University Physiotherapy Inc. and the Orthopaedic and Sports Medicine Clinic of Nova Scotia were recruited. The sample was chosen to detect a clinically significant difference in ROM (≥ 7∞) using variance measures from the literature at 0.05 level of significance with a power of 0.8. Intra-tester reliability for rotation
measures at the shoulder have been reported as excellent with intraclass correlation coefficients (ICC) of 0.88-0.98. Consent was obtained after participants received a study explanation and information regarding their rights as a participant in accordance with the Research Ethics Board of the Capital Health Centre for Clinical Research. Seventeen minimally to moderately symptomatic patients with shoulder subluxation, between the ages of 18 and 35 years were assigned to the instability group. Subjective inclusion criteria included complaints of pain with overhead movements, snapping and/or clicking, a sensation of the shoulder slipping out, and/or a position of apprehension. Participants were asked to rate their baseline intensity of shoulder pain/discomfort on a 10cm visual analog scale (VAS) with no descriptors, and scores of less than or equal to 4/10 were included. On objective examination, excessive translation of the head of the humerus on anterior stability testing at 90 degrees of abduction was observed. Assessment was performed for anterior load and shift, which is known to have good to excellent inter-examiner agreement with ICCs of 0.72-0.79. Each shoulder met Hawkins Grade I-II classification for instability (Figure 1). History of dislocation without spontaneous reduction resulted in exclusion. Each subject met each of the diagnostic criteria to be included.

The control group consisted of healthy physiotherapy clients with no history of shoulder injury or dysfunction, between the ages of 18 and 35 years. They were randomly selected from those attending the QEII Health Sciences Centre. The study was described, and 14 agreed to participate. Their condition or reason for attendance to the QEII Health Sciences Centre could have no impact on shoulder function. A brief history was taken to ensure they had no current or previous shoulder pathology. These participants were assigned to a control group of asymptomatic healthy individuals.

The investigation was a comparative study between healthy subjects and those with shoulder subluxation. The primary dependent measure was ROM in degrees. The secondary dependent measure was symptoms on a 10cm VAS. The VAS was chosen to represent only the level of discomfort/pain associated with their condition and the symptom-provoking activity performed in the evaluation and was not used to measure the impact of their condition or disability. The control group was evaluated following a full study explanation, including information regarding their rights as a participant. Signed consent was obtained along with descriptive data including age, height, mass, sex, and participation in overhead sporting activities as these factors have all been suggested to affect ROM measures.Samples were compared on these descriptive variables to ensure equal groups.

The control group shoulder (left or right) to be evaluated was randomly assigned with a coin toss. The humerus was manually stabilized at 90 degrees abduction and neutral flexion/extension by an examiner. The scapula was manually stabilized at the lateral border. Three repeated movements into lateral rotation were produced until a R2 end-point (a point at which increased force does not appear to increase range) was obtained (Figure 2). Each passive movement was sustained for 15 seconds and the measurement was taken on the third repetition using a universal goniometer. The procedure was designed to reduce the contractile component of resistance and improve the reliability of the measurement as muscle that is loaded slowly and passively has reduced EMG activity. The same procedure was followed, and medial rotation ROM was measured. The scapula was manually stabilized over the superior/posterior aspect with the examiner’s thumb resting anteriorly over the coracoid process and clavicle. Landmarks were used according to standard shoulder goniometry principles as described by Norkin and White. Standardization of the reference point (zeroing) was ensured by fixating a 10-inch carpenter’s level to the stationary arm of the
Examiners were blinded as to which group (control vs. instability) the participants represented. The measuring examiner remained constant throughout the evaluations sessions to eliminate concerns regarding inter-tester reliability. Universal goniometry is reported to have excellent intra-tester reliability at the shoulder with ICCs of 0.85-0.99. Each participant was asked to perform exercise with 5 pounds of resistance using a Hanoun wall pulley resistance system (Hanoun Medi Sport Inc., Toronto, Ont). With the superior pulley adjusted to shoulder height, they simulated a throwing motion with the measured limb (Figure 3). The participant was instructed to complete the exercise until they perceived a moderate discomfort in the shoulder area of the measured limb. The throwing activity was designed to simulate symptomatic shoulder subluxation presentation. Both lateral rotation and medial rotation measures were repeated after the symptom-provoking activity. Level of symptoms was recorded using a 10cm VAS before and after the symptom-provoking activity.

The instability group was classified as multi-directional (MDI) or uni-directional based on the presence or absence of a Sulcus Sign and Posterior Load and Shift test. They were assigned as multi-joint lax if three of four joints were deemed to hyperextend on passive ROM assessment, including the elbow, wrist, proximal interphalangeal joint, and knee joint. Hyperextension was defined as passive ROM at the elbow and interphalangeal in excess of 0 degrees extension, greater than 90 degrees wrist extension, and more than 3 degrees of knee extension beyond neutral. The instability group was evaluated, using the same procedure as the control group, on the affected side. Symptoms were again recorded on the VAS before and after the symptom-provoking activity.

Independent t-tests were used to determine differences between the instability group and control group in age, mass, or height. A mixed model two-factor analysis of variance (ANOVA) with repeated measures on the symptom provoking factor was used to test the null hypothesis that no significant difference in passive rotation ROM would be found in the instability group compared to the control. Also, no difference would exist between groups in the presence of mild to moderate symptoms. Two factor ANOVA was used to assess VAS scores between groups and within groups pre and post test. Group and symptom-provoking activity interaction was evaluated. A 0.05 level of significance was used for all the analyses. Bonferroni corrections were applied to statistically significant interactions from the ANOVA.

### RESULTS

Descriptive statistics for the demographics of both the control and instability group are summarized in Table 1. No statistical difference between the two groups for age, height, or mass was found.

The instability group was 35.3% male and 64.7% female, while the control group was 64.3% male and 35.7% female. Participation in overhead sporting activities was present in 25% of the instability group and 16.7% of the control group. Multi-directional classification in the instability group was 59%. The remainder, 41%, were considered uni-directional. The majority (82%) of patients with shoulder subluxation were considered to have multi-joint laxity.

Results of the two-factor ANOVA are represented in Figures 4-7. No significant difference was found between groups in lateral rotation ROM (df = 1).
Also, no differences existed within groups before and after symptom-provoking activity (df = 1,29, F = 0.65, P = 0.426). The instability group had significantly less medial rotation ROM (df = 1,29, F = 37.30, P = 0.000). Both groups increased medial rotation in the post test (df = 1,29, F = 11.12, P = 0.002). A significantly larger ratio of lateral rotation to medial rotation ROM existed among the instability group pre (df = 1,29, F = 27.30, P = 0.000) and post test (df = 1,29, F = 4.78, P = 0.0370), and both groups decreased this ratio due to increases in medial rotation ROM post test. The control group had greater total ROM (df = 1,29, F = 11.48, P = 0.002) and both groups increased total ROM post test due to an increase in medial rotation ROM measures (Figure 7).

Visual analog symptom scale results were significantly higher in the instability group (df = 1,29, F = 12.91, P = 0.001) both pre and post test and increased significantly (df = 1,29, F = 125.36, P = 0.000) in both groups after the symptom-provoking activity (Figure 8).

**DISCUSSION**

Descriptive statistics representing the control and instability groups do not reflect any significant difference between the two groups. The control group demonstrated passive ROM characteristics consistent with those found in healthy adults in the age range reported in the inclusion criteria. Passive ROM measures in this study (Figures 4-7) are in excess of those reported in normative active ROM data and in excess of what was originally anticipated by the investigators, particularly for the asymptomatic control group.19, 24

Sex differences between groups were noted with a greater portion of the instability group being female. A slightly higher percentage of the instability group also participat-
ed in overhead sporting activities. Both of these group differences could skew the data toward larger ROM findings in the instability group. Skewed data was not the case, with larger total ROM findings in the control group. Changes in ROM associated with limb dominance, if present, could affect results. Control shoulders were randomly assigned for evaluation and subluxation group shoulders included dominant and non-dominant symptomatic limbs.

The concept that glenohumeral hypermobility is associated with subluxation was not supported by the results of the investigation. Instead, a relationship between a lack of medial rotation passive ROM and shoulder subluxation was observed. This is also reflected in the reduced ratio of lateral rotation to medial rotation in the instability group versus the control. This altered ratio of motion may be more reflective of flexibility imbalances, often described in the clinical literature, rather than the expected hypermobility that is assumed by some authors to accompany shoulder subluxation. The Humeral Anterior Glide Syndrome described by Sahrmann or the recently coined Glenohumeral Internal Rotation Deficiency (GIRD) found in throwing athletes are consistent with this type of length/tension imbalance. The instability group did not demonstrate overall larger ROM measures as would be expected with generalized joint laxity. With no greater total ROM noted in the instability group, a pathological shift in the functional ROM away from medial rotation may be indicated of individuals with shoulder subluxation.

Reduced length of the posterior rotator cuff musculature and the posterior shoulder capsule have been implicated in the development of internal impingement. Increased anterior translation may be necessary to allow a posterior shift in the axis of rotation and abutment of the humerus with the posterior/superior glenoid rim.

Concern existed that the presence of symptoms in the instability group may mask true passive ROM assessment due to muscle guarding or protective reaction. To reflect this variable, the assessment after a symptom-provoking activity was included. As expected, symptoms were greater in the instability group. Discomfort/pain as measured with the VAS did not seem to impact ROM findings pre-test. A trend toward a “warm-up” effect was noted in the control group after the symptom-provoking activity with ROM measures increasing. The same increase in passive ROM was not observed in the instability group post-test. Symptoms may prevent flexibility increases associated with activity in this pathological group. No loss of ROM was observed with increased scores on the VAS post-test. Symptoms may have to be in excess of those provoked in the study to impact ROM findings.

Increased passive ROM or excessive flexibility may indeed not provide any supportive evidence of shoulder subluxation. Instead, flexibility imbalances may be more indicative of, and even causative in, the development of low-grade shoulder instability. While most (82%) of the participants in the study were classified with multi-joint laxity, certainly not all were. A high degree of flexibility may exist at one joint and not at others. No universally inclusive relationship between multi-joint laxity and shoulder subluxation existed. A slight majority (59%) of the instability group were classified as multi-direction instability. Perhaps the presence of a ROM imbalance combined with a certain degree of local flexibility is jointly causative in the development of shoulder subluxation. The fact that many of our instabilities only subluxated in one direction supports the possible necessity of an imbalance or even cumulative microtraum in etiology of shoulder subluxation.
Reduced length of posterior shoulder structures (rotator cuff, capsule, posterior deltoid) may, in part, be responsible for restriction of motion and reduced medial rotation in subjects with shoulder subluxation. Treatment techniques directed at lengthening these structures and restoring normal joint length/tension balance may be indicated in this client population. Future study in this area could look at PROM findings in shoulder instability of greater degree. Interventions could be analyzed to determine effectiveness at restoring a more neutral flexibility balance and symptom response. Also, electromyographic activity which would provide information on the active component muscle force that restricts the ROM was not measured. In future work, EMG activity could help ascertain the cause of the change in ROM.

CONCLUSION
In summary, no overall increase in passive rotation ROM was observed among shoulder subluxators. Loss of medial rotation ROM was noted in the subluxation group compared to the asymptomatic control group. An imbalance of lateral to medial rotation ROM may be associated with symptomatic shoulder subluxation. The presence of mild to moderate symptoms (≤ 6/10 on VAS) does not seem to alter passive rotation ROM findings of the shoulder but may limit the ability to increase ROM associated with activity. Imbalance in lateral to medial ROM findings may be more clinically relevant in screening for shoulder subluxation than assessment of total rotation ROM of the shoulder or classification of generalized joint hypermobility. Findings may have implications for treatment technique selection with shoulder subluxation clients.

REFERENCES


ABSTRACT

Background. Mixed martial arts (MMA) is currently the fastest growing sport in the United States and has recently surpassed boxing as the most popular full contact sport. Due to the physical nature of the sport, MMA is associated with various types of injuries.

Objective. The purpose of this study was aimed at identifying prevalence and assessing the severity, location, and type of injuries in MMA athletes sustained during MMA related activities in the twelve month period prior to the survey.

Methods. A total of fifty-five subjects between the ages of 18 to 39 participated in the study. Participants were given a two-part questionnaire to collect demographic and injury data.

Results. Two hundred seven injuries were reported in the study. Low belt ranks had significantly more injuries more than any other belt rank, resulting in more than two times higher injury rate. Professional fighters had significantly more injuries than amateur fighters, resulting in three times higher injury rate. The most common body region injured was the head/neck/face (38.2%), followed by the lower extremities (30.4%), upper extremities (22.7%), torso (8.2%), and groin (0.5%). Injuries to the nose (6.3%), shoulder (6.3%), and toe (6.3%) were the most common. The most common type of injury was contusions (29.4%), followed by strains (16.2%), sprains (14.9%), and abrasions (10.1%).

Conclusion. Injury prevention efforts should consider the prevalence and distribution of injuries and focus on reducing or preventing injuries to the head/neck/face in MMA related activities. Preventative measures should focus on improving protective equipment during training, and possible competition rule modifications to further minimize participant injury.

Keywords: sports injuries, mixed martial arts, MMA, combat sports

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INTRODUCTION

Martial arts are ancient forms of combat, modified for modern sport and exercise. Participation in martial arts is increasing and provides health promoting and meaningful exercise for millions of practitioners. Martial arts has been shown to improve participants' cardiovascular endurance, strength, balance, flexibility, body fat composition, stress and relaxation, confidence, and socialization. As with regular physical activity, martial arts can be associated with reducing the risk of premature mortality, hypertension, coronary artery disease, diabetes mellitus, colon cancer, and obesity. In addition to these health benefits, however, martial arts activities also carry the obvious risk of injury. Risks can possibility be reduced by using protective equipment, including mouth guards, headgear, groin protectors, and other forms of padding.

Mixed Martial Arts (MMA) competition, which is also referred to as no holds barred (NHB) fighting, ultimate fighting, and cage fighting, has its roots in ancient Greece. In 648 BC it was referred to as pankration and was featured at the 33rd Ancient Olympics. Pankration, which is Greek for “all powerful,” was the hybridization of boxing and wrestling into a freestyle fighting sport. Pankration was spawned from unarmed combat on the battlefield and became an extremely popular sport. The sport was revered in ancient Greece and served as the climactic final event of the Olympics for centuries. Since the time of Alexander the Great in 325 BC, pankration attracted attention because of its sheer violence and brutal competition.

Mixed martial arts emerged into America pop culture in the early 1990s and has grown immensely in popularity. Mixed martial arts has not always been in the limelight, as it was almost banned completely in the United States due to its brutal nature and limited rules. Mixed martial arts was first introduced in the United States with the First Ultimate Fighting Championships (UFC) in 1993 and immediately faced scrutiny from legislators and the medical community. In the UFC’s conception, competitors battled against one another with no time limits, no weight classes, and few rules. Referred to as “human cock fighting,” the UFC lost their cable television contracts in 1997 and survived underground through the Internet and word of mouth. In 2001, UFC organizers agreed to a modification of rules that allowed the Nevada State Athletic Commission and the New Jersey State Athletic Control Board to sanction MMA competitions. Re-establishing cable television contracts followed, and the sport’s popularity grew greatly in the years to follow. Initially promoted as a violent and brutal sport, MMA has dramatically changed and now has revised rules and improved regulations to minimize the risk of injury.

Mixed martial arts competitions consist of three five-minute rounds (non-championship bouts) or five five-minute rounds (championship bouts), followed by one-minute rest periods between rounds. Competitors are matched according to designated weight classes and similar experience levels (i.e., fight record). Competitors wear protective equipment consisting of a mouth guard, groin protector, and 4 to 6 oz. MMA gloves. Competitors are not allowed to wear shoes, competing barefooted. Mixed martial arts bouts are decided or stopped by a referee if a competitor submits to his or her opponent, suffers a knockout (KO) or technical knockout (TKO), or is disqualified because of rule infractions. A bout can also be stopped if the scheduled match time limit expires.

Mixed martial arts bout stoppages due to KO, TKO, and submission can be classified into three major categories: head trauma, musculoskeletal stress, and neck choke. Head trauma causing bout stoppages includes a competitor exhibiting altered mental status to the point of defenselessness. Defenselessness is defined as when a competitor loses all unconsciousness and responsiveness (KO) or partial responsiveness (TKO) exposing him or her to further punishment. Musculoskeletal stress causing bout stoppages includes a competitor being submitted by either a joint lock or other musculoskeletal trauma. A neck choke causing bout stoppages includes a competitor submitting or losing consciousness, due to the application of a neck choke causing asphyxiation, cephalic hypoperfusion, or syncope.

In regards to safety, MMA has been compared to other combat sports, such as boxing. Mixed martial arts has a safer track record in respect to serious injury and death. Knockout rates are lower in MMA competitions than in boxing, suggesting a reduced risk of traumatic brain injury (TBI) in MMA competitions compared to other events involving striking. Since MMA’s conception in the mod-
ern era, only four deaths have been documented. Deaths have occurred in Tijuana, Mexico; Kiev, Ukraine; Samsongdong, South Korea; and the United States. All the MMA documented deaths occurring outside the United States were in unsanctioned fights. The Journal of Combative Sport has documented seventy-one deaths from 1993 to 2007 in boxing with total of 1,355 deaths from 1890 to 2007, averaging 11.6 deaths per year during the modern history of the sport.13

Mixed martial arts is currently the fastest growing sport in the United States and has recently surpassed boxing as the most popular full contact sport.14,15 As of June 2009, amateur MMA is legal and sanctioned in thirty-five states, and professional MMA is legal and sanctioned in forty states.16 Due to the physical nature of the sport, MMA is associated with various types of injuries. These injuries range from small contusions and abrasions to more serious conditions including concussions and risk of death.9,5,17 Current literature reporting MMA injuries have only focused on injuries in competition alone and no studies have looked at MMA injuries in regular training.9,5,7 It is not clear from the literature what risks of injuries exist with regular training.

The purpose of this study was aimed at identifying prevalence and assessing the severity, location, and type of injuries in MMA athletes sustained during MMA related activities in the 12-month period prior to the survey. A secondary objective is to indicate protective equipment self-reported utilization. This study is unique, as it looked at what type of injuries occurred, injury locations on the body, whether the injuries were previous or repeated, amount of time off (rest) from training as a result of the injuries, whether any medical attention was sought, and the setting in which the injuries occurred. Frequently sustained injuries identified within the study will assist in making fighter safety recommendations aimed at preventing future injuries and reoccurrences.

METHODS
A total of fifty-five subjects between the ages of 18 to 39 participated in the study. Participants assessed were men and women of both amateur and professional status. Participants were given a two-part questionnaire (See Appendix) to retrospectively collect demographic and injury data. The questionnaire was developed by the author and assessed via face validity by a board certified sports physical therapist with 21 years of experience. Part one of the questionnaire included assessing each participant’s age, sex, primary martial art style, years of training experience, hours of training per week, protective equipment used, and current fighter status (amateur vs. professional). Part two of the questionnaire included assessing thirty injured body regions, types of injuries, repeated injuries, required time off from training, medical attention sought, and setting in which the injuries occurred. Participants were also given an injury diagnosis sheet (See Appendix), which gave a definition of all the injury types listed on part two of the questionnaire. Injury definitions were provided in laymen terms for better participant understanding of injury types. The questionnaire did not allow the recording of multiple injuries to the same anatomical location. To accommodate for this, participants were given multiple copies of the survey tool to record multiple injuries.

Mixed martial arts facilities were selected due to their close proximity from the researchers resulting in a sample of convenience. Twenty-four MMA training facilities across the Midwest including Missouri, Kansas, and Illinois were identified and contacted for their participation in the study. Eight of the twenty-four MMA training facilities agreed to participate in the study. Each MMA training facility was contacted by the author via phone or e-mail. Each facility was then scheduled a site visit by the researchers to survey their fighters either before or after one of their training sessions. Both amateur and professional MMA fighters were asked to participate. Care was taken to make sure that all participants surveyed were fighters who were currently training for a future MMA bout.

The training session appointments were organized where participants were verbally explained the study’s procedures, benefits and risks of participation, and confidentiality. All the subjects were given an informed consent that was required to be signed before the subject was allowed to participate in the study. Approval was obtained by the Research Review Board (RRB) at Southwest Baptist University, Springfield, Missouri to conduct the study. The subjects then received their individual questionnaire packets, which took approximately five to ten minutes to complete. Questionnaires were placed in an envelope and sealed. At a later date, the collected data from the participants was compiled and analyzed thoroughly.
Confidentiality of the data was maintained throughout the study in two ways. First, no names or personal identification was required to complete the questionnaire. Second, each participant was given a separate individual questionnaire which was sealed in an envelope when completed.

**Data Analysis**

The injury data was transferred into SPSS (Statistical Package for Social Sciences) version 12 for analysis. Injury rates were analyzed per total number of participant injuries by age, sex, martial art style, belt rank, years of training experience, hours of training per week, and fighter status. The t-tests were used for sex and fighter status, and analysis of variance (ANOVA) was used for remaining groupings. Scheffe post hoc was used to analyze the significant differences of the ANOVA results. The initial alpha level was set at \( p < 0.05 \). Given that four ANOVAs and one t-test were used (a total of five comparisons), a Bonferroni correction of \( 0.05/5 = 0.01 \) was used for analysis.

**RESULTS**

Of the fifty-five subjects participating in the study, 33.3% were ages 18 to 21, 27.8% ages 22 to 25, 22.2% ages 26 to 29, 11.1% ages 30 to 33, and 5.6% ages 34 to 39. The injury rate among participants ages 30 to 33 averaged 6.2 injuries (SD = 4.2) per subject. Participants ages 22 to 25 averaged 5.2 injuries (SD = 6.1) per subject, followed by 3.3 injuries (SD = 2.5) per subject for ages 26 to 29, 3.3 injuries (SD = 2.3) per subject for ages 34+, and 2.4 injuries (SD = 2.3) per subject for ages 18 to 21. \( F = 1.335, df = 54, p > .05 \)

Sex differences were also accessed during the study. Of the participating subjects, 94.5% were male and 5.5% were female. Males and females averaged different injury rates. Male participants averaged 3.9 injuries (SD = 4.3) per subject and female participants averaged 2.3 injuries (SD = 2.5) per subject. \( t = 0.595, df = 53, p > .05 \)

Two hundred seven injuries were reported in the study. Twenty-seven of the injuries reported were multi-injurious in nature, resulting in a total of two hundred twenty-eight separate injury outcomes. Multi-injurious is defined as an injury resulting in multiple outcomes, such as leg kick causing a simultaneous contusion and sprain. The most common body region injured was the head/neck/face (38.2%), followed by the lower extremities (30.4%), upper extremities (22.7%), torso (8.2%), and groin (0.5%). (See Table 1) This result seems plausible since a major target area of MMA competition is the head/neck/face. When looking at specific body region injury, the nose (6.3%), shoulder (6.3%), and toe (6.3%) were the most commonly injured followed by eye (5.8%), neck (5.8%), knee (5.8%), head (5.3%), ear (5.3%), and ankle (4.8%). (See Table 2 for all thirty injured body regions and their percentage of injuries.)

The most common type of injury reported by the participants was contusions (29.4%), followed by strains (16.2%), sprains (14.9%), abrasions (10.1%), joint trauma (9.2%), fractures (5.7%), lacerations (5.3%), other miscellaneous trauma (4.8%), dislocations (2.6%), concussions (1.8%), and internal organ trauma (0.0%). (See Table 3) Of these injuries, 32.4% were repeated or previous injuries, 20.1% required medical attention, and 77.9% occurred in training compared to 22.1% that occurred in competition. The most common amount of time off (rest) required after the injuries was 0 days (56.8%), followed by 4 to 6 days (11.5%), 1 to 3 days (10.9%), 7 to 9 days (10.4%), and 10+ days (10.4%).

The most common martial art style was wrestling (36.2%), followed by jiu-jitsu (34.0%), freestyle (21.3%), kickboxing (8.5%), and boxing (0.0%). For analysis purposes, injury rates were reported for those participants who declared only one primary martial art style. Those participants who selected multiple primary martial art styles were excluded. The injury rate among participants with a jiu-jitsu martial art style averaged 6.0 injuries (SD = 4.8) per subject, followed by 3.8 injuries (SD = 3.7) per subject for freestyle, 2.5 injuries (SD = 4.6) per subject for wrestling, and 2.0 injuries (SD = 2.8) per subject.

<table>
<thead>
<tr>
<th>Table 1 General Region of Injury (n = 55)</th>
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<td><strong>Body region injured</strong></td>
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<tr>
<td>Head/face/neck</td>
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<tr>
<td>Lower extremities</td>
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<td>Upper extremities</td>
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<tr>
<td>Torso</td>
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<td>Groin</td>
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<td><strong>Total</strong></td>
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</table>

ject for kickboxing. (F = 1.865, df = 54, p > .05)

Experience level of the subjects was evaluated by accessing (a) martial art belt rank and (b) years of martial arts training. Since belt ranks are different among various martial arts, low and high belt ranks were used to distinguish experience levels. Low belt ranks are participants who possess a novice skill level. Whereas, high belt ranks are participants who possess a more seasoned skill level. The only constant belt ranks among martial arts that use a belt rank system are white belt (beginner) and black belt (expert). There are martial arts, such as boxing, kickboxing, and wrestling, that do not use a belt rank system and these participants are designated in this study as having no belt rank. Of the participating subjects, 62.9% held no belt rank, 16.7% held white belt rank, 9.3% held low belt ranks, 9.3% held high belt ranks, and 1.8% held black belt rank. The highest injury rate among belt ranks was low belt ranks, averaging 12.2 injuries (SD = 6.1) per subject. Low belt ranks had significantly more injuries than any other belt rank, resulting in more than two times higher injury rate. White belt rank averaged 5.2 injuries (SD = 3.1) per subject, followed by 5.0 injuries (SD = 2.8) per subject for high belt ranks, 5.0 injuries were reported by the one black belt rank, and 2.0 injuries (SD = 2.6) per subject for no belt rank. For analysis purposes, the black belt group was removed. (F = 16.519, df = 52, p = 0.000)

In regards to martial arts training experience, 47.3% had less than 1 year training experience, 14.5% had 1 to 2 years training experience, 10.9% had 2 to 3 years of training experience, 9.1% had 3 to 4 years of training experience, and 18.2% had 4+ years of training experience. The injury rate among participants with 3 to 4 years of martial arts training experience averaged 7.8 injuries (SD = 3.0) per subject. Participants with 2 to 3 years training experience averaged 4.8 injuries (SD = 6.5) per subject, followed by 4.8 injuries (SD = 5.4) per subject with 4+ years training experience, 3.5 injuries (SD = 4.0) per subject with 1 to 2 years training experience, and 2.4 injuries (SD = 2.9) per subject with 1 year or less of training experience. (F = 2.195, df = 54, p > .05)

Hours of training per week were accessed showing 36.4% train 12 or more hours per week, 23.6% train 6 to 8 hours per week, 21.8% train 3 to 5 hours per week, 14.6% train 9 to 11 hours per week, and 3.6% train 2 hours or less per week. The injury rate among participants with 6 to 8 hours of training per week averaged 5.1 injuries (SD = 5.2) per subject. Participants who trained 12+ hours per week averaged 4.0 injuries (SD = 4.6) per subject, followed by 3.4 injuries (SD = 4.3) per subject who trained 9 to 11 hours per week, 2.8 injuries (SD = 2.4) per subject who trained 3 to 5 hours per week, and zero injuries per subject who trained 2 hours or less per week. Injury rate calculated among participants occurred in both training and competition settings. (F = 0.866, df = 54, p > .05)
Fighter status was assessed showing 92.7% were amateur fighters compared to 7.3% that were professional fighters. Professional fighters had significantly more injuries than amateur fighters, resulting in three times higher injury rate. Professional fighters averaged 11.0 injuries (SD = 6.3) per subject and amateur fighters averaged 3.2 injuries (SD = 3.6) per subject. (t = -3.985, df = 53, p = 0.000)

The most common protective equipment used was a mouth guard (100%), followed by a groin protector (87.1%), MMA gloves (83.9%), hand wraps (64.5%), shin guards (58.1%), boxing gloves (45.2%), head gear (38.7%), knee pads (19.4%), wrestling shoes (19.4%), and other equipment (16.1%). (See Table 4)

DISCUSSION

In this study, a significant difference was observed showing low belt ranks reporting a significantly higher injury rate than all other belt groupings. The author believes this could be contributed to low belt ranks having less training experience and being exposed to the identical amount of live sparring as more experienced fighters (higher belt ranks), thus increasing their risk to injury. By tradition, low belt ranks have less training experience resulting in less overall skill, proper technique execution, and defensive strategies. During live sparring against more experienced fighters, the author believes low belt ranks suffer a higher injury rate secondary to less overall experience compared to their more experienced training partners. The author believes white belts have an overall lower exposure to injuries, due to limited exposure to live sparring. Due to their limited experience level and “beginner” status, white belts do not participate in live sparring to the same degree (intensity, duration, or frequency) as low and high belt ranks.

A significant difference was observed showing professional fighters reporting a three times higher injury rate than amateur fighters. The author believes this difference could be contributed to rule modification for professional bouts compared to amateur bouts. Within professional bouts, fighters are allowed to utilize elbow strikes to their opponents’ head and body. This rule modification may increase the likelihood of injuries to both participants in a professional bout. Other possible reasons of increased incidence of injuries to professional fighters may be due to longer rounds in professional fights compared to amateur fights (5 minutes versus 3 minutes). This increased incidence of injury exposure may allow for more injuries to occur within a professional MMA bout.

The relative high incidence of injuries in combat sports has been well documented in the literature. Martial art styles that involved striking—such as boxing, kickboxing, karate, and tae kwon do have been shown to have a higher incidence of injury than styles that involve grappling alone, such as collegiate wrestling. Injuries in the striking martial arts are prevalent not only in the target areas of the face and torso, but...
also the hands in boxing and the upper and lower extremities in kickboxing and karate.\textsuperscript{9}

Zazryn et al\textsuperscript{18} reported overall injury rates of professional boxers and kickboxers in Victoria, Australia, over a 16 year period. An injury rate of 25 injuries per 100 fight participations were reported in professional boxers. An injury rate of 109.7 injuries per 1,000 fight participants were reported in professional kickboxers with the head/neck/face (52.5\%) being the most common body region injured, followed by the lower extremities (39.8\%), upper extremities (3.2\%), and trunk (2.3\%). Injuries to the lower leg (23.3\%), face (19.4\%), and intracranial region (17.2\%) were the most common. The most common injury type was superficial contusion (39.5\%), followed by laceration (24.9\%) and concussion (17.5\%).\textsuperscript{9,19}

Bledsoe et al\textsuperscript{20,9} reported an overall injury rate of professional boxers of 17.1 per 100 fight participations or 3.4 per 100 boxing rounds. Facial laceration was the most common injury reported and accounted for 51\% of all injuries, followed by injuries to the hand (17\%), eye (14\%), and nose (5\%).\textsuperscript{20,9} The high incidence of head/face injuries in boxing suggest that efforts should be made to devise better materials that reduce the transfer of impact forces from the upper extremity to the head/face during a strike.\textsuperscript{21}

Bledsoe et al\textsuperscript{9} reported an overall injury rate of professional MMA athletes of 28.6 injuries per 100 fight participations or 12.5 injuries per 100 competitor rounds.\textsuperscript{9} Facial laceration was the most common injury accounting for 47.9\% of all injuries, followed by injuries of the hand (13.5\%), nose (10.4\%), and eye (8.3\%). Mixed Martial Arts competitions demonstrate a high rate of overall injury; however, keeping with other striking combat sports, such as boxing, kickboxing, karate, and tae kwon do.\textsuperscript{9}

Grappling sports have demonstrated much lower injury rates compared to striking martial arts. Collegiate wrestling has been documented to have injury rates as low as 1 injury per 100 participations during practice and competition with the upper extremities (44.3\%) being the most common body region injured, followed by lower extremities (20.5\%), trunk (17.9\%), and head/face (16.9\%).\textsuperscript{9,22,21} Strains and sprains were the most common injury reported and accounted for 36.4\% of all injuries, followed by fractures (21.3\%) and contusions and abrasions (16.0\%).\textsuperscript{9} Unlike boxing, wrestling involves grappling and maneuvering the opponent which frequently results in extreme positions for the joints. The forces and positions encountered in wrestling may frequently result in elongation of the muscles and ligaments beyond their physiologic range.\textsuperscript{21}

The highest percentage of MMA injuries was contusions occurring to head/neck/face, followed by strains and sprains to lower and upper extremities. The study’s results of injury prevalence, type, and location were consistent among other combat sports according to the existing literature. Mixed Martial Arts involves both striking and grappling components resulting in similar injury type and location. Striking styles (such as boxing and kickboxing) show contusions and lacerations to the head/neck/face as the most prevalent injury, and grappling styles (such as wrestling) show strains and sprains as the most prevalent injury.

This study shows that over three times the amount of injuries occurred in training rather than actual competition. Of the fighters surveyed, 61.3\% do not use head gear during training. The highest percentage of MMA injuries occurred to the head/neck/face, resulting in 38.2\% of the total injuries. Of all the fighters surveyed, 87.1\% wore groin protectors, which was the second most utilized piece of equipment next to mouth guards. This resulted in 0.5\% total groin injuries.

Studies indicate that the risk of an orofacial sports injury was 1.6 to 1.9 times higher when a mouth guard was not worn.\textsuperscript{23} Of all the fighters surveyed, 100\% wore mouth guards indicating the highest use of protective equipment among participants. This resulted in only 2.4\% total jaw injuries indicating the lowest incidence of injury for any head/neck/face anatomical area. Impact studies have shown that compared with no mouth guard, mouth guards composed of many types of materials reduce the number of fractured teeth and head acceleration.\textsuperscript{23}

Limitations of this study include a limited sample size and the participants’ specific geographical area. Participants surveyed in this study lived and trained in the Midwest. Mixed Martial Arts competitors who train outside the Midwest may train differently, thus predisposing them to different injury rates, various injury types, and assorted injury prevention practices. The majority of participants in this study declared a form of grappling (wrestling and jiu-jitsu) as their primary martial art style, which may have exposed them to specific injuries and locations than those
who declared a form of striking as their primary martial art style (boxing and kickboxing). Increasing the sample size, geographic area surveyed, and primary martial art style distribution accessed would further increase the study's validity.

Even though participants were given an injury diagnosis sheet, which gave a definition of all the injury types listed on the participant questionnaire, self-assessment of injury diagnoses may have been inaccurate. Injuries sustained during training could have been falsely assumed to be the same type of injuries that occurred in competition. Other limitations of this study include determining the number of participants that refused to participate in the study and the lack of the participant questionnaire (survey tool) being validated by an outside source. Additional studies should focus on improving upon these limitations, which would help strengthen and validate some of its findings and conclusions.

CONCLUSION

Despite the attempts to ban it by legislators and the medical community, MMA grew in the 1990s from an underground spectacle into an internationally sanctioned sport. This transformation was driven by modifying the rules to make the competition safer to the athletic governing commissions. This ultimately led to increased event exposure, more lucrative incentives offered to the competitors, and ultimately leading to the sport's growing popularity.5,12,24

With the ever-growing popularity of MMA, more participants are getting involved in the sport and increasing their risk of injury.

The growing popularity of MMA has forced the medical community to take notice and focus on preventative measures to reduce the MMA participant's risk of injury. Preventative measures should focus on improving protective equipment during training, and possible competition rule modifications to further minimize participant injury. However, recommendation of rule modifications is premature and future studies are warranted to validate this claim. This study will hopefully be the first of many instruments for making future recommendations to keep MMA fighters safe and competing at their best.

REFERENCES


QUESTIONNAIRE: PART I – DEMOGRAPHIC DATA

Please read and answer the following eight (8) questions by circling the letter that most represent you. Thank you for your participation in this survey!

1. What is your age?
   a. 18-21 yrs, b. 22-25 yrs, c. 26-29 yrs, d. 30-33 yrs, e. 34+ yrs

2. What is your gender?
   a. Male, b. Female

3. Which is your primary martial art/style?

4. What is your belt rank?

5. How many years of training have you had?
   a. 0-1 yrs, b. 1-2 yrs, c. 2-3 yrs, d. 3-4 yrs, e. 4+ yrs

6. How many hours of training per week do you practice?
   a. 0-2 hrs/wk, b. 3-5 hrs/wk, c. 6-8 hrs/wk, d. 9-11 hrs/wk, e. 12+ hrs/wk

7. What protective equipment do you wear? (circle all that apply)
   g. Wrestling Shoes, h. Boxing Gloves, i. MMA Gloves, j. Other

8. What is your current fighter status?
   a. Amateur, b. Professional
ABSTRACT

Background. The importance of the scapular stabilizing muscles has led to an increased interest in quantitative measurements of their strength. Few studies have measured isometric or concentric isokinetic forces. Additionally, limited reports exist on the reliability of objective measures for testing scapular protraction and retraction muscle strength or scapular testing that does not involve the glenohumeral (GH) joint.

Objective. To determine the reliability of four new methods of measuring the maximal isometric strength of key scapular stabilizing muscles for the actions of protraction and retraction, both with and without the involvement of the glenohumeral (GH) joint.

Methods. The Isobex® stationary tension dynamometer was used to measure the maximal isometric force (kg) on thirty healthy females (ages 22-26 years). Three measures were taken for each method that was sequentially randomized for three separate testing sessions on three non-consecutive days.

Results. Intraclass correlations (ICC2,3) for intrasession reliability and (ICC3,3) for intersession reliability ranged from 0.95 to 0.98, and 0.94 to 0.96 respectively. The standard errors of measurement (95% confidence interval [CI]) were narrow. Scatter grams for both protraction and retraction testing methods demonstrated a significant relationship, 0.92 for protraction (95% CI 0.83 to 0.96) and 0.93 for retraction (95% CI 0.87 to 0.97). Bland-Altman plots indicated good agreement between the two methods for measuring protraction strength but a weaker agreement for the two methods measuring retraction strength.

Discussion/Conclusion. The four new methods assessed in this study indicate reliable options for measuring scapular protraction or retraction isometric strength with or without involving the GH joint for young healthy females.

Key Words: scapular stabilizing muscles, isometric strength, static tension dynamometer

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INTRODUCTION
Significance of Problem
The importance of the scapular stabilizing muscles has led to an increased interest in quantitative measures of strength for protraction and retraction, especially for portions of the trapezius and serratus anterior muscles. \(^1\text{-}^{16}\) Several studies have attempted to measure the strength of the scapular stabilizing muscles by measuring isometric or concentric isokinetic forces. \(^16\text{-}^{26}\) Although strengthening of the scapular muscle stabilizers is a common intervention for scapular dyskinesia, \(^27\) objective measurement of scapular stabilizing muscle strength is likely uncommon in most clinical settings. Simple and reliable objective strength measurement capabilities for the scapular stabilizing muscles could assist the clinician in identifying weakness, muscle imbalance, or both during a shoulder evaluation and could be used as an outcome measure following selected intervention exercises. Objective strength testing of the scapular stabilizing muscles is difficult since the commonly used procedures require a resistive contact force on the upper extremity, or the glenohumeral (GH) joint is positioned at or above 90 degrees elevation, while assuming the GH joint and rotator cuff muscles are normal. The same difficulties exist for manual muscle testing (MMT) of the serratus anterior when using the upper extremity. For example, the original MMT position advocated by Kendall for testing the serratus anterior applied the resistance force against the fist with the arm extended. Using this method, Donatelli did not report protraction isometric force data in a study of baseball players since the intrarater reliability was only 0.266. Similarly, Michener modified the Kendall MMT procedure for the serratus anterior by flexing the elbow to 90° and applying the resistance force to the olecranon along the long axis of the humerus. While hand-held dynamometers used in objective strength testing have reported good reliability, the reliability is dependent on the strength of the tester. \(^28\)

Isokinetic equipment that may be used for scapular stabilizing muscle testing \(^22\text{-}^{23}\) are hindered by equipment costs and manpower time. Further, movements and positions used are often uncommon in activities of daily living, work place, athletics, or with common positions used for training and therapy. \(^29\)

Purpose of the Study
Clinically there is a need for simple and objective strength measurements of the scapular stabilizing muscles. \(^30\) Strength can be defined as an individual's ability to exert maximum muscular force statically. \(^29\) The purpose of this study was to determine the reliability of four new methods that measure maximal isometric strength of key scapular stabilizing muscles for protraction (serratus anterior, upper trapezius, and pectoralis minor muscles) and retraction (middle trapezius and rhomboid muscles) movements, with and without the involvement of the GH joint and rotator cuff muscles.

METHODS
Subjects
Thirty females (mean age = 24 years, SD 1.5, range 22 to 28 years) volunteered to participate in the study. The study was approved by the East Tennessee State University/Veteran's Administration Medical and the Rocky Mountain University of Health Professions Institutional Review Boards, and written consent was obtained from all subjects. Only females were recruited because of the likely inherent variances and strength differences between males and females, and to avoid the possibility of healthy males exceeding the force measuring capabilities of the testing apparatus. Exclusion criteria included pregnancy and history of neck or shoulder pain/dysfunction within the last three months that required a medical consultation or intervention. Potential subjects were then asked to complete the modified American Shoulder and Elbow Surgeons Questionnaire (ASESQ). \(^31\) A previous study reported a test-retest intraclass correlation coefficient (ICC) of 0.96 for the ASESQ. \(^31\) Individuals who scored lower than 95 on the ASEQ were informed that they were not eligible to participate in the study.

After meeting all study inclusion criteria, subjects were assigned a random identification number to aid in assuring confidentiality. All subjects completed a short questionnaire that inquired about their age (years) and upper extremity dominance relative to their preference for writing or throwing a ball. Height (cm) and weight (kg) were measured using a standard stadiometer.

Instrumentation
The Isobex® static tension dynamometer (Medical Device Solutions, AG; Burgdorf, Switzerland) was used to measure each subject's isometric force. The Isobex® dynamometer has been used in post-operative shoulder follow-up studies for measuring the strength portion of the Constant-Murley

\[\text{Isobex}\]
shoulder score. The dynamometer was attached to a special track that was anchored to the wall that then allowed vertical level adjustment of the dynamometer. The instrument’s measurement range is 10-450 Newtons (N), resolution of 1 N, precision ± 2 N, and the frequency of measurement is 10 measurements/second. Leggin et al. reported the intrarater reliability of the Isobex® instrument was 0.95 to 0.98 and the interrater reliability was 0.90 to 0.97 when measuring maximal isometric force for humeral abduction and internal/external rotation.

**Testing Positions**

**Position 1 - Scapular protraction with GH joint and rotator cuff muscles**

A portable stabilizing bench with a padded vertical trunk pad (A87 Pressing Chair, Magnum Fitness Systems, Milwaukee, WI, USA) was used to position each subject (Figure 1). A laser beam (Acculine Laser Levels Pro, 40-6164) was used to align the center of the humerus with the tension attachment perpendicular to the dynamometer that was anchored on the wall. The height of the dynamometer was adjusted so that the tension line was parallel to the floor and in the sagittal plane. The subject was seated facing away from the wall with the chest against the vertical bench pad. A padded stabilizing strap was draped around the subject's trunk, vertical bench pad, and over the opposite shoulder for increased trunk and hip stabilization. The humerus of the subject's dominant shoulder was elevated to 90° with the scapula in a neutral resting position (midway between maximal protraction and retraction) and the elbow extended. The dynamometer handle was positioned with the subject's thumb up. Tension in the dynamometer tension line was adjusted until there was no slack. During testing, emphasis was placed on the subject pushing against the handle while trying to isolate protraction of the shoulder without using the trunk or lower extremity muscles.

**Position 2 - Scapular protraction without GH joint and rotator cuff muscles**

The position and stabilization were the same as Position 1. However, the arm position and resistive contact area were different (Figure 2). The humerus of the subject's dominant shoulder was placed at the subject's side with the elbow flexed at 90°. A padded shoulder strap circumscribed the shoulder in the sagittal plane while passing under the axilla and attached to the dynamometer tension line. If necessary, the tester lightly held the top of the strap to keep it from sliding down prior to achieving the maximal tension force. The primary contact area over the shoulder for the resisted movement was the anterior aspect of the shoulder and the lateral aspect of the pectoral region. Tension in the dynamometer tension line was adjusted until there was no slack in the dynamometer tension line. During testing, emphasis was placed on the subject pushing forward against the strap while trying to isolate protraction of the shoulder without the use of the trunk or lower extremity muscles.

**Position 3 - Scapular retraction with GH joint and rotator cuff muscles**

The positioning and stabilization were similar to Positions 1 and 2. However, the subject's back was stabilized against the vertical trunk pad and the subject faced the wall and the dynamometer (Figure 3). The humerus of the dominant shoulder was elevated to 90°, the scapula in a neutral resting position, and the elbow extended. Subjects were then instructed to grasp the dynamometer handle with their thumb up. The dynamometer tension line was adjusted until there was no slack. During testing, emphasis was placed on the subject pulling against the handle while trying to isolate retraction of the shoulder without using the trunk or lower extremity muscles.
Position 4 - Scapular retraction without GH joint and rotator cuff muscles

The position and stabilization were the same as Position 3. However, the subject's arm position and the resistive contact area were different (Figure 4). The humerus of the subject's dominant shoulder was placed at the subject's side with the elbow flexed at 90°. A padded shoulder strap circumscribed the shoulder in the sagittal plane while passing under the axilla and attached to the dynamometer tension line. If necessary, the tester lightly held the top of the strap to keep it from sliding down prior to achieving the maximal tension force. The primary contact area over the shoulder for the resisted movement was the posterior aspect of the shoulder and the lateral aspect of the scapula. The dynamometer tension line was adjusted until there was no slack. During testing, emphasis was placed on the subject pulling back against the strap while trying to isolate retraction of the shoulder without using the trunk or lower extremity muscles.

Testing Procedures

For each of the three data collection sessions, three measurements were conducted for each of the four methods (Figures 1-4) for a total of twelve strength measurements per session. Two testing methods were administered to determine protraction strength (one each with or without involvement of the GH joint or rotator cuff muscles), and two testing methods were for retraction strength (again, one each with or without involvement of the GH joint or rotator cuff muscles). The sequence of the four methods tested was randomized for each of the four sessions to minimize the influence of learning effect or fatigue.

The subject was positioned in the appropriate sitting position for each testing method. A brief warm-up consisted of three to four repetitions of active shoulder rolls, humeral circumduction, shoulder elevation, protraction, and retraction. The procedure was explained to the subject, followed by sub-maximal tests to practice the sequence of testing until the subject felt comfortable with the testing protocol, generally one to three times. The dynamometer automatically calibrated prior to each measurement. Then, an acoustic start signal from the dynamometer was triggered, and the subject pushed or pulled against the dynamometer maximally for a total duration of 5 seconds as recommended by the American Society of Exercise Physiologists.

A consistent verbal command was used during the 5 second period of testing to encourage maximal effort. The subject would stop exerting force when a second acoustic sound was heard from the dynamometer. The average force over the 5 seconds that subjects exerted their maximal force for each test was measured and recorded in kilograms (1 kg = 9.81 N). Subjects were given 1 minute rest periods between measurements for each method.

A minimum of three-minute rest intervals were used between the four methods. Testing was measured and recorded over three separate testing sessions with intervals of one to three days. One investigator administered all testing procedures. All testing was performed on the dominant extremity.

Data Analysis

Descriptive statistics (mean, SD, and range) were used to describe the subjects' age (yrs), height (cm), weight (kg), body mass index (BMI) [kg/m²], and score on the modified American Shoulder and Elbow Surgeons questionnaire (ASESQ). Means and standard deviations were also calculated for the maximal isometric force measurements (kg) of the four methods of testing key scapular stabilizing muscles. Intersession reliability of the measurements was determined using intraclass correlation coefficients (ICC) with 95% confidence intervals along with the standard error of measure (SEM) to provide an estimate of error associated with the measurement. The intrasession reliability was determined using intraclass correlation coefficients (ICC) with
95% confidence intervals along with the standard error of measure (SEM) to provide an estimate of error associated with the average force measurement for each method between the three testing sessions. Additional comparisons of the two methods for protraction and retraction were conducted using Pearson Product-Moment Correlation Coefficient, scattergrams, and a Bland-Altman Plot. Pearson Product-Moment Correlation Coefficients determined the amount of relationship between the two methods. The scattergram provided a graphic representation between the force measurements of each subject for one method against the force measurements of the other method. Bland-Altman plots were created to visually inspect agreement of the two testing methods for both protraction and retraction (with and without the GH joint and rotator cuff muscles). The Bland-Altman plot provided a visual means to look at the difference between the two methods plotted against the mean score for each subject. Within the Bland-Altman plots were lines that indicated the mean difference between methods and lines for two standard deviations above and below the mean difference. To assist in visualizing any bias between methods, data points were fitted with a linear regression line. All statistical calculations were performed using the Statistical Package for the Social Sciences 15.0 statistical package (SPSS, Inc., Chicago, IL) and Microsoft Excel software package (Microsoft, Redmond, Washington).

RESULTS
Characteristics of the sample are presented in Table 1. Mean force (kg) and standard deviations for each of the four scapular muscle strength testing methods across three separate testing sessions are shown in Table 2. The intrasession reliability ICC (2,3) for each of the four methods with their corresponding 95% CIs and standard error of measurements (SEM) are presented in Table 3. The reliability correlation coefficients for the four methods of strength testing ranged from 0.95 to 0.98. The standard error of measurement (SEM) ranged from 0.9 to 1.10 kg for protraction with the GH joint, and 0.7 to 1.0 kg for protraction without the GH joint. The SEM for retraction ranged

Table 1. Characteristics of the study sample (n = 30 females)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Mean</th>
<th>SD</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>24.0</td>
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<tr>
<td>Height (cm)</td>
<td>166.8</td>
<td>8.8</td>
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<td>BMI (kg/m²)</td>
<td>23.1</td>
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<td>17.3-34.7</td>
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<tr>
<td>ASESQ score*</td>
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<td>1.9</td>
<td>95-100</td>
</tr>
</tbody>
</table>

SD, Standard deviation; BMI, Body mass index.
* Modified American Shoulder and Elbow Surgeons questionnaire (ASESQ). Maximum score is 100 points.

Table 2. Mean Scores (kg) and Standard Deviation (SD) for Isokinetic Dynamometer (n = 30)

<table>
<thead>
<tr>
<th>Position</th>
<th>Session 1</th>
<th>Session 2</th>
<th>Session 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protraction + GH</td>
<td>13.2</td>
<td>13.8</td>
<td>14.7</td>
</tr>
<tr>
<td>Protraction – GH</td>
<td>14.5</td>
<td>15.2</td>
<td>15.8</td>
</tr>
<tr>
<td>Retraction + GH</td>
<td>20.3</td>
<td>22.8</td>
<td>23.8</td>
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<tr>
<td>Retraction – GH</td>
<td>15.8</td>
<td>17.8</td>
<td>18.2</td>
</tr>
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</table>

GH, Glenohumeral joint

Table 3. Intrasession Reliability of the Protraction and Retraction Measurements

<table>
<thead>
<tr>
<th>Method</th>
<th>ICC (2,3)</th>
<th>95% CI</th>
<th>SEM*</th>
<th>ICC (2,3)</th>
<th>95% CI</th>
<th>SEM*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protraction</td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>Session 1</td>
<td>0.97</td>
<td>0.95 - 0.99</td>
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<td>0.96</td>
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<td>1.1</td>
<td>0.96</td>
<td>0.93 - 0.98</td>
<td>0.9</td>
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<tr>
<td>Session 3</td>
<td>0.96</td>
<td>0.93 - 0.98</td>
<td>1.4</td>
<td>0.96</td>
<td>0.93 - 0.98</td>
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With Glenohumeral Joint

<table>
<thead>
<tr>
<th>Method</th>
<th>ICC (2,3)</th>
<th>95% CI</th>
<th>SEM*</th>
<th>ICC (2,3)</th>
<th>95% CI</th>
<th>SEM*</th>
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</thead>
<tbody>
<tr>
<td>Protraction</td>
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<td>0.95 - 0.99</td>
<td>1.3</td>
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<td>0.96 - 0.98</td>
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<td>1.5</td>
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<td>0.93 - 0.98</td>
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Without Glenohumeral Joint

ICC, Intraclass correlation coefficient; CI, Confidence Interval
*SEM, Standard error of the measurement in kg.
between 1.3 and 1.5 kg for retraction with the GH joint, and 0.9 to 1.5 kg for retraction without the GH joint. The ICC’s (3,3) for each of the four methods with their corresponding 95% CI’s and standard error of measurement (SEM) for intersession reliability are presented in Table 4. Intersession reliability correlation coefficient estimates ranged from 0.94 to 0.96 while the SEM were between 1.2 and 1.5 kg.

A scattergram of the force output for protraction with the GH joint as a function of the force output without the GH joint indicated a significant relationship of 0.92 between the methods (95% confidence interval: 0.83 to 0.96) (Figure 5). The Bland-Altman plot for protraction (Figure 6) was representative of the differences between the two methods as a function of the average of the two methods. The line for the mean difference between the methods was -1.31. For protraction, there were a minimal number of outliers outside the two standard deviations of the mean differences, indicating general agreement between the two methods. However, as the force output increased, the difference between the methods also increased.

The scattergram of the force output for retraction with the GH joint as a function of the force output without the GH joint is shown in Figure 7. A significant relationship of 0.93 was found between the methods (95% confidence interval: 0.87 to 0.97). The Bland-Altman plot for retraction (Figure 8) again was representative of the differences between the two methods as a function of the average of the two methods. However, the middle line indicating the mean difference between the two methods was 5.83. The two lines indicating two standard deviations from the mean difference showed there was one outlier and a varied spread of the mean difference. Furthermore, the regression line indicated that as more force was generated, a greater difference between the methods was observed.

**DISCUSSION**

The two methods for testing protraction maximal isometric strength and the two methods for testing retraction maximal isometric strength indicated high intrasession and intersession reliability with a small standard of error of measurement. According to Portney and Watkins, values of ICC above 0.90 are indicative of good reliability for clinical studies.

The importance of these findings is twofold. First, these new procedures for measuring scapular muscle strength for protraction and retraction offer a possible clinical alternative to manual muscle testing. Second, two of the procedures offer an alternative to measuring protraction and retraction strength while avoiding the use of the humerus and rotator cuff.

The intraclass correlations (ICC’s) found in our study were high and were similar to reports that used the Isobex® static dynamometer or measured protraction and retraction strength with other static dynamometers with a custom stationary apparatus or a modified isokinetic machine. The ICC’s observed in this study were higher than the 0.27 intrarater reliability for protraction (serratus anterior muscle) performed on baseball players using the traditional manual muscle testing method of applying a downward force on the subject’s hand. This may have been due to the disparity of strength between the baseball players and testers, as well as the difficulty with the subject’s coordination and stability when a force is applied at the distal end of the upper extremity kinetic-chain. One aim of this study was to determine if there was similar agreement between two alternative methods of measuring force output for protraction and retraction, with the difference between the two methods being the inclusion or exclusion of the GH joint during testing. Many studies
Figure 5. Scatterplot of Protraction with GH as Function of Protraction without GH

Figure 6. Bland-Altman Plot for Protraction

Figure 7. Scatterplot of Retraction with GH as Function of Retraction without GH

Figure 8. Bland-Altman Plot for Retraction
have used Kendall et al’s testing protocols which involve the GH joint when testing protraction and retraction. However, because some individuals may also present with GH joint dysfunction, it raises the issue if excluding GH joint during testing may affect force outcome measures. Although our ICC’s agreement findings were considered strong, the Bland-Altman plots indicated that not involving the GH joint affected the readings.

For the two retraction methods there was only one outlier for the thirty force outputs at two standard deviations from the mean difference of 1.31. The small mean difference visually indicated that there was minimal disparity between the two methods of force measurement for protraction. However, as the force output increased there was a small bias towards the method not involving the GH joint. This bias may be due to the unaccustomed movement pattern and also to the perceived increased coordination necessary to involve the unsupported upper extremity.

For the two retraction methods there was only one outlier for the thirty force outputs at two standard deviations from the mean difference of 5.83. While both methods of measuring retraction were reliable, a mean difference of 5.83 indicated that the methods were not likely interchangeable. The bias towards retraction involving the GH joint may be due to the fact that pulling is a common movement pattern. In addition, since the humerus was elevated to ninety degrees when involving the GH joint, there may have been some affect from the deltoid and latissimus dorsi muscles. Furthermore, for retraction, there was a greater spread of force measurements within two standard deviations at all levels of force output.

There were limitations to this study. First, restricting the subject sample to young healthy females limits the generalizability of the findings. However, the intent was to establish reliability of the new measuring procedures in a confined homogenous population to minimize confounding. The reliability of these new testing methods and positions need to be further investigated with various population groups, validated, and taught to clinicians so they can assess scapular musculature without incorporating the GH joint. Second, the testing procedures appear to require stabilization from both sides of the trunk in the upright sitting position, both for countermovement stabilization and for prevention of synergistic trunk muscle activity in the direction being tested. Stabilization benches used for weight training purposes are readily available; however, one has to consider the width so it allows stabilization of the trunk while offering mobility of the shoulder girdle being tested. Alternative positioning methods using the supine and prone positions also deserve further study. The width of the trunk stabilization pad and the determination of the neutral position of the scapula should be considered. Third, some subjects had difficulty learning to quickly respond to the audio stimulus, which may have initially made it difficult to provide a maximal contraction effort for the full 5-second duration. Subjectively, it appeared that subjects that were athletic and familiar with resistance exercises learned the procedure more easily. Fourth, there was a trend of increasing mean force scores noted over the three testing sessions for all four methods. This suggested that there may have been some learning effect in spite of randomization and a strict testing procedure. However, further post hoc analysis using repeated-measures ANOVA revealed there was no real learning effect observed. Using three trials and using the mean measure helped to insure the truest score possible. Finally, while the Isobex® static dynamometer maximum measuring capability of 450 Newtons (approximately 46 kg) is appropriate for testing a normal patient population, it may not be sufficient for measuring individuals with strong, athletic physiques. With the appropriate stabilization it is unlikely that most athletes would exceed 450 Newtons. If extremely strong athletes are being tested there are various tension dynamometers that are available that could be used for the same protocol.

There were two key strengths of the study. First, several advantages of our new procedures using the Isobex® static tension dynamometer is that it is 1) a relatively inexpensive dynamometer, 2) is a more objective than manual testing grades, 3) is relatively easy to learn to use, 4) is not dependent on the tester’s strength, and 5) can be set-up in a typical patient management setting. Although the Isobex® dynamometer was chosen for this study, there are many other dynamometers that are commercially available. Second, it has been common to incorporate the GH joint when evaluating scapular dysfunction. This study did not resolve the issue of whether to include or not include the GH joint when evaluating the scapular musculature in the healthy individual, and further study is warranted. However, in a clinical situation where the patient being evaluated for scapular muscle strength has problems such as limited GH range of motion, impingement with the GH joint at 90 degrees flexion, painful or...
dysfunctional rotator cuff musculature, elbow or wrist problems, or problems with their grip, then methods not requiring the upper extremity would seem prudent. The maximal strength force measurement is limited by the weakest link in the kinetic-chain.

The clinical application of this study is that it offers the clinician additional reliable, objective, and efficient quantitative methods for measuring force in the scapular stabilizing muscles, as well as being able to test subjects even if the subject has GH joint dysfunction or upper extremity problems. The clinician will be able to collect quantitative baseline information during the initial evaluation to determine muscle weakness or imbalances, as well as using the testing procedures for outcome measurements to determine the effect of interventions used for strengthening the scapular stabilizing muscles.

CONCLUSION
The four new methods in our study provided reliable options for quantitatively measuring scapular protraction and retraction maximal isometric strength with a stationary static tension dynamometer that was not dependent on the tester’s strength as when testing with a hand-held compression dynamometer. Additionally, two of the new methods allowed measurement of scapular protraction and retraction isometric strength without involving the GH joint or rotator cuff muscles. Therefore, the findings of our study suggest that these four methods of measurement might be trustworthy when measuring protraction and retraction strength in a healthy population of females. Further research with patient and athletic populations will be needed to validate the usefulness of these new testing procedures.

REFERENCES


