2022

The Effectiveness of Myofascial Release on Overhead Athletes with Posterior Shoulder Tightness

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51 Pages

Context: Posterior shoulder tightness is common among collegiate overhead athletes due to repetitive overhead patterns, often resulting in altered range of motion patterns. This may be associated with additional non-painful hypersensitive areas of taut muscle called latent myofascial trigger points (LTrPs), which have been linked to muscle imbalances, muscular weaknesses, impaired motor recruitment, and internal rotation (IR) range of motion (ROM) deficits. Evidence supports improvements in glenohumeral ROM and isometric strength through instrument assisted manual therapy techniques on MTrPs in baseball players. Ischemic compression (IC) is a form of therapeutic myofascial release that can be performed by any clinician trained in manual therapy. Although improvement in ROM and isometric strength have been indicated within other regions of the body, it is unknown if IC treatment of LTrPs will improve glenohumeral ROM and isometric strength in overhead athletes.

Objective: The purpose of this study was to determine the relationship between short- and long-term repeated IR ROM and ER isometric strength measurements before and after IC treatment compared to sham compression.

Study Design and Setting: Single-blinded randomized controlled trial in a controlled athletic training laboratory.

Patients or Other Participants: Forty healthy Division I collegiate overhead athletes (age: 20.3±1.6 years) from baseball, cheer, circus, softball, swimming, track and field, and volleyball were included in this study. Participants were excluded if they did not have a total arc ROM deficit of ≥5° in the dominant shoulder compared to the ideal 180° for overhead athletes or deficits of ≥20° of IR compared to the contralateral shoulder, had at least two LTrPs in the dominant shoulder infraspinatus muscle, or scored <70% on the Kerlan-Jobe Orthopedic Clinic scores (KJOC) or Penn Shoulder Scores (PSS) questionnaires.

Intervention: Participants were randomly allocated to one of two intervention groups; IC or sham IC. Participants in the IC group completed passive IR glenohumeral ROM and ER isometric strength measurements before and immediately after IC treatment session #1, within 24-48 hours of IC treatment session #1, and final measurements taken within 24-48 hours after IC treatment session #2. The sham IC group completed the same procedures as the IC group, except investigators did not apply manual pressure to MTrPs.

Main Outcome Measures: Passive glenohumeral IR ROM, ER isometric strength, and pain-pressure threshold (measured by a digital pressure algometer). The KJOC and PSS were used to determine each participant's perceived level of dominant shoulder function before and after interventions.

Results: Dominant shoulder passive glenohumeral IR ROM increased following the IC and sham interventions. Individuals who received IC did not demonstrate significant ER strength gains compared to baseline, but individuals who received sham compression demonstrated a significant decrease in overall ER isometric strength during the final measurement time-point compared with baseline (mean change score=-1.63 ±1.04kg) versus the IC group (-0.20±1.49kg; $F_{1,38}$=2.33, p<0.001, η^2_p=0.18). Pain-pressure threshold showed a greater decrease in the 1st LTrP at the first post-intervention time-point compared to baseline in the IC group (mean change score=-1.49±1.56) versus sham (-0.53±1.23, p=0.042). No differences in pain-pressure threshold in the first LTrP were found at the other time-points.

Conclusion: Our findings suggest that ischemic compression may be an effective treatment method for improving glenohumeral IR ROM but not ER isometric strength. Additional research is required to completely understand and implement the use of ischemic compression on LTrPs as a treatment for glenohumeral IR ROM and ER isometric strength in healthy collegiate overhead athletes.

KEYWORDS: external rotation, infraspinatus, internal rotation, isometric strength, latent trigger point, range of motion

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A Thesis Submitted in Partial
Fulfillment of the Requirements
for the Degree of

MASTER OF SCIENCE

School of Kinesiology and Recreation

ILLINOIS STATE UNIVERSITY

2022

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ACKNOWLEDGMENTS

I would like to thank my amazing research advisor, Dr. Nicole Hoffman for all of the help and effort she put into not only my thesis, but in me as well. Without her mentorship and her confidence in my abilities there is no way I would have been able to complete this thesis. The millions of emails and drafts we sent back and forth were fun, but I will not miss them. I would also like to thank my second committee member, Dr. Justin Stanek for all of his input and assistance throughout the process as well. In addition, I would also like to thank my best friend Jamie Tabor, who so happily agreed to be my assistant in data collection. Without her constant support and help in the lab I would not have finished. Last but not least, I would like to thank my husband, family, and friends for their encouragement and believing in my ability to see this thesis through. Thank you all for the constant encouragement and helping me get here through all of the ups and downs of research.

B.R.

CONTENTS

TABLES

FIGURES

CHAPTER I: INTRODUCTION

Posterior shoulder tightness is common among overhead athletes (e.g., baseball, softball, volleyball). The development of posterior shoulder tightness comes from the repetitive tensile load placed on the glenohumeral joint during overhead motions such as throwing.(Laudner, Wong, et al.) Due to the physiological demands from repetitive overhead motions, athletes may develop altered shoulder mobility secondary a bony adaptation called humeral retroversion, which results in increased external rotation and decreased internal rotation in the dominant arm.(Greenberg et al.; Passigli, Plebani and Poser) This bony adaptation creates a mechanical advantage for overhead athletes.(Greenberg et al.) However, this adjusted rotation of the humerus within the glenohumeral joint and the continued stress placed on the joint may overtime lead to the development of unwanted soft-tissue adaptations (e.g. muscular and capsuloligamentous), causing posterior shoulder tightness.(Laudner, Wong, et al.) Muscular and capsuloligamentous adaptations may contribute to decreased strength and altered total arc range of motion, putting the athlete at risk for injuries such as subacromial impingement or other rotator cuff pathologies.(Laudner, Wong, et al.) Collegiate overhead athletes are especially at risk for the development of posterior shoulder tightness in addition to humeral retroversion due to the heavy workload of daily practices, games, and/or workouts they undergo.(Chepeha et al.) Posterior shoulder adaptations due to muscular and capsuloligamentous structures may result in an even larger gain in external rotation range of motion, further diminished internal rotation and horizontal adduction range of motion, and decreased external rotation strength of an athlete's dominant shoulder.(Laudner, Wong, et al.) Literature states that whether the alteration in shoulder range of motion is due to soft-tissue tightness, or to structural adaptations such as humeral retroversion, or a combination of both is currently unknown. Although the cause of posterior shoulder tightness is not entirely understood, the soft-tissue aspect of the pathology can be effectively treated.(Greenberg et al.; Hall and Borstad)

Recommended intervention for posterior shoulder tightness is when it is caused by soft-tissue adaptations. Posterior shoulder tightness in overhead athletes may lead to decreased range of motion and strength due to the tight soft-tissue structures.(Hall and Borstad) Although it is unknown which soft-tissue structures exactly are benefiting from different treatment techniques, evidence shows that treating posterior shoulder muscles contributes to the restoration of shoulder range of motion.(Hall and Borstad; Chepeha et al.; Laudner, Compton, et al.) When posterior shoulder muscles such as the infraspinatus are tight, possibly caused by myofascial lesions called trigger points, they can decrease internal rotation range of motion. This reduction of range of motion will affect the comparison of total arc range of motion between the two shoulders, placing the athlete at an increased risk for injury.(Rose and Noonan) Not only do myofascial trigger points affect a muscle's ability to move through its entire range of motion, but it can also decrease the strength the muscle is able to produce.(Celik and Mutlu) This places an athlete at an increased risk for injury, with decreased range of motion, and diminished strength effectively taking away their mechanical advantage for play.(Hall and Borstad) Preventative treatment of posterior shoulder tightness, specifically on the infraspinatus, is recommended however, the form of treatment is up to clinicians.(Hall and Borstad)

Semi-invasive and non-invasive treatments such as dry needling, instrument assisted soft tissue mobilization, and dry cupping have all been found to be successful treatment approaches for releasing myofascial trigger points in the shoulder.(Kashyap, Iqbal and Alghadir; Hall and Borstad) However, these techniques all require the use of an instrument and are specific to clinicians who are trained in these forms of soft tissue mobilization.(Kashyap, Iqbal and

Alghadir) Ischemic compression technique, a form of manual massage therapy called myofascial release, can target specific lesions within a muscle.(Knight and Draper) Despite evidence supporting the use of instrument assisted tools(Passigli, Plebani and Poser; Chi et al.; Laudner, Compton, et al.) it is possible that the use of ischemic compression technique, being a more readily available intervention, is just as effective as other soft tissue mobilization treatments in regaining strength and range of motion of the shoulder.(Kashyap, Iqbal and Alghadir) In using the ischemic compression technique, clinicians may be preventing overhead athletes from injuries of the muscle such as rotator cuff pathologies and impingement syndrome. In addition to increased shoulder internal rotation range of motion, the release of latent myofascial trigger points of the infraspinatus may also result in increased shoulder external rotation strength and stabilization strength in addition to regaining the lost shoulder internal rotation.(Celik and Mutlu) This may help with the prevention of other shoulder injuries including labral pathologies by lessening the load on other anatomical aspects of the joint during stabilization. The return of shoulder external rotation strength may also play a role in increased performance of overhead athletes. Therefore, the purpose of this study was to determine if treating muscular posterior shoulder tightness through the application of ischemic compression technique on the infraspinatus muscle will improve internal rotation range of motion and external rotation strength in dominant shoulders of collegiate overhead athletes. We hypothesized that releasing latent myofascial trigger points within the infraspinatus of an otherwise healthy overhead athlete's dominant shoulder would allow for increased shoulder internal rotation range of motion and external rotation isometric strength. Our secondary prediction was that overhead athletes who increased internal rotation range of motion and external rotation isometric strength would self-report as having higher function of their dominant arm after ischemic compression intervention.

CHAPTER II: REVIEW OF LITERATURE

The repetitive nature of overhead sports can overtime lead to adaptations in athletes' dominant shoulder mobility.(Chepeha et al.; Borsa, Laudner and Sauers) Changes can include soft-tissue such as muscle and capsuloligamentous or bony alterations.(Johnson et al.; Chepeha et al.; Borsa, Laudner and Sauers) Muscular adaptations to the repetitive motions may result in posterior shoulder tightness, which can be treated with manual therapy interventions.(Chepeha et al.) If posterior shoulder tightness is left untreated, it may lead to overuse of shoulder muscles such as the infraspinatus.(Borsa, Laudner and Sauers) The shoulder is one of the most frequently injured joints in the body,(Häberle et al.) and evidence shows that shoulder injuries may be linked to myofascial trigger points (MTrP).(Kamali, Sinaei and Morovati) There are benefits of releasing MTrPs using various advanced manual therapy interventions (e.g. dry needling and Graston Technique) compared to manual pressure to improve shoulder pain and/or range of motion.(Laudner, Compton, et al.; Passigli, Plebani and Poser) However, there is very little research discussing ischemic compression (IC) on the release of MTrPs and its effects on range of motion (ROM) and strength on healthy college-aged overhead athletes with posterior shoulder tightness.

Shoulder Anatomy

The shoulder is a complex joint of the upper extremity of the human body. There are several muscles, ligaments, and bony articulations that form the shoulder girdle. Dynamic stabilizers include the rotator cuff (RTC), deltoid, and scapular stabilizing muscles. Static stabilizers include the glenoid labrum, glenohumeral (GH) joint capsule, and the surrounding ligaments. Movements of the shoulder complex require all involved structures to work together as one coherent unit. This allows for the greatest ROM of any joint found in the human body, but also contributes to decreased joint stability.(Terry and Chopp)

Bone

The three bones that make up the shoulder complex include the humerus, scapula, and clavicle. The largest long bone in the upper extremity is the humerus, which can be divided into different segments within the shoulder. Structures at the proximal aspect of the humerus include the proximal shaft and head of the humerus, greater tuberosity, lesser tuberosity, and bicipital groove. The head of the humerus articulates with a smaller glenoid fossa, forming the GH joint. The greater and lesser tuberosities are found on the neck of the humerus and serve as attachment points for the RTC muscle group. This creates a continuous circle from the posterior-inferior aspect to the anterior-inferior aspects of the humeral neck. The long head of the biceps brachii runs through the bicipital groove, which is found in between the two tuberosities.(Terry and Chopp)

The scapula is a thin triangular flat bone found on the posterolateral aspect of the thorax and covers ribs two through seven. The overall function of the scapula is to serve as a muscle attachment site to scapular stabilizers. Similar to the humerus, the scapula can be broken down into different segments and includes the spine, coracoid process, acromion, and glenoid. The spine is located on the superior portion of the scapula and continues laterally and superiorly to form the base of the acromion. The coracoid process extends laterally and anteriorly from the upper border of the scapula. The glenoid cavity, or fossa, articulates with the head of the humerus in the GH joint. In comparison to the humeral head, the articulating surface of the glenoid cavity is only one third to one fourth the size of the head of the humerus. This ratio only allows the cavity to contribute a small amount of GH joint stability.(Terry and Chopp)

The clavicle is a small, curved bone that connects the shoulder girdle to the trunk through the sternoclavicular (SC) joint and acromioclavicular (AC) joints. The lateral one third is an attachment site for muscles and ligaments, the medial one third undertakes axial loads, and the middle one third is the thinnest and weakest portion of the bone. Overall the primary function of the clavicle is to be an attachment site for muscles, protect neurovascular structures deep to the bone, and act as a stabilizer to the shoulder girdle.(Terry and Chopp)

Glenohumeral Joint

The GH joint is the articulation between the head of the humerus and the glenoid cavity of the scapula. It is a highly mobile joint that can be attributed to the large surface area of the head of the humerus in articulation with the smaller glenoid fossa. To account for this difference, the glenoid articular cartilage is thicker around the edges. This deepens the fossa and creates a better fit for the humeral head in the glenoid cavity, increasing joint stability. The articular conformity is responsible for creating the foundation for the concavity-compression effect, which is produced by the RTC and other surrounding muscles. Within the sealed joint there is typically very little fluid. This allows for negative intra-articular pressure, which creates a suction-like effect to resist translation of the humeral head. The combination of bony, capsuloligamentous, and muscular structures that make up the GH joint all work to create a stabile yet mobile joint.(Terry and Chopp)

Connective Tissue

Glenohumeral Joint Capsule

The completely sealed joint capsule is made up of collagen fibers that varies in thickness and surrounds the GH joint.(Di Giacomo et al.) The capsule takes up about twice as much surface area as the humeral head.(Terry and Chopp) Working in combination with GH ligaments,(Di Giacomo et al.; Terry and Chopp) it acts as a static stabilizer by tightening up when the shoulder nears the joint's end of external rotation (ER) and abduction (ABD) ROM.(Terry and Chopp) The thinner, weaker portions of the capsule are typically found where GH ligaments are absent.(Di Giacomo et al.) During mid-ranges of motion the capsule is typically relaxed, and the shoulder relies on the RTC muscles to act as stabilizers.(Terry and Chopp)

Ligaments

There are three ligaments that contribute to the stabilization of the glenohumeral joint: the superior glenohumeral, middle glenohumeral, and inferior glenohumeral ligaments. The superior GH ligament is attached at one end to the anterosuperior aspect of the glenoid and the superior aspect of the lesser tuberosity of the humerus on the other end. The coracohumeral ligament assists the superior GH ligament to not only stabilize the head of the humerus in the GH joint but also to resist inferior translation of the humerus while it is in adduction (ADD) and posterior translation of the humeral head while the joint is in forward flexion, adduction, and internal rotation (IR). The attachment points of the middle GH ligaments, which is absent in about eight to thirty percent of individuals, include the supraglenoid tubercle, superior labrum, or scapular neck and the medial aspect of the lesser tuberosity of the humerus. It primarily functions to restrict anterior translation of the humeral head while the joint is in 60° to 90° of abduction and inferior translation when the arm is at the side. The inferior glenohumeral ligament, the thickest one, can be divided into three other segments: the anterior band, axillary pouch, and posterior band. The anteroinferior glenoid rim, labrum, and the lesser tuberosity of the humerus serve as attachment sites for the anterior band, with its primary function being to resist anterior translation of the head of the humerus with the shoulder in an abducted and externally rotated position, a typical throwing position.(Terry and Chopp)

Glenoid Labrum

The labrum is made up of dense collagen in a triangular shape that lines the glenoid cavity. It functions to pull the humeral head into the socket, deepen the glenoid fossa, and acts as an attachment point for capsuloligamentous structures. Creating a larger contact area between the head of the humerus and glenoid fossa, thus increasing the stability of the articulation.(Terry and Chopp; Di Giacomo et al.) The anterosuperior aspect of the labrum is typically described as having a meniscus like shape with a fluctuating groove depth depending on location. The inferior aspect of the labrum is described as being more continuous with the articular cartilage and having a closer connection to the glenoid rim than other sections.(Di Giacomo et al.)

Fascia

Fascia is a strong, web-like connective tissue that surrounds structures including bones, organs, veins, nerves, and muscles. The tissue is made up of a wide variety of different cells, fiber types, and ground substances.(Kumka and Bonar; Whiting and Zernicke) The fascia is divided into three sections: superficial layer, layer of potential space, and the deep layer. Fibers within each layer are arranged in many different orientations, running in different directions.(McKenney et al.) It covers the entire body, acting as a cushion and supplying support along with stability.(Kumka and Bonar; Whiting and Zernicke; Barnes; McKenney et al.) When an area undergoes trauma, the fascia tightens as a defense mechanism to underlying muscle. As the fascia tightens in one area, the restriction of web connective tissue occurs throughout the body. This can lead to an overall loss of function through factors such as decreased strength and poor biomechanics, which can negatively affect ROM.(Barnes; McKenney et al.)

Muscle

The muscles in the shoulder must make up for the otherwise unstable joint, working to both stabilize and create movement at the shoulder. The RTC muscle group, including the infraspinatus, is a primary stabilizer during unresisted GH ABD and ADD,(Schenkman and Rugo de Cartaya; Di Giacomo et al.) and a primary mover during ER with the joint in 0°-70° of ABD and during IR with the joint in 70°-0° of ADD.(Schenkman and Rugo de Cartaya) The RTC includes the supraspinatus, subscapularis, teres minor, and infraspinatus but is not the only muscle group working to rotate the shoulder. Other surrounding muscles that contribute to shoulder rotation include the deltoid, latissimus dorsi, and pectoralis major.(Schenkman and Rugo de Cartaya) However, the RTC muscle group has a greater role in humeral stabilization based on its close proximity to the axis of rotation, which results in its ability to create concavity compression of the humeral head in the glenoid fossa with symmetric contraction, rotate the shoulder with asymmetric contraction, and assist in general stability of the GH joint.(Schenkman and Rugo de Cartaya; Di Giacomo et al.; Terry and Chopp)

A primary muscle involved in glenohumeral stability includes the infraspinatus, which originates on the posterior aspect of the scapula in the infraspinous fossa, inserts on the greater tubercle of the humerus and is deep to the posterior deltoid and trapezius muscles. The primary action of this muscle is to ER the GH joint along with ADD of the GH joint and the stabilization of the head of the humerus in the glenoid cavity.(Terry and Chopp; Di Giacomo et al.) Due to the high demands of shoulder elevation and repeated stress often placed on the infraspinatus during overhead activities, this muscle is a common site of MTrPs.(Bron et al.)

Posterior Shoulder Tightness

Posterior shoulder tightness is a common impairment in overhead athletes.(Passigli, Plebani and Poser; Dashottar, Costantini and Borstad; Johnson et al.; Laudner, Wong, et al.; K. G. Laudner, M. T. Moline and K. Meister; Laudner, Stanek and Meister) The decreased shoulder internal rotation ROM can be caused by bony adaptations such as increased humeral retroversion, contractures of the posterior capsule, or infraspinatus muscle tightness.(Passigli, Plebani and Poser)

Posterior Shoulder Tightness Background and Causes

The tightening of posterior shoulder dynamic structures may be attributed to neuromuscular influences causing muscle reflex activity of the capsule mechanoreceptors from the repetitive tensile load.(Hall and Borstad) The muscle most commonly affected by the protective reflex activity is the infraspinatus, which tightens as an external rotator and inhibits shoulder IR.(Hall and Borstad) This can ultimately cause a condition known as glenohumeral internal rotation deficit (GIRD).(Johnson et al.) This glenohumeral deficit can be defined as a difference of greater than or equal to 20° of passive internal rotation when compared to the uninvolved shoulder,(Rose and Noonan) along with a total arc of motion deficit greater than 5°.(Rose and Noonan) (Bailey et al.) To date the leading known cause of GIRD is RTC muscle tightness, such as the infraspinatus, and posterior shoulder capsule tightness.(Rose and Noonan) GIRD is an adaptive process that is often associated with a greater risk of injury,(Johnson et al.; Bailey et al.) such that an athlete may be 2.5 to 9 times more likely to sustain an injury to the shoulder.(Bailey et al.) Common pathologies that have been linked to decreased shoulder IR include RTC tears, labrum tears, and subacromial impingement.(Laudner, Stanek and Meister; Johnson et al.; Rose and Noonan) Decreased ROM in overhead athletes can also be due to humeral retroversion, posterior capsule thickening, or RTC muscle tightness.(Bailey et al.; Johnson et al.) Injuries typically occur from the repetitive trauma to anterior structures due to the tightness of the posterior structures that never received treatment.(Johnson et al.)

Humeral retroversion is related to the assessment of shoulder internal rotation and horizontal adduction.(Bailey et al.) Humeral retroversion is a bony adaptation that results in increased shoulder ER and decreased IR prior to being inhibited by capsuloligamentous restraints in the dominant arm compared to the non-dominant.(Passigli, Plebani and Poser) However, the total arc of motion is still comparable to the non-dominant shoulder, just adjusted to be rotated more externally. This adaptation occurs during the adolescent years of overhead athletes and is thought to be due to the repetitive forced external rotation. Researchers speculate that these ROM differences between dominant and non-dominant arms, often resulting in GIRD, may be attributed to humeral retroversion. Any differences found in the total arc of motion between the dominant and non-dominant arms may be attributed to soft tissue alterations, specifically to the shoulder capsule or surrounding muscles(Greenberg et al.) (e.g. infraspinatus, posterior deltoid, teres minor, and teres major).(Bailey et al.)

Shoulder ROM deficits may be a significant injury risk factor among overhead athletes. Evidence shows that shoulder ROM deficits in asymptomatic, determined by self-reported pain and disability questionnaires (e.g. Penn Shoulder Score), baseball players may be due to posterior RTC stiffness, humeral torsion, or GH joint mobility.(Bailey et al.) One study addressed infraspinatus stiffness by treating MTrPs using instrument-assisted soft tissue mobilization (IASTM) and stretches, which resulted in an increase in shoulder IR and horizontal adduction, but no changes in humeral torsion and GH joint mobility. Reducing posterior stiffness may have a significant effect on shoulder IR and horizontal ADD ROM deficits to decrease the risk of injury as opposed to factors such as humeral torsion and GH joint mobility/stability. However, the researchers attributed the increased horizontal ADD to the stretching of the posterior capsule in combination with the posterior rotator cuff, which was primarily resulted in increased IR ROM.(Bailey et al.) Their findings make sense when compared to the actions of the infraspinatus muscle. Since horizontal abduction is not an action of the infraspinatus muscle, increased horizontal ADD ROM would not be expected after treatment of the tight muscle whereas shoulder ER is a primary action of the infraspinatus, so improved IR ROM is to be expected after releasing the tight muscle. It instead makes more sense to attribute the increased horizontal ADD ROM to the release of the posterior capsule.(Terry and Chopp; Di Giacomo et al.)

Clinical Measurement Tools

Measuring shoulder ROM can be done with the use of a handheld digital inclinometer. This is a common instrument used due to it being lightweight and portable that incorporates the use of constant gravity as a reference point for assessing the GH joint's mobility.(Kolber and Hanney) Although this device can be stabilized against the patient with one hand, patient position extremely important when measurements are being taken by one clinician. The digital inclinometer has been found to be a valid and reliable tool for measuring shoulder internal and external rotation range of motion.(Kolber and Hanney) One study determined the interclass correlation coefficient (ICC) was 0.97 for shoulder internal rotation and 0.98 for external rotation.(Kolber and Hanney)

The Penn Shoulder Score (PSS) is a 100-point self-reported shoulder-specific patient questionnaire. It includes three subscales: pain, function, and satisfaction. The pain subscale is out of 30 possible points, with lower scores indicating greater pain. The function subscale has 60 possible points (the lower the score the greater the difficulty) and includes 20 items, all based on a 4-point Likert scale: 0 = can't do it at all, 1 = much difficulty, 2 =with some difficulty, 3 = no difficulty. If the question did not apply to the individual, an option of "did not apply before injury" was available. The total function score possible was reduced by three each time this option was chosen. The satisfaction subscale is a 10-point numeric rating scale for an individual's current level of function, with endpoints being 0 = not satisfied to 10 = very satisfied. A total score of 100 points on this questionnaire indicates low pain, high functioning, and high satisfaction with the shoulder. The PSS is a reliable and valid way for clinicians to measure patient outcomes of different shoulder pathologies.(Leggin et al.) The test-retest ICC reliability of this study was 0.94, internal consistency analysis was found to have a Cronbach Alpha score of 0.93, and the minimal clinically important difference for improvement was found to be 11.4 points.(Leggin et al.)

Another self-reported patient questionnaire is the Kerlan-Jobe Orthopaedic Clinic (KJOC), an assessment tool specifically designed for overhead athletes.(Alberta et al.) This is a 100-point possible questionnaire made up of 10 item that targets detection of upper extremity dysfunction in overhead athletes.(Alberta et al.; Franz et al.) Each question is answered by placing a mark on a 10-cm visual analog scale, with the mark indicating the individual's difficulty participating in overhead sport movements (such as throwing). Marks made on the visual analog scales are measured to the nearest millimeter from the left, or 0, and the distance is their score out of a possible 10 (e.g. 72mm from 0 is equal to 7.2/10 points).(Franz et al.; Alberta et al.) Higher the scores indicate a higher level of performance and function. Studies have found the use of the KJOC score to be valid and reliable, (Alberta et al.; Franz et al.) with a reliability value of 0.88 when used on overhead athletes.(Alberta et al.)

Posterior Shoulder Tightness Assessment

In order for clinicians to create appropriate treatment plans, it is important to properly examine the shoulder to determine which structures are contributing to the posterior shoulder tightness. The evaluation and treatment of patients showing signs and symptoms of posterior shoulder tightness need to be carefully considered due to the overall joint dysfunction that may result. Treatment of tight posterior muscles could be a preventative measure of other more serious injuries such as impingement or superior labrum anterior-posterior lesions.(Laudner, Stanek and Meister) One study was conducted to identify an optimal shoulder position for determining the mechanism of posterior tightness through muscle fatigue. Findings showed that after fatiguing the infraspinatus and teres minor muscles, there was an immediate decrease in shoulder internal rotation, scapular plane abduction, and low flexion ROM with the joint placed in extension, but not horizontal adduction.(Dashottar, Costantini and Borstad) Another study measured GH horizontal ADD ROM with the subject lying supine and determined the position to be a reliable and valid technique of assessing posterior shoulder contracture, including the infraspinatus.(Laudner, Stanek and Meister) These findings not only assist clinicians with identifying optimal positions to assess for posterior shoulder tightness,(Dashottar, Costantini and Borstad; Laudner, Stanek and Meister) but also supports the involvement of the infraspinatus muscle as an inhibitor of shoulder IR.(Dashottar, Costantini and Borstad)

Measuring strength of the shoulder for IR for overhead athletes using only one clinician is also important. One study sought to identify an optimal testing position when measuring shoulder flexion, extension, internal rotation, and external rotation with the humerus elevated in three different positions (sitting, supine, and prone).(McLaine et al.) The investigators selected an elevated position for the humerus above 90° of abduction because elevating the humerus puts the athlete in a more sport-specific position, allowing for a better comparison to their functional activities for clinicians.(McLaine et al.) Researchers used a handheld dynamometer for rotational strength testing and found that testing multiple directions is best done with the patient in a supine position. This not only increases the stabilization of the scapula, which can be difficult to ensure with only one clinician, but also keeps the patient from having to change positions.(McLaine et al.) The use of a handheld dynamometer to measure shoulder rotational strength has been found to be a reliable tool when the shoulder is elevated.(McLaine et al.; Chen et al.)

The handheld dynamometer is an inexpensive and portable device that clinicians can use to measure isometric strength.(Chen et al.; Hirano and Katoh; Decleve et al.) The force applied to the handheld dynamometer is measured in kilograms (kg).(Decleve et al.; Hirano and Katoh; McLaine et al.) Relative inter-class reliability and intra-class reliability of the device are 0.84-0.94 and 0.84-0.99, respectively.(Hirano and Katoh) The handheld dynamometer is fixated while measuring the muscle strength during a strength test.(Hirano and Katoh) However, a clinician using their hand to fixate the handheld dynamometer has also shown to be clinically reliable.(Hirano and Katoh) Intra-class reliability was observed in a study that used the clinician's hand to fix the handheld dynamometer while measuring horizontal adduction of the shoulder with the patient in a supine position.(Hirano and Katoh) Using the same method for measuring isometric internal and external rotation strength had been found to be a reliable and valid method for measuring strength in a supine position.(Decleve et al.; Chen et al.)

The Relationship between Posterior Shoulder Tightness and Other Pathologies

In addition to impingement and superior labrum anterior-posterior lesions,(Johnson et al.; Laudner, Stanek and Meister) studies have also found that posterior shoulder tightness is often associated with scapular dyskinesis. One study stated that the decreased ADD ROM specifically at the GH joint caused by posterior tightness can be a predictor of forward scapular posture.(K. G. Laudner, M. T. Moline and K. Meister) Another study not only looked at the forward scapular posture, but also at how the involved shoulder's subacromial joint space and GH elevation ROM was effected by posterior shoulder tightness in baseball pitchers. Findings suggested that the subacromial joint space was smaller, scapular posture was more forward, and GH elevation ROM was decreased in the shoulder with increased posterior shoulder tightness compared to pitchers with acceptable amounts of posterior shoulder tightness.(Laudner, Wong, et al.) Ultimately this can alter the biomechanics of the shoulder even more when comparing the dominant arm to the non-dominant arm, especially in baseball players.(K. G. Laudner, M. T. Moline and K. Meister; Laudner, Wong, et al.)

In another study determining the link between posterior shoulder tightness and shoulder external rotator strength, researchers found there to be little to no relationship between the two. The rationale behind finding the lack of a relationship between stretching the posterior shoulder muscles and an external rotation strength is that a decrease in external rotation strength may not be due to muscular weakness as originally hypothesized. Instead, findings suggested that the weakness may be due to the posterior capsule resisting the motion. Although stretching posterior shoulder musculature does improve range of motion, it does not have an impact on external rotation strength of the muscles and the treatment is better suited for preventative measures from further injury rather than improving performance.(K. G. Laudner, M. Moline and K. Meister) This study was performed on professional baseball players and focused on stretching,(K. G. Laudner, M. Moline and K. Meister) so their findings may not be true when assessing different interventions or other patient populations when examining other overhead sports. The lack of evidence available in other populations makes it difficult to make inferences on the relationship between posterior shoulder tightness and external rotation strength, therefore warrants further investigation.

Myofascial Trigger Points

Muscle tightness may be caused by adhesions within the muscle fibers called myofascial trigger points. These MTrPs may lead to myofascial pain in the shoulder and contribute to generalized shoulder discomfort. In relation to the shoulder and posterior tightness, it is possible that the restricting effect the infraspinatus, being an external rotator, has on shoulder IR is caused by the presence of MTrPs.

MTrP Background and Causes

A MTrP is a hyperirritable palpable nodule located within a taut band of skeletal muscle. MTrPs are formed by the tightening of fascia that surrounds the muscle, as it tightens it loses its flexibility, creating tension in the muscle and resulting in pain and dysfunction.(Barnes) There are two types of MTrPs: active and latent. Signs and symptoms of active trigger points (ATrPs) typically include pain at rest, tenderness in a taut band of muscle, a localized twitch response with manual stimulation, and referred pain with direct pressure. Latent trigger points (LTrPs) are minor neuromuscular lesions that can be found in pain-free muscles but can become ATrPs through constant irritation and continued stimulation through the repetitive movement or activity that originally produced the MTrP. LTrPs cause pain and/or tenderness only with direct compression. Instead of the patient feeling pain at rest, they may experience neuromuscular dysfunction that can include muscle fatigue and weakness, reduced range of motion, induced muscle cramps, and alternating muscle activation patterns.(Celik and Mutlu)

Minimal evidence exists on the causal relationship of MTrPs. However, abnormal electrical activity, also known as endplate noise, has been found in patients with latent and/or active myofascial trigger points.(Celik and Mutlu; Bron et al.; Abbaszadeh-Amirdehi et al.) This occurs at the neuromuscular junction,(Abbaszadeh-Amirdehi et al.) or the synapse between the ends of muscle neurons and muscle fibers.(Whiting and Zernicke) The theory states that an excess amount of acetylcholine is released at the junction,(Abbaszadeh-Amirdehi et al.) creating the endplate noise. This noise has been found to occur in motor endplates with MTrPs more often than sites without any MTrPs.(Simons, Hong and Simons) Hyperactivity of the neuromuscular junction can hinder the ability of the muscle fiber to properly activate, negatively effecting strength.(Passigli, Plebani and Poser)

MTrP Assessment

There are no laboratory or diagnostic imaging tests available for diagnosing MTrPs, but there are several options for their evaluation.(Celik and Mutlu) Common methods for evaluation include manual palpation, intramuscular needling, surface electromyography-guided assessment, pain-pressure threshold (PPT), laser Doppler flowmetry, and infrared thermography.(Celik and Mutlu) Clinicians currently use the combination of manual palpation, patient history, and symptoms to assess MTrPs in the clinical setting.(Bron et al.) More advanced diagnostic techniques such as PPT and intramuscular needling are also increasing in popularity. Intramuscular needling can be done through the insertion of dry needles directly into a trigger point within the muscle.(Ge, Fernández-de-Las-Peñas, et al.; Celik and Mutlu) Pressure pain threshold is typically used to assess the MTrPs tenderness to palpation using an algometer, which measures the amount of pressure being placed on MTrPs. With the use of manual palpation, intramuscular needle techniques, and PPT clinicians look for a local twitch response and ask patients to state whether or not they experience any local or referred pain. This aids in the identification of MTrPs and the ability to make a distinction between ATrPs and LTrPs.

The digital pressure algometer is a handheld device that measures pain-pressure threshold, which quantifies a patient's point tenderness.(Kinser, Sands and Stone; Park et al.) The device can be used to determine the maximum amount of pressure an individual can tolerate on a single point, which is when the patient complains of pain from the force.(Kinser, Sands and Stone) This device has a 1-cm^2 surface for applying pressure.(Kinser, Sands and Stone; Park et al.) Force readings on the algometer are displayed in either kilograms or newtons (N) of force. To increase reliability of the device the rate of force application should be 1 $kg \cdot cm^{-2} \cdot s^{-1}$ or 10 $N \cdot s^{-1}$.(Kinser, Sands and Stone; Park et al.) Investigators and clinicians should apply the force perpendicular to the surface of the body.(Kinser, Sands and Stone) Males have been found to have a higher PPT compared to females.(Park et al.) The reliability of using an algometer for PPT can range from .990 to .999, and has been found to be both reliable and valid for use in clinical practice.(Kinser, Sands and Stone) One study found the sensitivity and specificity of using an algometer for PPT on the infraspinatus muscle to be 0.61 and 0.52 on the right side and 0.66 and 0.56 on the left side.(Park et al.) The "cut-off" value for the infraspinatus in which subjects complained of pain for the right side was 3.35 while the left was 3.76.(Park et al.) The intra-rater reliability values using Cronbach's Alpha for the infraspinatus on the right side was 0.934 while the left was 0.963.(Park et al.) The infraspinatus PPT for the right side was 4.0±2.0 kg/cm^2 while the left was 5.0±1.7kg/cm^2.(Park et al.)

Common MTrP Treatment Techniques

The primary goal of treating MTrPs is to release or inactivate the taut band of muscle. Treatment can result in pain reduction and the return of previously inhibited muscle strength and restricted ROM. Inactivation of MTrPs can be done through either invasive or non-invasive techniques.(Abbaszadeh-Amirdehi et al.; Celik and Mutlu; Bron et al.) Common invasive techniques include dry needling and injection therapies,(Kashyap, Iqbal and Alghadir; Cummings and White) where non-invasive treatments often include manual techniques such as ischemic compression, instrumented assisted soft tissue mobilization (IASTM), dry cupping, or muscle energy techniques along with cryotherapy, thermotherapy, electrotherapy, and therapeutic ultrasound.(Kashyap, Iqbal and Alghadir) However, to our knowledge, the most effective interventions to improve pain, PPT, blood flow, and ROM in treating MTrPs are manual techniques and dry needling.(Kashyap, Iqbal and Alghadir; Cummings and White)

Dry needling is a minimally invasive treatment method of MTrP release that in recent years has increased in popularity.(Abbaszadeh-Amirdehi et al.) The intervention involves the insertion of an acupuncture needle into the MTrP in the muscle. The needle is directly inserted into the MTrP without injecting anything such as pain relief or anti-inflammatory medications.(Abbaszadeh-Amirdehi et al.) There is evidence to show that it works by decreasing hyperactivity of the sympathetic nervous system and decreasing irritation at the motor endplate.(Abbaszadeh-Amirdehi et al.) Dry needling has been found to improve overall shoulder ROM and pain based on this same theory.(Passigli, Plebani and Poser) However, there has also been evidence that dry needling without the injection of a substance could be working as a placebo more than anything.(Cummings and White) Also, only certain medical professionals can administer dry needling as treatment, which changes from state-to-state.(Unverzagt, Berglund and Thomas)

IASTM creates a soft tissue mobilization effect on scar tissue and MTrPs using different specialized tools, including Graston. By giving clinicians a mechanical advantage during manual therapy, through a decrease in stress placed on their hands, they are able to apply an increased amount of pressure,(Cheatham et al.) along with an increased ability to detect changes in tissue properties by creating an altered sensation through the tool.(Kim, Sung and Lee) In general, IASTM has been shown to increase ROM and decrease pain but testing has primarily been done on tendon injuries or animals.(Kim, Sung and Lee) There is specific evidence to support the use of IASTM to acutely increase shoulder IR and horizontal ADD ROM posterior shoulder tightness on collegiate baseball players with posterior shoulder tightness.(Laudner, Compton, et al.)

Dry cupping is a traditional Chinese medical intervention that has been practiced for thousands of years.(Kim et al.; Chi et al.) The technique involves the application of suction, through a vacuum seal, to the skin using a cup. The negative pressure created results in capillary rupture in the skin causing it to exhibit signs of petechiae and ecchymosis.(Kim et al.; Chi et al.) It is commonly used to treat low-back, neck, and shoulder pain.(Chi et al.) However, to our knowledge there is little research on the use of dry cupping as treatment for posterior shoulder tightness. Theoretically, dry cupping can improve swelling, healing rate,(Chi et al.) and pain.(Chi et al.; Al-Bedah et al.; Nasb et al.) There is new evidence to support the increase in blood circulation, parasympathetic activity, and peripheral blood supply that can be linked to decreased pain after treatment,(Nasb et al.) but the physiological effects of dry cupping are still being debated.(Kim et al.)

Ischemic Compression Technique

The IC technique is also commonly referred to as manual compression,(Celik and Mutlu) manual pressure release, or trigger point release.(Kashyap, Iqbal and Alghadir) Technically being a form of therapeutic massage, indications and contraindications are the same as other massage techniques. Indications for the intervention include: muscle spasm reduction, the need for systemic relaxation, increased venous return, pain relief, and wherever local blood flow is necessary.(Knight and Draper) Contraindications of IC include: bleeding disorders, low blood platelet counts, or individuals taking blood thinners, areas with blood clots, fractures or weakened bones, and open or healing wounds including skin infections. Cancer patients and women who are pregnant should consult with their overseeing health care provider before receiving this intervention.(Knight and Draper) Clinicians should notify their patients that temporary bruising, swelling, pain and/or discomfort are all possible side effects of the technique.(Knight and Draper) Overall IC is an easy and cost-effective treatment that can be used by any clinician trained in manual therapy techniques in any clinical setting.(Kashyap, Iqbal and Alghadir)

IC is thought to induce healing through the lengthening and relaxation of fascia and muscle fibers.(Akbaba et al.) This treatment is used to intentionally block blood flow to the treatment site with compression, resulting in increased blood flow to the area once pressure is released. Treatment procedures commonly involve the clinician applying pressure over an identified MTrP for a predetermined length of time using either their thumb or fingertip. The clinician applies just enough pressure over MTrPs to provoke a tolerable pain for around 60-90 seconds.(Celik and Mutlu) This pressure can be repeated as many times as necessary, but 60-90 seconds is the typical time needed before a clinician feels the MTrP release. However, to our knowledge, there is currently no standardized amount of pressure or application time for this treatment since manual treatment techniques rely heavily on the experience and skill level of the clinician.(Celik and Mutlu; Kashyap, Iqbal and Alghadir)

The use of IC can decrease pressure pain sensitivity in both ATrPs and LTrPs and improve ROM.(Celik and Mutlu) One study examined IC on MTrPs in the neck and shoulder and its effects on muscle strength, ROM, pain sensitivity, and disability in office workers.(Cagnie et al.) Findings suggested that the IC technique improved general neck and shoulder ROM, pain, and strength, but had no long term effect on disability.(Cagnie et al.) Among the muscles tested in this study was the infraspinatus, which after treatment did show increased strength through testing external rotation with the elbow tucked to the side.(Cagnie et al.) Investigators focused on ATrPs in office workers and shoulder ROM, specific to the infraspinatus, was not measured.(Cagnie et al.) IC may have contributed to improved strength through two possibilities. First, the pressure held during the treatment lengthened the shortened sarcomere in the MTrP. And second, the pressure applied broke up the inhibitory reflex action protecting the infraspinatus, therefore regaining its full strength abilities.(Cagnie et al.)

Another study compared the use of passive to active soft tissue therapies on releasing LTrPs in the upper trapezius muscle and their effects on ROM and pain. The researchers found that both active (participants seated and actively moving necks during treatment) and passive (participants laying supine during treatment) soft tissue therapies improved pain and active cervical contralateral flexion (ACFL) ROM. However, subjects in the control group (participant seated and received no more than 1kg/cm^2 of pressure on the MTrP) also showed similar results for ACFL.(Kojidi et al.) Investigators of this study inferred that the improvement in pain and ROM of the LTrP after passive soft tissue therapy was from mechanoreceptor stimulation and improved blood circulation. This resulted in reduced muscle spindle activity, therefore reestablishing the muscle's normal ROM.(Kojidi et al.) Although this study was performed on the necks of only women, the results combined with other information can be used to support the use of IC on LTrPs in the shoulder and infraspinatus. Muscular posterior shoulder tightness is most likely from mechanoreceptors within the joint causing an increased muscle spindle activity that creates a protective muscle reflex for the infraspinatus.(Hall and Borstad) This neuromuscular dysfunction is in response to the repetitive tensile load placed on the shoulders of overhead athletes.(Hall and Borstad) And since LTrPs are small neuromuscular lesions that can inhibit ROM and strength of a muscle acting on a joint,(Celik and Mutlu) and LTrPs have been effectively treated through IC in other parts of the body,(Kojidi et al.) theoretically, clinicians should be able to perform IC on the infraspinatus muscle to improve shoulder IR ROM and ER strength. To our knowledge, there is a lack of evidence discussing the effects of MTrP release through IC on the infraspinatus muscle on shoulder ROM and strength.

Summary

The shoulder is a complex joint in the body that collegiate overhead athletes are continuously placing under stress. Overtime, these repetitive motions of overhead athletes can lead to posterior shoulder tightness causing decreased range of motion and strength, easily resulting in shoulder disorders. Latent trigger points are a known cause of decreasing range of motion and strength in a given muscle. Treating these trigger points can not only help with the prevention of injuries but could also prevent the athlete from developing persistent pain with movement since latent trigger points are only painful with palpation. There are already known interventions that can help in preventing more serious injuries through the treatment of myofascial trigger points in overhead athletes. However, none are as readily available to any trained clinician in any setting as ischemic compression. Therefore, the purpose of this study was to determine if treating muscular posterior shoulder tightness by applying the ischemic compression technique on the infraspinatus muscle will improve internal rotation range of motion and external rotation strength in dominant shoulders of collegiate overhead athletes.

CHAPTER III: METHODOLOGY

Study Design

This study was a single-blinded randomized controlled trial that evaluated the clinical effectiveness of using manual myofascial release via ischemic compression to treat latent myofascial trigger points (LTrPs) in the infraspinatus muscle to improve dominant shoulder range of motion (ROM) and strength in overhead athletes with no history of shoulder pain. Participants underwent IR shoulder range of motion and ER isometric strength measurements obtained at baseline, immediately before and after the two treatment sessions, and a final measurement within 24-48 hours after treatment session #2. Each treatment session was administered 24-48 hours apart. Self-reported questionnaires were administered at baseline and treatment session #2.

Participants

A total of 40 healthy collegiate overhead athletes (age: 20.3±1.6 years) were assessed from one large-sized Midwest university. Participants were asked to self-report demographic information including age, gender, institution setting, sport(s) played, position(s) played, medical history (e.g., history of shoulder surgery or pain). Participants were included if they indicated they were a collegiate level athlete playing a sport that required repetitive overhead motions, had a total arc ROM deficit of ≥5° compared to the ideal 180° for overhead athletes,(Bailey et al.; Chepeha et al.; Reinold et al.) or a loss of ≥20° of IR compared to the contralateral shoulder,(Rose and Noonan) and presented with at least two LTrPs in the infraspinatus muscle of the dominant shoulder. LTrPs were identified in the infraspinatus by a palpable taut band of muscle that was only painful during palpation,(Calvo-Lobo et al.; Celik and Mutlu) did not produce any referred pain with palpation, and had no twitch response with palpation.(Celik and

Mutlu) Subjects were excluded if they reported any time lost from participation in their sport due to dominant shoulder pain within the past 3 months,(Bailey et al.) had a previous history of surgery on either shoulder within the past year, or scored <70 out of 100 points for pain or disability on the Penn Shoulder Score (PSS)(Bailey et al.) and Kerlan-Jobe Orthopaedic Clinic (KJOC) questionnaires, where lower scores indicated poorer satisfaction and function and higher pain.(Bailey et al.) Participants were asked to refrain from taking anti-inflammatory drugs throughout the duration of their participation in this study and were asked not to schedule their next treatment session within an hour of their last practice and/or conditioning session. Based on exclusion criteria, 6 participants were removed from the study [loss of ≥20° of IR compared to the contralateral shoulder (n=6)]. Out of 48 participants, 2 did not finish the study in its entirety [inclement weather and scheduling], with a final sample of 40 collegiate athletes. The University's Institutional Review Board approved this study and informed consent was obtained from each participant before proceeding with treatments and measurements.

Instrumentation

Three objective measures: a handheld digital inclinometer, digital pressure algometer, and handheld dynamometer and two subjective questionnaires (PSS and KJOC) were utilized in this study. Measurements were taken by the same investigator at each time-point [baseline, post-treatment session #1, within 24-48 hours post-treatment session #2, and within 24-48 hours post-treatment session #2]. Self-reported questionnaires were administered at baseline to aid in determining participant eligibility and after the last day of shoulder range of motion, strength, and PPT measurements to identify any functional differences prior to and at the end of the study.

Digital Inclinometer

A digital inclinometer (Pro 3600 digital inclinometer SPI-Tronic, Garden Grove, CA) was used to measure passive shoulder internal and external rotation range of motion of each participant. This device can measure up to 360° indicated by the manufacturer's specifications. The same wall in the laboratory was used to zero out the digital inclinometer for each measurement session. The average of three IR ROM measurements was used for data collection at three time points: baseline and immediately after treatment session #1, immediately after treatment session #2, and final measurements 24-48 hours post-treatment session #2. Both IR and ER ROM measurements were taken before treatment session #1 to determine eligibility of participants.

We assessed priori reliability of IR ROM measurements. The lead investigator measured 5 shoulders (separate participants from the current study) without previous injury or shoulder surgery within the last year using a test-retest intraclass correlation coefficient formula (ICC) with two-way mixed effects. Each participant's ROM was measured and reassessed a minimum of 24 hours later by the same rater, where the ICC=0.704

Digital Pressure Algometer

A digital pressure algometer (Lafayette Manual Muscle Test System™, Model 01163, Lafayette Instrument Company, Indiana, USA) with a 1.7 cm^2 circular probe and 0-136.1 kg pressure range was used to measure the pain-pressure threshold (PPT) of LTrPs in all participants. The infraspinatus was identified by having the participant perform active external rotation while the second investigator palpated for the infraspinatus muscle. Once LTrPs were identified within the infraspinatus, the device was placed over the specific point on the infraspinatus perpendicular to the skin, while pressure was gradually increased until the participant indicated pain or reached the predetermined maximum pressure of $8.16 kg/cm^2$.(Kinser, Sands and Stone; Park et al.; Ge, Fernández-de-Las-Peñas, et al.) If more than two LTrPs were identified in the infraspinatus, the two identified by the participant as the most painful to palpation, with the lowest PPT, were used in the study. Measurements were collected at the three time points: baseline, post-treatment session #1, immediately post-treatment session #2, and 24-48 hours post-treatment session #2. The average value of three trials for each LTrP was used for data analysis.

Handheld Dynamometer

A handheld dynamometer (Lafayette Manual Muscle Test System™, Model 01163, Lafayete Instrument Company, Indiana, USA) was used to record quantitative shoulder external rotation isometric strength in kilograms. We did not perform our own pilot study because we assumed intrarater validity and reliability of the testing apparatus based on previous studies. Measurements were collected at the three time points: baseline, post-treatment session #1, immediately post-treatment session #2, and 24-48 hours post-treatment session #2. The average of three ER isometric strength tests was used for data analysis for each time point.

Subjective Questionnaires

The Penn Shoulder Score (PSS; 100-point self-reported patient questionnaire) was used to measure 3 subscales, including participant satisfaction with their shoulder function, the overall shoulder function, and pain. The questionnaires were administered at baseline as a part of the eligibility screening. This was to ensure asymptomatic (pain-free) athletes were the only participants in the study. The PSS was administered again to participants at the completion of the study (post treatment session #2) and compared to their baseline results on satisfaction, function, and pain level. The Kerlan-Jobe Orthopaedic Clinic (KJOC; 100-point self-reported shoulder and elbow questionnaire)(Alberta et al.; Franz et al.) was used to determine shoulder dysfunction in participants. The administration of the questionnaire and the determination of participant eligibility followed the same protocol as the PSS, where participants were excluded if they scored <70 out of 100 possible points.(Kraeutler et al.)

Procedures

Participants were recruited through random sampling at one large Midwest university. The institution provided recruits with instructions on the purpose and details of the study. Overhead athletes interested in participation were instructed to wear sports bras (if female) and bring a t-shirt they can put on after the intervention but not to wear any sport-identifying gear (e.g., team shirts, hats, pants) and were brought into the research laboratory where they were first provided the PSS and KJOC questionnaires. Demographic information was collected upon their arrival (age, gender, sport(s) played, primary position played, medical history).

Range of Motion Measurements

Participants were placed in a supine position with their involved shoulder slightly on the edge of the treatment table for all measurements. The lead investigator [B.R.] started with the non-dominant shoulder (for comparative reasons) measuring passive internal and external rotation with a digital handheld inclinometer. The participant was instructed to lay supine with their eyes closed in order to ensure relaxation. The lead investigator then passively moved their shoulder into 90° of shoulder abduction and their elbow to 90°, and with one hand leading them through the motion while securing the digital inclinometer to their lateral forearm, just distal to the ulnar styloid process, and the other hand stabilizing the shoulder on the table. A small bolster (the size of a folded towel) was placed under the humerus to ensure a neutral horizontal position.(K. G. Laudner, M. Moline and K. Meister) Slight overpressure was applied at the end of internal and external rotation ranges of motion prior to measurement readings.

Isometric Strength Measurements

For isometric strength testing, the participants were placed in a supine position. Participants were allowed one practice trial at 50% strength to ensure they understood the movement and were instructed to use 100% of their strength on the next three trials. For each trial, the lead investigator applied an external force in the opposite direction of which the participants were instructed to maximally contract, this was done until the investigator broke the subject out of the testing position. The force required to break the participant's contraction was recorded as the relative strength of glenohumeral ER, the average of three trials was used in data analysis. Participants had 10 seconds timed on a stopwatch to rest between each trial to prevent fatigue.(Chen et al.) Standing lateral to the participant, between the involved arm and torso, the lead investigator fixated the handheld dynamometer just proximal to the dorsal side of the ulnar styloid process with one hand while the other stabilized the anterior shoulder to measure ER isometric strength.

Once subjects were determined to have met the inclusion criteria, the lead investigator left the exam room, while a second investigator [J.T.] provided the participant an identification number. All participants were randomly allocated into one of two treatment groups (1) IC intervention or (2) sham IC intervention using a systematic random sampling method. The lead investigator and participants were blinded to group allocation.

Interventions

In order to ensure blinding, the second investigator performed the predetermined intervention based on group allocation on two LTrPs in the infraspinatus muscle using a digital pressure algometer. The second investigator determined the two LTrPs in the infraspinatus muscle using the predetermined criteria. Each participant was provided instructions to verbally express when a sensitive spot was identified. Once the LTrPs were determined, the second investigator marked the skin with a surgical pen to ensure consistent application for each trial. The same LTrPs were used for both treatment session #1 and #2 and all measurements.(Cagnie et al.) For participants in the IC intervention, the second investigator placed the digital pressure algometer over the mark until the subject indicated pain. The investigator then removed the digital algometer and placed their thumb over the LTrP, applying pressure until the participant verbally stated pain, and held for 90 seconds timed on a stop watch.(Kinser, Sands and Stone) This was repeated 3 times for both LTrPs. For participants in the sham IC intervention, the same protocol was completed, however the investigator placed their thumb over the trigger points, indenting the skin but not applying any excess pressure for 90 seconds and was repeated three times. The sham IC intervention was included to analyze whether the perception of manual treatment had any impact on shoulder ROM and isometric strength. The average of the three PPT trials was used for analysis for each group.

The second investigator instructed participants not to provide any treatment details to the lead investigator before they re-entered the exam room. All participants were scheduled to return within 24-48 hours after their first treatment session, where the lead investigator repeated the steps taken for the baseline ROM and isometric strength measurements to get the post-intervention measurements of the first treatment session. The second investigator then repeated the individual participant's first treatment protocol (treatment session #1). The participants were then scheduled one more time within 24-48 hours after treatment session #2 to have their final post-intervention ROM and strength measurements taken.

Statistical Analysis

A 2 (group) x 2 (time-point) mixed model ANOVA was conducted to examine perceived level of shoulder function and satisfaction using the KJOC and PSS between groups before (baseline) and after (final) treatment interventions. Several 2 (group) x 4 (time-point) mixed model ANOVAs were performed to evaluate the effect of ischemic compression vs. sham compression on pain-pressure threshold, IR ROM, ER isometric strength across four measurement time-points: 1) baseline, 2) post-treatment #1, 3) within 24-48 hours of treatment #1, and 4) within 24-48 hours of treatment #2. Alpha level was set a priori at $p<0.05$. Statistical analysis was performed using SPSS (IBM SPSS Statistics for Windows, version 25.0; IBM Corp, Armonk, NY).

CHAPTER IV: RESULTS

Demographics are depicted in Table 1. There were no differences between groups based on age. Based on study frequencies, 75% were females and 90% of participants were right-arm dominant. Participant distribution within sports were as follows: baseball (15%) cheer (27.5%), circus (22.5%), softball (20%), swimming (2.5%), track/field throwers (7.5%), and volleyball (5.0%). Upon visual inspection, sports were mostly equally represented between intervention groups.

Table 1. Demographics for Ischemic Compression and Sham Groups

Demographic Information	Ischemic Compression (n=20)	Sham Compression (n=20)	*P Value*
Age: *M*±*SD* (years)	20.3±1.5	20.3±1.7	0.922
Sex: n(%)			
Males	6(30.0)	4(20.0)	
Females	14(70.0)	16(80.0)	
Arm Dominance: n(%)			
Right	19(95.0)	17(85.0)	
Left	1(5.0)	3(15.0)	

Significant differences in pain-pressure threshold were only observed in the first LTrP at the time-point between baseline and immediate post-intervention measurement #1. Pain-pressure threshold showed a greater decrease in the 1st LTrP at the first post-intervention time-point compared to baseline in the IC group (mean change score=-1.49±1.56) versus sham (-0.53±1.23,

p=0.042). No differences in pain-pressure threshold in the first LTrP were found at the other time-points. No differences in pain-pressure threshold were found for the second LTrP between baseline and immediate post-intervention, within 24-48 hours following treatment session #1, or 24-48 hours following treatment session #2. No significant group × intervention time-point interaction effects were found for KJOC or PSS questionnaires. However, a significant time effect existed for both groups, where individuals in the IC and sham groups self-reported a better perception of shoulder function as per the KJOC ($F_{1,38}$=9.80, p=0.03, η^2_p=0.21) and PSS ($F_{1,38}$=8.05, p=0.07, η^2_p=0.18) over time. Partial eta squared was considered a large effect size for both the KJOC and PSS (small: 0.01; medium: 0.06; large: 0.14).(Cohen)

Descriptive statistics are presented in Table 2. Figures 1 and 2 depict mean trajectories of IR ROM and ER isometric strength across intervention time-points. No significant group × intervention time-point interaction effects were found for IR ROM or ER isometric strength. However, a significant time effect was observed in both IR ROM and ER isometric strength scores between groups over the course of 3-4 days. Individuals in both treatment groups demonstrated a significant increase in IR ROM over time ($F_{1,38}$=34.91, p<0.001, η^2_p=0.48). Individuals who received IC did not demonstrate significant strength gains compared to baseline, but individuals who received sham compression demonstrated a significant decrease in overall ER isometric strength during the final measurement time-point compared with baseline (mean change score=-1.63 ±1.04kg) vs. the IC group (-0.20±1.49kg; $F_{(1, 38)}$=2.33, p<0.001, η^2_p=0.18).

Table 2. IR ROM and ER Isometric Strength Descriptive Statistics

Measurements	Group	Mean ± SD
IR ROM Baseline (º)	IC	64.31±7.58
	Sham IC	68.27±8.31
IR ROM Post-treatment #1 (º)	IC	68.55±9.21
	Sham IC	70.68±10.18
IR ROM Post-treatment #2 (º)	IC	74.29±10.26
	Sham IC	74.678±9.35
IR ROM Final (º)	IC	74.89±7.67
	Sham IC	77.51±8.71
ER Isometric Strength Baseline (kg)	IC	14.16±3.94
	Sham IC	14.99±3.49
ER Isometric Strength Post-treatment #1 (kg)	IC	13.47±4.31
	Sham IC	13.34±2.60
ER Isometric Strength Post-treatment #2 (kg)	IC	13.45±4.65
	Sham IC	13.05±2.88
ER Isometric Strength Final measurement (kg)	IC	13.96±3.90
	Sham IC	13.36±2.45

IR ROM = internal rotation range of motion. ER = external rotation. IC = ischemic compression.

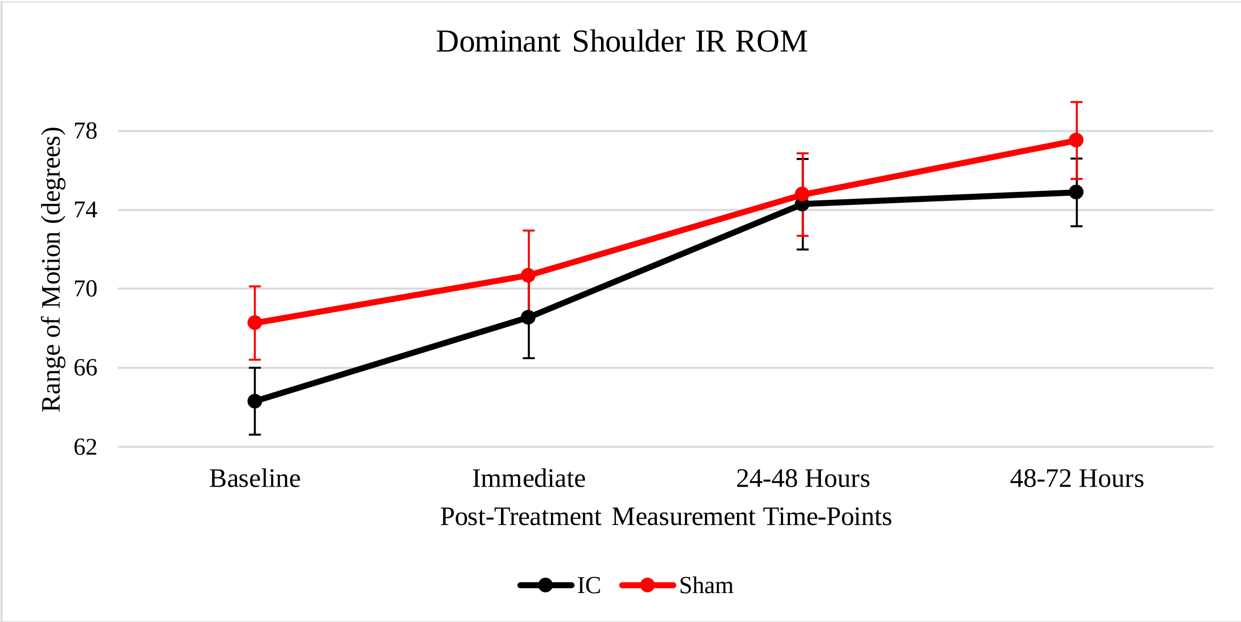

Figure 1. Dominant shoulder IR ROM means between ischemic compression and sham compression groups over time.

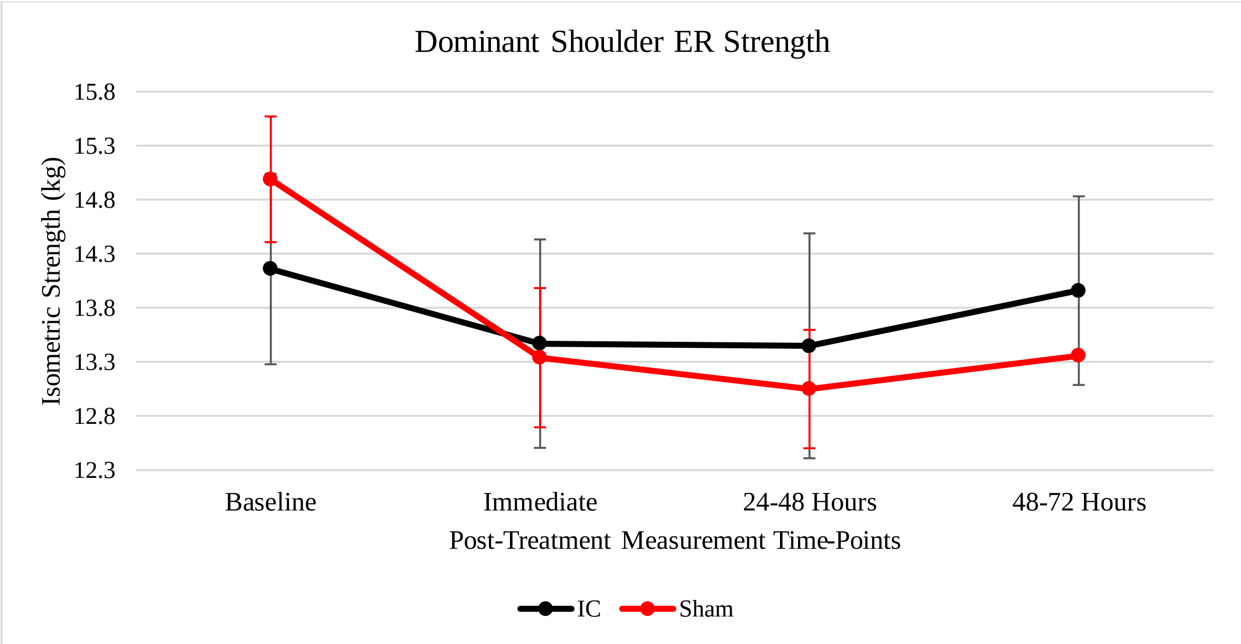

Figure 2. Dominant shoulder ER isometric strength means between ischemic compression and sham compression groups over time.

CHAPTER V: DISCUSSION

The purpose of our study was to determine if IC intervention on LTrPs in the dominant infraspinatus muscle would improve glenohumeral IR ROM, ER isometric strength, and pain-pressure threshold. There were clinically meaningful findings of improved IR ROM in both treatment groups over time. Participants in the IC group presented with no change in ER isometric strength, but those in the sham group had a significant decrease in ER isometric strength over time. Pain-pressure threshold and perceived shoulder function and satisfaction remained unchanged throughout the interventions, except individuals in the IC group experienced a temporary decrease in PPT following the first treatment compared to baseline vs. the sham group. Participants in both the IC and sham IC groups also self-reported improvements in perceived function of their dominant shoulder following treatments.

There were significant findings for IR ROM measurements in both treatment groups (IC and sham IC). Similar to another study that found immediate improvements in IR ROM through the use of IASTM on the dominant shoulder,(Laudner, Compton, et al.) and another using IASTM and a stretching protocol,(Bailey et al.) our study used manual IC as the intervention and found significant IR ROM improvements over time in both groups. The study that assessed the use of IASTM with a stretching protocol for glenohumeral IR ROM on healthy athletes compared their primary treatment to stretching alone. Both the stretching and the combined intervention groups had improved shoulder ROM immediately following treatment, and effectively supporting the use of stretching for shoulder IR ROM improvements.(Bailey et al.) This could explain why participants in both the IC and sham IC groups in our study showed IR ROM improvements. It is possible that the repetitive passive ROM measurements where the primary investigator applied slight over pressure to each repetition, acted as a form of passive stretching and activated the stretch reflex of the infraspinatus and surrounding musculature, resulting in improved shoulder IR ROM.(Prentice) LTrPs are linked with negatively affecting a muscle's ROM,(Celik and Mutlu) the use of IC as a form of treatment with our parameters [maintaining pressure over the LTrP until the patient verbally reports pain felt for 90 seconds] does seem to have an effect on the infraspinatus muscle's ROM. However, based on our results showing that both groups improving in IR ROM, it is hard to say if it was the stretch reflex or the IC intervention that caused the improvements. It may be that between group differences would have been observed if the treatment went on for more than 3-4 days. To our knowledge, we are the only study that has examined the effects of treating LTrPs beyond immediate measurements.

Glenohumeral ER isometric strength was targeted for this study due to the effects that LTrPs have on motor function of muscles.(Ge, Monterde, et al.; Celik and Mutlu) In addition to this, decreased shoulder ER isometric strength has been linked to increased likelihood of upper extremity injuries in professional baseball pitchers.(Amin et al.; Byram et al.) Our immediate findings of both groups support the lack of a relationship between glenohumeral ER weakness and IR ROM in relation to posterior shoulder tightness similar to another study.(K. G. Laudner, M. Moline and K. Meister) Since both of our treatment groups had improvements in IR ROM but only the sham group decreased in ER isometric strength, our results support that there is no direct relationship between the two. If there was a direct relationship between IR ROM and ER isometric strength, then we most likely would have seen both groups end with decreased ER isometric strength. Previous investigators recommended focusing on lengthening/stretching of soft tissue glenohumeral IR ROM inhibitors over strengthening ER rotator muscles (such as the infraspinatus).(K. G. Laudner, M. Moline and K. Meister) Our findings are consistent with previous studies where ER isometric strength did not improve (as measured by a handheld dynamometer) in the final measurements for either group. However, the sham IC group demonstrated a greater decrease in ER isometric strength compared to baseline. This could be due to the infraspinatus muscle getting fatigued with the repeated measurements of ER isometric strength. Since the sham group was not actually receiving IC as treatment, we would not expect the motor function to improve within the muscle due to a lack of IC treatment. The findings of this group may have begun to follow the findings of another study, that observed increased IR ROM after fatiguing the shoulder external rotators.(Dashottar, Costantini and Borstad) If our study would have continued over a longer period of time, we may have started to observe effects that would further support those findings. With the infraspinatus fatiguing from days of repeating the same manual muscle test, it could be an additional explanation of the increase in glenohumeral IR ROM that we observed in both groups. To our knowledge, minimal detectable changes have not been identified in defining ER isometric strength gains as clinically meaningful using a handheld dynamometer. Therefore, similar to our findings of glenohumeral IR ROM, it may be beneficial for future studies to track changes over a longer period of time based on our observations of glenohumeral ER isometric strength trajectories (Figure 2).

In addition to glenohumeral ROM and isometric strength measurements, we observed decreases in the LTrP #1 pain-pressure threshold measurements immediately after the first treatment, where the first LTrPs may have been more tender to the touch immediately after treatment. It is possible that the participants were still sore from pressure being held over the LTrP during the IC intervention. We observed no other significant effects on PPT at the other time-points for LTrP #1 or any time-points for LTrP #2. Although pain is an identification factor used in finding LTrPs,(Ge, Fernández-de-Las-Peñas, et al.; Ge, Monterde, et al.; Celik and Mutlu) the IC and sham IC treatment did not demonstrate any notable effects on PPT. We did not anticipate a large change in PPT after treatment because of our target population being healthy overhead athletes. Each participant completed a subjective questionnaire as part as the eligibility screening to better understand their perceived function and pain rating of their shoulder. Each athlete had to have scored at least a 70% or better on both the KJOC and PSS so we could verify their shoulder did not cause them pain. This would lead us not to expect great differences in PPT measurements at each time-point. However, this lack of change could also be due to targeting LTrPs in the dominant shoulders of healthy athletes rather than ATrPs that produce referred pain and/or tenderness without direct palpation.(Celik and Mutlu; Bron et al.; Ge, Fernández-de-Las-Peñas, et al.) Previous studies that observed improvements of PPT after treating LTrPs with IC techniques were performed on muscles, such as the upper trapezius, in the neck rather than the infraspinatus muscle located in the shoulder.(Cagnie et al.; Kojidi et al.) Another study bilaterally assessed PPT of LTrPs and ATrPs in the infraspinatus muscle, comparing the participant's painful shoulder to their non-painful shoulder. They concluded that the LTrPs of the non-painful side had a higher PPT than the painful side. Again, since our healthy athletes did not report pain the results of our study support the findings of the study in which improvements in PPT were not as great in LTrPs of the non-painful shoulder.(Ge, Fernández-de-Las-Peñas, et al.)

There are several limitations with our study. The effectiveness of blinding participants to which treatment group they were in may have been affected depending on any previous experiences and knowledge of IC treatment. Also, due to the use of the second investigator's thumb for administering both the IC and sham IC treatments, it was not possible to ensure consistency of the pressure throughout treatment. Although for each participant in the IC group pressure was applied until they verbally stated they felt pain and the thumb was placed to indent the skin of the sham IC group, there was no way to control that the same amount of pressure was applied throughout the 90 seconds for treatment. Finally, although we were targeting the infraspinatus muscle, we relied solely on the second investigator's palpation skills to locate and isolate the infraspinatus muscle. Without the ability to use more invasive techniques, the investigators were relied on palpation and manual muscle tests to identify the targeted muscle of interest.

Further investigation is needed to rule out IC as a manual treatment option for improving glenohumeral IR ROM and/or ER isometric strength when applied to LTrPs in the infraspinatus muscle. Investigators should track the effects of IC over a longer period of time (e.g., >3-4 days). We began to see improvements several days following the initial treatment. It may be that the intervention needs to be extended out further to fully examine glenohumeral ROM and/or isometric strength. In addition to long-term effects, we suggest further research in differences of treatment effects on different sports and/or positions. Although we had a wide variety of healthy participants involved in different overhead sports and positions, our sample sizes were not large enough to make this comparison. It may also be beneficial to compare the use of IC treatment with a stretching protocol to a group who only receives the stretches.

In conclusion, the results of this study support the use of IC treatment on LTrPs in the dominant shoulder's infraspinatus muscle in healthy collegiate overhead athletes to improve glenohumeral IR ROM. However, we cannot solely attribute the gain in ROM to the IC intervention as some of it may have been due to a stretch reflex. In addition, our results do not support the use of IC treatment on LTrPs in the dominant shoulder's infraspinatus muscle in healthy collegiate overhead athletes to improve glenohumeral ER isometric strength. This study has provided additional evidence supporting the lack of an immediate relationship between ER isometric strength and IR ROM. Future research should continue to investigate the theories of IC in order to better understand and implement the use of IC treatment in clinical practice on its own or in combination with a stretching protocol.

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