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The Effect of Upper-String Musician Practice Session on Scapular Kinematics

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THE EFFECT OF UPPER-STRING MUSICIAN PRACTICE SESSION ON SCAPULAR KINEMATICS

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APPROVAL OF THESIS

We, the faculty supervising the work of Connor James Brown, affirm that the thesis, *The Effect of Upper-String Musician Practice Session on Scapular Kinematics*, meets the high academic standards for original scholarship and creative work established by the Master of Science in Exercise Science and the College of Health Professions. This work also conforms to the editorial standards of our discipline and the Graduate College of Marshall University. With our signatures, we approve the manuscript for publication.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Background: Shoulder pain is common in the upper-string musician population. [43,49] Pain has been linked with injury and impairments. Altered scapular kinematics has been associated with patients diagnosed with shoulder injury or impairment. Fatigue of the shoulder complex through repeated arm motions has been shown to alter scapular kinematics, resulting in shoulder pathologies, including rotator cuff impingement syndrome. [12,15,28] Upper string musicians have been documented with practicing multiple hours in a day and it could be inferred those practice sessions could be fatiguing. [24,49]

Purpose: This study aimed to examine the effect of upper string musician practice session has on scapular kinematics. The study has three alternative hypotheses. The first being that following the practice session there will be decreased upward scapular rotation during arm elevation. The second being that following the practice session there will be decreased external scapular rotation during arm elevation. Finally, following the practice session there will be decreased posterior scapular tilt during arm elevation.

Methods: Six upper-string musicians were recruited for this study. Participants performed five-arm elevation followed by a predetermined test piece for scapular kinematic pre-measures. Participants then practiced for 45 minutes. Following the practice session, the participants performed the predetermined test piece then the five-arm elevation for post-measures. Strength measures were recorded following the practice session as well. Pre-fatigue/ fatigue scapular motion and strength measures was explored using paired t-test and analysis of variance (ANOVA) were appropriate. Statistical significance was determined a $P < 0.05$.

Results: Following the practice session there was no statistically significant change in upward scapular rotation for either the left ($P = 0.392$) or right ($P = 0.43$) during arm elevation. External scapular rotation measures were not found to be statistically significant pre- and post-practice session for either the left (P = 0.801) or right (P = 0.282) arm during arm elevation. Posterior scapular tilt was found to not be statistically significant for the left (p = 0.069) or right (P = 0.814) arm during arm elevation. It was also found that during arm elevation angle main affect was not statistically significant for posterior scapular tilt (P = 0.251) on the left arm. Arm elevation angle main affect was not found to be statistically significant for external scapular rotation (P = 0.126) or posterior scapular tilt (P = 0.917) for the right arm.

Conclusion: Following the practice session specific for upper-string musicians, the results showed no statistically significant decrease for upward scapular rotation, external scapular rotation, or posterior scapular tilt. The study did find. However, that arm elevation did not influence external scapular rotation or posterior scapular tilt. Further research with more participants is needed to determine if the results are population-specific or not.

CHAPTER 1

INTRODUCTION

The amount of research in playing-related musculoskeletal disorders for musicians has increased within the past few years. The research has shown that there is increased recognition of the prevalence of injury for musicians. [24, 55] The prevalence of playing-related musculoskeletal disorders (PRMD) has been recorded to upwards of 89%. Specifically, shoulder injuries in upper-string musicians have been shown to around 55%. [49] The most common playing-related musculoskeletal disorders for upper string musicians have been recorded in the neck and shoulder. [24] Playing-related musculoskeletal disorders can cause the temporary stoppage of play. Some musicians stop their music playing careers due to complications of PRDM. Due to the prevalence of injuries that occur within the neck and shoulder, further research is needed to understand these injuries' mechanisms.

Injuries in musicians are a common occurrence through the repetitive movements that the musicians complete during training sessions. [46] Musicians have been documented as having to practice upwards of thousands of hours a year while learning to play their instruments. [24,55] Experienced upper-string performers practice their music for multiple hours a day while performing the same motions repetitively. Repetitive motions have been linked with the fatigue of the muscles that surround the shoulder complex. [7,23,51] Understanding how fatigue, through these repetitive motions, alters the mechanics of the shoulder complex gives a practitioner a better understanding how these mechanics can lead to injury.

Muscle fatigue alters scapular kinematics, literature has described that fatigue of the shoulder muscle occurs through repetitive arm motions. [23,31] During arm elevation, it has been reported that the scapula moves through increasing degrees of upward rotation, external rotation, and posterior tilt. [12,50] In a fatigued state, altered kinematics occur at the scapulothoracic joint. One of the leading beliefs is that scapular movement would decrease in upward rotation, external rotation, and posterior tilt of the scapula. However, studies have found an increase in external rotation and/or posterior tilt of the scapula following fatiguing protocols. [2,7,12,21,23,50] In recent studies, scapular dyskinesis is present in upwards of 47% of upper string musicians. [14] The most common occurrence for altered scapular kinematics is the fatigue of the shoulder complex muscles. [11,55] These effects have been widely studied in other disciplines, including athletics and industrial workers, but they have not been widely studied in musicians. [21,32,51]

Within the athletic and non-athletic working populations, scapular motion changes have been related to injury prevalence of both the neck and shoulder. [22,32,51] Injury for these individuals most commonly presents increased pain felt either in the neck or shoulder. An individual will utilize altered motions of the shoulder complex to decrease pain to continue to perform their desired activity. These altered motions decrease proficiency of the desired task that an individual wishes to complete and can lead to further injury. [22,31,38] In the performing arts and specifically musicians, altered scapular kinematics is not a well-researched topic.

This study aims to explore the effect of a practice session specific to upper-string musicians on scapular kinematics. During arm movement, the scapula moves through a series of tilts and rotations. [22] Scapular dyskinesis is defined as an abnormality from normal scapular kinematics. [17,22] Altered scapular kinematics has been reported to be present in patients that suffer from shoulder pain. The changes in scapular kinematics have been described as the “forgotten cause”. [38] With the high intensity and long practice hours that these musicians must complete excelling in their preferred profession, it can be interpreted that changes in scapular motion due to muscle fatigue could contribute to the development of shoulder pain in musicians. [14,21,49]

Statement of the Problem

The recognition of playing-related musculoskeletal disorders has been on the rise within music programs. Playing-related musculoskeletal disorders can become detrimental to the musician as playing is their means for compensation. [46,49] Though scapular kinematics is a well-researched topic, scapular kinematics in musicians has just become a recent exploration topic and needs to be researched more.

Research Question

Does the muscle fatigue produced during a practice session affect scapular motion in experienced upper-string musicians?

Null Hypothesis

H_0: The practice session will not affect the kinematics of the scapula during arm elevation.

Alternative Hypothesis

H_1: Following the practice session, the upward scapular rotation will decrease during arm elevation.

H_2: Following the practice session, the external scapular rotation will decrease during arm elevation.

H_3: Following the practice session, the posterior scapular tilt will decrease during arm elevation.

CHAPTER 2

LITERATURE REVIEW

Introduction

Recent studies have shown that there is increased recognition of the prevalence of playing-related musculoskeletal disorders for musicians. [16,52] Playing-related musculoskeletal disorders can result in temporary or complete stoppages of play. Injuries that occur can result in time loss from activity, decreased income and added medical expenses for the musician. [16,21]

Recent studies have found that the prevalence of playing-related musculoskeletal disorders has been recorded upwards of 80%. [49] The most common playing-related musculoskeletal injury have been located within the neck and shoulder when looking at upper string musicians. [16] A shoulder injury has been commonly linked to repeated arm motion, and for upper-string musicians, this would include the hours they spend practicing their music. [15,16] Research has shown that injury to the shoulder complex has led to alterations in scapular kinematics. [13,15] To our knowledge, scapular kinematics has not been well studied in the upper-string population.

This study aimed to explore the effect of a practice session specific to upper string musicians on scapular kinematics. The investigation tested three hypotheses that revealed the impact of an acute bout of upper-string playing on changes in scapular kinematics. This literature review provided a study of the anatomy of the shoulder complex, the motions of the scapula, how fatigue affects the motions of the scapula, injury rates of musicians, and how an injury affects the motions of the scapula.

Boney Anatomy

The boney anatomy that composes the shoulder girdle includes the humerus, scapula, clavicle, and acromion. [21] The shoulder girdle is composed of three joints: the glenohumeral, scapulothoracic, and acromioclavicular joint. [21,26] The shoulder complex boney and articular anatomy allow for complex motion and motor functions that occur at the shoulder.

The scapula is a triangular bone located posterior to the thoracic spine and rib cage located between T2 and T7. [23] The scapula serves as the bridge between the trunk and the upper extremity. The anterior portion of the scapula glides across the ribs during shoulder movements. [38,55] The movements that occur at the scapula includes upward/downward rotation, anterior/posterior tilt, internal/external rotation, and protraction/retraction. [21,23] The scapula rotates with the scapula's inferior angle moving laterally and superiorly across the thoracic cage during the upward scapular rotation. [21,23,55] During downward rotation, the scapula's inferior angle moves medially and inferiorly on the thoracic cage. The anterior tilt of the scapula occurs when the acromial angle moves in an anterior direction. During posterior scapular tilt, the acromion moves in a posterior direction. [21,23,56] Anterior and posterior tilt of the scapula occurs around a transverse axis. [21,23,56] During the scapula's internal rotation, the scapula's medial border moving away from the thoracic cage, while during external scapular rotation, the medial border moves towards the thoracic cage. Scapular external and internal rotation occurs on a vertical axis. [21,23,56] During protraction, the scapula translates laterally across the thoracic, while during scapular retraction, the scapula moves medially towards the spine. [21,23,56] The scapula moves in conjunction with the humerus to ensure the stability of the head of the humerus within the glenoid fossa. [21,56] The glenoid fossa sits on the lateral portion of the scapula. The glenoid fossa and the head of the humerus form to create the glenohumeral joint. [7,8,21]

The glenohumeral joint is the articulation of the head of the humerus on the glenoid fossa. [7,8,55] The joint is classified as a ball and socket joint with the head of the humerus and the glenoid fossa, respectively. The motions that occur include flexion, extension, abduction, adduction, horizontal adduction, external rotation, and internal rotation. [5,8,21] Glenohumeral abduction occurs when the arm is raised from an individual's side in the sagittal plane, increasing the humerus and trunk angle. Adduction occurs in the sagittal plane but decreases the humeral trunk angle by lowering the arm. [16,56] Flexion at the glenohumeral joint occurs when the arm is raised anteriorly in the frontal plane. [16,56] Extension occurs when the arm is moved posteriorly in the frontal plane. [16,56] Both flexion and extension occur parallel to the trunk. The external rotation occurs in the transverse plane and is the rotation of the humerus posteriorly. [16,56] Internal rotation occurs in the transverse plane and is the rotation of the humerus anteriorly. [16,56] The glenohumeral joint moves in conjecture with the scapulothoracic joint during movement to maintain the stability of the ball-and-socket joint of the glenohumeral joint. [16,23] During shoulder abduction, the glenohumeral joint and the scapulothoracic joint move at a ratio. The ratio is dependent on the arc of motion that the humerus is at from rest to 120º. [5,9]

The acromioclavicular joint is formed by the scapula's acromion process and the distal end of the clavicle. [45] The joint allows for a screw axis that aids in a rotation point for the scapula. [45] During arm abduction, the scapula moves around the screw axis in a counterclockwise direction. [45] The acromioclavicular joint is an anatomical constraint for the scapula's motion that limits the range of motion that the scapula's upward rotation during the arm abduction. [9,28]

Movements that occur at one specific joint have implications for the other joints within the shoulder complex. [21,40,45] The musculature that interacts with the shoulder joints also adds their constraints to each joint's movement patterns and their constraints to each joint's movement patterns, and their constraints to each joint's movement patterns. Alterations to the musculature structure like injury or fatigue can have major implications on how the shoulder motion. [21,40,45]

Muscular Anatomy

The shoulder girdle's musculature anatomy includes muscles that produced the shoulder motion and dynamic stability. [9,23,55] The musculature shoulder girdle musculature is broken down into two subcategories. Muscles acting on the humerus and muscles acting on the scapula. [55] Each muscle that acts on the shoulder works primarily as a dynamic stabilizer or gross motor mover, with some having a secondary function in aiding with the other function. [23,44]

Muscles that act on the humerus can be both categorized as stabilizers and gross motor movers. The stability muscles that act on the humerus are the rotator cuff muscles comprised of the supraspinatus, infraspinatus, teres minor, and subscapularis. [26] The rotator cuff muscles originate on the scapula and insert on the humerus. The rotator cuffs stabilize the humeral head into the glenoid fossa. The secondary action of the rotator cuff muscles is to aid in gross motor movements. The supraspinatus aids in shoulder abduction, while the subscapularis secondary aids in shoulder internal rotation. The infraspinatus and teres minor aid in external rotation and adduction of the shoulder. [23]

The muscles that act on the scapula include the trapezius, rhomboid major/ minor, levator scapulae, and serratus anterior. The trapezius originates at the external occipital protuberance, medial portion of the superior nuchal line, and spinous processes of C-7 through T-12. The trapezius inserts at the lateral one-third of the clavicle, acromion, and scapula's spine. The trapezius is separated into the upper, middle, and lower bundles of the muscle. The trapezius works on the scapula through upward rotation (upper/lower), elevation (upper), retraction (middle), and depression (lower). [35] The rhomboids originate on the C-7 to T-5 spinous processes and insert on the scapula's medial border. The dynamic movement of the rhomboid major and minor act to retract the scapula and stabilize the scapula's medial portion. [35] The levator scapulae originate on the transverse processes from C-1 to C-4, inserting on the scapula's medial border superior to the scapula's spine. The levator scapula acts on the scapula through elevation and downward rotation. [35] Another function of the levator scapula is to stabilize the medial border of the scapula to the thorax. The serratus anterior originates on the ribs 1-9 inserting on the scapula's anterior medial surface. The serratus anterior is the primary stabilizer of the scapula through protraction, upward rotation, depression. Muscles that act on the scapula's primary function is to stabilize the scapula during movement. [23,26]

The scapula moves across the thoracic cage during arm movement to maintain the stability of the glenohumeral joint. Muscles that act on the scapula's main function are to maintain the scapula's stability through shoulder movement. [23,26] The musculature of the shoulder provides both movements of the arm and stability of the glenohumeral and scapulothoracic joint. Through the muscles' contraction, moving the shoulder complex joints allows for complete arcs of motion.

Scapular Kinematics

Many studies have looked at scapular kinematics during arm motion. Few studies have looked at passive or resisted arcs of motions. A better understanding of normal scapular kinematics in a healthy shoulder in different arcs of motion is needed. By understanding a healthy shoulder's normal kinematics, determining altered scapular kinematics becomes more detectable. [11,27] As stated, the shoulder girdle comprises a multijointed complex where the other joint stability determines movement. [21]

During arm abduction, the humerus moves in conjuncture with the glenoid while increasing the humerus and trunk angle. During abduction of the shoulder, the glenohumeral elevation and scapular upward rotation move in a ratio of 2:1 after the first 30º of motion. This ratio is described as scapulohumeral rhythm. [18] During the first 30º of glenohumeral elevation, the scapula remains in a downward rotation position. The scapula begins to move into upward rotation after 30º of glenohumeral elevation. [2,11,27] The translation of the head of the humerus changes during shoulder flexion. While performing the first 60º of shoulder flexion, the humeral head translates posteriorly, followed by an anterior translation to 120º of shoulder flexion. [25] During shoulder abduction and scapular plane abduction, the humerus' head moves in an anterior and inferior translation to the glenoid.

Many studies that look at abduction of the shoulder have been reported in active arm elevation. It has been found that the scapula does not begin to rotate until 30º of glenohumeral elevation. [2,11,27] Once the glenohumeral elevation passes 30º, the scapula increases upward, external rotation, and posterior tilt. [13,27] A study produced by Lee et al. [27] compared the scapular kinematics between passive and active arm elevation at different degrees throughout the arc of motion. The study had found that there was a statistical difference between upward rotation and posterior tilt. The scapular upward rotation is greater during passive than active arm elevation (43.3º± 4.47º vs. 39.7º ± 6.81º respectively). The scapular posterior tilt had a greater change in degrees during active arm elevation than passive arm elevation (15.6º ± 4.89º and

15.4º ± 2.99º respectively). There was no statistical difference between active and passive arm elevation for the degrees of external rotation. [27]

Conversely to the study produced by Lee et al. [27], Ebaugh et al. [11] found that there was no statistical significance in the difference of degrees posterior tilt between passive and active range of motion. The study also found a significant difference in the scapular external rotation when comparing active and passive arcs of motion. Scapular external rotation was found to have a higher degree of active motion range over a passive range of motion. However, the study did state a statistical difference in upward scapular rotation between active and passive arm elevation. Scapular upward rotation was found to have a higher degree at the end range of motion. [11]

The study produced by Ebaugh et al. [11] also looked at the clavicula's response during arm elevation. During arm elevation, the clavicle elevates 4º for every 10º of arm elevation. During arm elevation, as the scapula begins to rotate, the clavicle rotates in the frontal plane externally, and the clavicle retracts posteriorly in the sagittal plane. [18] In the Ebaugh et al. [11] study, there was increased elevation/ retraction of the clavicle during active arm elevation compared to passive arm elevation. [11] Through active and passive studies, it can be inferred that muscle activation or lack thereof can affect scapular kinematics. [11,27]

Studies that looked at scapular kinematics in comparison to muscle activation have helped to show the relationship between muscle activation and scapular kinematics. Camci et al. [13] studied a study looking at the effect of resistance on scapular kinematics during arm elevation. The study used healthy men that had not presented with any shoulder pathologies. Scapular kinematics were collected with a Flock of Birds electromagnetic tracking device (Ascension Technology Corporation, Shelburne, VT). The study found that the scapula was more internally rotated during the resisted arm elevation than during unresisted arm elevation (37.6º and 36.2º respectively). The study also found that during resisted arm elevation, the scapula was downwardly rotated at the 30º of arm elevation compared to unresisted arm elevation (mean difference of 2.8º). [13] As discussed earlier, the scapula begins to enter to rotate at 30º of arm elevation upwardly. [34-36] Adding resistance to arm elevation can infer a decrease in the scapula's upward rotation and external rotation. [14]

The scapulothoracic joint is described as the link to the arm and the rest of the upper extremity. [14] Scapular kinematics studies have helped to show that the joints within the shoulder complex can rarely move independently of one another. [11,18] Though many authors have studied the subject, there is still debate on what normal scapular kinematics pattern during arm motion. Many studies that have been produced have produced different results on the effect that active/passive or resisted motion has on scapular kinematics. These studies have identified is that scapular kinematics is affected by the type of muscle activation that occurs during arm elevation. [13,33,40,42] Like muscle activation, it can be inferred that muscle fatigue would be another restrictor on scapular kinematics.

Fatigue and Scapular Kinematics

Neuromuscular fatigue is defined as a muscle's reduced ability to produce strength or power, commonly after physical activity that affects the scapular motion. [4] Fatigue of the shoulder muscles has been reported as a decrease in the muscle force output of the muscle by at least 20% from pre-fatigue measures on the handheld dynamometer after completing physical activity. [8,31,33] Muscle fatigue has been documented as causing altered scapular kinematics. [10,38] Muscle fatigue is common with repetitive movements, and with musicians' long hours of practicing their music, muscle fatigue is likely. [10,46]

The muscles that work on the scapula provide stability of the scapula during gross motor movements. Fatigue to the scapular muscles has been shown to alter the motions that occur at the scapulothoracic joint. Rich et al. [41] produced a study that looked at general muscle fatigue protocol in tennis musicians and its effect on upward scapular rotation. The upward scapular rotation was measured during glenohumeral elevation starting at rest, then 60º, 90º, and 120º. The study found that immediately after the general fatigue protocol, there was a decrease in upward scapular rotation at 60º, 90º, and 120º (2.21º±2.16º, 3.22º±2.09º, and 3.99º±1.29º respectively). [41] The study helps to demonstrate that fatigue of the musculature can cause altered scapular motions but does not answer the question of specific muscles.

The serratus anterior is the primary stabilizer of the scapula through protraction, upward rotation, and depression. Umehara et al. [53] looked at the scapular kinematic alterations after serratus anterior muscle fatigue. The study results found that after the serratus anterior was fatigued, there was a statistically significant increase in the scapulothoracic joint's external rotation. There was no significant difference in pre- and post-fatigue for upward scapular rotation or posterior tilting. This study was able to help us interpret that fatiguing of the specific muscles that act on the scapula can alter scapular kinematics.

Humeral muscle fatigue has been shown to decrease scapulothoracic motion harming glenohumeral stability. McQuade et al [33] study looked at scapulohumeral rhythm response to a maximum resistive shoulder elevation fatigue protocol. The study found that there was an increase in the scapula's external rotation toward the end range of motion, which alters the scapulohumeral rhythm.

Ebaugh et al. [10] explored the effects of an external glenohumeral rotation fatigue protocol on glenohumeral and scapulothoracic kinematics. Following the fatigue protocol, the study found an increase in the scapula's upward rotation and external rotation with decreased humeral external rotation and clavicular elevation. [10] Conversely in a study that looked at external rotation fatigue protocol produced by Joshi et al. [42] found that following the external rotation fatigue protocol, there was no difference in external scapular rotation the external rotation fatigue protocol. The musculature measured to show the fatigue for the external rotation includes the upper trapezius, lower trapezius, anterior deltoid, posterior deltoid, and infraspinatus. [19,25]

Many studies have shown that general fatigue of the shoulder complex or specific muscle fatigue effectively alters scapular kinematics. The movement patterns that the scapula has after the fatiguing protocol is particular to the fatigued muscles. It is still a debated topic on how the scapula reacts to fatigue as studies have documented different results of external rotation, upward rotation, and posterior tilt.

Injury and Musicians

Injury in the music population is starting to become an area of research. However, the amount of research in this field is lacking. The incidence of musicians' injury is associated with many risk factors, including sex, experience level, time spent playing, and many other factors. [1,16, 46] Playing-related musculoskeletal disorders (PRMD) have been documented to affect a range between 77% to 89% in professional musicians. [1,34] PRMD has been described in the literature as an overarching term for any musculoskeletal problems associated with playing a musical instrument. [1,34] Many studies that look at PRMD have been produced using surveys to denote if the individual has experienced pain within regions of the body.

Steinmetz et al. [49] surveyed professional orchestra musicians in Berlin, Saxony, and Saxony-Anhalt belonging to one of ten classical orchestras. The survey consisted of a numeric rating scale for different body regions from zero (no pain) and ten (worst imaginable pain). The study's goal was to find pain in other instrument groups and the different body regions. The study found of those that responded to the survey that 89.5% had experienced musculoskeletal pain. When dividing the study between male and female, it was found that 87.7% and 91.9% respectively had reported PRMD. The most reported region of pain was found within the neck/cervical spine at 72.8%. The painful areas that followed were the left shoulder, left wrist, right shoulder, and right wrist (55.1%, 55.1%, 52.2%, and 50.7%, respectively). The average pain rating that was given for these regions was recorded between 3.9 and 4.7 on the numeric rating scale. Of the musician groups, it was reported that 9.7% of upper-strings, 9.4% of lower strings, 13.1% of woodwinds, 16.4% of brass, and 15.4% of percussion musicians reported not having any painful regions. The group that was reported to have the most recorded painful regions was the upper-string musicians. [49]

In upper-string musicians, the occurrence of injury occurs primarily in the upper extremities. It has been recorded that at the neck and shoulder have been upwards of 55% of upper string musicians had experienced pain. [16,52] Upper-string musicians were also documented in having pain within the lower back and wrists (39% and 42%, respectively). Upper-string musicians have also experienced pain within the elbow. It has been recorded that elbow pain was seen between 10% and 14% of violinist surveyed. [24] In the Kochem and Silva [24] study, they also compared DASH scores to the relationship of developing PRMD. They found that if a violinist scored below a 10.1 on the DASH, they were three times more likely to develop PRMSD. The PRMD experienced by violinists had accounted for 8.1% to have had a temporary stoppage of musical activity.

The most common injury that is seen in musicians consist of overuse injuries and neurological entrapment. [44, 45] A study of upper-extremity disorders for computer users, musicians, and other occupations found that 78% of the population had protracted shoulders, and 71% presented with a forward neck posture. [39] The study also found that there was 13% of the participants presented with shoulder impingement. Of the 13%, 12% of the population had shoulder impingement on the right shoulder, and 5% was reported for the left shoulder. The study found that 70% of the population also presented with thoracic outlet syndrome symptoms.

Studies looking into the scapular motion of musicians are limited, and there is a lack of research looking into the actual diagnosis of their injuries. Musicians face occupational hazards when it comes to their chosen profession. Many musicians have reported having to temporarily stoppage their music playing, with some having to stop completely. These stoppages affect the musician's livelihoods as their ability to play is their means for income. [24,46] Like muscle fatigue injury to the shoulder's musculature complex can be interpreted that injury can alter scapular kinematics.

Injury and Shoulder Kinematics

Injury to the shoulder complex and the surrounding muscles can alter the shoulder kinematics. [12,15,42] Pain that an individual feels is a messenger to the brain that an injury has occurred in the area that it occurs. In relationship to scapular kinematics, the pain has been linked with scapular dyskinesis. Scapular dyskinesis is the altered scapular motion and position concerning the thoracic cage. [22] Many documented disorders have been linked to altered scapular kinematics, including shoulder impingement, glenohumeral instability, and rotator cuff pathology. [49]

Shoulder impingement syndrome is a common injury that has been documented with patients that have altered scapular kinematics. [13,42] Patients that have been diagnosed with shoulder impingement syndrome have shown to have a decreased upward rotation/external rotation and increased anterior tilting during arm elevation. [28,42] Upward rotation of the scapula during arm elevation is necessary to prevent impingement by elevating the acromion during arm elevation. [28]

Individuals with glenohumeral instability have been found to have altered scapular kinematics during arm elevation. Patients with glenohumeral instability have downward scapular rotation than those with normal glenohumeral stability. [49] It has been documented that during arm elevation, there is an increase in scapulohumeral rhythm. This increase in scapulohumeral rhythm and decreased upward rotation leads to glenohumeral joint instability. [37,49]

Patients diagnosed with rotator cuff tendinopathy have also been shown to have altered scapular kinematics compared to those with healthy shoulders. [13,15] Some patients diagnosed with rotator cuff tendinopathy have shown an increase in internal scapular rotation and anterior tilt. However, there was not enough evidence to conclude if these results are normal. Patients with rotator cuff tendinopathy often had trouble with arm elevation. [13,15]

Like fatigue, injuries have been documented, both having different results for their effect on scapular kinematics. The inconclusive evidence on how the shoulder is affected after injury or fatigue is why more research is needed. It is essential to understand the scapular motion patterns for both injuries and fatigue to see similarities between them.

Conclusion

Injury in musicians is not a thoroughly investigated subject. Yet, the consequences for musicians suffering from injuries could be detrimental to not only their ability to play but even their livelihood. Scapular kinematics has been shown to alter depending on the injury that has occurred to the shoulder complex. Injury can change the degree of upward/downward scapular rotation, external/internal scapular rotation, or anterior/posterior scapular rotation. The investigation tested three hypotheses that revealed the impact of an acute bout of upper-string playing on changes in scapular kinematics.

The most common region of pain for upper string musicians has been recorded in the shoulder. Improved understanding of upper string musicians' scapular kinematics can help shed light on the mechanisms leading to the development of shoulder pain in upper string musicians, leading to the development of intervention strategies to reduce shoulder pain and increasing the quality of life of violists. To our knowledge, no studies explored the effect of muscle fatigue developed during an acute bout of upper string playing and scapular kinematics.

CHAPTER 3

METHODS

Introduction

The purpose of this study was to determine the effects of an upper-string practice session on shoulder kinematics. The design of this study was a repeated measure and within-group comparison studying the before and after measures for each participant. The null hypothesis was that the fatiguing protocol will not affect scapular kinematics. Our hypotheses for this study were that following the practice session participants will have decreased degrees of upward scapular rotation, posterior scapular tilt, and external scapular rotation during arm elevation.

Participants

Six participants were recruited from the Marshall University music department. The participants needed to be Marshall University student or faculty and be upper-string instrument performers. Inclusion criteria consist of anyone greater or equal to the age of 18, and they are either student or facility of Marshall University School of Music or Professional Musician. Exclusion consists of any of the one exclusion criteria being met. The exclusion criteria include: any person less than or equal to the age of 17, active or passive cervical spine range of motion produces shoulder symptoms, does not play the upper string, systemic musculoskeletal disease, shoulder and/or upper extremity pain greater than or equal to 7/10 on the numeric pain scale.

This study was approved (IRBNET #1667905-1) by the Marshall University Institutional Review Board (IRB). (See Appendix A). All participants provided written informed consent before participation.

Protocol

Participants arrived at the testing lab in Gullickson Hall during the agreed-upon appointment. The participants were asked to wear loose enough clothing so that the shoulder girdle would be easily accessible. A certified athletic trainer examined the participants for inclusion criteria. The participants' external rotation, internal rotation, shoulder abduction, serratus anterior, low trapezius, middle trapezius, and grip strength was measured using handheld dynamometry. The participants also had a trunk posture measure. Arm length was measured for both the upper and lower arm. The shoulder range of motion was measured for each participant. The shoulder range of motions that were measured includes external rotation, internal rotation, abduction, and flexion.

The subjects' shoulder girdle kinematics was measured using a three-dimensional electromagnetic tracker through the Ascension trackStar electromagnetic-based motion capture system (Ascension Technology, Shelburne, VT). The position of the trackers followed the protocol presented by Wu et al.. [56] The validity and reliability of three-dimensional electromagnetic tracker have been shown in the study by Michener et al. [34]

After placement of the trackers on the participants performed five repeated weighted arm elevations, following the repeated weighted arm elevation data collection, the participant performed predetermined composition before beginning the practice session. The practice session consisted of a 45 minute practice. The post-practice session, the participants completed the predetermined composition, followed by the five repeated weighted arm elevations. Immediately following the subject had their strength retested.

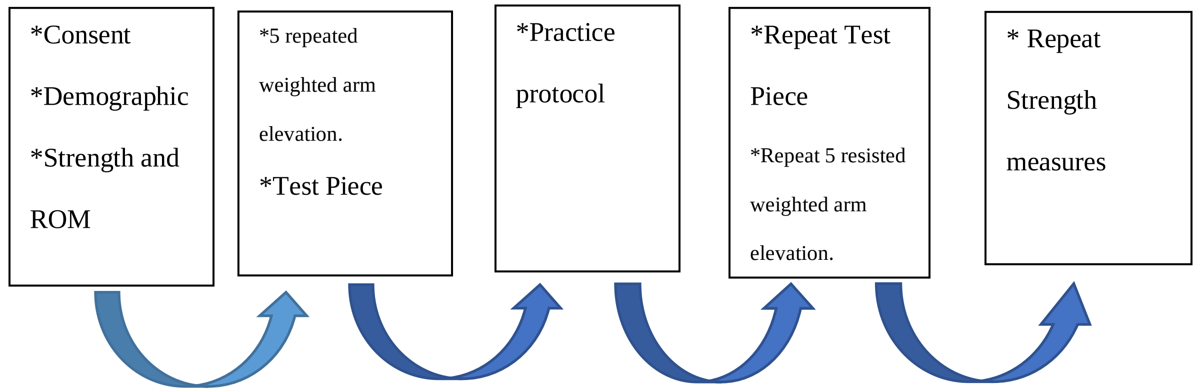

Figure 1. Methods Flow Chart
This is a figure that represents the procedure for the methods in which this study will be conducted

Musical Pieces

Participants performed two separate musical pieces. The first musical piece (appendix d) that was performed was the test piece and that consists of a musical composition that was specifically written for upper string musicians of the desired skill level. The test piece was written by the faculty of the Marshall University School of Music. The second piece that was performed was the practice piece. This piece was provided by the Marshall University School of Music faculty to produce the normal levels of fatigue for the skill level of the musician. The practice session was 45 minutes in duration.

Shoulder Pain Assessment

Shoulder pain and disability was assessed using the Penn Shoulder Score (PENN) questionnaire. The PENN is a 25-question questionnaire. The PENN questions assess a participant's pain, function, and overall satisfaction with their shoulder. The PENN is scored from a zero to one-hundred score with one hundred showing that the participant has no pain or disability as well as complete satisfaction of their shoulder. Pain was also assessed during strength measures as they were asked to rate their pain on a numerical pain scale from zero to ten. Zero represents no pain and ten represents the worst pain imaginable.

Strength Testing

Strength testing for the shoulder girdle was performed using the techniques that Kendall and McCreary describe. [20] Shoulder external rotation, internal rotation, serratus anterior, shoulder abduction, lower trapezius, and middle trapezius strength was assessed. Grip strength was also assessed. Force measures was assessed with a handheld dynamometer (microFET2, Hoggan 676 Scientific LLC, Salt Lake City, UT).

External Rotation

External rotation was assessed with the participant's elbow bent and the shoulder abducted to 90º. The athletic trainer stood at the side of the participant to stabilize the elbow. The athletic trainer then instructed the participant to rotate their shoulder while applying resistance at the wrist externally. A handheld dynamometer was placed at the wrist, and the examiner resisted the motion.

Internal Rotation

Internal rotation was assessed with the participant's elbow bent and the shoulder abducted to 90º. The athletic trainer stood at the side of the participant to stabilize the elbow. The athletic trainer then instructed the participant to rotate their shoulder while applying resistance at the wrist internally. A handheld dynamometer was placed at the wrist and the examiner resisted the motion.

Shoulder Abduction

Shoulder abduction was assessed by having the participant moved passively into shoulder abduction by the athletic trainer. The subject was instructed to abduct their arm. The athletic trainer placed a handheld dynamometer at the participant's wrist and resisted the motion.

Serratus Anterior

The serratus anterior was assessed by using a break test. The break test was performed by having the participant's arm elevated to 120º in the scapular plane with their thumb pointing up to the ceiling. The athletic trainer then placed the handheld dynamometer at the participant's elbow and apply downward force. The participant was instructed to resist the force.

Lower Trapezius

The lower trapezius was assessed by having the participant prone with their arm abducted to 120º and internally rotated. The athletic trainer then placed the handheld dynamometer at the participant's elbow and apply anterior force. The participant was instructed to resist the force.

Middle Trapezius

The middle trapezius was assessed by having the participant prone with their arm abducted to 90º. The athletic trainer then placed the handheld dynamometer at the participant's elbow and apply anterior force. The participant was instructed to resist the force.

Grip strength

The participant's grip strength was determined for both arms. Grip strength was assessed using a Jamar Hand Dynamometer (Lafayette Instruments, Lafayette, IN, USA). Grip strength was assessed by having the participant seated with their elbow bent to 90º and their forearm resting on their thigh. The participant grabbed the handheld dynamometer and was instructed to squeeze. Grip strength was assessed at both the second and third positions on the handheld dynamometer.

Range of Motion

Shoulder range of motion measures that was assessed includes external rotation, internal rotation, abduction, and flexion. Shoulder range of motion was determined using a digital inclinometer (The Saunders Group Inc., Chaska, MN). All measurements were assessed bilaterally.

External Rotation

External rotation was assessed with the participant standing. The clinician passively placed the participant into shoulder abduction at 90º and the elbow flexed to 90º. The clinician instructed the participant to externally rotate their forearm toward the ceiling.

Internal Rotation

Internal rotation was measured with the participant standing. The clinician passively placed the participant into shoulder abduction at 90º and the elbow flexed to 90º. The clinician then instructed the participant to internally rotated their forearm toward the floor.

Shoulder Abduction

Shoulder abduction was performed with the participant standing. With the participant's arm at their side, they were instructed to abduct their arm. If the participant can abduct their arm to their ear a measure of 180º was given.

Shoulder Flexion

Shoulder flexion was assessed with the participant standing. The participant with their arms at their side was instructed to raise their arm forward and overhead. If the participant can elevate their arm to their ear a measure of 180º was given.

Posture Assessment

Posture assessment was conducted by measuring the T1-T3 angle and the T10-T12 angle. Measurements was performed with the participant in a relaxed standing position. Measurements was recorded with a bubble inclinometer. The T1-3 and T10-12 angles was measured twice and recorded in the degrees of inclination. The average of the two measures was used for data analysis. The kyphosis angle was calculated by adding T1-3 angle and T10-12 angle. The test-retest reliability of this method was excellent with an ICC = 0.96 and 0.96.

T1-T3 Angle

T1-T3 angle was assessed with the participant standing. The clinician palpated the spinous process of T1 and placed the superior aspect of the bubble inclinometer. The inferior aspect of the bubble inclinometer was placed at T3.

T10-T12 Angle

T10-T12 angle was assessed with the participant standing. The clinician palpated the spinous process of T10 and placed the superior aspect of the bubble inclinometer. The inferior aspect of the bubble inclinometer was placed at T12.

Three-Dimensional Electromagnetic Tracking

A three-dimensional electromagnetic tracker Ascension trackStar electromagnetic based motion capture system (Ascension Technology, Shelburne, VT) was used for the analysis of the kinematics of the shoulder girdle. The Ascension trackStar used the Motion Monitor software (Innovative Sports Training, Inc, Chicago, IL).

There are five sensors placed onto the body. The sensors track the relationship between the movement of the humerus, scapula, and the trunk of the subjects. The position of the sensors included the bilateral humeral shaft, bilateral posterior aspect of the acromion, and the spinous process of the second thoracic vertebrae. All sensors were fixated to the skin with double-sided adhesive tape, cover roll tape was used to stabilize the sensor and cables. There was a sixth sensor that was used to digitize anatomical landmarks to define and locate body segments within local and global coordinate systems. A 3D model of the trunk, upper extremities, and scapular was defined as described by the International Society of Biomechanics. [56]

Shoulder kinematics was measured during the playing of a predetermined composition provided by the Marshall University School of Music faculty and the five repeated weighted arm elevations. Scapular measurements were recording during pre-and post-testing of the composition provided by the Marshall University School of Music faculty and the five repeated weighted arm elevations.

Scapular (upward rotation, posterior tilt, and external rotation) positions was measured at discrete arm elevation angles (0^o, 30, 60, 90, 120, and maximum elevation). [34,56] Measurements were recorded to the nearest hundredth. Upward scapular rotation, posterior scapular tilt, and external scapular rotation were recorded in positive degrees. The middle three of the five arm elevation trials were analyzed, the mean of the three trials was used for statistical analysis.

Practice Session

Once the subject completed the pre-practice strength testing and had three-dimensional trackers placed, the subject performed the five repeated weighted arm elevations and then was seated to play the predetermined composition. After completion of the compositions, the participants entered the practice session consisted of a 45 minute practice. Once the subjects complete the practice session, they played the composition and repeated the five repeated weighted arm elevations to look for any changes in the kinematics of the shoulder complex. The participants then completed the strength measures post-practice.

The practice session consisted of a 45 minute practice that the subjects performed under the instruction of an upper-string instructor from the Marshall University School of Music. Pre-practice strength measures and post-practice strength measures was taken.

Data Analysis

All subject and clinician-generated data was recorded on paper documents and entered in electronic data for analysis. All statistical analysis was performed with SPSS 21.0 (SPSS, Chicago, Il). Descriptive means and standard deviations were reported for all demographic variables and scapular kinematic data. Pre-practice/ post-practice scapular motion and strength measures were explored using paired t-test, and variance (ANOVA) analysis was appropriate. Statistical significance was determined a $P < 0.05$.

CHAPTER 4

RESULTS

Demographic

The participant's demographic information was recorded prior to the evaluation. Six healthy participants were used in the gathering of this data. See table 1.

	Age	PENN Function	PENN Total	Height (cm)	Weight (kg)
Mean	25.67	58.00	93.833	172.083	78.917
N	6	6	6	6	6
Std.	10.309	2.608	6.6758	9.5705	32.4085

Table 1. Demographic
Note: A table showing the participant demographic for this study. Age is reported in years old; PENN is reported out of 100; Height is reported in centimeters; Weight is recorded in kilograms. Abbreviations: N, number of participants; Std, standard deviation.

Strength Measures

Strength measures were recorded both pre- and post-practice session for both arms. Strength measures for the right and left arms are represented in the tables 2 and 3 respectively below. For the right arm there was a statistically significant decrease in force output for external rotation (mean difference = -2.41, t = 2.614, p = 0.047), abduction (mean difference = -4.15, t = 5.215, p = 0.003), and serratus anterior (mean difference = -1.61, t = 3.9, p = 0.011). Force output was also trending toward significant decrease for internal rotation (mean difference = -2.02, t = 3.026, p = 0.059) for the right arm. On the left arm there was a statistically significant mean difference of force reduction in internal rotation (mean difference = -2.28, t = 3.395, p = 0.019), serratus anterior (mean difference = -2.02, t = 3.026, p = 0.029), and grip position 2 (mean difference = 3.17, t = 3.23, p = .023).

	Pre-Mean (kg)	Post-Mean (kg)	Mean Difference (kg)	% Change	t	p
External rotation	16.79 ± 2.37	14.38 ± 2.93	2.41 ± 2.26	14.4%	2.614	0.047
Internal Rotation	17.96 ± 2.48	16.18 ± 3.93	1.78 ± 1.79	9.9%	2.429	0.059
Abduction	21.31 ± 7.05	17.16 ± 5.93	4.15 ± 1.95	19.5%	5.215	0.003
Serratus Anterior	16.69 ± 6.08	15.08 ± 5.82	1.61 ± 1.01	9.6%	3.900	0.011
Middle Trapezius	11.18 ± 2.66	12.6 ± 4.21	-1.12 ± 2.2	-10%	-1.496	0.195
Lower Trapezius	9.48 ± 3.28	10.6 ± 4.77	-1.42 ± 2.32	-15%	-1.242	0.269
Grip 2	36.83 ± 8.86	36.83 ± 11.84	0 ± 5.55	0%	0.000	1.000
Grip 3	32.67 ± 13.05	32.5 ± 9.22	0.17 ± 3.25	0%	0.126	0.905

Table 2. Right Arm Strength Measures

Note: A table that displays the muscular strength of the right arm average pre- and post- practice. Values are expressed in kilograms (mean ± standard deviation).

Abbreviations: Pre-Mean, strength averages before practice session; Post-Mean, strength measurements after practice session; t, test statistic; p-value, sig (2-tailed); (-), increasing force output.

	Pre-Mean (kg)	Post-Mean (kg)	Mean Difference (kg)	% Change	t	p
External Rotation	16.11 ± 0.97	14.19 ± 3.26	1.92 ± 2.93	11.9%	1.601	0.170
Internal Rotation	16.18 ± 2.01	13.89 ± 2.62	2.28 ± 1.65	14.1%	3.395	0.019
Abduction	18.43 ± 4.99	15.61 ± 5.15	2.82 ± 3.61	15.3%	1.911	0.114
Serratus Anterior	16.59 ± 4.5	14.58 ± 4.67	2.02 ± 1.63	12.2%	3.026	0.029
Middle Trapezius	12.37 ± 3.42	13.58 ± 6.94	-1.63 ± 2.25	-13.2%	-0.722	0.502
Lower Trapezius	8.8 ± 2.65	10.43 ± 6.94	-1.21 ± 4.1	-13.8%	-1.775	0.136
Grip 2	37.5 ± 9.23	34.33 ± 9.73	3.17 ± 2.4	8.5%	3.230	0.023
Grip 3	30.17 ± 10.34	30.83 ± 9.6	-0.67 ± 3.88	-2.2%	-0.421	0.691

Table 3. Left Arm Strength Measures

Note: A table that displays the muscular strength of the left arm average pre- and post- practice. Values are expressed in kilograms and as mean ± standard deviation.

Abbreviations: Pre-Mean, strength averages before practice session; Post-Mean, strength measurements after practice session; t, test statistic; p-value, sig (2-tailed); (-), increase in force output.

Scapular Kinematics

Scapular kinematics were recorded during five consecutive arm elevations, both pre- and post-practice. The middle three repetitions were used for analysis. Scapular kinematics were recorded in distinct arm elevation angles positions during the five-arm elevations (30°, 60°, 90°, 120°) for both the ascending phase and the descending phase. Scapular kinematics were recorded for the left and right shoulder, see tables 4 and 5, respectively. Each of the scapular motions are reported separately in sections below.

Left Arm Scapular Kinematics				
	Ascending		Descending	
	Pre	Post	Pre	Post
External Rotation				
30°	-26.22 ± 9.16°	-24.76 ± 18.60°	-23.90 ± 10.71°	-22.02 ± 18.03°
60°	-25.54 ± 11.16°	-23.82 ± 20.32°	-22.13±21.21°	-19.65 ± 21.21°
90°	-26.19 ± 12.61°	-24.78 ± 22.03°	-23.71±23.69°	-22.23 ± 23.69°
120°	-32.43 ± 18.24°	-30.40 ± 26.77°	-33.91±21.29°	-30.65 ± 28.82°
Upward Rotation				
30°	-5.51 ± 6.24°	-3.45 ± 8.26°	-6.25±8.50°	-3.55 ± 10.34°
60°	2.98 ± 4.81°	5.25 ± 7.05°	1.74 ± 8.70°	4.12 ± 10.69°
90°	10.94 ± 4.13°	13.33 ± 7.11°	9.94±8.40°	12.06 ± 8.69°
120°	15.13 ± 5.74°	16.35 ± 9.19°	13.17±8.42°	15.49 ± 10.82°
Posterior Tilt				
30°	-17.78 ± 7.88°	-15.79 ± 8.09°	-16.48 ± 8.39°	-13.58 ± 9.22°
60°	-19.31 ± 8.57°	-16.56 ± 8.41°	-16.47 ± 8.85°	-13.27 ± 9.55°
90°	-19.15 ± 9.88°	-17.03 ± 9.72°	-15.06 ± 9.12°	-11.37 ± 9.84°
120°	-21.13 ± 10.22°	-19.54 ± 9.04°	-15.78 ± 11.01°	-12.41 ± 11.23°

Table 4: Left Arm Scapular Kinematics
A table showing pre- and post-practice scapular kinematic measurements in degrees during specific arm elevations for the left arm. Positive degree measurements represent external rotation, upward rotation, and posterior tilt. Negative degree measurement represents internal rotation, downward rotation, and anterior tilt. Measurements are recorded in mean ± standard deviation.

Right Arm Scapular Kinematics				
	Ascending		Descending	
	Pre	Post	Pre	Post
External Rotation				
30°	-24.25 ± 16.28°	-28.34 ± 21.00°	-24.78 ± 14.31°	-26.66 ± 18.50°
60°	-21.23 ± 17.22°	-17.56 ± 22.73°	-21.27 ± 17.69°	-23.17 ± 22.55°
90°	-20.39 ± 18.55°	-28.05 ± 25.26°	-21.06 ± 20.80°	-23.05 ± 26.11°
120°	-24.32 ± 22.22°	-33.29 ± 30.04°	-26.81 ± 24.80°	-30.16 ± 31.18°
Upward Rotation				
30°	-4.36 ± 9.81°	-4.83 ± 11.21°	-4.62 ± 11.33°	-5.57 ± 14.10°
60°	5.55 ± 9.78°	3.76 ± 10.86°	4.31 ± 13.09°	2.53 ± 15.41°
90°	15.25 ± 10.77°	12.66 ± 12.26°	12.67 ± 16.27°	11.48 ± 18.28°
120°	19.67 ± 20.22°	17.18 ± 22.17°	17.17 ± 23.39°	15.31 ± 25.68°
Posterior Tilt				
30°	-17.95 ± 11.64°	-17.49 ± 11.10°	-17.79 ± 11.52°	-17.33 ± 11.56°
60°	-20.38 ± 13.55°	-19.14 ± 12.03°	-17.40 ± 15.25°	-16.80 ± 14.30°
90°	-19.50 ± 15.71°	-19.05 ± 14.31°	-15.01 ± 19.03°	-13.88 ± 18.26°
120°	-18.64 ± 19.29°	-18.92 ± 18.51°	-15.59 ± 21.57°	-16.11 ± 22.14°

Table 5: Right Arm Scapular Kinematics
A table showing pre- and post-practice scapular kinematic measurements in degrees during specific arm elevations for the right arm. Positive degree measurements represent external rotation, upward rotation, and posterior tilt. Negative degree measurement represents internal rotation, downward rotation, and anterior tilt. Measurements are recorded in mean ± standard deviation.

Left Upward Scapular Rotation

The scapula of the left shoulder followed a pattern of increasing upward scapular rotation with increasing arm elevation angle (figure 2). Data analysis revealed significant arm elevation angle main effect during the ascending phase ($F_{(15,3)} = 159.712$, $p < 0.001$) and the descending phase ($F_{(15,3)} = 44.221$, $p < 0.001$), The practice main affect was not statistically significant during either the ascending ($F_{(5,1)} = 0.878$, $p = 0.392$) or descending phase ($F_{(5,1)} = 1.384$, $p = 0.292$). The practice by arm angle interaction was not statistically significant during the ascending ($F_{(15,3)} = 0.742$, $p = 0.543$) and descending phase ($F_{(15,3)} = 0.073$, $p = 0.974$).

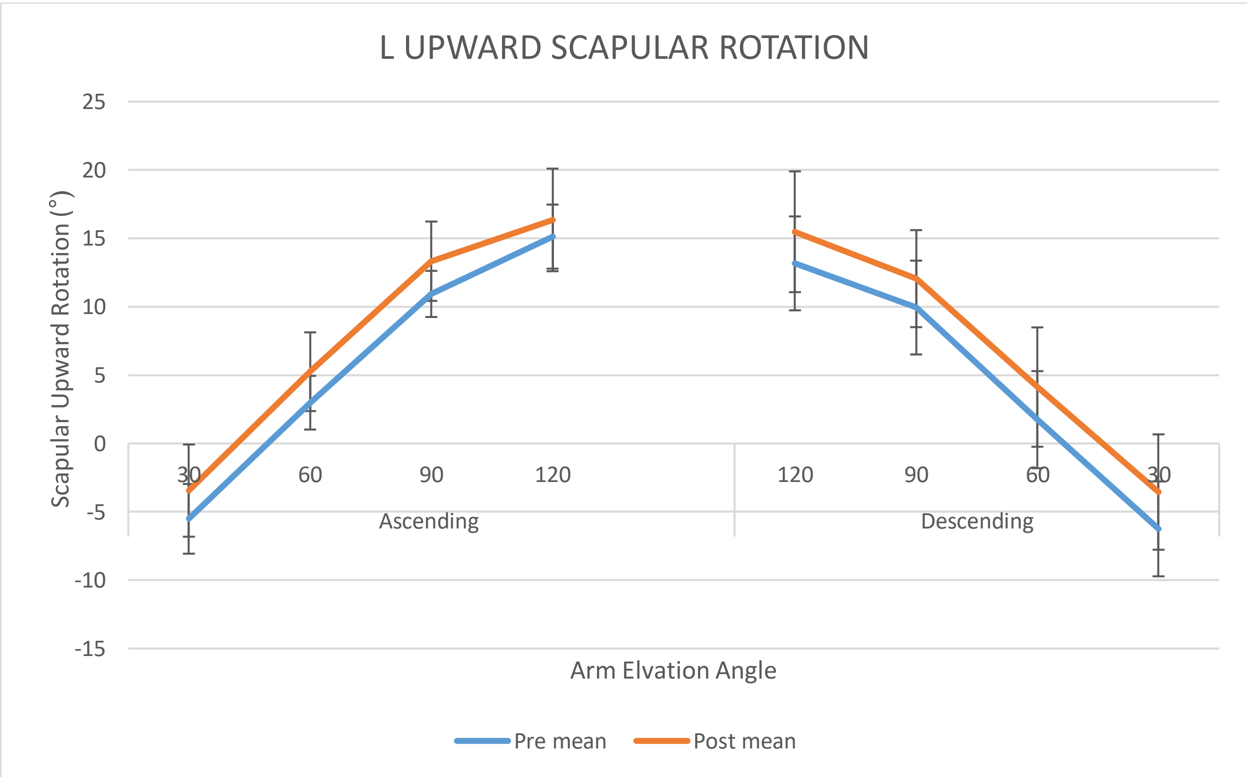

Figure 2: Left Upward Scapular Rotation
A line graph demonstrating the mean upward scapular rotation of the left shoulder during the five-arm in the ascending (left) and descending (right) phase. Error bars indicate the standard error. Positive direction describes upward scapular rotation.

Left External Scapular Rotation

The scapula moved from a position of internal rotation towards external rotation but did not reach a position of external rotation (Figure 3). The arm main affect was found to be statistically significant during both the ascending ($F_{(15,3)} = 3.739$, $p = 0.035$) and descending phase ($F_{(15,3)} = 7.328$, $p = 0.003$) of arm elevation. The practice main affect for external scapular rotation was not statistically significant during the ascending ($F_{(5,1)} = 0.071$, $p = 0.801$) and descending phase ($F_{(5,1)} = 0.131$, $p = 0.733$). The practice by arm elevation angle interaction was also not statistically significant during the ascending ($F_{(15,3)} = 0.044$, $p = 0.987$) and descending phase ($F_{(15,3)} = 0.294$, $p = 0.829$).

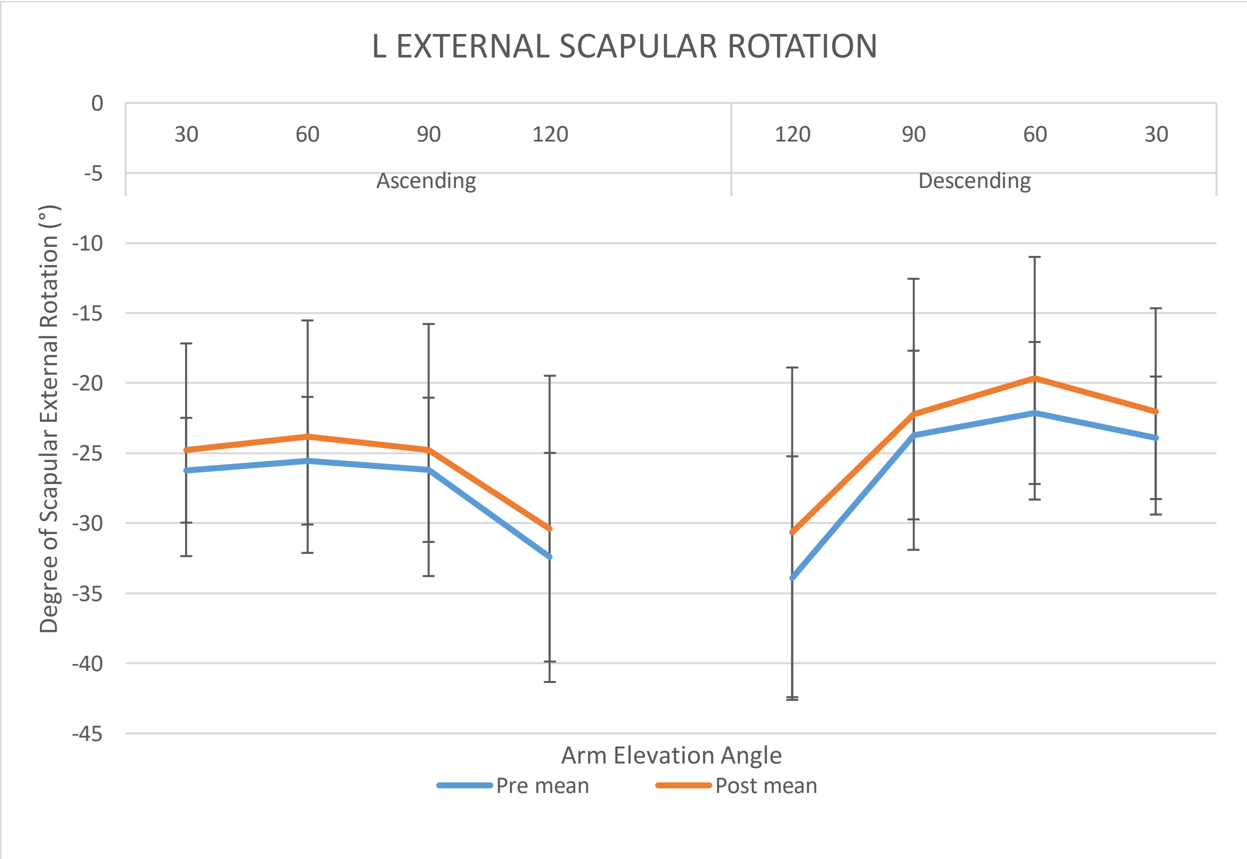

Figure 3: Left External Scapular Rotation
A line graph demonstrating the mean degree of internal scapular rotation of the left shoulder during the five-arm elevation in the ascending (right) and descending (left) phase. Error bars indicate standard error. Positive direction indicates external scapular rotation.

Left Posterior Scapular Tilt

The scapula of the left shoulder started in an anterior tilted position; during arm elevation the scapula moved towards anterior tilt. (figure 4). However, the arm main affect was found to not be statistically significant during ascending ($F_{(15,3)} = 1.516$, $p = 0.251$) and descending phase ($F_{(15,3)} = 0.584$, $p = 0.63$). The practice main affect was not statistically significant but trending toward statistical significance in the ascending phase ($F_{(5,1)} = 5.309$, $p = 0.069$) and statistically significant during the descending phase ($F_{(5,1)} = 8.346$, $p = 0.015$). The left scapula was in a position of less posterior tilt follow the practice. The practice by arm interaction affect was found to not be statistically significant during both the ascending ($F_{(15,3)} = 1.120$, $p = 0.372$) and descending phase ($F_{(15,3)} = 0.721$, $p = 0.547$).

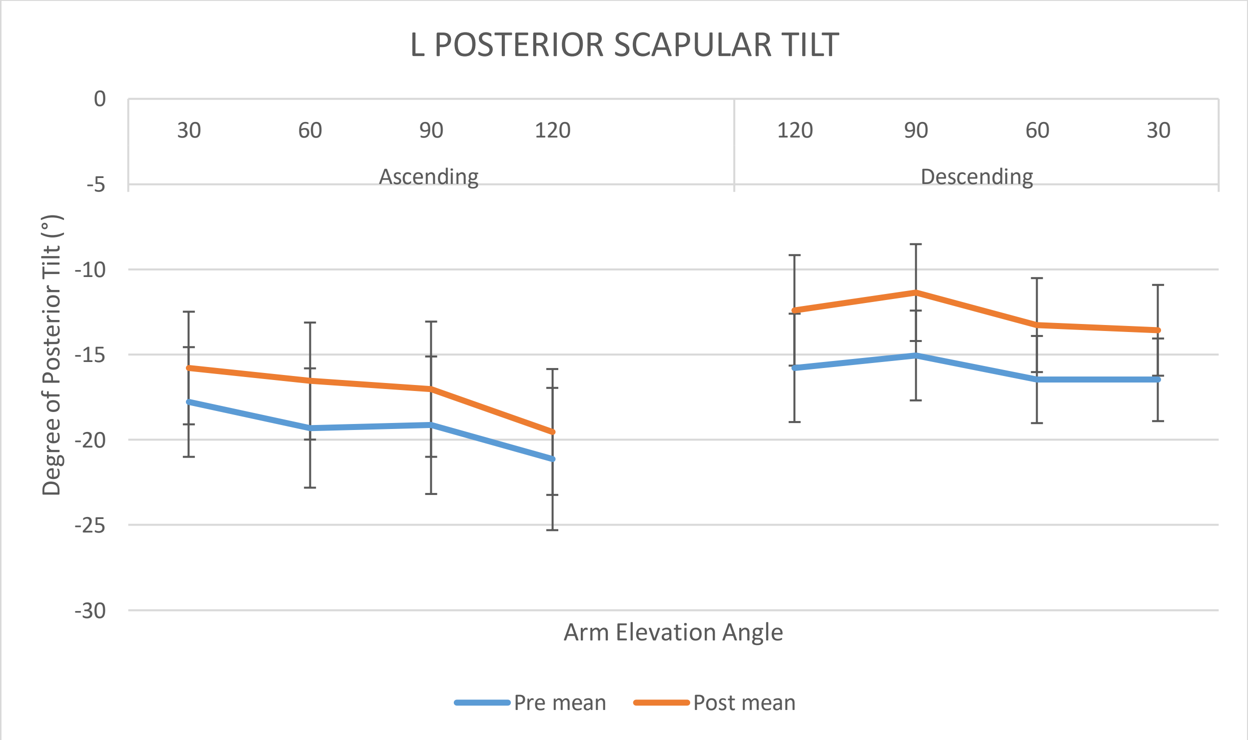

Figure 4: Left Posterior Scapular Tilt
A line graph that illustrates the mean posterior scapular tilt degree of the right shoulder during the five-arm elevation in the ascending (left) and descending (right) phase. Error bars indicate standard error. Positive directions indicate posterior scapular tilt.

Right Upward Scapular Rotation

The scapula started in downward scapula rotation; during arm elevation the scapula moved into upward scapular rotation and during descending phase the scapula moved into downwardly scapular rotation (figure 5). Arm elevation angle main affect analysis showed to be statistically significant during both the ascending ($F_{(15,3)} = 12.396$, $p < 0.001$) and descending phase ($F_{(15,3)} = 8.856$, $p \leq 0.001$). Practice main affect was shown to not be statistically significant during either ascending ($F_{(5,1)} = 0.737$, $p = 0.43$) or descending phase ($F_{(5,1)} = 0.472$, $p = 0.523$). The practice by arm elevation angle interaction was not found to be statistically significant during ascending ($F_{(15,3)} = 2.516$, $p = 0.098$) and descending phase ($F_{(15,3)} = 0.478$, $p = 0.702$).

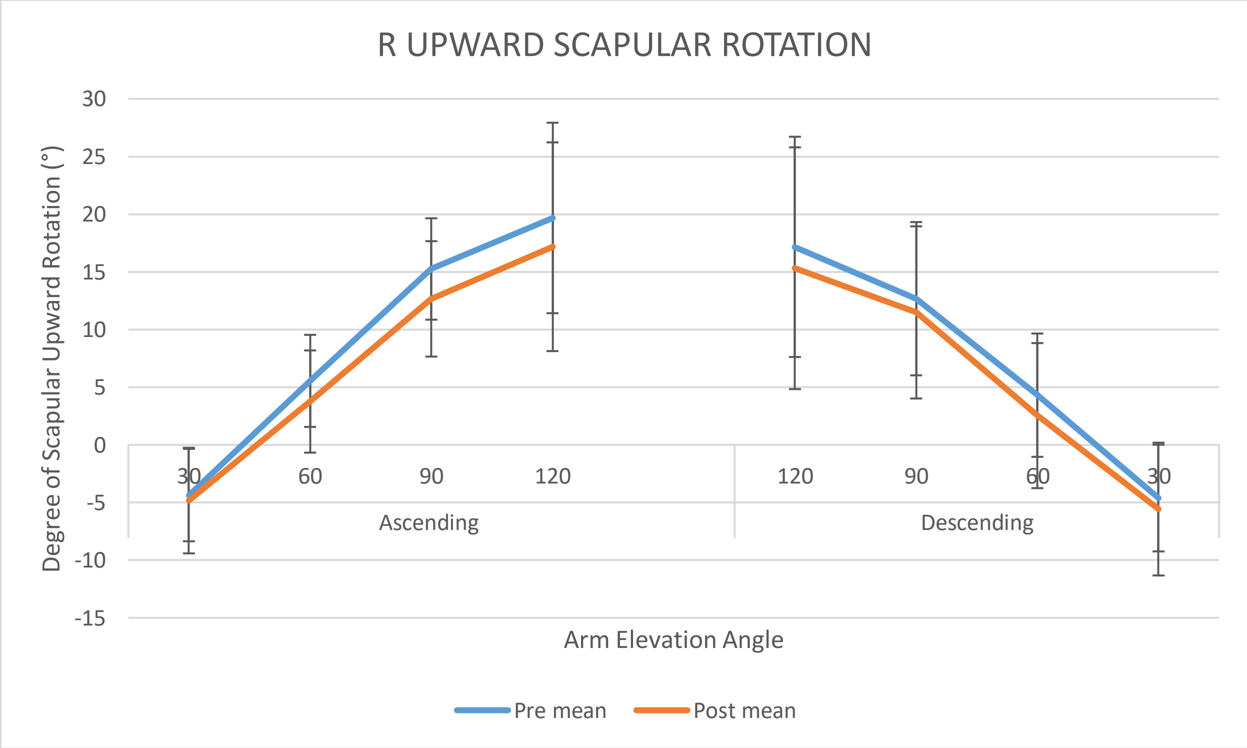

Figure 5: Right Upward Scapular Rotation
A line graph that demonstrates the mean upward scapular rotation degree of the right shoulder during the ascending (right) and descending (left) phase of the five-arm elevation. Error bars indicate standard error. Positive direction indicates upward scapular rotation.

Right External Scapular Rotation

The scapula of the right shoulder began in internal scapular rotation; during arm elevation the scapula began to rotate externally, and after 90°, the scapula moves into internal scapular rotation. During descending phase, the scapula began in internal scapular rotation and moved into more external rotation but did not reach a position of external rotation. The arm main affect did not show statistical significance in the ascending phase ($F_{(15,3)} = 2.238$, $p = 0.126$) but was statistically significant during the descending phase ($F_{(15,3)} = 2.948$, $p = 0.047$). The practice main affect was shown to not be statistically significant during either the ascending ($F_{(5,1)} = 1.451$, $p = 0.282$) or descending phase ($F_{(5,1)} = 0.434$, $p = 0.524$). The practice by arm elevation angle interaction to be not statistically significant during both ascending ($F_{(15,3)} = 2.088$, $p = 0.145$) and descending phase ($F_{(15,3)} = 0.606$, $p = 0.616$).

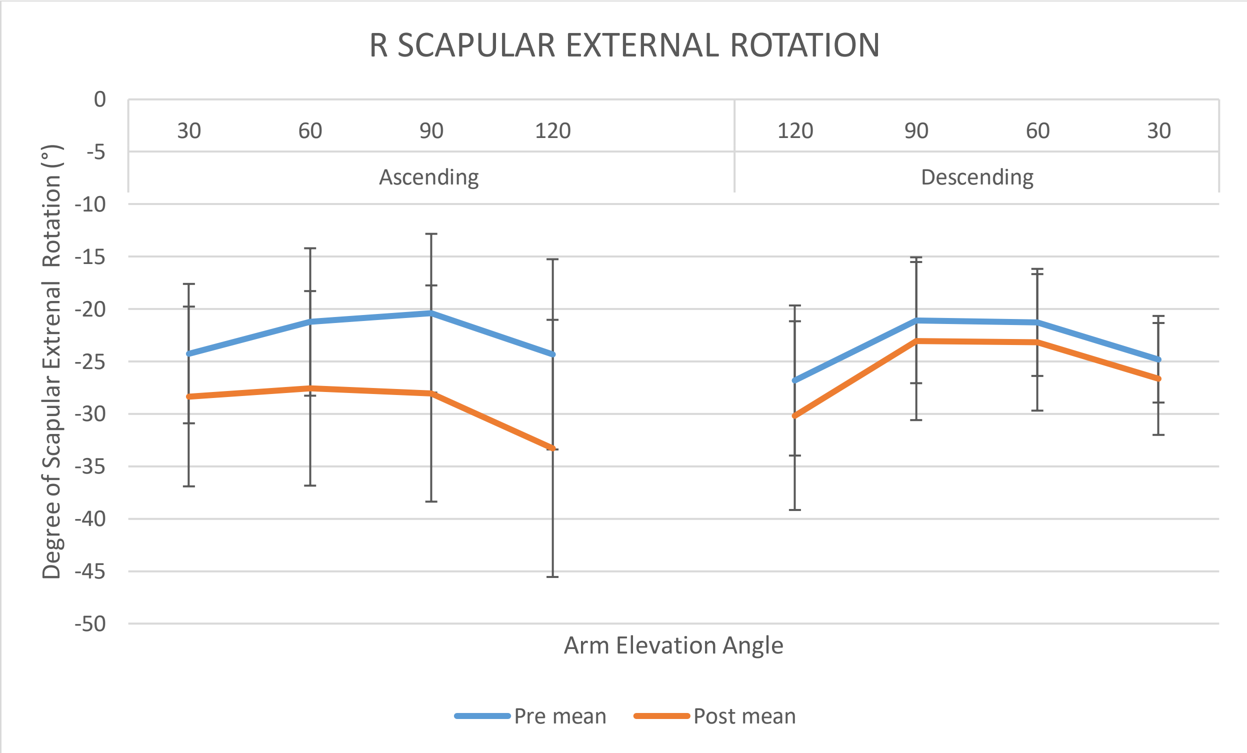

Figure 6: Right External Scapular Rotation
A line graph that illustrates the mean degree internal scapular rotation of the right shoulder during five-arm elevation in the ascending (right) and descending (left) phase. Error bars indicate standard error. Positive direction indicates external scapular rotation.

Right Posterior Scapular Tilt

The scapula began in anterior scapular tilt; during arm elevation the scapula began to increase anterior scapular tilt (Figure 6). During the descending phase, the scapula started in anterior scapular tilt and moved into increased posterior scapular tilt (Figure 6). The arm elevation main affect analysis showed no statistical significance in both the ascending ($F_{(15,3)}$ = 0.167, p = 0.917) and descending phase ($F_{(15,3)}$ = 0.257, p = 0.855). The practice main affect also showed no statistical significance during the ascending ($F_{(5,1)}$ = 0.061, p = 0.814) and descending phase ($F_{(5,1)}$ = 0.059, p = 0.818). The practice by arm elevation angle interaction showed no statistical significance in either ascending ($F_{(15,3)}$ = 1.375, p = 0.289) or descending phase ($F_{(15,3)}$ = 1.049, p = 0.401).

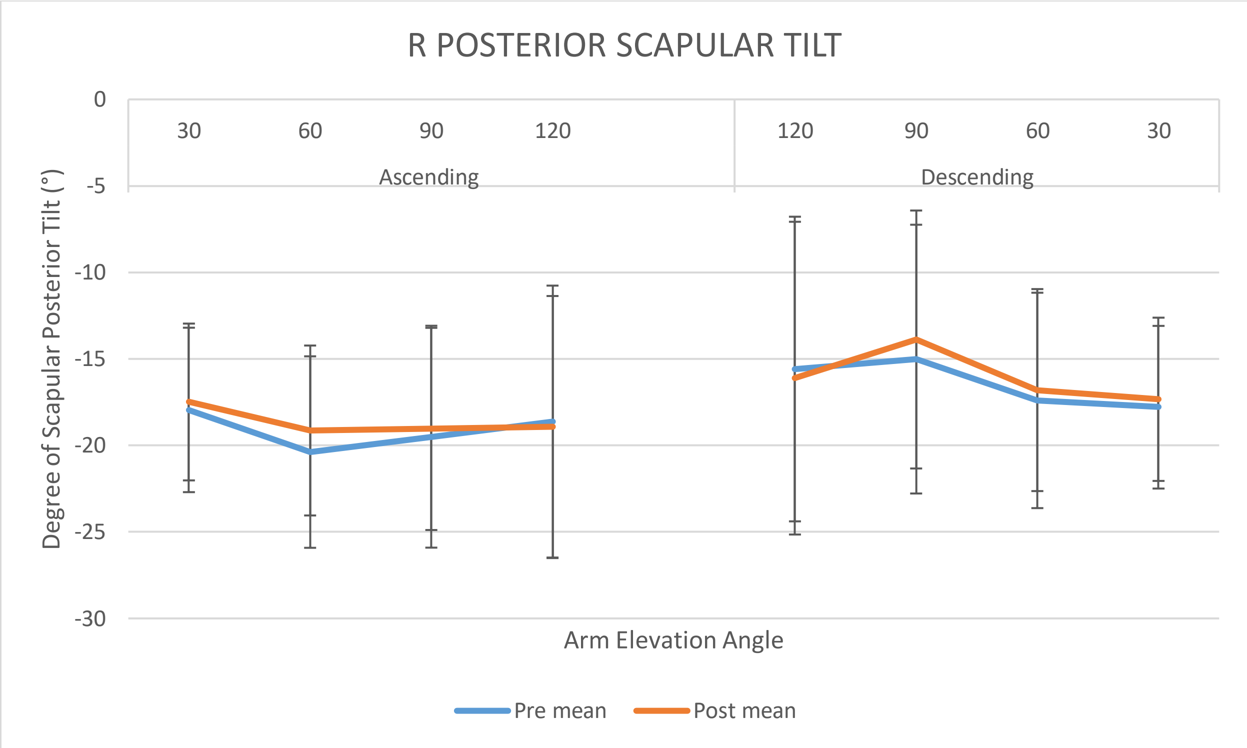

Figure 6: Right Posterior Scapular Tilt
This is a line graph demonstrating mean degree posterior scapular tilt of the right shoulder during the ascending (right) and descending (left) phase of the five-arm elevation. Error bar indicates standard error. Positive direction indicates posterior scapular tilt.

CHAPTER 5

DISCUSSION

The purpose of this study was to examine the effect a practice session for upper string musicians had on their scapular kinematics. The alternative hypotheses were that following the practice session, the upward scapular rotation, external scapular rotation, and posterior scapular tilt decreased during arm elevation following the practice session. The practice session did not have the hypothesized decrease on scapular upward or external rotation for either the right or left arm. The exception was for scapular posterior tilt on the left side, where posterior scapular tilt increased during the descent increased ($p = 0.015$) and was trending towards significance during the ascent ($p = 0.069$). The scapular posterior tilt finding does not support the hypothesized decrease. The data analysis showed that upper-string musicians presented abnormal scapular kinematic patterns during arm elevation. The abnormal motion patterns were found on the left and right sides.

The upper string musicians experienced less than expected upward scapular on the left (mean = 20.6°) and right (mean = 24.0°). The current study found that upper string musicians during left arm elevation experienced scapular internal rotation (decreasing external scapular rotation, mean = -6.2°) and an anterior tilt (less posterior scapular tilt, mean = 3.3°). During right arm elevation, the scapula experienced no external scapular rotation position (mean = -0.1°) and an anterior tilt (mean = -0.7°). Normal scapular kinematics and the minimal detectable change (MDC) have been found to have an increase in upward rotation (30°, MDC = 7.44°), external rotation (4.8°, MDC = 2.39°), and posterior tilt (13.7°, MDC = 2.37°). [13,23,27,30] The scapula position of upper string musicians differs from the published literature in both magnitude and direction and the difference was greater than the published error for measures of scapular position.

The left arm is the support arm for the upper-string musicians. It was observed that the left arm sits in flexion in the scapular plane with the elbow flexed. Once the left arm was set in this position there was little movement that occurs depending on the skill level of the musicians. It was seen that the more experienced musicians would externally and internally rotate their left shoulder to change the position of the instrument. The right arm is the bow arm for upper-string musicians. During play, the bow arm was observed to move through abduction, horizontal flexion, internal rotation, and external rotation without an angle great enough to go overhead. [52] The observed scapular motion of upper string musicians could be an adaptive movement pattern developed by the musician due to the specific demands of playing the chosen instrument. [29,47] The current study looked at the upper string musician population with the same measurement standards. It could be inferred that the discrepancies between the literature and the current study could come from the current population that was being studied.

The current study found that following the practice session, no statistically significant decrease in upward scapular rotation for either the left (-0.84°) or right (-2.02°) arm. These findings differ from what Rich et al. [41] found when examining the effect of acute fatigue from tennis serving fatigue protocol. Rich et al. [41] found that there was a statistically significant decrease of 3.99° for upward scapular rotation following the fatigue protocol. However, the current study has similar results to the study produced by Umehara et al. [53] Umehara et al. [53] found that following a serratus anterior specific fatigue protocol there was no statistically significant change in upward scapular rotation (-1°). The study produced by Rich et al. [41] followed a similar fatigue protocol to the practice session of the current study by having a sport-specific fatigue protocol. The difference in results could be inferred that the tennis serving protocol was more significant in creating fatigue than a normal practice session that an upper string musician may receive. The similarity between the Umehara et al. [53] study and the current study could be interpreted through the difference in strength measures that were found for the current study (see table 3 and 4). In the current study, it was found that there was a statistically significant decrease in force output for the left (12.2%) and right (9.6%) serratus anterior measures.

The current study also found that there was no statistically significant change in external scapular rotation during arm elevation for either the left (0.56°) or right (-4.88°) arm following the practice session. The findings in the current study are consistent with the results produced by Ebaugh et al. [10] Ebaugh et al. [10] studied the effect of an external glenohumeral rotation fatigue protocol on scapular kinematics during arm elevation. In the study, Ebaugh et al. [10] found no statistically significant difference in external scapular rotation (-0.3°) following the fatigue protocol. However, the current study was not consistent with the findings from the study produced by Umehara et al. [53] Umehara et al. [53] studied the effect of a serratus anterior fatigue protocol on scapular kinematics during arm elevation. The Umehara study found that following the serratus anterior fatigue protocol, there was a statistically significant decrease in external scapular rotation (-5°). Indicating that the serratus anterior muscle assists in the external scapular external rotation that occurs during arm elevation. [53] The current study also found a decrease in serratus anterior strength following the practice session but also found that the lower and middle trapezius muscle strength was not affected. The decrease in serratus anterior strength could explain the increase in internal scapular rotation following the practice session. Ebaugh reported an increase in the serratus anterior and the lower trapezius muscles to follow the glenohumeral fatigue protocol. [10] The difference in results from the current study to the Umehara et al. [53] study could be inferred that in the current study, external glenohumeral rotators fatigue was significant enough following the practice session to not affect external scapular rotation consistent with the results that were seen in the Ebaugh et al. [10] study.

The current study results found following the statistical analysis a statistically significant increase in posterior scapular tilt following the practice session for the left arm (0.47°) during the descending phase and trends to a significant decrease in posterior scapular tilt (-0.4°) during the ascending phase. Following the statistical analysis, the right arm posterior scapular tilt was not found to be statistically significant in either ascending (-0.74°) or descending (-0.98°) phase of arm elevation. The two-way ANOVA found that there was a statistically significant change, but the change was not detectable by what has been found to be the MDC for posterior scapular tilt in the literature of 2.37°. [6,10,28] Ebaugh et al. [10] found that following the external glenohumeral rotation fatigue protocol, and there was a statistically significant decrease in posterior scapular tilt (-2.5°) from rest to the first 60° of arm elevation. In the Ebaugh et al. [10] study, they also found that there was a decrease in lower trapezius (-5.1kg, 6.6% change), where in the current study, it was found that there was an increase in lower trapezius strength for both the left (1.63kg, 13.2% change) and right (1.42kg, 15% change) arm. The lower trapezius aids in posterior scapular tilt during arm elevation, the strength change that was seen may be effective enough to not allow for the decrease in posterior scapular tilt following the practice session.

The observed scapular motion patterns of upper string musicians during arm elevation and the effect of the practice session on scapular motion are different than expected. On the right arm, there was no detectable change for either external scapular rotation or posterior scapular tilt during arm elevation. During arm elevation, the scapula was only moving in upward scapular rotation. Less than expected external rotation and posterior tilt were seen on the left side. Upper string musicians move their left and right arms in distinct patterns while playing their instrument. The right arm of the upper string musician moves through abduction, horizontal flexion, internal rotation, and external rotation without angles great enough to go overhead. [55] The published literature has explored the scapular motion patterns of individuals with repeated overhead motions, but then there was a paucity of information on the individual who repeatedly raises their arms over their head. Without the demand of going overhead for their performance, it could be inferred that the upper string musician adapted to their scapular movement patterns to produce the patterns observed in the current study.

Along with scapular kinematics, muscular force outputs were collected for both the right and left arms. The strength measurements showed that in the right shoulder, there was a significant decrease in force output for external rotation, abduction, and serratus anterior. The left-arm strength analysis showed that there was significant force output for internal rotation, serratus anterior, and grip strength for the second position. Participants demonstrated statistically significant decrease in force output for internal rotation (-2.28kg, 14.1% change), serratus anterior (-2.02kg, 12.2% change), and grip strength in position two (-3.17kg, 8.5% change) on the left arm. On the right arm participants saw a statistically significant decrease in force output for external rotation (-2.41kg, 14.4% change), abduction (-4.15kg, 19.5% change), and serratus anterior (-1.61kg, 9.6% change). Participants also showed trends toward significant internal rotation force output reduction (-1.78kg, 9.9% change). Ebaugh et al. [10] study found that following the external glenohumeral rotation fatigue protocol serratus anterior fatigue saw a decrease in force output (-6.4kg, 44.9 % change). However, the study also found a decrease in the lower trapezius force output (-5.5kg, 6.6% change). In the current study, we found an increase of strength for in the middle and lower trapezius on both the right (1.12kg, 10% change and 1.42kg, 15% change respectively) and left arm (1.63kg, 13.2% change, and 1.21kg, 13.8% change respectively) following the practice session. This could help to infer why the current study saw similar results for no change in external scapular rotation but not a decrease in posterior scapular tilt in comparison to Ebaugh et al. [10]

This study was not without its limitations. The first limitation would be the sample of convenience of 6 participants for this study. There was not pilot data collected to determine the number of subjects for the study to have reliability measures of standard error and minimal detectable change. A larger sample size would also help to provide a more accurate representation of the upper-string musicians' population. Secondly, there was no EMG data collected to show if the practice session was a fatiguing enough activity to induce altered scapular kinematics. It could be inferred that if the practice session were not fatiguing enough that could be why the study did not find any significant changes in posterior scapular tilt or external scapular rotation. Finally, there was a wide range in experience level and age of the upper string musicians that were tested. This complicates the applicability of the results because of the variability in those experience levels.

Recommendations for Future Research

Future research should focus on the experience level and number of the participants that they are studying. The experience level of the musician changes how an upper-string musician handles their instrument on their support arm. Those with less experience tended to hold their instrument stationary, while those with more experience were shown to rotate their instrument underneath the bow while playing. These different scenarios could lead to different strength and scapular kinematic findings on the support arm.

Future research should also focus on the collection of electromyography data as well as the kinematic data. This could help to answer the question on how for some strength measurements their stronger force outputs were. Future research could also perform follow-up data collection as the individual participants gain more experience to study the effect of experience on scapular kinematics.

Clinical Implications

The results of this study suggest that the upper string musician's scapular kinematics have adapted to the demand of playing their chosen instrument. Common preventative exercises for shoulder conditions included stabilizing the scapula and working on the posture of the patient to gain what has been found to be normal scapular kinematics. The normal scapular kinematics during arm elevation is helping to increase the subacromial space to keep the acromion from pinching onto the rotator cuff tendons. [22,23,55] Changing the way that the scapula moves for upper string musicians could alter the performance that they can give. It could be inferred that this population could benefit from eccentric loading techniques to strengthen the tendon and to reduce the pain of the acromion pinching on the rotator cuff tendons. [35,43]

Conclusion

Following the practice session specific for upper string musicians the results showed that there was not a statistically significant decrease for upward scapular rotation, external scapular rotation, or posterior scapular tilt. The study did find; however, that arm elevation did not influence external scapular rotation or posterior scapular tilt. Further research with more participants is needed to determine if the results are population-specific or not.

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APPENDIX A: IRB APPROVAL

MARSHALL UNIVERSITY
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Office of Research Integrity
Institutional Review Board
One John Marshall Drive
Huntington, WV 25755

FWA 00002704

IRB1 #00002205
IRB2 #00003206

October 12, 2020

Mark Timmons, PhD
School of Kinesiology, Marshall University

RE: IRBNet ID# 1667905-1
At: Marshall University Institutional Review Board #1 (Medical)

Dear Dr. Timmons:

Protocol Title:	[1667905-1] The Effects of Muscle Fatigue on Upper Extremity Motion and Function of Musicians.	
Site Location:	MU	
Submission Type:	New Project	APPROVED
Review Type:	Expedited Review	

In accordance with 45CFR46.110(a)(4), (6), and (7) the above study was granted Expedited approval today by the Marshall University Institutional Review Board #1 (Medical) Chair. An annual update will be required on October 12, 2021 for administrative review and approval. The update must include the Annual Update Form and current educational certificates for all investigators involved in the study. All amendments must be submitted for approval by the IRB Chair prior to implementation and a closure request is required upon completion of the study.

If you have any questions, please contact the Marshall University Institutional Review Board #1 (Medical) Coordinator Margaret Hardy at (304) 696-6322 or hardyma@marshall.edu. Please include your study title and reference number in all correspondence with this office.

Sincerely,

Bruce F. Day, ThD, CIP
Director, Office of Research Integrity

- 1 -

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APPENDIX B: CONSENT FORM

<u>Informed Consent to Participate in a Research Study</u>

The Effect of Exercise on Upper Extremity Pain and Function in Musicians

Mark Timmons PhD, Principal Investigator

Marshall University IRB

Approved on:	10/12/20
Study number:	1667905

Key Information

You are invited to participate in a research study. Research studies are designed to gain scientific knowledge that may help other people in the future. You may or may not receive any benefit from being part of the study. Your participation is voluntary. Please take your time to make your decision and ask your research investigator or research staff to explain any words or information that you do not understand. The following is a short summary to help you decide why you may or may not want to be a part of this study. Information that is more detailed is listed later in this form. The purpose of the study is to investigate how the motion of your shoulder changes while you are playing your musical instrument. You will be asked to play your musical instrument for about 60 minutes. We will make several measures of your shoulder motion and strength before and after you play your instrument. We will also take several ultrasound images of your shoulder. We expect that you will be in this research study for about 90 minutes. The primary risk of participation is fatigue or mild pain in the shoulder or arm following playing.

How Many People Will Take Part in The Study?

About 30 people will take part in this study. A total of 50 subjects are the most that would be able to enter the study.

What Is Involved in This Research Study?

You will fill out several forms asking about your shoulder, arm and back. These forms will not include your name, a number that we assign will identify your records. These forms will help us determine the level of function of your arm and shoulder, and if there are symptoms of shoulder injury. After completing the forms, we will make several measurements of your shoulder and arm strength and range of motion. We will use small handheld devices to make the measurements of your arm length, strength (arm, grip, and shoulder) and shoulder range of motion. After these measurements, we will use an ultrasound machine to make several images of your shoulders. We will need to put your arm in several positions to make these images. We will then place several small sensors around your shoulder and arm, these sensors will help us measure your arm and shoulder motion and your muscle activity. You will then play your musical instrument for about 50 minutes; we will provide you instruction and the sheet music for what you will play. We will then repeat the strength, motion, and ultrasound measure procedures.

What about Alternative Procedures?

You do not have to participate in this study.

Subject's Initials ________

What Are Your Rights as A Research Study Participant?

You may choose not to take part, or you may leave the study at any time. Refusing to participate or leaving the study will not result in any penalty or loss of benefits to which you are entitled. If you decide to stop participating in the study, we encourage you to talk to the investigators or study staff first.

The study investigator may stop you from taking part in this study at any time if he/she believes it is in your best interest; if you do not follow the study rules; or if the study is stopped.

Detailed Risks of The Study

We will need to put your arm in several positions to take the ultrasound images. Some of these positions could be uncomfortable, if necessary, we can change the position to make it more comfortable. The strength testing and music playing could produce fatigue of your arm and shoulder muscles like the feelings you have while playing your instrument in practice, rehearsal, or concerts sessions. You also might experience pain while playing your musical instrument. Please inform the investigators if you do experience pain at any time during the testing.

What About Confidentiality?

We will do our best to make sure that your personal information is kept confidential. However, we cannot guarantee absolute confidentiality. Federal law says we must keep your study records private. Nevertheless, under unforeseen and rare circumstances, we may be required by law to allow certain agencies to view your records. Those agencies would include the Marshall University IRB, Office of Research Integrity (ORI) and the federal Office of Human Research Protection (OHRP). This is to make sure that we are protecting your rights and your safety. If we publish the information we learn from this study, you will not be identified by name or in any other way.

What Are the Costs of Taking Part in This Study?

There will be no cost to you for taking part in this study.

Will You Be Paid for Participating?

You will receive no payment or other compensation for taking part in this study.

What About Identifiable Private Information or Identifiable Biospecimens?

Your information collected as part of the research, even if identifiers are removed, will not be used, or distributed for future research studies.

Whom Do You Call If You Have Questions or Problems?

For questions about the study or in the event of a research-related injury, contact the study investigator, **Mark Timmons at 304 696 2925**. You should also call the investigator if you have a concern or complaint about the research.

Subject's Initials _______

For questions about your rights as a research participant, contact the Marshall University Office of Research Integrity (ORI) at (304) 696-4303. You may also call this number if:

- You have concerns or complaints about the research.
- The research staff cannot be reached.
- You want to talk to someone other than the research staff.

You will be given a signed and dated copy of this consent form.

SIGNATURES

You agree to take part in this study and confirm that you are 18 years of age or older. You have had a chance to ask questions about being in this study and have had those questions answered. By signing this consent form, you are not giving up any legal rights to which you are entitled.

____
Subject Name (Printed)

____ _______________
Subject Signature Date

____
Person Obtaining Consent (Printed)

____ _______________
Person Obtaining Consent Signature Date

Subject's Initials ________

APPENDIX C: DATA COLLECTION FORM

Subject ID number: **Date: / /**

Data Collection Forms

The Effects of Muscle Fatigue on Upper Extremity Motion and Function of Musicians.

Procedure Checklist

1. Inclusion & exclusion criteria
   a. Eligibility Screening exam
2. Subject Informed Consent
   a. Read, discuss, ask questions, sign
3. General Questions
   a. Intake information
   b. Patient reported outcomes (PENN, DASH)
   c. Demographic (Height, Weight, Arm length, posture assessment)
4. Clinical Evaluation (DYSK, RTC, Elbow)
5. Strength Procedure
   a. ER
   b. IR
   c. ABd
   d. Grip strength
6. Ultrasound Imaging
7. Motion capture and EMG
8. Musician fatigue protocol
9. Repeat motion capture and EMG
10. Repeat strength procedure
11. Repeat Ultrasound imaging

Inclusion criteria:

___1. Greater than or equal to 18 years of age
___2. Student or Faculty of the MY School of Music or Professional Musician

Exclusion criteria (any 1 excludes):

1. Greater than 70 years
2. Active or passive cervical spine range produces shoulder symptoms
3. Does not play musical instrument
4. Systemic musculoskeletal disease
5. Shoulder and / or upper extremity pain ≥7/10

Participant meets inclusion/exclusion criteria (circle one):

1= Yes, continue **2= No**, stop

Page **1** of **11**

Research Study Questionnaire
Participant completes:

DOB (mm/dd/yy): ____/___/____

Age: _____ (years) Sex: 1 = Female 2 = Male

1. What is your primary musical instrument? ________________________________
2. At what age did you start playing this instrument? ____________________________
3. On an average day, how many hours per day do play/practice?__________________
4. During an average week, how many days per week do play/practice?
5. Which side is your dominant side? Which hand do your write with or throw a ball with?
   1 = Right
   2 = Left
   3 = Ambidextrous
6. **Do you have any systemic musculoskeletal disease (like Rheumatoid Arthritis)?**
   (Circle One) 1 = Yes If yes, please list______________________
   2 = No
7. **Do you have shoulder pain or have had shoulder pain in the last 6 months?**
   (Circle One) 1 = Yes 2 = No
8. **Which shoulder is your dominant shoulder?**
   1 = Right
   2 = Left
   3 = Ambidextrous
9. **How would you rate your shoulder today (as "a percentage of normal")?**
   (0% - 100% with 100% being normal) = ______**%**
10. **Do you have a known shoulder problem/ pathology?**
    1 = Yes 2 = No
    a. If yes, which shoulder? 1 = Right 2 = Left 3= Both
    b. If yes, have you sought treatment for this problem
       1 = Yes 2 = No
    c. If yes, when did your shoulder pain start?
       1 ____ Less than 6 weeks ago
       2 6-12 weeks ago
       3 ____ More than 12+ weeks ago
       4 ____ I do not have shoulder pain
    d. If yes, please describe: ____________________________________
       ____
       ____

____
____

11. **How would you rate your upper extremity today as "a percentage of normal"?**
(0% - 100% with 100% being normal) = ______**%**

12. **Do you have a known upper extremity problem/ pathology?**
1 = Yes 2 = No
    a. If yes, which upper extremity? 1 = Right 2 = Left 3= Both
    b. If yes, have you sought treatment for this problem
    1 = Yes 2 = No
    c. If yes, when did your extremity pain start?
    1 ____ Less than 6 weeks ago
    2 ____ 6-12 weeks ago
    3 ____ More than 12+ weeks ago
    4 ____ I do not have shoulder pain
    d. If yes, please describe: ______________________________

13. **How would you rate your neck / upper trunk today as "a percentage of normal"?**
(0% - 100% with 100% being normal) = ______**%**

14. **Do you have a known neck / upper trunk problem/ pathology?**
1 = Yes 2 = No
    a. If yes, which **neck / upper trunk**? 1 = Right 2 = Left 3= Both
    b. If yes, have you sought treatment for this problem
    1 = Yes 2 = No
    c. If yes, when did your **extremity** pain start?
    1 ____ Less than 6 weeks ago
    2 ____ 6-12 weeks ago
    3 ____ More than 12+ weeks ago
    4 ____ I do not have shoulder pain
    d. If yes, please describe: ______________________________

Subject ID number: Date: / /

Penn Shoulder Score

PENN SHOULDER SCORE **Part I: Pain & Satisfaction:** Please circle the number closest to your level of pain or satisfaction	
Pain at rest with your arm by your side: 0 1 2 3 4 5 6 7 8 9 10 No Pain Possible — Worst Pain	office use only _______ (10 - # circled)
Pain with normal activities (eating, dressing, bathing): 0 1 2 3 4 5 6 7 8 9 10 No Pain Possible — Worst Pain	_______ (10 - # circled)
Pain with strenuous activities (reaching, lifting, pushing, pulling, throwing): 0 1 2 3 4 5 6 7 8 9 10 No Pain Possible — Worst Pain	_______ (10 - # circled)
PAIN SCORE:	=____**/30**
How satisfied are you with the current level of function of your shoulder? 0 1 2 3 4 5 6 7 8 9 10 Not Satisfied — Very Satisfied	=____**/10** (# circled)

Page 4 of 11

Subject ID number: Date: / /

Part II: Function: Please circle the number that best describes the level of difficulty you might have performing each activity.	No difficulty	Some difficulty	Much difficulty	Can't do at all	Did not do before injury
1. Reach the small of your back to tuck in your shirt with your hand.	3	2	1	0	X
2. Wash the middle of your back/hook bra.	3	2	1	0	X
3. Perform necessary toileting activities.	3	2	1	0	X
4. Wash the back of opposite shoulder.	3	2	1	0	X
5. Comb hair.	3	2	1	0	X
6. Place hand behind head with elbow held straight out to the side.	3	2	1	0	X
7. Dress self (including put on coat and pull shirt on overhead.	3	2	1	0	X
8. Sleep on affected side.	3	2	1	0	X
9. Open a door with affected side.	3	2	1	0	X
10. Carry a bag of groceries with affected arm.	3	2	1	0	X
11. Carry a briefcase/small suitcase with affected arm.	3	2	1	0	X
12. Place a soup can (1-2 lbs.) on a shelf at shoulder level without bending elbow.	3	2	1	0	X
13. Place a one gallon container (8-10 lbs.) on a shelf at Shoulder level without bending elbow.	3	2	1	0	X
14. Reach a shelf above your head without bending your elbow.	3	2	1	0	X
15. Place a soup can (1-2 lbs.) on a shelf overhead without bending your elbow.	3	2	1	0	X
16. Place a one gallon container (8-10 lbs.) on a shelf Overhead without bending your elbow.	3	2	1	0	X
17. Perform usual sport/hobby.	3	2	1	0	X
18. Perform household chores (cleaning, laundry, cooking).	3	2	1	0	X
19. Throw overhand/swim/overhead raquet sports. (circle all that apply to you)	3	2	1	0	X
20. Work full-time at your regular job.	3	2	1	0	X
SCORING: Total of columns = (a) Number of "X's" x 3 = (b), 60 – (b) = (c) (if no "X's" are circled, function score = total of columns) Function Score = ____(a) / ____(c) = ____ x 60 = ____/60					

Page 5 of 11

Screening Exam
Research Team completes

Subject height: __________(cm) **Subject weight:**_______________(Kg)

Pulse __________________ **BP** ____________________

Posture assessment	measure 1	measure 2
T1-T3 angle	___________	___________
T10-T12 angle	___________	___________

Arm Length

	Right	Left
Upper arm	Right	Left
Trial 1 (cm)	___________	___________
Trial 2 (cm)	___________	___________
Lower arm	Right	Left
Trial 1 (cm)	___________	___________
Trial 2 (cm)	___________	___________

Shoulder PROM:	Right	Left
ER	___________	___________
IR	___________	___________
Abduction	___________	___________
Flexion	___________	___________
Hort. Flex	___________	___________

Cervical motion reproduces shoulder pain: Yes No

Right lateral flex	___________
Left lateral flex	___________
Flexion	___________
Extension	___________
Right rotation	___________
Left rotation	___________

Subject ID number: Date: / /

Force, Pain

Trial	LEFT		RIGHT	
	Pain (0-10)	Force (lbs.)	Pain (0-10)	Force (lbs.)
ER 1				
IR 1				
ABD 1				
SA 1				
ER 2				
IR 2				
ABD 2				
SA 2				
Grip 2_1				
Grip 2_2				
Grip 3_1				
Grip 3_2				
LT 1				
MT 1				
LT 2				
MT 2				

	Right 1	Right 2	Left 1	Left 2
2nd Pad grip				
3rd Pad grip				
4th Pad grip				
Key Grip				

PRE-Scapular Dyskinesia Test, External load, 0 lbs. 3 lbs. (BW < 68.2kg, 150lbs), 5 lbs. (BW >68.2kg, 150)

Left

Flexion	Normal	Subtle	Obvious
Classification	Winging	Shrugging	Dumping

Right

Flexion	Normal	Subtle	Obvious
Classification	Winging	Shrugging	Dumping

Pulse ____________________ **BP** ______________________

******************************POST FATIGUE******************************

Pulse ____________________ **BP** ______________________

Post Fatigue Force, Pain

Trial	LEFT		RIGHT	
	Pain (0-10)	Force (lbs.)	Pain (0-10)	Force (lbs.)
ER 1				
IR 1				
ABD 1				
SA 1				
ER 2				
IR 2				
ABD 2				
SA 2				
Grip 2_1				
Grip 2_2				
Grip 3_1				
Grip 3_2				
LT 1				
MT 1				
LT 2				
MT 2				

	Right 1	Right 2	Left 1	Left 2
2nd Pad grip				
3rd Pad grip				
4th Pad grip				
Key Grip				

POST Fatigue Scapular Dyskinesia, External load, 0 lbs. 3 lbs. (BW < 68.2kg, 150lbs), 5 lbs. (BW >68.2kg, 150)

Left

Flexion	Normal	Subtle	Obvious
Classification	Winging	Shrugging	Dumping

Right

Flexion	Normal	Subtle	Obvious
Classification	Winging	Shrugging	Dumping

Posture assessment	measure 1	measure 2
T1-T3 angle	____________	____________
T10-T12 angle	____________	____________

US Imaging Shoulder Characteristics

*****************************PRE FATIGUE******************************

Right Shoulder File name (on US machine): ________________________

Bicep tendon cross section (arm on thigh, mm) **Image 1** **Image 2**

Right shoulder, image# _______ _____ _____

Supraspinatus Tendon Images B-mode, modified Crass position

Tendon x-section thickness in mm (thickest portion): **Image 1** **Image 2**

Right shoulder, image# _____ _____ _____

Tendon longitudinal thickness in mm **Image 1** **Image 2**

Right shoulder, image# _____ _____ _____

Acromial Humeral Distance

Right shoulder (posterior, mm) **Image 1** **Image 2**

Arm at 0°, image# ________ _____ _____

Arm at 45°, image# ________ _____ _____

Left Shoulder File name (on US machine): _________________________

Bicep tendon cross section (arm on thigh, mm) **Image 1** **Image 2**

Left shoulder, image# __ _____ _____

Supraspinatus Tendon Images B-mode, modified Crass position

Tendon x-section thickness in mm (thickest portion): **Image 1** **Image 2**

Left shoulder, image# ________ _____ _____

Tendon longitudinal thickness in mm **Image 1** **Image 2**

Left shoulder, image# ________ _____ _____

Acromial Humeral Distance

Left shoulder (posterior, mm) **Image 1** **Image 2**

Arm at 0°, image# _______ _____ _____

Arm at 45°, image# _______ _____ _____

Subject ID number: Date: / /

******************************POST FATIGUE******************************

Right Shoulder File name (on US machine): ____________________

Bicep tendon cross section (arm on thigh, mm) **Image 1** **Image 2**

Right shoulder, image# _______ _____ _____

Supraspinatus Tendon Images B-mode, modified Crass position

Tendon x-section thickness in mm (thickest portion): **Image 1** **Image 2**

Right shoulder, image# ______ _____ _____

Tendon longitudinal thickness in mm **Image 1** **Image 2**

Right shoulder, image# ______ _____ _____

Acromial Humeral Distance

Right shoulder (posterior, mm) **Image 1** **Image 2**

Arm at 0°, image# _________ _____ _____

Arm at 45°, image# ________ _____ _____

Left Shoulder File name (on US machine): ____________________

Bicep tendon cross section (arm on thigh, mm) **Image 1** **Image 2**

Left shoulder, image# ___ _____ _____

Supraspinatus Tendon Images B-mode, modified Crass position

Tendon x-section thickness in mm (thickest portion): **Image 1** **Image 2**

Left shoulder, image# ________ _____ _____

Tendon longitudinal thickness in mm **Image 1** **Image 2**

Left shoulder, image# ________ _____ _____

Acromial Humeral Distance

Left shoulder (posterior, mm) **Image 1** **Image 2**

Arm at 0°, image# ________ _____ _____

Arm at 45°, image# _______ _____ _____

APPENDIX D: PREDETERMINED MUSICAL PIECE