RELATIONSHIP BETWEEN THE OBSERVATION OF TYPES OF SCAPULAR DYSKINESIS AND PEAK MUSCLE ACTIVITY OF THE SCAPULAR STABLIZING MUSCLES

A THESIS

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INTRODUCTION

The shoulder complex is very intricate and includes articulations at the acromioclavicular joint, sternoclavicular joint, glenohumeral joint, as well as the scapulothoracic articulation. Technically, the scapulothoracic articulation is not a true joint, but scapular movement plays a large role in glenohumeral rhythm.[1] The shoulder has the largest degree of freedom compared to other joints in the body, but this freedom comes with a loss of stability. This puts increased stress on dynamic stabilizers such as the rotator cuff and static stabilizer such as the glenoid labrum. The articulations which make up the shoulder complex, need to be functioning properly to avoid injury and to ensure maximum athletic performance.[2]

Overhead sports which require overhead motion past 90° such as swimming, volleyball, baseball, and softball demand more of the shoulder complex because of the nature of the sport. Since these sports require repetitive overhead motion of the shoulder, if the articulations are not working properly, an injury is likely to occur. If the movements through the kinetic chain are not completed appropriately and failure occurs at some point, it could be for many reasons. Biomechanical, musculature, ligament, bone, and nerve issues could all be a culprit for putting the athlete at risk for injury.[3] Because of the complexity of shoulder movement; certified athletic trainers must understand the kinetic chain concept and master the anatomy to be able to accurately assess any injury.

A common shoulder dysfunction that has been observed is scapular dyskinesis, which can be defined as: "an alteration in the normal position or motion of the scapula during coupled scapulohumeral movements".[4] The scapula needs to maintain proper alignment along the thoracic wall in order to stabilize the glenohumeral joint and allow transfer of forces through the shoulder. Causes of dyskinesis may be from bony malalignment, muscular imbalance, or a loss of protraction/retraction control. If scapula function is altered entire kinetic chain can be affected by changing the force on the glenohumeral and elbow joints, decrease the efficiency of the rotator cuff and possibly result in impingement, instability, and labral injuries.[1]

The muscles that have been shown to be most important for scapular stabilization are the rhomboids, serratus anterior, lower trapezius, and upper trapezius.[1,5] The serratus anterior originates along the first 7-10 ribs and the intercostal muscles, and inserts under the scapula on the lower medial scapular border.[6] The trapezius is a broad, triangular muscle originating from the occiput of the skull to the lower thoracic spine and inserting onto the clavicle, acromion, and spine of the scapula.

The serratus anterior and lower trapezius have been found to be most susceptible to inhibition and a likely cause for muscle related scapular dyskinesis. The serratus anterior, rhomboids, and lower trapezius make up the crucial lower force couple and are responsible for the inferior stabilization as well as upward rotation of the scapula.[5,6] These muscles work together to control retraction and general stability of the scapula.[5]

Inhibition can result in a loss of force generated by the muscle and an alteration in the normal muscle firing and muscle coupling in the shoulder.[1] Through rehabilitation and implementation of Moseley scapular core exercises, the surrounding muscles of the scapula can regain their activity.[6] The Moseley core exercises which have shown to generate the most activity of scapular stabilizers in healthy subjects include; push-up plus, low row, press-up, and scaption.[6] Moseley's core exercises can be found within many scapular rehabilitation programs, but there are many more exercises to choose from that activate the scapular stabilizers.

The lower trapezius has been shown to be weak in common shoulder injuries and is often difficult to target with exercises. The lawnmower exercise, with the pulling motion, has been effective at activating the lower trapezius to clinically moderate levels as well as activating the upper trapezius and serratus anterior.[5] The serratus anterior has been shown to be weakened with injured throwers and this is thought to be because of a change in activation patterns while in motion. The push-up plus exercise has been found to be able to activate the serratus anterior to very high levels.[6] The shoulder-shrug exercise has been most effective at producing the greatest amount of electromyography (EMG) activity within the upper fibers of the trapezius.[6]

The purpose of this study was to analyze EMG activity of the serratus anterior, upper trapezius, and lower trapezius during selective exercises in individuals with normal and abnormal scapular motion. An observational descriptive study between EMG activity and three types of scapular dyskinesis will be performed. It is anticipated that specific scapular stabilizing muscles would show a decrease in activity, resulting in scapular dyskinesis. Additionally, the study examined if a relationship exists between muscle activity and types of scapular dyskinesis.

METHODS

The purpose of this study was to determine if decreased scapular stabilizing muscle activity as shown by electromyographic (EMG) analysis would lead to types of scapular dyskinesis. This information can be found by comparing the observation of four groups of scapular dyskinesis with EMG activity readings of the serratus anterior (SA), lower trapezius (LT), and upper trapezius (UT).

The following is discussed: Research design, Subjects, Preliminary Research, Instruments, Procedures, Hypothesis, and Data Analysis.

Research Design

This study was an observational descriptive study design. There were three independent variables; serratus anterior, lower trapezius, and upper trapezius peak percentage of muscle activity during the two exercises. The peak percentage was found by dividing the maximal voluntary isometric contraction (MVIC) by the peak activity of each muscle during both exercises. The trend between types of scapular dyskinesis and muscle activity was found with the subject’s mean value from each muscles average peak contraction for each exercise and compared with what type of dyskinesis they were categorized as.

Two independent variables were utilized in this study. The first was the independent between subject's variable of type of scapular dyskinesis. There was a grading scale of four types of scapular dyskinesis: Type 1: prominence of the inferior medial scapular border and is primarily an abnormal rotation around a transverse axis; Type 2: prominence of the entire medial border and represents abnormal rotation around a vertical axis; Type 3: superior translation of the entire scapula and prominence of the superior medial scapular border; and Type 4: none, presenting with symmetrical scapular movement.[4,5] The second independent variable was the within subject variable of exercises performed during the EMG testing; the lawnmower exercise, and the push-up-plus. By measuring EMG activity of the serratus anterior, upper trapezius, and lower trapezius we were able to observe any decrease in firing and compare those results with the type of scapular dyskinesis the subject presented with to find a trend.

Subjects

Subjects included 22 NCAA Division II Baseball players. Overhead athletes were defined as athletes participating in any sport which requires arm movement beyond 90° of humeral abduction. The subjects were Division II collegiate student-athletes from California University of Pennsylvania. The inclusion criteria included:

(1) Being a collegiate overhead athlete

(2) Between the ages of 18-30

(3) Have full clearance from a physician to participate in their sport

(4) No history of shoulder surgery within the last six months.

With this study being observational there was not very much physical activity demanded of the subject creating a very low risk of injury. Demographic information was gathered via a data collection sheet and included: (1) Weight (either over or under 150 pounds), (2) Sport played, (3) Position played, and (4) Dominant arm. An informed consent was read and signed by each participant prior to the beginning of the study (Appendix C1).

Preliminary Research

The purpose of preliminary research was to familiarize the researcher with the procedures of the EMG equipment. In order to conduct this study effectively, it was necessary for the researcher to become efficient in experiment set-up, become quick with appropriate EMG electrode placement, and be able to effectively communicate directions. Additionally, the preliminary research allowed the researcher to determine approximate time for each subject to complete the study, which took approximately forty minutes.

Instruments

The researcher used a demographic sheet (Appendix C5) to determine dominant arm, position played, sport played, and weight for either over or under 150 lb. The study used the following equipment: Theraband® [Akron, OH] (green and black), 5lb dumbbell, 3lb dumbbell, Biopac MP150® [Goleta, CA], pre-gelled disposable Ag-AgCl surface electrodes with a diameter of one centimeter, and a metronome.

Identifying Scapular Dyskinesis

The movements performed for the identification of types of scapular dyskinesis included horizontal humeral abduction in the sagittal, frontal, and 45° in-between sagittal and frontal planes. The subjects' movements were recorded in the data collection sheet by the observations of the researcher. The dumbbells were used for resistance to accentuate any presentation of scapular dyskinesis with the athlete. The metronome was used to keep track of speed regulation during the movements; subjects were given three beats up and three beats down.[9]

Exercise Testing

For exercise testing the subjects used Therabands® of medium resistance (green) for warm-ups before the EMG analysis with the sagittal, frontal, and 45° in-between with thumbs-up and thumbs-down arm raises. The exercises for the EMG analysis included the lawnmower exercise, and push-up plus (Figure 1 and 2). These exercises were selected based on their ability to target the serratus anterior and lower trapezius muscles during activity.[5,6] The serratus anterior and lower trapezius form an important force couple with the translation of the scapula and both have been shown to have decreased activity in subjects presenting with scapular dyskinesis.[5] The metronome was utilized while performing the exercises for the EMG analysis as well as the exercises for scapular dyskinesis in order to control for time taken to complete the movements.

This timing for the metronome was three beats up and three beats down.[9] The exercises were repeated five times each with the repetitions being averaged for one value. If exercises were not completed as directed, that repetition was thrown-out and the exercise was repeated until five complete repetitions were gathered.

Push-up Plus Exercise

The push-up plus is a multijoint exercise that takes the common pushup a little bit further. The participant starts with hands shoulder width apart, fingertips facing forward, back straight, and legs together with body weight on toes. The subjects perform a regular push-up keeping elbows into the side of the torso while lowering body to the ground. When their chest hit the floor surface they were instructed to begin pushing body weight up, when their elbows got to the extended position, they were asked to push their body a little further up by protracting the scapulas and rounding shoulders toward the ground. (Figures 1 and 2)

Figure 1. Start of Push-Up-Plus

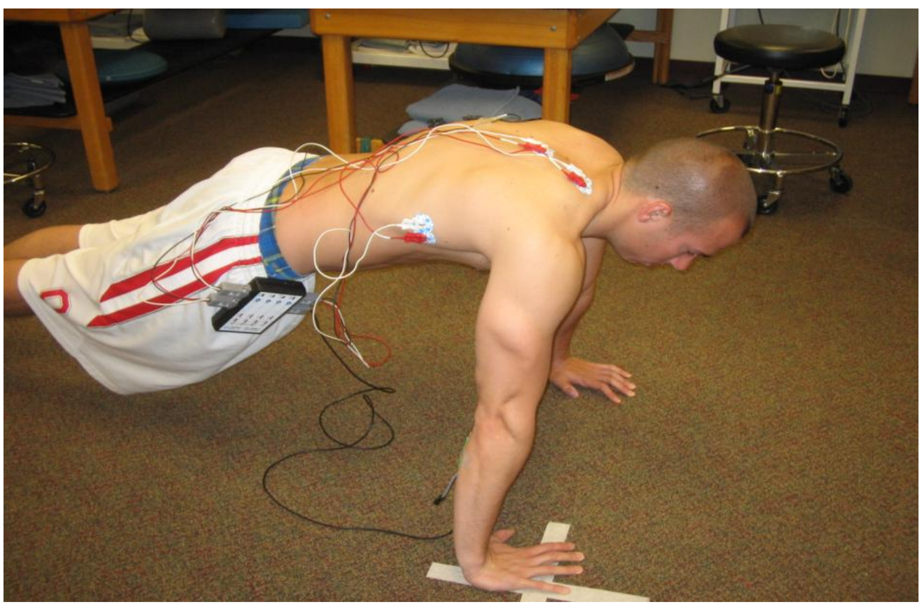


Figure 2. End of Push-Up-Plus

Lawnmower Exercise

The lawnmower exercise is a multijoint exercise that mobilizes joints in a diagonal pattern from the contralateral leg through the trunk to the ipsilateral arm. These multijoint exercises use force-dependent integrated muscle activation patterns to coordinate the motions of connected joints and to produce efficient and stable distal joint positions though the production of interactive moments. They have been found to generate higher gains in strength than single joint exercises because of the facilitation of the force-dependent patterns by increase in neurological activity.[5] This exercise used the motion of hip/trunk extension, trunk rotation, and scapular retraction to activate the muscles to assist in positioning the scapula in retraction.

Targeted muscles for the lawnmower exercise were the SA and LT.[5] Although the SA is often characterized as a scapular protractor, a major component of scapular retraction, the SA is oriented to maintain this position. This is demonstrated by high and early levels of activation as is seen in cocking (scapular external rotation) in baseball, tennis, and arm elevation. It is also shown by the fact that scapular position in long thoracic nerve palsy is one of internal rotation and anterior tilt, which is more characteristic of loss of external rotation control.[1,7] For this study, subjects began the exercise with their trunk flexed and rotated to the contralateral side from the instrumented arm with their hand at the level of their contralateral patella. Subjects were instructed to rotate the trunk toward the instrumented arm and extend the hip and trunk to a vertical orientation while simultaneously placing their instrumented arm at shoulder level. Body movement was smooth, but the retraction position was to be completed with a strong contraction of the muscles.[5] For this study resistance with a grey Theraband® was used to allow for improved EMG readings from the tested muscles.(Figures 3 and 4)

Figure 3. Start of Lawnmower Exercise

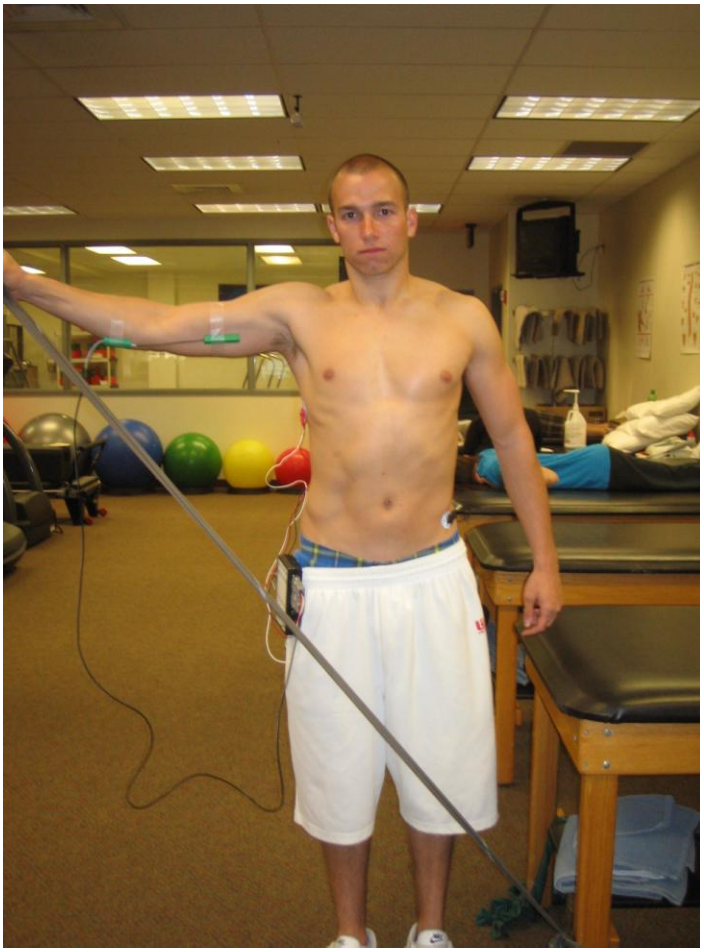


Figure 4. End of Lawnmower exercise

EMG Data

In collecting the EMG data, the researcher used four channels from a Biopac MP150® electromyography machine. Three channels were designated for the muscles tested and the other channel was connected to an electronic biaxial goniometer. The Biopac MP150 was connected to a Microsoft Windows based personal computer with the Biopac's AcqKnowledge® program [Goleta, CA] to collect and analyze the data. The study utilized pre-gelled disposable Ag-AgCl surface electrodes with a diameter of one centimeter. The electrodes were placed on their dominant arm over the motor points of each muscle belly with a center-to-center spacing of 2.5 centimeters.[5] The goniometer was applied to the subject's elbow for both EMG analysis exercises to measure the beginning and end degree of movement.

The raw EMG signal was band pass filtered at 10 and 1000 Hertz (Hz). The researcher utilized a sampling rate of 100 Hz using the AcqKnowledge software. The signals were rectified and normalized before the data analysis was completed. Peak percentage of muscle activity was found from dividing the values of each muscle during MVIC and dividing it by the values found from the same muscle during each exercise. (Appendix C4, Table 4)

Procedures

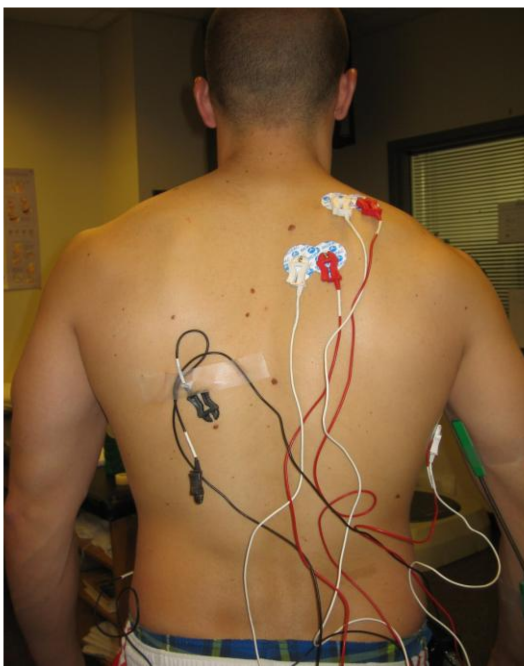
These subjects first signed the informed consent and answered questions about position and arm-dominance. Anyone who had a pre-existing condition or surgery to either arm in the past six months was disqualified. The researcher was also the certified athletic trainer for the team so all pre-existing conditions were known. This did not however affect the team with volunteering; they were able to sign-up on a sheet posted outside of the door during treatments without any pressure.

Identifying Types of Scapular Dyskinesis

The subjects first performed the identifying types of scapular dyskinesis portion of the study. Type of scapular dyskinesis was categorized by instructing the subject to perform humeral horizontal abduction in three planes. With this data collected the subjects were asked to hold either 3lb or 5lb dumbbells, according to the subject's body weight. If they were less than 150 lbs they took the 3 lb. weight, if they were over 150 lbs they took the 5 lb. weight. This weight was added to accentuate any abnormal movement of the scapula that may be produced.[9,11] It has been stated in previous research that muscular fatigue may directly affect scapulohumeral rhythm, resulting in compensatory increased rotation or destabilization of the scapula, which suggests the need to assess with resistance.[9] The subjects were visually assessed one time by a certified athletic trainer while performing humeral horizontal abduction in the frontal and sagittal plane, as well as at 45° in-between frontal and sagittal with thumbs up and down. These movements did not go above 90° to avoid irritation of the supraspinatus.

Electromyographic Analysis

After the movements for identifying types of scapular dyskinesis, the athletes had EMG electrodes placed on the serratus anterior (SA), upper trapezius (UT), and lower trapezius (LT). These muscles were chosen because of previous research showing they are the most important muscles in force couples that control scapular position and motion.[5] (Figure 5 and 6)



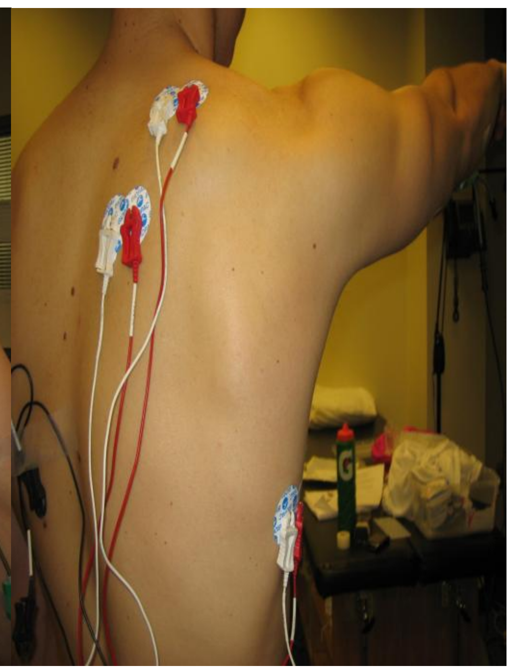


Figure 5. Electrode Set-Up **Figure 6.** Electrode Set-Up

Before testing, each subject performed a warm-up routine consisting of Theraband® exercises with medium resistance bands. These exercises included; low-row, frontal and sagittal plane horizontal arm abduction, and arm extension.

Placement of the electrodes and position of exercise is described in appendix C4, table 4. The positions where chosen for the MVIC based on their performance to best isolate each respective muscle based on standard muscle strength testing positions.[5] Five MVICs for each muscle were performed for three-seconds and then the peak was recorded in order to gather normalization of EMG data and also to provide a reference of electrical activity for each muscle.

The two exercises used to analyze EMG activity of the muscles included the push-up plus (PUP), and lawnmower (LM). Subjects practiced the exercises before the testing to become comfortable with the correct performance movements. Time was kept by a metronome and subjects were given three beats up and three beats down to complete the exercise.[9] Verbal feedback was given by the researcher for correction of exercise. The subjects were instructed to perform each exercise five times. If any exercise was not performed correctly, additional repetitions were added on until five correct exercises were performed.[5] The addition of a one or two exercises occurred approximately three times with two subjects.

Hypotheses

The following hypotheses were tested with this study:

1) There will be a decrease in peak muscle activation of the serratus anterior, upper trapezius, and lower trapezius during exercises (2) performed depending on scapular dyskinesis (4).
2) There will be a relationship between specific muscle inactivity and the presentation of a certain type of scapular dyskinesis.

Data Analysis

All data will be analyzed by SPSS version 17.0 for Windows at an alpha level of ≤ 0.05. The research hypotheses will be analyzed using a 4x2 Factorial MANOVA. (Table 2) All EMG scores were reported as percentage of maximal voluntary contraction. There will also be descriptive statistical information reported with the means of the peak muscle contractions from all three muscles during both exercises compared with the grouping of the subjects into types of scapular dyskinesis. (Table 1)

RESULTS

The purpose of this study was to determine if any of four types of scapular dyskinesis would correlate with a decrease of peak muscle activity from the muscles tested during two exercises. The following section contains the data collected through the study and is divided into three subsections: Demographic Information, Hypotheses Testing, and Additional Findings.

Demographic Information

There were 22 physically active, healthy subjects who participated in this study. The age range was from 18-23 years old. All 22 subjects were active members of the California University of Pennsylvania baseball team consisting of 10 pitchers (45%) and 12 position players (56%). Of these players 18 (82%) were right handed, the remaining 3 (18%) were left hand dominant.

Hypothesis Testing

The following hypotheses were tested in this study. All hypotheses were tested with a level of significance set at $\alpha \leq 0.05$. A 4x2 repeated measures factorial ANOVA was calculated for the effect of muscle activity on types of scapular dyskinesis observed. Descriptive statistics were used to find a trend between peak muscle activity of the three scapular stabilizers; serratus anterior, lower trapezius, and upper trapezius. (Table 1) A complete list of raw statistics is listed in Appendix C4 under table 5.

Table 1. Descriptive Mean Statistics

	Exercise 1 Lawnmower			Exercise 2 Push-Up-Plus		
Type	Peak SA	Peak LT	Peak UT	Peak SA	Peak LT	Peak UT
1	1.67	1.43	1.3	1.77	3.77	2.56
2	1.5	1.5	1.15	.077	5.03	0.37
3	2.1	2.4	2.2	1.3	1.7	1.75
4	1.03	2.05	1.25	4.1	1.7	1.21

Hypothesis 1: There will be a decrease in peak muscle activation of the serratus anterior, upper trapezius, and lower trapezius during exercises performed depending on scapular dyskinesis.

A 4x2 factorial MANOVA was calculated examining the effect of peak muscle activity of the serratus anterior, upper trapezius, and lower trapezius during two exercises on types of scapular dyskinesis observed. (Table 2)

Table 2. Effect of Peak Muscle Activity* During Exercises on Types of Scapular Dyskinesis

Effect	Value	Hypothesis df	Error df	Sig.
Exercise	.887	3	34	.246
Type	.701	9	82.898	.181
Exercise and Type	.696	9	82.898	.170

*Activity in serratus anterior, lower trapezius, and upper trapezius.

Conclusion: No significant effect was found between exercises and peak activity of the muscles tested (*Lambda*(3,34)=.887, p/>.05), or between type of dyskinesis and peak activity of the muscles tested (*Lambda*(9,82.9)=.701, p/>.05). No significant effect was found between the interactions of peak muscle activity and exercises or types of scapular dyskinesis observed (*Lambda*(9, 82.9)=.696, p/>.05).

Hypothesis 2: There will be a relationship between specific muscle peak activity and a certain types of scapular dyskinesis.

Conclusion: There was an analysis of descriptive statistics comparing means of peak muscle activity of the three scapular stabilizing muscles during the two exercises with the four types of scapular dyskinesis which the subjects were put into. (Table 1) With the descriptive mean statistics there was a trend found between a decrease in lower trapezius peak activity during the lawnmower exercise with type one and two dyskinesis. For those who presented with scapular dyskinesis all of their serratus anterior peak activity during the push-up plus exercise was lower compared with the non-dyskinesis group. There was also an increase in peak activity of the upper trapezius during the lawnmower within the type three group compared with other groups.

Additional Findings

There were not any statistically significant findings for the first hypothesis; there were however a few observations made throughout the study by the researcher. Hypothesis two had an observation of a few trends between mean peak muscle activity of certain scapular stabilizers and those presenting with certain types of scapular dyskinesis. Although this data was not collected, there was a pattern of non-dominant scapular dyskinesis present in those who did not present with dyskinesis in their dominant arm. The reason for this observation of non-dominant dyskinesis is not quite clear and there is not literature supporting this finding. This was mostly found with those who were right hand dominant; their left scapula would have a medial border or inferior angle prominence. Their dyskinesis type is consistent with type 1 and type 2, not the more involved type 3 which is superior upward rotation and found to be present in 100% of those with chronic instability and common among those with impingement as well.[4] From those who were observed to have non-dominant arm scapular dyskinesis all were position players. Of those position players many were pitchers in high school, but not starters. The altered demands of the sport, increased attention to scapular stabilizing strength in the weight room, and focusing on mechanics when they made the transition to DII sports could be the reason their dominant arm presents without scapular dyskinesis. The reason why their non-dominant arm would present with dyskinesis though needs further investigation.

Another observation was that of the three subjects recorded as having type two scapular dyskinesis (medial border prominence) all of them were position players. This finding was not unusual because most overhead athletes will present with medial border prominence, but it was interesting that all of the subjects were position players.[13] Because of literature supporting medial border prominence in overhead athletes I was surprised that only three subjects (13.64%) presented with and that a majority of the subjects (59.1%) presented without any scapular dyskinesis at all. This could be due to the fact that they all participate in a weight lifting program which focuses on scapular stabilizing exercises, and our strength and conditioning coach is aware of the importance of scapular stabilizers and their relationship with the kinetic chain.

Of the three subjects recorded as having scapular dyskinesis type 3 (superior border elevation) all were pitchers.(Table 3) The type 3 dyskinesis has the most potential for causing future shoulder injuries because when the scapulas anterior tilt around the horizontal axis is altered it affects the acromion process and its relationship with the humerus in the subacromial space. When the scapula has early movement with anterior tilting it causes the superior border to elevate which can lead to the timing and magnitude of acromion motion changing, the distance of the subacromial space being altered, the angle of the glenohumeral arm may be increased, and maximal muscle activation may be decreased.[7] Within this study there were not any subjects who presented with any shoulder problems.

Table 3. Type of Dyskinesis and Athlete

Type of Dyskinesis	Pitcher	Position
Type 1	2	1
Type 2	0	3
Type 3	3	0
Type 4	5	8

Another observation while doing this study was that the senior pitcher who has had many shoulder problems in years past did not present with any scapular dyskinesis. He throws almost every day and does not complain of any pain beside the occasional tightness. From the intensity of his daily training plan and history of injury it would seem as though he would have scapular dyskinesis. However, he performs scapular exercises everyday and makes sure that everything is proper form, even his posture. After he had those shoulder problems his physical therapist taught him the importance of the scapula with shoulder function and that he has to do those exercises to stay healthy enough to throw. Although the entire team is exposed to scapular strengthening exercises, they do not do them every day or keep a straight posture throughout the day either. If a program were introduced to the baseball team for scapular muscle strengthening and enforced daily there could be the possibility that other pitchers would experience the same positive effects that the one has had throughout the past two seasons.

DISCUSSION

The purpose for this study was to examine the difference of the primary scapular stabilizing muscles activity; serratus anterior, lower trapezius, and upper trapezius during two exercises, observing for four types of scapular dyskinesis which have been identified in previous research. The second hypothesis for this study was developed with the idea that there would be a significance found between certain muscle peak activity and types of dyskinesis; if a person presented with a weak lower trapezius they would be more likely to present with a specific type of dyskinesis. With that prediction the purpose for this study was to find what muscular weakness would present with what kind of dyskinesis so that when an athlete presents with that type we can present a protocol for them specific to certain muscle groups. By determining a relationship between certain muscular imbalances from the stabilizing scapular muscles with a certain type of dyskinesis there could have been more specific protocols for those presenting with dyskinesis. The following section is divided into three subsections: Discussion of Results, Conclusions, and Recommendations.

Discussion of Results

Upon completion of this study it was found that muscle activation patterns of the primary stabilizing muscles of the scapula during the two exercises was not significantly related, but showed a trend on types of scapular dyskinesis observed. Recent literature has focused on the relationship of scapular movement being related to shoulder function and possibly leading to shoulder injuries if scapular dyskinesis is present.[1] It is hard to determine the exact relationship of the scapula and shoulder because there are so many other factors that play a role in the biomechanical function of the upper extremity.[1,4] By continuing to learn more about the relationship between scapular movements and the shoulder there might be a protocol developed to prevent possible injury to the shoulder and elbow. With overhead athletes it is important that proper mechanics of the entire kinetic chain is taught in order for complete transfer of forces from the legs to the trunk through the shoulder and elbow to the hand, which will also help them avoid injury.[4]

By using a sample of overhead athletes who are all currently participating in DII athletics and uninjured it seemed likely that there would be a significant relationship between peak muscle activity and types of scapular dyskinesis in order to better understand why the dyskinesis occurs. The athletes included were all from the baseball team and tested during their in-season. The sample included pitchers and position players in order to do a comparison in Post Hoc testing if any significance was found. However, it was later realized that although some of the players are now position only, many of them were once pitchers in high school.

There is research stating that overhead athletes will present with some abnormalities on their dominant side because of stretching of the surrounding tendons and ligaments, but that has only been shown to affect the dominant shoulder presenting as lower than the non-dominant.[12] With this in mind, it made sense that they may present with scapular dyskinesis from the altered shoulder position, but this study did not find that to be true.

This study involved a limited subject base which was all baseball players and almost all with pitching backgrounds. With other sports involved in the study such as tennis, volleyball, and swimming the results would include athletes who have altered muscular demands of their arms and therefore may present with different findings than just one population.[13] Previous research supporting the fact that gender does not have a significant effect on scapular positioning makes the inclusion of men only more acceptable.[13]

Another possible reason for not finding significant values with the first hypothesis would be that there is human error involved in the study as well as other variables. During the MVIC testing the researcher may not have provided enough resistance to engage the muscle to full potential which might explain why many values for the peak activity for exercises are over 100%. These values can be found in table 6 in C4. While performing the exercises there also could have been error with the electrodes coming off the skin and therefore disrupting the EMG reading for that muscle. There were steps taken such as cleaning the skin surface and taping the electrodes to the skin to prevent them from peeling off; but when the subjects moved around, it was especially difficult to keep the lower trapezius electrodes on because of the medial border of the scapula translation. Mathematical error was minimized from entering all data into SPSS version 17.0 and finding the statistics from the data output.

The purpose of this study was to find a difference between the three primary scapular stabilizing muscles and identifying three types of scapular dyskinesis. The results from the 4x2 MANOVA statistical analysis showed that there was not a significant finding between any of the variables. The results were a little frustrating because they went against what the literature suggests would be true. From past research done with the importance of strengthening the surrounding scapular musculature it would make sense that if there were to be a decrease in muscle activity the subject would be more likely to present with scapular dyskinesis.[5,6] The recent literature describing three types of scapular dyskinesis supports the idea that there must be a reason why the scapula presents with different patterns of abnormality.[9,11] The explanation behind the identification of the types of scapular dyskinesis is missing from literature. This study was focused on the possibility of a difference in scapular stabilizer activity of individuals grouped into three types of scapular dyskinesis compared with a non-dyskinesis group for the reason of why subjects present with different types of scapular dyskinesis. After not finding any statistical significance with the 4x2 Factorial MANOVA there was a descriptive mean statistical analysis done to figure out more with the second hypothesis.

Although the first hypothesis did not have statistical support, there was still a lot of information gathered and this can show us as athletic trainers that the scapula needs to be taken into consideration with shoulder preventative and rehabilitative programs. From the descriptive mean statistics with the second hypothesis, we can see there is a trend between those presenting with lower trapezius weakness and type one and two scapular dyskinesis.(Table 1) There was also a trend that from the dyskinesis group, type two had the lowest peak lower trapezius activity during the push-up plus exercise. This makes sense because the lower trapezius allows for the translation of the center of rotation for the scapula and provides a straight-line pull for scapular rotation.[1,9] If the scapula is not able to translate properly or cannot maintain stabilization along the medial border the inferior angle and medial border will become more prominent. There is also a trend between all types of scapular dyskinesis presenting with a decrease peak activity of the serratus anterior. (Table 1) The serratus anterior plays a role as an external rotator of the scapula as well as preventing scapular winging by anchoring the scapula to the underlying ribs.[1,9] With the type three dyskinesis group there was a trend of an increase in activation of the upper trapezius which would create the superior border elevation that distinguishes type three.[1,9] The descriptive mean statistics of the peak values have helped determine there is a trend between muscle activity during the lawnmower and push-up-plus exercise and subjects presenting with different types of scapular dyskinesis but further research needs to be done to determine the exact relationship.

Scapular strengthening programs should still take athletes into individual consideration such as sport specific, any shoulder injuries, or other issues that they may have experienced or are experiencing. When programs are not individualized they could be overlooking deficits of some muscles groups and overworking the dominant muscle groups which could prolong the healing process even longer or not taking into consideration injury history. These muscle groups may not even be the scapular stabilizing muscles, but larger groups such as the deltoid and pectoralis major. When putting a program together for scapular dyskinesis a proper evaluation should be done to identify all postural distortions, imbalances, and possible underlying injuries that need to be taken into consideration and this needs to be done on a case by case basis.

Conclusions

This study was looking at the peak percentage of muscular activity from the three main scapular stabilizers; serratus anterior, upper trapezius, and lower trapezius during the lawnmower and pushup plus exercises. Along with this data there was an observation performed for four types of scapular dyskinesis with one type representing absence of dyskinesis.

The subjects included 22 healthy DII baseball players from California University of Pennsylvania. From this study there were not any statistically significant findings with the relationship between peak percentages of muscle activity from the scapular stabilizing muscles and identifying scapular dyskinesis.

This study has determined that there is a trend between a decrease in peak activity of the serratus anterior during the push-up plus and with those presenting with scapular dyskinesis. There is also a trend of those presenting with type one and two scapular dyskinesis to have a decrease of peak activity of the lower trapezius during the lawnmower exercise. During the push-up plus it was shown that from the dyskinesis group, type three had the lowest lower trapezius peak activity. This relationship has only been supported by descriptive mean statistics using the peak muscle activity for each muscle during both exercises and comparing them by dyskinesis type one through four.

Even though significant results were not present there is still a known link between scapular movement and arm function, especially in the overhead athlete that has been made from previous research.[7,12,13] This relationship is called the kinetic chain and if there is an alteration in the biomechanics of how one part moves we can expect to see changes along the chain.

Although some of the literature states that there is a connection between scapular dyskinesis and shoulder pathologies there is also literature stating that there is not a relationship.[7,11] With conflicting literature it is hard to come to a concrete conclusion, but it does mean that there is not enough evidence to throw out scapular strengthening programs all together.

From this study it has been shown that there could be a relationship between the three prime scapular stabilizing muscles; upper trapezius, lower trapezius, and serratus anterior with identifying types of scapular dyskinesis. This means that when an athlete presents with scapular dyskinesis we should put them on a program to strengthen the entire surrounding structures. If a stronger relationship can be found between types of dyskinesis and either a decrease or increase in muscle activity we could specify those programs for each athlete. Not only would we take into account individual considerations like history and sport, but we could specify confidently which muscles are underactive or overactive and why. When that relationship is established we can then create programs specifically to activate or avoid which ever muscle groups are involved with the type of dyskinesis the athlete is presenting with. We now know that there could be a relationship between muscular activity of the scapular stabilizing muscles and those imbalances correlating with different types of scapular dyskinesis.

Recommendations

Assessing the relationship between scapular posture and various shoulder injuries can help reveal information on how to correct the abnormalities and establish full function once again. If this study were to be done again the inclusion of many types of athletes from different sports would help get a better idea of if the overhead athlete could have altered muscular patterns from the sports demands which could cause an imbalance resulting in scapular dyskinesis. Literature has stated that there has been no significant difference found between genders and scapular dyskinesis presentation so including females in this study would probably not have an effect on the outcome.[12] There could be a relationship across sports and their muscular patterns with previous shoulder injuries or even scapular posture. Further research into scapular posture possibly leading to shoulder injuries needs to be done to help us better understand if there is a correlation between the two.

Further research into the relationship between the observation of scapular dyskinesis and activity of the scapular stabilizers needs to be done. This study could be done again looking at the total time of muscular activity or peak activity at a given movement during exercise. There is evidence that there could be a relationship established, there just needs to be more research done in order to make a concrete statement that there definitely is a correlation. Including different exercises which have been shown to activate the scapular stabilizing muscles could lead to more findings, and even the inclusion of other scapular stabilizing muscles would most likely result in additional supporting information.

If this study were to be done again it would be a good idea to restrict activity of the subjects before testing. Recent literature has stated that muscle activity prior to observing for scapular dyskinesis can lead to adjustments and make it more difficult to correctly identify the types of dyskinesis.[9] For this study it was difficult to control the subject’s activity prior to testing because an entire day was blocked off with many subjects reporting throughout the day. Requesting the subjects to avoid physical activity for a whole day while in season is not practical, many came in for testing after lifting which could have affected the results and why there were so many who presented without scapular dyskinesis. A better way to do this would have been to have many days with just a couple hours of testing prior to practice or in the morning to ensure that physical activity is minimized before testing. This was not an option for this study because of time restraints and schedule changes with the baseball team. It would be interesting to see what the results would be with many testing days and the physical activity variable minimized prior to the subjects undergoing testing.

This study only required the subject to report for one day and all testing was done. It would be interesting to do repeated testing to see if results would change overtime; this would also allow the subjects to become used to the testing procedures and exercises involved. With this study it took awhile for the researcher to explain and show the exercises well enough for the subject to completely understand, and even then there were a few times the exercises had to be redone. It might have helped to have a short video of the exercises to be performed and how to do them properly, the subjects could have watched this before completing the exercises which might have helped them understand what was being asked of them.

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APPENDICES

APPENDIX A

Review of Literature

Introduction

The primary purpose of this study is to examine the relationship between types of scapular dyskinesis and activity of scapular stabilizing muscles. Sports requiring repetitive overhead motion such as baseball, softball, swimming, volleyball, and tennis are identified as at-risk populations for the development of subacromial shoulder impingement secondary to repetitive placement of the shoulder into vulnerable positions as well as high forces and loads.[1] This impingement causes a decrease in available space for the supraspinatus.[2] Many past research articles have shown there is a strong relationship between scapular dyskinesis and impingement.[3-16] This is because the subacromial and coracohumeral spaces decrease with active humeral elevation, which can create shoulder-impingement symptoms.[2,4,12-16] The resulting kinematic changes from impingement and altered scapular movement have been linked with a decrease in serratus anterior muscle activity, and an increase in upper trapezius muscle activity, or an imbalance of forces between the upper and lower parts of the trapezius muscle.[9,13,15,17]

There is existing evidence supporting scapular dyskinesis presenting as loss of control in external rotation and translation of scapular upward rotation leading to supraspinatus inactivation with shoulder impingement.[1,3,12-14] Research supports that scapular dyskinesis is found in as many as 68% of patients with rotator cuff abnormalities, 94% with labral tears, and 100% with glenohumeral instability.[8]

Scapular dyskinesis has been identified in subjects through various methods in the clinic, including postural asymmetries like scoliosis, muscle atrophy, bony contour, excessive scapular winging, and inferior angle prominence.[10,14,15,18] Overhead athletes will usually present with slight bilateral differences when measuring scapular movement.[1,12,15] These differences are caused by the common finding of the dominant shoulder being positioned lower than the nondominant shoulder. With overhead athletes this difference between dominant and nondominant is accentuated by the repetitive and forceful stretching of the ligaments, joint capsule, and muscles within the dominant shoulder, making it even noticeably lower.[12,15] By finding how certain scapular abnormal movements can possibly put an athlete at greater risk for injury, there should be a way to intervene and correct those movements before injury occurs.[19]

The Anatomy of the Scapula

The scapula is often referred to as the shoulder blade. It lays on the posteriolateral aspect of thoracic ribs 2-7.[15]

Bony landmarks anteriorly include the acromion process, subscapular fossa, and the coracoid process. The acromion is an important landmark of the shoulder anatomy because it is where shoulder impingement is most likely to occur.[3,7-10,13-15] Impingement often involves the supraspinatus, infraspinatus, and teres minor tendons, which all pass underneath the acromion.[2,20] The impingement can be primary or secondary. Primary impingement would be caused by a beaking of the acromion process, with three stages of severity. Secondary impingement is caused by overuse, usually overhead motions, where the rotator cuff muscles become irritated and inflamed, putting pressure underneath the acromion process.[14,20]

Along with the three rotator cuff muscles, there is also a subacromial (also called subdeltoid) bursa located between the acromion, coracoacromial ligament and deltoid superiorly and the supraspinatus tendon and joint capsule of the glenohumeral joint inferiorly.[20] This bursa prevents the tendons from rubbing against the bone, ligaments, or other tendons, and creates a smooth area where skin moves over bone without much underneath.[2,20]

The coracoid process provides an attachment site for the pectoralis minor and short head of the biceps tendon. The other landmark, the subscapular fossa, is the site of muscular attachment for the subscapularis. The subscapularis is part of the rotator cuff, but the only one that will actively pull the arm into internal rotation of the humerus because of the attachment onto the lesser tuberosity of the humerus.[20] The teres minor and infraspinatus muscles will create external rotation with their attachment onto the greater tuberosity of the humerus, along with other movements which will be discussed later.[20,22]

The fossae of the scapula are areas that contain muscle. Within the supraspinous fossa lays the supraspinatus muscle; the infraspinous fossa holds the infraspinatus muscle. As mentioned previously, these both are rotator cuff muscles.[20,22] The rotator cuff is considered a dynamic stabilizer of the glenohumeral joint, and all rotators except the teres minor have attachments to the scapula.[15,20] There are 17 muscles which attach or insert onto the scapula.[4] All of the muscles work with the rotator cuff, which stabilizes humeral movement, and together they create coordinated movements of the glenohumeral articulation by way of force couples.[2,4,16,22] This is a good indication that the scapula plays an important role in the functional movements of the shoulder. The supraspinatus has a primary role of stabilizing the humerus superiorly, but also performs abduction of the humerus.[20,22] The infraspinatus is entirely an external rotator.[20,22] The spine of the scapula serves as a separator between these muscles.[20]

The Glenohumeral Joint

The glenohumeral joint has the most degrees of freedom compared to any other joint in the body.[20] With this freedom comes a sacrifice, a decrease in stability.[2] The muscles surrounding the glenohumeral joint consist of the rotator cuff muscles; supraspinatus, infraspinatus, teres minor, and subscapularis. These muscles are the dynamic stabilizers of the joint; they help to hold the humeral head in the glenoid fossa by active contraction.[2] A static stabilizer of the glenohumeral joint is the glenoid labrum.[2] This labrum is a fibrocartilagenous rim that widens and thickens the glenoid fossa.[2,15,20] The glenoid fossa is not large enough to securely hold the humeral head in place; the labrum doubles the surface area allowing more stability.[15,20]

The scapula influences the glenohumeral joint in many ways. Research debates on whether dyskinesis can lead to, or is a product of shoulder injury.[24,25] In one study by Kibler et al. it was shown that 100% of the participants with shoulder pathologies, specifically instability, were also suffering from scapular dyskinesis.[3] When the arm is elevated in an overhead motion horizontally, the humerus is controlling most of the lower degrees of movement, but when the arm reaches 82° of flexion, the scapula dominates the upper levels of elevation. At 21° the scapula is inactive, at 82° the scapula has moved 14°, at 139°the scapula moves 48°, with 168° of glenohumeral abduction the scapula has moved 54°.[8] This ratio of humeral to scapular motion has been shown to be 2:1 throughout the full range of motion.[3,8,21] Most of the movement occurs at the glenohumeral joint during the first 30° of abduction and the first 60° of flexion at a ratio of 4:1; then it continues as a 5:4 ratio.[21] The scapula is responsible for upward rotation in order to clear the humerus from contacting the acromion, along with the supraspinatus which is responsible for keeping the humeral head stabilized within the glenohumeral joint. If this upward rotation does not occur, or if there is insufficient stabilizing musculature control of the scapula, or weakness of the supraspinatus, the humerus is unable to clear the acromion and this will lead to impingement.[2-5,13-15] Along with the upward rotation, other sources have stated that the scapular motions are more complex than that, involving posterior tilting and external elevation in order for clearance to happen.[8,12,15]

Proper position of the scapula is required for correct transfer of forces from the body through the shoulder to the hand.[26,27] With abnormal scapulohumeral rhythm the shoulder will not function optimally, and injury may result.[26] Scapular dyskinesis affects the scapulohumeral rhythm negatively. With abnormal scapular motion, the forces upon the glenohumeral and elbow joints change.[15,26] This is important for clinicians, who are working with overhead athletes, specifically pitchers and throwing athletes, because there are already so many unnatural torque forces that an increase can severely injure the athlete. Baseball pitchers in particular experience huge torque forces, with a maximum rotational velocity approaching 7,000° per second, possibly the fastest human motion in all sports.[15]

The Scapulothoracic Joint

The scapula and its translational movement over the thoracic ribs create the scapulothoracic joint.[7,28] This is not a true joint but it functions by translation and rotational movements over the thoracic ribs.[29] Without the scapula, the glenohumeral joint would be severely compromised and unable to move properly.[1-29]

Normal scapular movement consists of protraction, retraction, downward rotation, upward rotation, posterior tipping, anterior tipping, medial rotation, and lateral rotation.[1,12,15,29] The upward/downward rotation occurs around the horizontal axis perpendicular to the plane of the scapula, the internal/external rotation occurs around a vertical axis through the plane of the scapula, and anterior/posterior tipping occurs around a horizontal axis in the plane of the scapula.[3]

Kibler has defined four roles for the scapula: providing a site for muscle attachment, providing stability for the glenohumeral joint, providing retraction and protraction of the shoulder girdle around the thoracic wall during motion of the upper extremity, and elevation of the acromion process on the scapula.[4] Along with the biomechanical roles of the scapula, it also serves as an attachment and insertion site for seventeen muscles.[4] The rotator cuff, along with all of the attached muscles, works in coordination to control glenohumeral articulation.[19,20] These muscles create force couples to stabilize and move the scapula and arm.[15,16,19,26] The scapula acts as a stabilizing base from which the muscles can work.[4] It has been shown that with shoulder injuries there is a change in muscle activation patterns and strength.[9,27] Also, abnormal glenohumeral articulation can be a major factor in shoulder injuries, and should be given more attention clinically in order to avoid untimely injuries and rehabilitation.[7,8,30]

Scapular Dyskinesis

The most common definition found for scapular dyskinesis involves an alteration in the normal position or motion of the scapula during coupled scapulohumeral movements.[3,24,25] Scapular dyskinesis is also thought of as abnormal movements of the scapula, presenting bilaterally, or unilaterally.[12] Many overhead athletes will have bilateral differences between scapular movements because of the overuse of their dominant arm.[12] As clinicians it is important to know the likelihood of scapular dyskinesis affecting shoulder injuries.

Scapular dyskinesis has been found to be related to shoulder impingement.[1-3,12-15] In external impingement, the decreased posterior tilt and upward rotation of the scapula prevents elevation of the acromion, which places increased pressure on the rotator cuff and decreases subacromial space during arm elevation.[3] With internal impingement, massive scapular internal rotation and protraction of the dyskinetic position creates glenoid anterior tilting with increased mechanical movement of the humerus and supraspinatus against the glenoid and labrum, which can result in labral tears, and also ‘dead arm’ syndrome.[3]

Scapular dyskinesis can be brought on by either proximal or distal factors, both affecting the movement pattern. Proximal factors include postural alterations of the spine, hip or trunk weakness or inflexibility, scapular stabilizing muscle weakness or neurological lesions in the spinal cord or peripheral nerves.[3] Distal factors are usually the result of muscle inhibition due to injury such as labral tear, instability, rotator cuff tears, impingement, or soft tissue inflexibilities.[3] Muscle inhibition appears to be a nonspecific response to a painful condition of the shoulder rather than a response to specific shoulder pathology.[25,27] Inhibition results in a loss of force generation as well as an alteration in muscle firing and muscle coupling about the shoulder.[29,11] These distal anatomical injuries can be the cause of altered muscle imbalances or activation patterns; in order to correct this cycle, surgery is usually necessary.[3] The proximal causes are directly related to the scapula, while the distal causes are dealing mostly with the shoulder.[3]

A causative factor of scapular dyskinesis that is becoming more recognized is glenohumeral internal rotation deficit (GIRD). This is defined as a bilateral asymmetry of greater than 25° of shoulder range of motion.[30] If an athlete presents with 90° of humeral internal rotation on one side, and only 45° on the other side, they would be a candidate for identifying GIRD. Posterior capsule tightness can be a cause of GIRD and can create abnormal scapular movements during the "windup" of a throw. When the humerus is flexed forward, horizontally adducted, and internally rotated, the tight capsule and muscles pull the scapula into a position that is protracted, internally rotated, and anteriorly tilted.[30] The significance of this finding is that many overhead athletes, specifically throwers, will develop this posterior tightness. The posterior capsule and muscles can become overworked from the stress of repeatedly decelerating the arm, and therefore tightening and creating altered kinematics within the shoulder and possibly putting that athlete at a greater risk of injury.[15,30]

Biomechanical Factors

There are many different sports which use overhead athletes; softball, baseball, swimming, volleyball, tennis, shot put, and javelin. While there are different biomechanical forces occurring with each movement, most overhead throwing athletes will present with an increase in external rotation and a decrease with internal rotation when positioned with the shoulder and elbow at 90°-90°.[15] This can be explained by the rotation of the humerus about its central contact point on the glenoid. With external rotation, the inferior glenohumeral ligament tightens, and if the posterior band is shortened from overuse, there will be a shift of the glenohumeral contact point posterosuperiorly, during combined abduction and external rotation.[3] Because the arc of motion of the greater tuberosity has now shifted posterosuperiorly a greater degree of external rotation can be found.[3,15,26]

Baseball pitching has been known to have the greatest amount of torque put on the elbow and shoulder while performing. Consequently, there is a vast amount of research describing the sequence of events. There are many factors to take into consideration with all overhead athletes. One is the fact that the scapula and glenohumeral joint are closely related. The scapular stabilizer muscles (rhomboids, serratus anterior, middle and lower trapezius) are attached along the inferior, superior, and medial borders, allowing the scapula to move correctly in all of its motions.[11,15,20] The lower fibers of the trapezius are especially important in normal scapular kinematics because of their mechanical role in the translation of the instant center or rotation.[11,15] Weakness of the scapulothoracic muscles results in poor scapular stabilization and excessive movement of the scapula, causing abnormal motion of the humeral head relative to the glenoid fossa, and in turn leading to possible inflammation of the soft tissue.[3,15,29] The scapula acts as a link in the kinetic chain, and is an essential component for the proximal-to-distal transfer of velocity, energy, and forces that accompany overhead actions.[26] The scapula acts to collect and transfer forces to the upper extremity, and if insufficient constraint is provided by structures surrounding the scapula, such as the muscles, ligaments, joint capsule and bony structure, failure occurs in the kinetic chain.[15,26,29] Altered scapular position alters the scapulohumeral rhythm and can change the force on the glenohumeral and elbow joints, decreasing the efficiency of the rotator cuff, which is often associated with many common shoulder problems, including impingement, instability, and labral injuries.[4,8,15,21,26]

Bony posture must also be taken into consideration when evaluating an athlete or patient. Thoracic kyphosis or cervical lordosis may result in excessive scapular protraction, while acromial depression can lead to impingement of the rotator cuff tendons.[8] Clavicular malunions may cause significant shortening of the strut that maintains appropriate scapular positioning on the thoracic wall. Acromioclavicular instability will also affect the loss of communication since the clavicle makes direct contact with the scapula at the acromioclavicular joint such that any alteration would also influence the scapular patterns.[8,15,29] Lower grade instability or arthrosis of the acromioclavicular joint may cause changes in the instant center of rotation of the acromioclavicular joint and alter scapular mechanics. Higher grade instability will produce further protraction of the scapula and acromial depression, leading to loss of strength and impingement of the rotator cuff.[8] Acromioclavicular joint instability may result in a new abnormal motion of the joint with inferior and medial translation of the acromion beneath the clavicle causing further dysfunction of the scapulohumeral rhythm.[8,15]

Scapular motion is a 3-dimensional movement that involves a combination of translation and rotation, which act together to allow efficient humeral motion.[15] During humeral elevation in the scapular plane, the scapula provides a stable base for the upper extremity so that the rotator cuff muscles, specifically the supraspinatus, effectively compress the humeral head into the glenoid thereby decreasing the amount of translation between the glenoid and humeral head. The rotator cuff can lessen the risk of soft-tissue impingement under the coracoacromial arch.[3,23] Internal rotation has been demonstrated to produce greater scapular upward rotation than any other glenohumeral rotation.[15] If an athlete is displaying an increased amount of scapular upward rotation at humeral elevation with glenohumeral internal rotation, they could be at greater risk for subacromial and subcoracoid space impingement.[6,15] Compression of the rotator cuff tendons in the subacromial space alters the biomechanics of the glenohumeral joint causing weakness and reduced range of motion.[7,15] In previous studies, subjects with impingement have been shown to have different scapular kinematics when compared with a control group, showing anterior tilting and decreased posterior tipping of the scapula in the scapular-plane elevation.[3,14,21] Those subjects with shoulder impingement have also been shown to have excessive scapular upward rotation with simple arm movements.[21]

While scapular upward rotation is necessary to avoid impingement with humeral elevation, excessive amounts can have negative functional effects.[8] Determining excessive amounts can be done by bilateral comparisons of the scapulas, which should move in unison. Another abnormal movement is a protracted position of the scapula, which has been shown to be related to shoulder subluxations.[8] The inability to fully retract the scapula prevents the scapula from providing a stable base for cocking of the arm during throwing or elevation of the arm during forward flexion.[15] Loss of scapular retraction leads to excessive arm extension posterior to the plane of the scapula during the throwing motion. This causes increased strain on the anterior capsule and posterior superior labrum.[12]

When it comes to abduction of the arm, it has been said that the “true abduction” is not in the frontal plane, but in the “plane of the scapula”. This is because the scapula is angled at 30° to 45° anterior to the coronal plane. Within the scapular plan, the inferior part of the glenohumeral capsule is not twisted, while the deltoid and supraspinatus are also optimally aligned for elevation of the arm.[26]

All of the joints of the shoulder girdle move simultaneously, but with abduction the glenohumeral joint moves twice as much as the scapulothoracic joint. An analysis of abduction in the scapular plane found a ratio of 3:2 between glenohumeral and scapulothoracic motion. After 30° of abduction the ratio jumps to 5:4 for glenohumeral-to-scapulothoracic movement. This means that for a given arc of movement, the humerus moves 5° on the glenoid, while the scapula moves 4° on the thorax. The reason for the difference after 30° of abduction is because from 0°-30° most of the movement is glenohumeral and upward, while there is a lowering of the scapulothoracic joint for the motion of 30° and upward.[21]

Electromyographic Activity and Scapular Movements

In order to get a better understanding of the exercises which activate the scapular muscles, researchers' measure electromyographic (EMG) activation. The measurement of muscle activity is found by placing surface electrodes over the specific muscle fibers.[31] The exact placement is determined by resistive exercises to attempt to generate 100% muscle contraction or maximum voluntary isometric contraction.[11] Then the subject is asked to perform various movements, so that whichever movements activate the muscle the most can be determined as an effective activation movement for that particular muscle. Not all exercises will activate 100%, but if the exercise is able to generate at least 20%, it is considered a moderate strength gain.[11,32]

Muscle activity surrounding the scapula is important in order for the scapula to maintain its stable base of operation at the scapulothoracic joint.[15,27] If the muscles are not functioning properly because of abnormal motion or asynchrony of firing patterns, overhead athletes are at greater risk for injuries such as subacromial impingement and other overuse syndromes.[3-11,15,16,27]

The serratus anterior, trapezius, rhomboid, and pectoralis minor are scapular stabilizers that are often monitored during EMG research.[11,15-17,22,26,27] The serratus anterior forms a force couple relationship with the trapezius muscle to produce upward rotation of the scapula.[11,15,26] This movement is critical for overhead athletes in order to avoid impingement.[15] In the absence of proper activation of the trapezius and serratus anterior, an individual may present with scapular winging.[11,18,27] A classic case of scapular winging occurs with palsy to the long thoracic nerve, which innervates the serratus anterior.[18]

Function of the Scapula and Glenohumeral Joint

The relationship between the scapula and how the shoulder functions has been established. Scapulothoracic dysfunction has been increasingly recognized as a contributor to many common shoulder disorders.[3,7,8,16,18,26] In order to avoid injuries to the shoulder complex during overhead motions there must be an understanding of why and how the symptoms begin to develop. The close relationship between scapular upward rotation and positions of the greater and lesser tuberosities should be considered because of their relationship to glenohumeral rotation.[8,15,26] Glenohumeral rotation is an important factor in overhead sports and can affect performance negatively if not able to achieve full range of motion.[15] If the humeral-and scapular-control muscles become fatigued, a greater overload and muscle weakness and muscle imbalance will occur in the humeral force couples.[26] These force couples create an abnormal amount of compression and shear stress at the glenohumeral joint.[15,26]

The acronym SICK (scapular malposition, inferior medial border prominence, coracoid pain and malposition, and dyskinesis) has been created by Burkhart et al, who believes with this theory that asymmetry of the scapula is abnormal.[12] This acronym describes the asymmetry of the scapula commonly seen in overhead athletes with shoulder abnormalities. SICK is based upon the theory that asymmetry is a sign of the underlying alteration in the muscle activation associated with various shoulder conditions. A demonstration of this abnormality has not been shown in previous research because of the inability to describe scapular posture 3-dimensionally.[12] There has been support for the statement that an injured overhead athlete may display more asymmetry than healthy overhead athletes, and there may be a pathologic threshold for scapular posture asymmetry at which asymmetry becomes a problem.[12,15,29]

An abnormality seen in the overhead throwing population is the glenohumeral internal rotation deficit (GIRD).[3] This condition is presumed to develop secondary to posterior capsule tightness.[3,15,26,27,29] The percent deficit of internal rotation can be found by dividing the difference between the dominant arm and nondominant arm internal rotation values and multiplying by 100 [((ND-D)/ND)x100].[1] Glenohumeral internal rotation at 90° of humeral elevation significantly tightens the posterior capsule as well as bringing the supraspinatus in closer contact with the acromion.[3,30] When looking at scapular movement with GIRD it has been consistently found that there is an increased anterior tilt of the scapula in those individuals presenting with GIRD.[1,4,7,8]

When treating scapulothoracic disorders, the proximal and distal causative factors must be taken into consideration. Once the complete and accurate diagnosis of all factors causing or contributing to scapular and shoulder problems are established, scapular rehabilitation may be initiated.[1] Surgery might be an option for some of the issues like non-union of the clavicle or acromioclavicular joint.[18] The individual who presents with these symptoms will need rehabilitation back into normal functioning. The starting point for a rehabilitation program would be restoration of flexibility.[31] Stretching of the posterior capsule to regain glenohumeral internal rotation can be accomplished through 'sleeper stretches'.[30] The patient can do this stretch by laying on their side with the affected arm abducted, and the unaffected arm performing the internal rotation stretch.[31] A passive stretch for coracoid based tightness is performed by passive horizontal extension of the shoulders as in an open book position.[31] With this stretch it is important to keep the arms below 90° abduction to avoid thoracic outlet symptoms. General flexibility of the trunk has also been shown to help restore flexibility to the scapulothoracic joint.[12]

Many protocols begin with strengthening the surrounding scapular muscles, otherwise known as periscapular. The goal of this phase is to restore the correct position of external rotation and posterior tilt of the scapula, or retraction.[16,27] The periscapular muscles are often weak from disuse atrophy and inhibition due to pain. Initial strengthening should be performed with exercises that take advantage of the facilitation of periscapular activation through synergistic proximal trunk and hip muscle activation.[11,26,31] These exercises should be performed in a closed chain fashion to avoid straining the distal injured or repaired structures.[31] When starting a scapular muscle rehabilitation program scaption, rowing, push-up with a plus, and press-up exercises are common and often referred to as the Moseley scapular core exercises.[31]

Summary

The literature demonstrates that the scapula has a direct effect on the function of the glenohumeral joint. Muscles that make up the scapular stabilizers need to fire correctly in order for force to be correctly transferred from the torso to the glenohumeral joint. If there is an imbalance of muscle activation scapular dyskinesis can result. Without efficient transfer of forces the glenohumeral joint may suffer an injury. There is evidence that certain shoulder injuries, especially impingement, can also be correlated with scapular dyskinesis.

Different types of scapular dyskinesis are identified by various abnormal motions of the scapula during overhead arm movement. A reason for these variations of scapular dyskinesis is from an alteration in muscle firing. By identifying which muscles are associated with a certain type of scapular dyskinesis, a specific protocol for exercises that effectively activate the correct muscle can be developed. This means that for certain types of scapular dyskinesis, a specific protocol will be given instead of a general scapular stabilizer strengthening program. This will help the athletes because depending of the type of scapular dyskinesis a muscle group could be overactive or not firing at all. By giving them a general protocol it may worsen their symptoms by possibly not working the muscles that are not firing, but perhaps activating the already overactive muscles.

APPENDIX B

The Problem

THE PROBLEM

Sports requiring repetitive overhead motion such as baseball, softball, swimming, volleyball, and tennis are identified as at-risk populations for the development of subacromial shoulder impingement secondary to repetitive placement of the shoulder into vulnerable positions as well as high forces and loads.[8] This impingement causes a decrease in available space for the supraspinatus.[20] Past research has demonstrated a strong relationship between scapular dyskinesis and impingement.[1,2,3,4,5,6,22] This is because the subacromial and coracohumeral spaces decrease with active humeral elevation, which can create shoulder-impingement symptoms.[2,8,19] The resulting kinematic changes from impingement and altered scapular movement has been linked with a decrease in serratus anterior muscle activity, an increase in upper trapezius muscle activity, or an imbalance of forces between the upper and lower parts of the trapezius muscle.[22] The scapular stabilizer muscles (rhomboids, serratus anterior, middle and lower trapezius) are attached along the inferior, superior, and medial borders, allowing the scapula to move correctly in all of its motions.[4,5] The lower fibers of the trapezius are especially important in normal scapular kinematics because of their mechanical role in the translation of the instant center or rotation.[5,6] In one study the serratus anterior was shown to have decreased activity throughout all movements analyzed in those with shoulder impingment.[22] The purpose of this study was to examine the relationship between a decrease in activity from the scapular stabilizing muscles of the serratus anterior, lower trapezius, and upper trapezius during exercises and observe for three types of scapular dyskinesis.

Definition of Terms

The following definitions of terms were defined for this study:

1) Maximum Voluntary Isometric Contraction (MVIC): normalized the data collected by the EMG machine. Served as the reference value to compare the peak muscle activity levels which occurred during the movements.
2) Muscle Activation – The level of recruitment of muscle as sent via the efferent nerve pathway from the brain measured by EMG.
3) Strengthening – 20%-30% of MVIC is considered to be effective for moderate muscle strengthening.[19]

Basic Assumptions

The following were basic assumptions of this study:

1) There was no evidence that the volunteers would respond differently than random subjects.
2) The subjects answered truthfully on the demographic sheet.
3) The equipment was working correctly and properly calibrated.
4) The subjects were overhead athletes with no prior history of upper extremity injury within the last six months, and performed to the best of their ability.

Limitations of the Study

The following were possible limitations of the study:

1) The equipment that was available for this study may not have been the newest version available. This will not affect the study because the equipment that was used was still reliable and valid.
2) The participants may not have had any experience in scapular stabilization strengthening.

Delimitations of the Study

The following were the delimitations of the study:

1) The subjects were college students ages 18-30, from California University of Pennsylvania..
2) Pertained to an injury free populace.
3) Active individuals.

Significance of the Study

Scapular stabilization and activation of the surrounding muscles can help prevent imbalances that can lead to shoulder injuries. Programs involving scapular stabilizer strengthening are seen in the athletic training room, physical therapy clinic and weight room.

This study investigated the difference between decreases in scapular stabilizers and identifying scapular dyskinesis. If there is a relationship between the two, then the support for scapular stabilization programs will grow. Additionally, evidence of this relationship will help athletic trainers understand how to prevent dyskinesis and how to treat it when found. When identifying what type of scapular dyskinesis the athlete presents with, the athletic trainer will be better able to understand what muscles are active and what muscles need to be strengthened in order to correct the imbalance. Through this study a more specific protocol for those with scapular dyskinesis can be developed in order to correct the dyskinesis and prevent serious overuse injuries from occurring. From this study finding a trend with a lower mean average of peak muscle activity from specific scapular stabilizers during two exercises and presenting with a certain type of scapular dyskinesis there can be further research done to determine the relationship and specific protocol exercises to strengthen those muscles.

APPENDIX C

Additional Methods

APPENDIX C1

Informed Consent Form

California University of Pennsylvania

Informed Consent Form

1. Jenna Sherman, who is a Graduate Athletic Training Student at California University of Pennsylvania, has requested my participation in a research study at California University of Pennsylvania. The title of the research is Relationship Between the Observation of Types of Scapular Dyskinesis and Peak Muscle Activity of the Scapular Stabilizing Muscles.

2. I have been informed that the purpose of this study is to better understand the types of scapular dyskinesis and why there are different types. With this relationship there will be evidence that protocols for rehabilitation of scapular dyskinesis can be made specific to the type of dyskinesis instead of general scapular strengthening programs. I understand that I must be 18 years of age or older to participate. I understand that I have been asked to participate along with overhead athletes from baseball, softball, volleyball and swimming. I have no previous head injury, or upper body extremity injury within the last 6 months that might put me at risk for further injury. I also do not have any neurovascular disorders which could interfere with balance and performance of the tasks asked of me. I am physically active, as defined as participating in moderate to intense exercise at least 3 times a week. I am cleared for full participation in my sport by a physician for this current competitive year 2009-2010.

3. I have been invited to participate in this research project. My participation is voluntary and I can choose to discontinue my participation at any time without penalty or loss of benefits. My participation will involve filling out an injury history and demographic form before the study begins. I will be first asked to perform movements to identify types of scapular dyskinesis. These movements include horizontal arm abduction with dumbbell weights that will be performed along with a metronome with three beats up and three beats down. These weights will be determined by my body weight, if under 150lb I will use the 3lb dumbbell, if over 150lb I will use the 5lb dumbbell. The second part of the study involves electromyographic (EMG) analysis of three scapular stabilizing muscles. This involves having electrode pads placed on my skin over the muscle bellies. After placement of the electrodes I will be given an opportunity to warm-up and practice the exercises analyzed which include the lawnmower exercise and push-up plus. The warm-up involves horizontal arm movements with medium resistance Therabands® and 15 push-ups. After the warm-up I will practice the exercises and get used to the metronome of three beats up and three beats down. The first exercise that will be asked of me is the lawnmower, a multijoint exercise that has been shown activate the muscles which provide scapular retraction. The second exercise will be the push-up plus, which is also a multijoint exercise and is a basic push-up with an extension at the end of pushing the body further up by rounding the shoulders and protracting the scapulas. Neither one of these exercises will involve resistance.

4. I understand there are foreseeable risks or discomforts to me if I agree to participate in the study. With participation in a research program such as this there is always the potential for unforeseeable risks as well. Risks with this study are very low because of the use of light weights and constant monitoring of performance. For this study it is important that all movements be performed with good technique and form which decreases risk of injury further. This study does require upper extremity movement which may pose a risk of injury due to possible aggravation of the shoulder. To minimize these risks the researcher will be asking me questions about upper extremity injuries prior to the start of the study. The researcher will also stand by closely during the balance testing in case I need help or begin to lose form.

5. I understand that, in case of injury, I can expect to receive treatment or care in Hamer Hall's Athletic Training Facility. This treatment will be provided by the researcher, Jenna Sherman, under the supervision of the CalU athletic training faculty, all of which can administer emergency care. Additional services needed for prolonged care will be referred to the attending staff at the Downey Garofola Health Services located on campus.

6. There are no feasible alternative procedures available for this study.

7. I understand that the possible benefits of my participation in the research are going to help athletic trainers better understand scapular dyskinesis and create proper rehabilitation protocols. This study can help athletic trainers identify the different types of dyskinesis as well as making them aware that general scapular strengthening programs could potentially be treating the wrong muscles. Through my participation, an understanding of creating specific programs for each type of dyskinesis and strengthening the inactive muscles while treating the overactive muscles can be made.

8. I understand that the results of the research study may be published but my name or identity will not be revealed. Only aggregate data will be reported. In order to maintain confidentially of my records, Jenna Sherman will maintain all documents in a secure location on campus and password protect all electronic files so that only the student researcher and research advisor can access the data. Each subject will be given a specific subject number to represent his or her name so as to protect the anonymity of each subject.

9. I have been informed that I will not be compensated for my participation.

10. I have been informed that any questions I have concerning the research study or my participation in it, before or after my consent, will be answered by:

Jenna Sherman, ATC
STUDENT/PRIMARY RESEARCHER
She1570@calu.edu
269-788-4168

Edwin Zuchelkowski, Ph.D.
RESEARCH ADVISOR

zuchelkowki@cup.edu
724-938-4202

11. I understand that written responses may be used in quotations for publication but my identity will remain anonymous.

12. I have read the above information and am electing to participate in this study. The nature, demands, risks, and benefits of the project have been explained to me. I knowingly assume the risks involved, and understand that I may withdraw my consent and discontinue participation at any time without penalty or loss of benefit to myself. In signing this consent form, I am not waiving any legal claims, rights, or remedies. A copy of this consent form will be given to me upon request.

13. This study has been approved by the California University of Pennsylvania Institutional Review Board.

14. The IRB approval dates for this project are from: 09/01/2009 to May/07/2009.

Subject's signature:____________________________________
Date:____________________

Witness signature:____________________________________ Date:____________________

APPENDIX C2

Institutional Review Board –

California University of Pennsylvania

California University
of Pennsylvania

Proposal Number
Date Received

PROTOCOL for Research Involving
Human Subjects

Institutional Review Board (IRB) approval is required before beginning any research and/or data collection involving human subjects

(Reference IRB Policies and Procedures for clarification)

Project Title ***Relationship Between Muscle Activity of Scapular Stabilizers and Identifying Types of Scapular Dyskinesis***

Researcher/Project Director ***Jenna Sherman***

Phone # ***2697884168*** ***E-mail Address*** ***she1570@cup.edu***

Faculty Sponsor (if required) ***Dr. Zuchelkowski***

Department ***Health Science***

Project Dates ***September 2009*** ***to*** ***May 2010***

Sponsoring Agent (if applicable) _____

Project to be Conducted at *California University of PA, Washington and Jefferson*

Project Purpose: ☒ ***Thesis*** ☐ ***Research*** ☐ ***Class Project*** ☐ ***Other***

Keep a copy of this form for your records.

Approved, September 12, 2005 / (updated 02-09-09)

Please attach a typed, detailed summary of your project AND complete items 2 through 6.

1. *Provide an overview of your project-proposal describing what you plan to do and how you will go about doing it. Include any hypothesis(ses)or research questions that might be involved and explain how the information you gather will be analyzed. For a complete list of what should be included in your summary, please refer to Appendix B of the IRB Policies and Procedures Manual.*

The purpose of this study is to investigate the relationship between scapular stabilizers activity and types of scapular dyskinesis. The electromyographic (EMG) activity will be measured for each muscle to evaluate activity level and at what point the muscle was most active. There will also be an observation of subjects doing arm movements to identify if there is scapular dyskinesis and if so, what type they are presenting with. The data from the EMG analysis will be correlated with the types of scapular dyskinesis found to determine a relationship.

Hypotheses:

The following hypotheses were based upon previous research and the researcher's intuition based on a review of the literature.

1) There will be a difference in a peak muscle activation of the serratus anterior, upper trapezius, and lower trapezius depending on scapular dyskinesis type and exercise performed.

2) There will be a relationship between specific muscle inactivity and a certain types of scapular dyskinesis.

Procedure:

Once approval by the Institutional Review Board at California University of Pennsylvania is received and informed consent and a demographic sheet are obtained, there will be an explanatory session to inform the volunteers of the process. Volunteers will be chosen by verbal requests to the teams. Once the explanatory session has taken place and my volunteers are in place, they will be assigned a date and time to come to the athletic training room to gather the data. They will only be asked to volunteer for one day.

The first task that will be asked of the volunteers will be to perform the movements for identifying types of scapular dyskinesis. They will be instructed as to what the exercises will be; frontal, sagittal horizontal arm raises, as well as 45° in-between those two planes with thumbs up and thumbs down. During these instructions the volunteers will be instructed not to go above 90° of humeral abduction as to avoid irritation of the rotator cuff. They will also listen to the metronome to get used to the timing and to the allowed three beats up and three beats down. After explaining the exercises they will be weighed in to determine what amount of weight the volunteer will use for the dumbbells. Those who are under 150lb will use a 3lb dumbbell and those who are over 150lb will use a 3lb dumbbell. I will then make sure that the camera angle is correct and focusing on the posterior neck to lower back. The volunteers will then begin the exercises with frontal, sagittal, and then 45° in between those planes. Volunteers will perform these exercises for five repetitions each. If any movement is not done correctly it will be thrown out and the volunteer must repeat a proper movement for five repetitions.

After the movements for identifying types of scapula dyskinesis they will be asked to perform the second part of the study, the electromyographic (EMG) analysis of three muscles. First the volunteers will be told about where the EMG electrodes will be going; the skin above the muscle bellies of the serratus anterior, lower trapezius, and upper trapezius will be prepped with alcohol to assure cleanliness. The EMG electrode will then be placed on the designated areas prior to warm-up to allow the volunteer to adjust to having the electrodes on. Warm-up will begin with medium resistance Therabands® performing horizontal arm raises in the frontal and sagittal plane, and low-row exercise. After the Theraband® warm-up they will perform 15 push-ups. Post warm-up the volunteers will have the exercises explained to them and that they will be able to practice both exercises prior to gathering data. The exercises that the volunteers will be asked to perform include the lawnmower exercise and the push-up-plus with neither one requiring resistance.

These exercises will both be performed five times with the middle three being averaged and taken for data analysis. If any exercise is not performed correctly it will be thrown out and the volunteer will be asked to perform it again.

The lawnmower exercise is a multijoint exercise, it has been found to generate higher gains in strength than single joint exercises because of the facilitation of the force-dependent patters by an increase in neurological activity. This exercise uses the motion of the hip/trunk extension, trunk rotation, and scapular retraction to activate the muscles which assist in scapular retraction. Subjects begin the exercise with trunk flexed and rotated to the contralateral side from the side being tested with their tested side hand at the level of their contralateral patella. Subjects then will rotate the trunk toward the tested arm and extend the hip and trunk to a vertical orientation while simultaneously placing their tested arm at waist level and retracting their scapula so that they try to place an "elbow into the back pocket" position.

The push-up plus is also multijoint that takes the common pushup a little bit further. The participant starts with hands shoulder width apart, fingertips facing forward, back straight, and legs together with body weight on toes. The subjects will perform a regular push-up keeping elbows near to the torso while lowering the body to the ground. When chest is near to the floor, they will push back up until elbows are extended. Once the subjects get to this position they will push the body a little bit further up by rounding the shoulders and protracting the scapulas for the plus part of the push-up.

Data Analysis:

The research hypotheses will be analyzed using a 3x4x2 Factorial ANOVA and PostHoc data analysis. This means that the researcher will be observing peak percentage muscle activity of three different muscles, identifying four types of scapular dyskinesis, and using two exercises to activate the specific muscles. All data will be analyzed by Statistical Package for Social Sciences (SPSS) version 17.0 for Windows at an alpha level of 0.05. All EMG scores will be reported as percentage of maximal voluntary contraction.

2. *Section 46.11 of the Federal Regulations state that research proposals involving human subjects must satisfy certain requirements before the IRB can grant approval. You should describe in detail how the following requirements will be satisfied. Be sure to address each area separately.*

    a. *How will you insure that any risks to subjects are minimized? If there are potential risks, describe what will be done to minimize these risks. If there are risks, describe why the risks to participants are reasonable in relation to the anticipated benefits.*

    There will be minimal risks which will be monitored by taking every precaution possible. This study will use non-injured, physically active participants as to decrease the likelihood of injury. During the activity the researcher will be watching to assist the participant if necessary and also to give proper instruction while the participant is performing the activities. If at any time the subject begins to experience pain or discomfort they can discontinue the activity immediately. In the event of an injury there will be a Certified Athletic Trainer present to evaluate and provide treatment to the subject. The risk to the participants is reasonable with respect to the benefits because the risk is very low. The study can help athletic trainers identify the different types of scapular dyskinesis and give them a better understanding of what muscle are inactive and which ones are overactive. This study has the potential to create proper protocols for scapular stabilizer muscle rehabilitation programs by focusing on the type and exactly how the muscle is working. Specific protocols can provide more effective treatment and possibly prevent serious overuse injury of the shoulder if scapular dyskinesis can be identified early.

6. *Does your project involve the debriefing of those who participated?* ☐ *Yes or* ☒ *No*

   If Yes, explain the debriefing process here.

7. *If your project involves a questionnaire interview, ensure that it meets the requirements of Appendix___in the Policies and Procedures Manual.*

California University of Pennsylvania Institutional Review Board
Survey/Interview/Questionnaire Consent Checklist (v021209)

This form MUST accompany all IRB review requests

Does your research involve ONLY a <u>survey</u>, <u>interview</u> <u>or</u> <u>questionnaire</u>?

☐ **YES**—Complete this form

☒ **NO**—You MUST complete the "Informed Consent Checklist"—skip the remainder of this form

Does your survey/interview/questionnaire cover letter or explanatory statement include:

☐ (1) Statement about the general nature of the survey and how the data will be used?

☐ (2) Statement as to who the primary researcher is, including name, phone, and email address?

☐ (3) FOR ALL STUDENTS: Is the faculty advisor's name and contact information provided?

☐ (4) Statement that participation is voluntary?

☐ (5) Statement that participation may be discontinued at any time without penalty and all data discarded?

☐ (6) Statement that the results are confidential?

☐ (7) Statement that results are anonymous?

☐ (8) Statement as to level of risk anticipated or that minimal risk is anticipated? (NOTE: If more than minimal risk is anticipated, a full consent form is required—and the Informed Consent Checklist must be completed)

☐ (9) Statement that returning the survey is an indication of consent to use the data?

☐ (10) Who to contact regarding the project and how to contact this person?

☐ (11) Statement as to where the results will be housed and how maintained? (unless otherwise approved by the IRB, must be a secure location on University premises)

☐ (12) Is there text equivalent to: "Approved by the California University of Pennsylvania Institutional Review Board. This approval is effective nn/nn/nn and expires mm/mm/mm"? (the actual dates will be specified in the approval notice from the IRB)?

☐ (13) FOR ELECTRONIC/WEBSITE SURVEYS: Does the text of the cover letter or explanatory statement appear before any data is requested from the participant?

☐ (14) FOR ELECTONIC/WEBSITE SURVEYS: Can the participant discontinue participation at any point in the process and all data is immediately discarded?

California University of Pennsylvania Institutional Review Board
Informed Consent Checklist (v021209)

This form MUST accompany all IRB review requests

Does your research involve ONLY a survey, interview, or questionnaire?
☐ **YES**—DO NOT complete this form. You MUST complete the "Survey/Interview/Questionnaire Consent Checklist" instead.
☒ **NO**—Complete the remainder of this form.

1. **Introduction** (check each)
   ☒ (1.1) Is there a statement that the study involves research?
   ☒ (1.2) Is there an explanation of the purpose of the research?

2. **Is the participant.** (check each)
   ☒ (2.1) Given an invitation to participate?
   ☒ (2.2) Told why he/she was selected.
   ☒ (2.3) Told the expected duration of the participation.
   ☒ (2.4) Informed that participation is voluntary?
   ☒ (2.5) Informed that all records are confidential?
   ☒ (2.6) Told that he/she may withdraw from the research at any time without penalty or loss of benefits?
   ☒ (2.7) 18 years of age or older? (if not, see Section #9, Special Considerations below)

3. **Procedures** (check each).
   ☒ (3.1) Are the procedures identified and explained?
   ☒ (3.2) Are the procedures that are being investigated clearly identified?
   ☒ (3.3) Are treatment conditions identified?

4. **Risks and discomforts**. (check each)
   ☒ (4.1) Are foreseeable risks or discomforts identified?
   ☒ (4.2) Is the likelihood of any risks or discomforts identified?
   ☒ (4.3) Is there a description of the steps that will be taken to minimize any risks or discomforts?
   ☒ (4.4) Is there an acknowledgement of potentially unforeseeable risks?
   ☒ (4.5) Is the participant informed about what treatment or follow up courses of action are available should there be some physical, emotional, or psychological harm?
   ☒ (4.6) Is there a description of the benefits, if any, to the participant or to others that may be reasonably expected from the research and an estimate of the likelihood of these benefits?
   ☒ (4.7) Is there a disclosure of any appropriate alternative procedures or courses of treatment that might be advantageous to the participant?

5. **Records and documentation**. (check each)
   ☒ (5.1) Is there a statement describing how records will be kept confidential?
   ☒ (5.2) Is there a statement as to where the records will be kept and that this is a secure location?
   ☒ (5.3) Is there a statement as to who will have access to the records?

6. For research involving more than minimal risk (check each),

☐ (6.1) Is there an explanation and description of any compensation and other medical or counseling treatments that are available if the participants are injured through participation?

☐ (6.2) Is there a statement where further information can be obtained regarding the treatments?

☐ (6.3) Is there information regarding who to contact in the event of research-related injury?

7. Contacts.(check each)

☒ (7.1) Is the participant given a list of contacts for answers to questions about the research and the participant's rights?

☒ (7.2) Is the principal researcher identified with name and phone number and email address?

☒ (7.3) FOR ALL STUDENTS: Is the faculty advisor's name and contact information provided?

8. General Considerations (check each)

☒ (8.1) Is there a statement indicating that the participant is making a decision whether or not to participate, and that his/her signature indicates that he/she has decided to participate having read and discussed the information in the informed consent?

☒ (8.2) Are all technical terms fully explained to the participant?

☒ (8.3) Is the informed consent written at a level that the participant can understand?

☒ (8.4) Is there text equivalent to: "Approved by the California University of Pennsylvania Institutional Review Board. This approval is effective nn/nn/nn and expires mm/mm/mm"? (the actual dates will be specified in the approval notice from the IRB)

9. Specific Considerations (check as appropriate)

☐ (9.1) If the participant is or may become pregnant is there a statement that the particular treatment or procedure may involve risks, foreseeable or currently unforeseeable, to the participant or to the embryo or fetus?

☐ (9.2) Is there a statement specifying the circumstances in which the participation may be terminated by the investigator without the participant's consent?

☐ (9.3) Are any costs to the participant clearly spelled out?

☒ (9.4) If the participant desires to withdraw from the research, are procedures for orderly termination spelled out?

☐ (9.5) Is there a statement that the Principal Investigator will inform the participant or any significant new findings developed during the research that may affect them and influence their willingness to continue participation?

☐ (9.6) Is the participant is less than 18 years of age? If so, a parent or guardian must sign the consent form and assent must be obtained from the child

- ☐ Is the consent form written in such a manner that it is clear that the parent/guardian is giving permission for their child to participate?
- ☐ Is a child assent form being used?
- ☐ Does the assent form (if used) clearly indicate that the child can freely refuse to participate or discontinue participation at any time without penalty or coercion?

☒ (9.7) Are all consent and assent forms written at a level that the intended participant can understand? (generally, 8th grade level for adults, age-appropriate for children)

California University of Pennsylvania Institutional Review Board
Review Request Checklist (v021209)

This form MUST accompany all IRB review requests.
Unless otherwise specified, ALL items must be present in your review request.

Have you:

☒ (1.0) FOR ALL STUDIES: Completed ALL items on the Review Request Form?
Pay particular attention to:

- ☒ (1.1) Names and email addresses of all investigators
  - ☒ (1.1.1) FOR ALL STUDENTS: use only your CalU email address)
  - ☒ (1.1.2) FOR ALL STUDENTS: Name and email address of your faculty research advisor
- ☒ (1.2) Project dates (must be in the future—no studies will be approved which have already begun or scheduled to begin before final IRB approval—NO EXCEPTIONS)
- ☒ (1.3) Answered completely and in detail, the questions in items 2a through 2d?
  - ☒2a: NOTE: No studies can have zero risk, the lowest risk is "minimal risk". If more than minimal risk is involved you MUST:
    - ☒ i. Delineate all anticipated risks in detail;
    - ☒ ii. Explain in detail how these risks will be minimized;
    - ☒ iii. Detail the procedures for dealing with adverse outcomes due to these risks.
    - ☒ iv. Cite peer reviewed references in support of your explanation.
  - ☒ 2b. Complete all items.
  - ☒ 2c. Describe informed consent procedures in detail.
  - ☒ 2d. NOTE: to maintain security and confidentiality of data, all study records must be housed in a secure (locked) location ON UNIVERSITY PREMISES. The actual location (department, office, etc.) must be specified in your explanation and be listed on any consent forms or cover letters.
- ☒ (1.4) Checked all appropriate boxes in Section 3? If participants under the age of 18 years are to be included (regardless of what the study involves) you MUST:
  - ☐ (1.4.1) Obtain informed consent from the parent or guardian—consent forms must be written so that it is clear that the parent/guardian is giving permission for their child to participate.
  - ☐ (1.4.2) Document how you will obtain assent from the child—This must be done in an age-appropriate manner. Regardless of whether the parent/guardian has given permission, a child is completely free to refuse to participate, so the investigator must document how the child indicated agreement to participate ("assent").
- ☒ (1.5) Included all grant information in section 5?
- ☐ (1.6) Included ALL signatures?

☒ (2.0) FOR STUDIES INVOLVING MORE THAN JUST SURVEYS, INTERVIEWS, OR QUESTIONNAIRES:

- ☒ (2.1) Attached a copy of all consent form(s)?
- ☐ (2.2) FOR STUDIES INVOLVING INDIVIDUALS LESS THAN 18 YEARS OF AGE: attached a copy of all assent forms (if such a form is used)?
- ☐ (2.3) Completed and attached a copy of the Consent Form Checklist? (as appropriate—see that checklist for instructions)

☐ (3.0) FOR STUDIES INVOLVING ONLY SURVEYS, INTERVIEWS, OR QUESTIONNAIRES:

- ☐ (3.1) Attached a copy of the cover letter/information sheet?
- ☐ (3.2) Completed and attached a copy of the Survey/Interview/Questionnaire Consent Checklist? (see that checklist for instructions)
- ☐ (3.3) Attached a copy of the actual survey, interview, or questionnaire questions in their final form?

☒ (4.0) FOR ALL STUDENTS: Has your faculty research advisor:

- ☒ (4.1) Thoroughly reviewed and approved your study?
- ☒ (4.2) Thoroughly reviewed and approved your IRB paperwork? including:
  - ☒ (4.2.1) Review request form,
  - ☒ (4.2.2) All consent forms, (if used)
  - ☒ (4.2.3) All assent forms (if used)
  - ☒ (4.2.4) All Survey/Interview/Questionnaire cover letters (if used)
  - ☒ (4.2.5) All checklists
- ☒ (4.3) IMPORTANT NOTE: Your advisor's signature on the review request form indicates that they have thoroughly reviewed your proposal and verified that it meets all IRB and University requirements.

☒ (5.0) Have you retained a copy of all submitted documentation for your records?

Project Director's Certification

Program Involving HUMAN SUBJECTS

The proposed investigation involves the use of human subjects and I am submitting the complete application form and project description to the Institutional Review Board for Research Involving Human Subjects.

I understand that Institutional Review Board (IRB) approval is required before beginning any research and/or data collection involving human subjects. If the Board grants approval of this application, I agree to:

1. Abide by any conditions or changes in the project required by the Board.
2. Report to the Board any change in the research plan that affects the method of using human subjects before such change is instituted.
3. Report to the Board any problems that arise in connection with the use of human subjects.
4. Seek advice of the Board whenever I believe such advice is necessary or would be helpful.
5. Secure the informed, written consent of all human subjects participating in the project.
6. Cooperate with the Board in its effort to provide a continuing review after investigations have been initiated.

I have reviewed the Federal and State regulations concerning the use of human subjects in research and training programs and the guidelines. I agree to abide by the regulations and guidelines aforementioned and will adhere to policies and procedures described in my application. I understand that changes to the research must be approved by the IRB before they are implemented.

Professional Research

Project Director's Signature | Department Chairperson's Signature

Student or Class Research

Student-Researcher's Signature

Edwin M. Zurbellcowski

Supervising Faculty Member's Signature if required

Department Chairperson's Signature

ACTION OF REVIEW BOARD (IRB use only)

The Institutional Review Board for Research Involving Human Subjects has reviewed this application to ascertain whether or not the proposed project:

1. provides adequate safeguards of the rights and welfare of human subjects involved in the investigations;
2. uses appropriate methods to obtain informed, written consent;
3. indicates that the potential benefits of the investigation substantially outweigh the risk involved.
4. provides adequate debriefing of human participants.
5. provides adequate follow-up services to participants who may have incurred physical, mental, or emotional harm.

☐ Approved[ ] ☐ Disapproved

Chairperson, Institutional Review Board | Date

Approved, September 12, 2005 / (updated 02-09-09)

Dear Jenna,

Please consider this email as official notification that your proposal titled "Relationship Between Muscle Activity of Scapular Stabilizers and Identifying Types of Scapular Dyskinesis" (Proposal #09-039) has been approved by the California University of Pennsylvania Institutional Review Board.
The effective date of the approval is 01-28-2010 and the expiration date is 01-28-2011. These dates must appear on the consent form .
Please note that Federal Policy requires that you notify the IRB promptly regarding any of the following:

(1) Any additions or changes in procedures you might wish for your study (additions or changes must be approved by the IRB before they are implemented)
(2) Any events that affect the safety or well-being of subjects
(3) Any modifications of your study or other responses that are necessitated by any events reported in (2).
(4) To continue your research beyond the approval expiration date of 01-28-2011 you must file additional information to be considered for continuing review. Please contact instreviewboard@calu.edu

Please notify the Board when data collection is complete.
Regards,
Christine Gorby
IRB Graduate Assistant

Appendix C3

Individual Data Collection Sheet

Subject Number:

Right or Left Arm Dominant:

Scapula Dyskinesis Identified: Yes No

Type of Dyskinesis Identified:

1 Definition: prominence of the inferior medial scapular border. This motion is primarily abnormal rotation around a transverse axis.[4]

2 Definition: prominence of entire medial border and represents abnormal rotation around a vertical axis.[4]

3 Definition: superior translation of the entire scapula and prominence of the superior medial scapular border.[4]

Appendix C4

Figures and Tables

Table 4.
Electrode Placement and MVIC Test Positions for Normalization of EMG

Muscle	Electrode Placement	Position
Upper Trapezius	Electrodes placed 2 cm apart on the upper back halfway between C7 spinous process and the acromion process.	Subject: shoulders placed in a shrugged position. Examiner: One hand placed over upper trapezius between neck and acromion. Subject: Isometrically shrugged resisting shoulder depression
Lower Trapezius	Electrodes placed 2 cm apart on an oblique angle, 5 cm down from the scapular spine and outside the medial border of the scapula.	Subject: Prone with arm passively placed to 180 degrees of flexion. Examiner: One hand placed on back below scapula and one hand placed over distal humerus above elbow. Subject: Isometrically forward flexed resisting extension.
Serratus Anterior	Electrode placed 2 cm apart just below the axilla at the level of the inferior angle of the scapula (medial to the latissimus dorsi).	Subject: Arm forward to 130 degrees. Examiner: One hand placed over dorsal arm and one hand placed on lateral scapula for stability. Subject: Isometrically flexed resisting forward extension.

MVIC, maximal voluntary isometric muscle contraction; EMG, electromyography

1. Table 4. Kibler W, Sciascia A, Uhl T, Tambay N, Cunningham T. (2008). Electromyographic analysis of specific exercises for scapular control in early phases of shoulder rehabilitation. *The American Journal of Sports Medicine*, 36, 1780-1798

Table 5. Raw Data of 4x2 MANOVA

Descriptive Statistics

	exercise	Type	Mean	Std. Deviation	N
peak % UT	1	1	1.30139343333E0	1.039329004023E0	3
		2	5.01883340000E0	6.755330622089E0	3
		3	2.20110783333E0	1.965919819141E0	3
		4	1.09956941538E0	.833675117549	13
		Total	1.81174574545E0	2.656395717140E0	22
	2	1	2.54193343333E0	2.064431971826E0	3
		2	.35413568867	.371489342544	3
		3	1.16634622733E0	1.292708536360E0	3
		4	1.19366872462E0	1.455451507486E0	13
		Total	1.25931543036E0	1.464457616325E0	22
	Total	1	1.92166343333E0	1.611991161713E0	6
		2	2.68648454433E0	4.983655272948E0	6
		3	1.68372703033E0	1.592354832468E0	6
		4	1.14661907000E0	1.163061390076E0	26
		Total	1.53553058791E0	2.138134007268E0	44
peak % LT	1	1	1.45503228000E0	.723553040803	3
		2	2.12551893333E1	3.420198337362E1	3
		3	6.40316696667E0	7.049963191293E0	3

		4	1.01731642174E2	3.443890401816E2	13
		Total	6.40841597273E1	2.646977196167E2	22
	2	1	3.76246843333E0	3.709136894435E0	3
		2	5.02815706667E0	2.496619582275E0	3
		3	3.50672963047E0	4.650295558367E0	3
		4	4.42483402492E2	1.558155746655E3	13
		Total	2.63144377172E2	1.198338761175E3	22
	Total	1	2.60875035667E0	2.703658388613E0	6
		2	1.31416732000E1	2.343925091094E1	6
		3	4.95494829857E0	5.572046005217E0	6
		4	2.72107522333E2	1.119145462503E3	26
		Total	1.63614268450E2	8.635186095305E2	44
peak % SA	1	1	1.666353050000E0	.8739939405493	3
		2	3.821263333333E0	5.4010201535001E0	3
		3	1.534785224043E4	2.6579590768254E4	3
		4	2.925430782031E1	7.8701755727248E1	13
		Total	2.110923889642E3	9.8117339094250E3	22
	2	1	1.767297933333E0	.8583322435650	3
		2	.776455266667	.7595547580416	3
		3	1.991679454249E3	3.4486068715047E3	3
		4	3.083764539231E1	7.1998521858698E1	13
		Total	2.901617732931E2	1.2707039066799E3	22
	Total	1	1.716825491667E0	.7767218422482	6
		2	2.298859300000E0	3.8315054091627E0	6
		3	8.669765847341E3	1.8462481397503E4	6
		4	3.004597660631E1	7.3905165524151E1	26
		Total	1.200542831467E3	6.9751184816338E3	44

Table 6. Mean peak percentage values for each muscle and exercise

	Peak % UT LM	Peak % LT LM	Peak % SA LM	Peak % UT PUP	Peak % LT PUP	Peak % SA PUP
Mean and SD	3081.89 (8117.64%)	76.71% (84.26%)	7987.04% (36726.88%)	5642.37% (15114.56%)	6133.87% (28466.56%)	23059.21% (105049.66%)

Appendix C5

Demographic Information

Demographic Information

Weight in pounds: <150 or >150

Sport played: _________________

Position played: ______________

Dominant Arm: _________________

Number Assigned:

ABSTRACT

Title: RELATIONSHIP BETWEEN THE OBSERVATION OF TYPES OF SCAPULAR DYSKINESIS AND PEAK MUSCLE ACTIVITY OF THE SCAPULAR STABLIZING MUSCLES.

Researcher: Jenna M. Sherman

Advisor: Dr. Edwin M. Zuchelkowski

Date: May 2010

Research Type: Master’s Thesis

Purpose: To investigate the relationship between the peak activity of the three main scapular stabilizing muscles and identifying types of scapular dyskinesis.

Problem: There has been a strong correlation shown between scapular dyskinesis and resulting impingement.[1-6,22] Resulting kinematic changes from impingement and altered scapular movement has been linked with a decrease in serratus anterior muscle activity, an increase in upper trapezius muscle activity, or an imbalance between the upper and lower parts of the trapezius muscle.[22] This decrease in activity may result in a relationship between scapular stabilizing muscle activity and types of scapular dyskinesis. There has not yet to be research done looking at the scapular stabilizer activity and if an imbalance will lead to scapular dyskinesis occurring.

Method: This study was an observational descriptive study design investigating physically active, injury-free individuals. Testing took one day with an observation of scapular dyskinesis occurring first,then the electromyography data was collected. For the dyskinesis observation subjects were asked to hold either 3 lb. or 5 lb. dumbbells while performing four arm movement; sagittal plane, frontal plane, and 45° with thumbs up and 45° with thumbs down. While performing the arm movements the subjects

were instructed to move at a three beat up and three beat down rhythm, provided by the metronome. After the observation electrodes were placed on the upper trapezius, lower trapezius, and serratus anterior. These electrodes were connected to the Biopac MP150 electromyography machine the data was managed using AcqKnowledge Software. Before performing the exercises of low- row and push-up-plus the subjects were instructed to warm up on a green resistance Theraband® doing low-row, frontal plane, sagittal plane, humeral abduction, and humeral extension each performed fifteen times. After warm-up the subjects were verbally instructed on how to perform each exercise for five repetitions and to be done on the same three beat up and three beat down rhythm with the metronome as before. The subjects were allowed to practice this until they were comfortable with the exercise. A peak activation measurement was taken for each muscle during the five repetitions. For each muscle the data's absolute value was taken and smoothed.

Findings: The data was analyzed by using a factorial 4x2 MANOVA. There were no significant differences found with the peak muscle activity with the two exercises (α=0.246). There was no significance found between peak muscle activity and types of scapular dyskinesis observed (α=0.181). There were trends found however between types of scapular dyskinesis and activity of the three scapular stabilizers.

Conclusion: From this study a trend was found between the relationship of identifying scapular dyskinesis and muscle activity. Future testing should investigate the effects of this relationship.

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