RELATIONSHIP BETWEEN POSTURE AND PEAK SHOULDER MUSCLE ACTIVATION IN COLLEGiate SWimmers

A THESIS
Submitted to the Faculty of the School of Graduate Studies and Research of California University of Pennsylvania in partial fulfillment of the requirements for the degree of Master of Science

by Rachel Elizabeth Loan

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THEESIS APPROVAL

Graduate Athletic Training Education

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INTRODUCTION

It has been estimated that the average college swimmer completes one million strokes, with each arm, every year.\textsuperscript{1} In competitive swimming, it is said that 90\% or more of the propulsive force during the freestyle stroke comes from the upper extremity.\textsuperscript{2} Swimmers' shoulders need to have very mobile shoulders because mobility has been directly correlated with greater stroke length and speed.\textsuperscript{3}

The shoulder is a very complex area that is commonly injured. The fundamental skeletal segments of the shoulder include the humerus, scapula, clavicle, sternum, and the first eight thoracic ribs.\textsuperscript{4} Three synovial joints and one functional joint make up the shoulder complex. The only bony attachment between the axial skeleton and the shoulder complex is through the sternoclavicular (SC) joint.

Many muscles are involved in moving and stabilizing the shoulder complex. The majority of the muscles are involved in moving the various joints of this region. The serratus anterior is a major muscle of the scapulothoracic stabilizers and contributes to scapular control and stability.\textsuperscript{5,6,8} Control of the scapula is essential for coordination of the joint and instability can occur.\textsuperscript{7} The
serratus anterior also provides an upward rotation force during the early phases of elevation. The latissimus dorsi is a large muscle whose origin spans from the lower thoracic vertebrae, all five lumbar vertebrae, posterior iliac crest, sacrum, and lower three ribs. The latissimus dorsi functions to decrease the compression in the AC joint. The two origins of the pectoralis major are the clavicular and sternal heads and the muscle then inserts onto the humerus. The sternal fibers and the clavicular fibers twist so that the sternal fibers lie underneath the clavicular fibers. The short, or clavicular, fibers are placed under more tension and stressed than the sternal fibers.

Pink et al described the muscle activity patterns of 12 muscles in the normal shoulder during freestyle swimming. The muscles examined were the deltoids, rotator cuff, rhomboids, trapezius, serratus anterior, pectoralis major, and latissimus dorsi. They found that the serratus anterior was active during the entire freestyle stroke and the latissimus dorsi and pectoralis major muscles were important for the pull through phase of the stroke.

Scovazzo et al then did an EMG analysis of the muscle activity in painful swimmer’s shoulders and compared the results to the results from Pink et al. They found that
the serratus anterior was significantly less active in painful shoulders when compared to the activity of the muscle in non painful shoulders, especially after hand entry into the water. The serratus anterior activity was most significantly different and was stated as “dysfunctional and exhibited low levels of activity.”

Because of the recent popularity in swimming in the Olympics, technical advances, improvements in conditioning, and training equipment have also become more popular. Swimmers have been working with team coaches and strength and conditioning coaches to improve their strength, which will in turn improve their swimming velocity, stroke length, and stroke rates. Most traditional weight training programs for swimming fail to concentrate on the dynamic strength and the endurance provisions of swimming. This has been related to painful shoulder incidences because it causes muscle imbalances, fatigue, improper technique, and acute and chronic muscle and tendon injuries.

Imbalances in muscles are the major cause of improper alignment. Shortened muscles pull the origin and insertions of the muscles closer together, while the weaker antagonist muscles’ origins and insertions have a greater separation than normal. Perry et al described a variety of ways to measure posture including photographic analysis.
and manual measurements. Manual measurements can be done by using a plumb line.\textsuperscript{10-12} The plumb line is a line that is hung from an overhead bar and the “plumb bob” hangs to the board where the feet are at the standard base point.\textsuperscript{10}

Another tool used to assess posture is the Watson-MacDonncha Posture Analysis (WMPA). The WMPA is a valid and reliable way to test posture based on a scoring system for either 1, 3, or 5 points for 10 different anatomical places for postural defects.\textsuperscript{13} The WMPA measures ankle varus and valgus, knee interspace, knee hyperflexion and hyperextension, lordosis, kyphosis, scoliosis S and C curves, rounded shoulders, scapular winging/abduction, shoulder symmetry, and forward head.\textsuperscript{12,13} EMG shows the activation of muscles. Surface EMG measures the muscle activity if an electrode is placed on the skin directly above the belly of the muscle. The question that has not been researched as much as painful versus non-painful shoulders is that of different postures which may cause muscle imbalances, also cause muscle activity to vary.
METHODS

Research Design

A descriptive correlational design was used to measure shoulder posture and muscle activation levels of collegiate swimmers. Each athlete was measured for peak muscle activation during a functional shoulder extension exercise and a Watson-MacDonncha Posture Analysis (WMPA). The athletes were measured after the end of their season. The variables for this study are posture and peak muscle activation of the latissimus dorsi, pectoralis major, and serratus anterior during a functional extension exercise which mimics the pull through phase of the freestyle stroke.

Subjects

Subjects were volunteers (n=16) from the NCAA Washington and Jefferson College’s Division III swim team, who were recruited through a mass email sent by the researcher. Before the study was performed, informed
consent was administered to the athletes to educate them about the risks and procedures of the study. By signing the consent form, each subject indicated that their participation was completely voluntary and that all results would remain confidential (Appendix C1). A photographic release form was also signed since pictures of the subjects were taken. After consent and photographic release forms were signed, demographic information was collected (Appendix C2). Demographic information such as: age, year in school, number of consecutive years of competitive swimming, major swimming stroke and distance, and any prior injuries to the shoulder was also collected (Appendix C3). All of the subjects’ information was collected through self-report.

Preliminary Research

Preliminary research was done for the researcher to become familiar with the equipment that would be used in this study, including the Watson-MacDonncha Posture Analysis (WMPA), which was used to measure total body posture, and surface electromyography (EMG) which was used to measure activity in the selected muscles. Also, the appropriate time frame, of half an hour, for each
participant was determined by doing the preliminary research. Accurate measurements can be ensured with the researcher becoming proficient with the equipment after trial runs of the methods.

**Instruments**

The following measures were taken for the study: the WMPA and the EMG measured muscle activity.

**Posture Analysis**

The Watson-MacDonncha Posture Analysis (WMPA) is an instrument used to measure posture. The WMPA measures ankle varus and valgus, knee interspace, knee hyperflexion and hyperextension, lordosis, kyphosis, scoliosis S and C, rounded shoulders, scapular winging/abduction, shoulder symmetry, and forward head. Watson et al\(^\text{12}\) has reported the WMPA as being valid and the reliability of the posture scores is 0.85.

During the WMPA, each subject would stand on a platform that is 20cm high, 60cm long, and 40cm wide. Adhesive reflective dots were placed on landmarks on the subject. These markers are placed on the left auricle pinna, left axis of the glenohumeral joint, left patellar
notch, left greater trochanter, both clavicular heads, both anterior superior iliac spines (ASIS), both tibial tubercles, the center of both patellae, C7, T3, T6, T9, T12, L3, L5, the most prominent spot of the sacrum, and the center of both calcaneus.

Five photographs of each subject were taken. There was one anterior view photograph, one posterior view photograph, one lateral view, one at a 45° angle, and one front view photograph with the subject holding their subject number. There were three colored lines on the platform, a red one, blue one, and yellow one. The red one was placed vertically and is used for placement for the anterior and posterior views, the blue one was placed horizontally for the left lateral photograph, and the yellow one was set at a 45° angle from the left back corner to the front right corner of the platform for a posterior left lateral oblique photograph.  

The suggestion for the camera placement is that it is placed 10 feet from the platform and the camera lens be 120 cm from the floor. For the four photographs the subjects were asked to stand upright with their chins parallel to the ground. It was also asked that they fully extend their elbows and knees for the photographs.
The criteria for scoring the WMPA are located in Appendix C2. A score of 5 was given if there were no postural distortions. A score of 3 was given if there were moderate postural distortions. A score of 1 was given if there were moderate to severe postural distortions. Higher total scores indicate better posture.

Electromyography

In collecting the EMG data, the researcher used three channels from a Biopac MP150® electromyography machine. Three channels were designated for the muscles tested (pectoralis major, latissimus dorsi, serratus anterior). The Biopac MP150 was connected to a Microsoft Windows based personal computer with the Biopac’s AcqKnowledge® program [Goleta, CA] to collect analyze the data. The study utilized pre-gelled disposable Ag-AgCl surface electrodes with a diameter of one centimeter. The electrodes were placed on the subject’s dominate arm over the motor points of each muscle belly with a center-to-center spacing of 2.5 centimeters. The raw EMG signal was band pass filtered at 10 and 1000 Hertz (Hz). The researcher utilized a sampling rate of 2000Hz using the AcqKnowledge software. The signals were rectified and normalized before the data analysis was completed.
The AcqKnowledge® program computed the muscle activity in Hertz (Hz). The researcher computed the percentage of peak muscle activation by first doing a maximum voluntary contraction (MVC) of each muscle, using a functional shoulder extension exercise that mimics the freestyle swim stroke’s pull through phase. After the testing the maximum muscle activity during the MVC for functional shoulder extension exercise, the researcher computed a standard score for each subject by using the equation:

\[
\frac{\text{Max Muscle Activity During Pull Through}}{\text{Max Muscle Activity During MVC}}
\]

This will give us a percent of peak muscle activity.

Procedures

Before any descriptive statistics were measured, the researcher applied for and obtained approval from California University of Pennsylvania’s Institutional Review Board (Appendix C5). Preliminary research was conducted first so the researcher became proficient in the procedures of the WMPA and the EMG. All subjects signed an informed consent Appendix(C1) stating the reasoning for the study, how it would be conducted, and that they could withdraw from the study at any time. A photographic
release form was also signed Appendix (C2). The subjects also filled out a demographic form asking questions such as their years in competitive swimming, prior injury, and major swimming stroke. The subjects were asked to also state their dominant

When the subjects arrived for the assessment, they were first set up for the posture analysis. The subjects were asked to wear non-baggy shorts and tank tops if necessary so that the landmarks, curvatures, and any valgus or varus angles could be photographed.

Five photographs are taken of each subject as per the recommended procedures.¹³ The first one was just the subject number photograph for future referencing. For the second photograph, the subjects stood facing the camera with their heels on a red line. Each subject was asked that they keep their chin parallel to the ground, elbows and knees fully extended, and heels in contact with each other. The third photograph was from the posterior view; subjects faced away from the camera with the heels together on the red line, chin parallel to the ground and the knees and elbows fully extended. The fourth photograph was a left lateral view. Subjects were instructed to stand with their heels touching on the blue line, chin parallel to the ground and knees and elbows extended. The fifth photograph was taken
at an oblique angle. The subjects stood on a yellow line which was at a 45° angle from the left back corner to the front right corner.

The procedure for measuring the WMPA scores is as follows. First, a grid is placed over the top of each photograph of each subject with transparency paper. The grid is lined up with the plumb lines used in the photographs. A second transparency paper is placed on top with circle diameters which is used to determine the degrees of lordosis and kyphosis. A protractor and ruler were used to measure angles through the adhesive dots. A score of 5 is given if there is no marked deviation, a 3 is given if there were moderate deviations, and a 1 is given for extreme deviations for all body areas. (Appendix C4)

The next part of the process of the study was using the surface EMG to measure the muscle activation. Electrode pads were placed on the latissimus dorsi, pectoralis major, and serratus anterior muscle bellies (Appendix C4). The subjects then performed an upper body warm-up, consisting of internal and external rotations and practice of the functional shoulder extension exercise, using a Theraband® which helped determine which band would be used for the subject during testing.
After the warm-up was completed, the subject’s maximum voluntary contraction was then tested. For the pectoralis major, the subject was placed in humeral adduction with the shoulder in 90° of flexion and the palms together. The subject then applied the resistance by pressing the palms together. The latissimus dorsi movement to reach a maximum voluntary contraction was internal rotation and extension of the humerus with the shoulder in 30° of abduction with the elbow extended. Resistance was then applied at the distal forearm by the researcher. For the serratus anterior, the subject’s dominant arm was flexed forward to 130°. The researcher then placed one hand over the dorsal arm and one hand on the lateral scapula for stability. The subject then isometrically flexed while the researcher added resistance.¹³

After the maximal voluntary contraction testing was complete for the three muscles, subjects performed a functional shoulder extension exercise against resistance with a Theraband® which would mimic the pull-through phase of the freestyle stroke.

The subject would determine which of the three choices of Theraband® would have the best resistance for them by going through the motion with each of the three choices. Once established, the subject stood with enough room from
the stationary object holding the bands and bend at the waist at about 75° to imitate being in the water with their knees slightly flexed. Shoulder flexion at about 90° of flexion followed by their pull-through phase with the resistance of the Theraband®. This motion was repeated ten times to ensure valid measurements.

Hypothesis

The following hypothesis was tested in this study:

There will be a relationship among shoulder posture score and peak muscle activity in each of the following muscles: the pectoralis major, serratus anterior, and latissimus dorsi, during a functional shoulder extension exercise.

Data Analysis

A Pearson Product Moment Correlation was used to analyze the correlation among WMPA score and the peak muscle activity in each of these muscles. SPSS version 17.0 for Windows analyzed all data at P < .05. All EMG scores were reported as a percentage of maximal voluntary
contraction.
RESULTS

The purpose of this study was to examine the relationship between complete body posture and peak muscle activation in the shoulders of swimmers. Each subject came in one time for 30 minutes, and was tested using the WMPA and Biopac MP150 surface EMG. The WMPA was used to assign a posture score to each subject and the Biopac MP150 was used to analyze peak muscle activation in the latissimus dorsi, serratus anterior, and pectoralis major during a resisted functional shoulder extension exercise that mimicked the pull through phase of the freestyle swim stroke. All data was collected on each subject's Individual Data Collection Sheet (Appendix C7)

Demographic Information

There were 16 volunteers from Washington and Jefferson College’s Men’s and Women’s Division III swim teams. The WMPA and EMG testing were conducted in the same way and by the same researcher in order to increase internal validity.
Table 1: Demographic Information

<table>
<thead>
<tr>
<th>Sex</th>
<th>N</th>
<th>Average Age</th>
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<tr>
<td>Females</td>
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<td>19.92</td>
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<tr>
<td>Males</td>
<td>4</td>
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Table 2: Subjects Major Stroke

<table>
<thead>
<tr>
<th>Stroke</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freestyle</td>
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</tr>
<tr>
<td>Backstroke</td>
<td>7</td>
</tr>
<tr>
<td>Breaststroke</td>
<td>2</td>
</tr>
<tr>
<td>Butterfly</td>
<td>2</td>
</tr>
</tbody>
</table>

Hypothesis Testing

Hypothesis testing was performed by using the data collected by all 16 subjects who volunteered for the study. The hypotheses were tested at the $P < 0.05$ alpha level. A Pearson product correlation coefficient analysis was used for testing.

Hypothesis: There will be a relationship between WMPA score and peak muscle activity in the pectoralis major,
serratus anterior, latissimus dorsi muscles during a functional shoulder extension exercise.

Conclusions: A Pearson product correlation coefficient was calculated examining the relationship between the WMPA scores of all subjects with the during a functional shoulder extension exercise. A negative moderate correlation \(r(2) = -.448\) that was not significant was found for the pectoralis major \((p = .082)\). A positive moderate correlation \(r(2) = .390\) that was not significant was found for the serratus anterior \((p = .135)\). A negative moderate correlation \(r(2) = -.430\) that was not significant was found for the latissimus dorsi \((p = .096)\).

**Table 2: Descriptive Statistics**

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<th>N</th>
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<td>WMPA</td>
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<td>36.81</td>
<td>2.29</td>
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<tr>
<td>Pectoralis Major</td>
<td>16</td>
<td>277.37%</td>
<td>551.34</td>
</tr>
<tr>
<td>Serratus Anterior</td>
<td>16</td>
<td>318.83%</td>
<td>351.20</td>
</tr>
<tr>
<td>Latissimus Dorsi</td>
<td>16</td>
<td>264.03%</td>
<td>371.63</td>
</tr>
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</table>
Additional Findings

An outlier was removed for further testing to see if it changed any levels of significance. An outlier is defined as being double the standard deviation away from the mean. With the outlier removed, there was still no significant relationship between WMPA scores and percentage of peak muscle activity.

A one way MANOVA was calculated to examine the relationship between percentages of peak muscle activation and if the subject has a history of shoulder injury. No significant effect was found (Lambda(3,12) = .419, P > .05.) None of the percentages of peak muscle activation for the three muscles were significantly influenced by a history of injury.

The WMPA scores of subjects who were divided into groups depending on their major stroke were compared using a one-way ANOVA. No significant difference was found (F(3,12) = .478, P > .05). The subjects WMPA score did not differ significantly depending on their major stroke.

A one-way MANOVA was calculated examining the effect of major swim stroke (freestyle, breaststroke, butterfly, or backstroke) on percentage of peak muscle activation of each muscle (pectoralis major, serratus anterior,
latissimus dorsi). No significant effect was found (Lambda (9,24.5) = .784, \( P > .05 \)). None of the percentages of peak muscle activation of the muscles were significantly influenced by major swim stroke.
DISCUSSION

The following discussion is divided into three sections: 1) Discussion of Results, 2) Conclusions and 3) Recommendations.

Discussion of Results

Posture is an important component in making sure the kinetic chain is operating at its best. It has been stated that postural distortions can cause discomfort, pain and disability. Postural problems can lead to extra stress on joints and muscles which can cause muscle imbalances, such as shortening or lengthening the distance between the attachments of the muscles, and can cause athletes to voluntarily and involuntarily change their body mechanics.

This investigation was performed to determine if there was any relationship in WMPA score and percentage of peak shoulder muscle activation in Division III collegiate swimmers. The primary findings of this study indicated no significant relationship between posture scores (WMPA) and percentage of peak muscle activation in swimmers.
The results of this study showed that no matter what the WMPA score is, it should not affect muscle activity at all. However, if there was a greater array of WMPA scores our outcomes may have been different.

Overall, based on this study, no matter what the posture of a swimmer is the muscle activity in the three main muscles used during the pull through phase of the freestyle swim stroke, which include: latissimus dorsi, serratus anterior, and pectoralis major, is not affected.

A particular finding in this study was the difference in the muscle activity in the serratus anterior when compared with the latissimus dorsi and pectoralis major. The most commonly known function of the serratus anterior is to prevent scapular winging.\(^{15}\) The serratus anterior works with the trapezius to contribute extensively to posterior tilt of the scapula as well as scapular upward rotation.\(^{16}\) The serratus anterior works with the trapezius, levator scapulae, rhomboids, and pectoralis minor to control scapular movements.\(^{15}\) With the pectoralis minor, the serratus anterior abducts the scapula. With the upper and lower trapezius muscles, the serratus anterior upwardly rotates the scapula. By itself, the serratus anterior contributes to all concepts of the scapular movements in
all planes of motion during upward rotation, posterior tilt, and external rotation.\textsuperscript{15}

In this study, the descriptive statistics showed us a difference in numbers in the serratus anterior compared to the other two muscles tested. During the primary hypothesis testing to find a correlation between WMPA scores and peak percentages of muscle activity in the muscles there were no significant findings. However, the serratus anterior had the highest mean peak percent when compared to the latissimus dorsi and the pectoralis major mean peak percentages. The serratus anterior also had the lowest standard deviation of these scores.

It would be assumed that during the freestyle stroke, the serratus anterior is constantly active to keep the scapula stabilized throughout the entire stroke which entails a great deal of shoulder complex and scapular movement. This descriptive statistic tells us that in the Division III male and female swimmers, their serratus anterior activity is working constantly and effectively during this part of the stroke, this is following the findings of Pink et al\textsuperscript{2} who examined the serratus anterior as being a very active muscle throughout the entire freestyle stroke.
When looking at the descriptive statistics of the one-way ANOVA comparing peak percentages of muscle activity with the four strokes the subjects could choose from, the serratus anterior once again stands out among the three muscles. For the subjects that choose freestyle, the mean peak percentage of muscle activity in the serratus anterior was higher than the mean peak percentages of the latissimus dorsi and pectoralis major. This demonstrates a difference in findings then the previous statement and the serratus anterior is the least active muscle in the pull-through phase in freestyle swimmers when compared with subjects who listed their major stroke as butterfly, breaststroke, and backstroke. The swimming stroke that showed the most serratus anterior activity was the butterfly swimmers.

If these results are consistent in future research this will greatly help enhance the knowledge of training techniques for coaches, athletic trainers, and strength and conditioning coaches. Posture should be one of the first components of a program in the first place when in a corrective exercise phase of training, to prevent any injuries and biomechanical efficiencies. In swimmer’s who have swam all throughout their childhood until college, their posture may have developed to have the classic rounded shoulders and forward head that are common in
swimmers. These may be harder to correct because the swimmer is accustomed to doing their activities of daily living and their swim stroke to be comfortable enough for them, yet still perform each stroke at maximal effectiveness.

Conclusions

After completing this study, there was no relationship found between posture and percentage of peak muscle activation in swimmers or not. In this current study, all the subjects had similar posture scores that were slightly higher than the middle range of scores. Total posture scores could range from 10-50, which has a median number of 30, and the subjects mean WMPA score was 36.81 with a standard deviation of + 2.29. This fact made it difficult to examine any correlation between the posture scores and percentage of peak shoulder muscle activation because the subjects WMPA scores were within 6 points of each other.

However, although there were no significant findings in the hypothesis testing and additional findings, the descriptive statistics showed a lot of information about the serratus anterior. Serratus anterior is more active from the other two muscles when the peak percentages of
muscle activity when correlated with the WMPA scores and when the peak percentages of muscle activity is compared between the four different swimming strokes.

Recommendations

It is still unknown whether or not posture can effect muscle activation in swimmers. Further research is recommended with doing testing closer to the end of the season. At the time of this testing, subjects had had no practice in almost two months, unless they swam on their own. Another recommendation for future research would be to have more subjects, with more variety of major swim strokes. Of the subjects in this study, only two listed their major stroke as breaststroke, and another two listed their major stroke as butterfly.

If more specific procedures were implemented during the EMG testing, comparable scores may have been obtained. Each of the 16 subjects all had different variations of the freestyle pull through phase.

Also, if there was EMG used to look at muscle firing patterns rather than peak percentages, we may be able to find out more information about the serratus anterior throughout the entire freestyle stroke.
REFERENCES


APPENDICES
APPENDIX A

Review of Literature
Swimmers, throwers, tennis, volleyball, and water polo players are all included in the classification of overhead athletes. Each of these sports has unique and individual functional requirements. Swimmers shoulders need to be very mobile because mobility has been directly correlated with greater stroke length and speed. In competitive swimming, it is said that 90% or more of the propulsive force during the freestyle stroke comes from the upper extremity. Also, it has also been estimated that the average college swimmer completes one million, with each arm, every year.

Shoulder Anatomy

The fundamental skeletal segments of the shoulder include the humerus, scapula, clavicle, sternum, and the first eight thoracic ribs. Three synovial joints and one functional joint make up the shoulder complex. The only bony attachment between the axial skeleton and the shoulder complex is through the sternoclavicular (SC) joint. The clavicular notch of the manubrium is the site where the clavicle articulates with the sternum. The other shoulder
joints are the acromioclavicular (AC) joint, scapulothoracic articulation, and the glenohumeral (GH) joint.

The AC joint is the articulation between the distal end of the clavicle and the acromion, which is a bony process of the scapula. This joint is similar to the sternoclavicular joint because they both are covered with fibrous cartilage and the AC joint is separated with an intraarticular disc.\textsuperscript{4,6} The scapula is a flat shaped bone that creates a mobile connection with the thorax.\textsuperscript{6} This is not considered a true joint because the synovial characteristics of a joint are not present.\textsuperscript{5} The scapular creates a scapular rhythm that is seen in all movements of the shoulder. The GH joint is the articulation between the head of the humerus and the shallow, concave glenoid fossa of the scapula.\textsuperscript{5,6} Only 30\% of the humeral head fits in contact with the relatively small glenoid fossa.\textsuperscript{5,6} The GH joint is very mobile for unrestricted motion and is reinforced by the rotator cuff muscles as the dynamic stabilizers.\textsuperscript{6} As mobility in the shoulder is increased, stability is decreased.
Shoulder Musculature

Many muscles are involved in moving and stabilizing the shoulder complex. The majority of the muscles are involved in moving the various joints of this region. One group of muscles that receives attention in this region is the rotator cuff muscle group.

The rotator cuff includes the supraspinatus, infraspinatus, subscapularis, and teres minor. The supraspinatus is responsible for the first stage of abduction and it is said that increased activation of the supraspinatus can cause upward rotation of the humeral head in the glenoid fossa. The infraspinatus and teres minor for lateral rotation, and the subscapularis is responsible for medial rotation. The subscapularis may be the most powerful muscle of the rotator cuff, and is critical for normal performance of shoulder motion. EMG shows that the supraspinatus is a major muscle that is triggered for arm elevation, overhead throwing, swimming, and golf. The four muscles of the rotator cuff, together, constrains the humeral head during elevation and work as dynamic stabilizers of the GH joint by compressing the head of the humerus into the glenoid fossa, particularly the supraspinatus.
The biceps muscle is also another muscle that acts on the shoulder and can potentially be a site of injuries. Collectively, at the shoulder, the biceps motions are shoulder flexion, abduction and adduction. The long head is primarily responsible for abduction, while the short head is primarily responsible for adduction. The deltoids are considered “the most important mover and dynamic inferior stabilizer of the GH joint”. It is composed of upper, middle, and lower portions. Its actions include shoulder elevation, adduction, upper rotation, and depression.

The primary scapulothoracic muscles include the rhomboid, serratus anterior and the trapezius. These muscles stabilize and control the scapula during GH movement. These scapulothoracic muscles have the function of upward rotation of the scapula when the arm is being elevated, and also are responsible for resisting downward rotation, which may be produced by the muscles of the GH joint working on the scapula. The serratus anterior and these scapulothoracic stabilizers contribute to scapular control and stability. Control of the scapula is essential for coordination of the joint and instability can occur. The serratus anterior also provides an upward rotation force during the early phases of elevation.
The latissimus dorsi is a large muscle whose origin spans from the lower thoracic vertebrae, all 5 lumbar vertebrae, posterior iliac crest, sacrum, and lower 3 ribs. The latissimus dorsi functions to decrease the compression in the AC joint.

The two origins of the pectoralis major are the clavicular and sternal heads and the muscle then inserts onto the humerus. The sternal fibers and the clavicular fibers twist so that the sternal fibers lie underneath the clavicular fibers. The short, or clavicular, fibers are placed under more tension and stressed than the sternal fibers.

Shoulder Activity in Swimming

Freestyle Swimming Technique

Competitive freestyle swimming is the act of cycling the arms as fast as possible, to move through the water, at a given distance, with a varying amount of kicks per arm cycle. Freestyle swimming performance depends exclusively on the propulsive and resistive forces. The phases of freestyle swimming consist of early and late pull-through and early and late recovery. The pull-through phases are compared to the acceleration phases in throwing
sports. Early pull-through begins when the hand enters the water and ends when the humerus is perpendicular to the body. Late pull through is the completion of the pull through till the hand exits the water. The recovery phase’s first indication is the elbow lift. Once the hand exits the water till when the humerus is perpendicular to the body above the water, this is early recovery. From here until the hand once again enters the water is the late recovery phase.

Pink et al described the muscle activity patterns of 12 muscles in the normal shoulder during freestyle swimming. The muscles examined were the deltoids, rotator cuff, rhomboids, trapezius, serratus anterior, pectoralis major, and latissimus dorsi. The serratus anterior had a constant level of activity in non-painful shoulders, except when activity increased in the pull through phases and when the hand exited the water. The pectoralis major and latissimus dorsi had sharp peaks of activity during the pull through, then immediately dropped back to resting levels. These two muscles, the pectoralis major and latissimus dorsi, are responsible for the increased strength in swimmers compared to non-swimmers.

It has been stated that a performance by swimmers can only be enhanced by reducing the drag that acts on the body.
or by increasing the propulsive forces.\textsuperscript{15} The propulsive forces and resistive forces, or drag, are generated by the arm movements, which generates a swimming velocity.\textsuperscript{13,17,18} Along with swimming velocity, studies have been done to analyze the relationships between stroke length and stroke rate.\textsuperscript{13,19,20}

The shoulders of swimmers have unique and altered mobility, stability, and functional requirements to meet the demands of swimming.\textsuperscript{1} This shoulder hypermobility is advantageous to the swimmers because it has been directly correlated with stroke length, speed, and swimming performance.\textsuperscript{1,3,25}

**Shoulder Issues in Swimmers**

Because of the recent popularity in swimming in the Olympics technical advances, improvements in conditioning, and training equipment have also become more popular.\textsuperscript{9} Swimmers have been working with team coaches and strength and conditioning coaches to improve their strength, which will in turn improve their swimming velocity, stroke length, and stroke rates. Most traditional weight training programs for swimming fail to concentrate on the dynamic strength and the endurance provisions of swimming.
It has been estimated that between 40 to 80 percent of competitive swimmers have complained about pain in their shoulders which may influence with training and competition.\textsuperscript{9,21-23} This shoulder pain that swimmer’s experience is considered ‘swimmers shoulder’. This ‘injury’ includes symptoms resembling a combination of rotator cuff tendinitis, subacromial bursitis, impingement syndrome, and instability.\textsuperscript{9,21-23} Variables that are probable factors that lead to swimmers shoulder include shoulder fatigue, flexibility, improper technique, and strength imbalances.\textsuperscript{9,21-23} Swanik et al state that there has been a limited amount of research done of preventative measures of this pathology.\textsuperscript{9}

Kennedy stated that overhead athletes develop their own normal range of motions that are related to their sport.\textsuperscript{24,25} This is true in swimmers, who are likely to have stronger internal rotators and adductors that are hypertrophied compared to their antagonist muscles.\textsuperscript{26} These and other biomechanical changes in swimmers, and all overhead athletes, are reasons why there are frequent shoulder injuries.\textsuperscript{24,25} Muscle fatigue is a contributor to impingement symptoms because it causes improper techniques, particularly when the hand enters the water.\textsuperscript{9}
Shoulder pain in swimmers is commonly caused by impingement injuries. McClure et al\textsuperscript{27} found that their subjects with the signs and symptoms of impingement had clear deficits to shoulder range of motion and also the force production of the shoulder in a variety of directions. Shoulder pain has been concluded to occur in swimmer’s of both genders, in both arms, for all strokes, at all distances, and at all levels of competition.\textsuperscript{3} Weldon and Richardson state that “shoulder pain can be prevented by spending an equal amount of time stretching the posterior and anterior capsules and performing scapular positioning muscle exercises.”\textsuperscript{3}

Scovazzo et al did an electromyographical analysis of the muscle activity in painful swimmer’s shoulders.\textsuperscript{28} They found that the serratus anterior was significantly less active in painful shoulders when compared to the activity of the muscle in non painful shoulders, especially after hand entry into the water.\textsuperscript{28} The serratus anterior activity was most significantly different and was stated as “dysfunctional and exhibited low levels of activity."\textsuperscript{28}
Posture Assessment

The Posture Committee of the American Academy of Orthopedic Surgeons defines posture as:

"Posture is usually defined as the relative arrangement of the parts of the body. Good posture is that state of muscular and skeletal balance which protects the supporting structures of the body against injury or progressive deformity, irrespective of the attitude (erect, lying, squatting, or stooping) in which these structures are working or resting. Under such conditions the muscles will function most efficiently and the optimum positions are afforded for the thoracic and abdominal organs. Poor posture is a faulty relationship of the various parts of the body which produces increased strain on the supporting structures and in which there is less efficient balance of the body over its base of support."

Posture is a main component in assessing and evaluating acute and chronic injuries, since it can lead to pain and discomfort and improper mechanics. Imbalances in muscles are the major cause of improper alignment. Shortened muscles pull the origin and insertions of the muscles closer together, while the weaker antagonist muscles’ origins and insertions have a greater separation than normal. Therefore, therapeutic exercises to restore proper posture include stretching of the shortened muscles and strengthening of the weaker muscles.

Perry et al described a variety of ways to measure posture including photographic analysis and manual
measurements. Manual measurements can be done by using a plumb line.\textsuperscript{7,29,30} The plumb line is a line that is hung from an overhead bar and the “plumb bob” hangs to the board where the feet are at the standard base point.\textsuperscript{7} There are four types of body postures that are assessed using a plumb line. They are ideal posture, kyphotic-lordotic posture, flat back posture, and sway back posture. Swimmers can present forward head/rounded shoulder postures because of their tight shoulder internal rotators and adductors.

The plumb line will hypothetically divide the body into front and back sections with equal weight, and these sections are not symmetrical. The line of reference for the plumb line is the ear lobe.\textsuperscript{7,30} From the side view, ideally, the plumb line should pass through the shoulder joint, which the point of reference would be the acromion process. In the ideal posture, the head is neither tilted forward or back.\textsuperscript{7,30} The cervical spine has a slightly convex curve anteriorly, the thoracic spine has a slight posterior convex curve, and the lumbar spine is also has a slightly curve anteriorly like the cervical spine. The pelvis’s anterior superior iliac spines (ASIS) are in the same vertical plane as the pubic symphysis. The hips aren’t either flexed or extended, and the knee joints are neither
flexed or hyperextended. The ankle joints show a right angle with the vertical leg and the sole of the foot.\textsuperscript{7}

Another tool used to assess posture is the Watson-MacDonncha Posture Analysis (WMPA). The WMPA is a valid and reliable way to test posture based on a scoring system for either 1, 3, or 5 points for 10 different anatomical places for postural defects.\textsuperscript{30} The WMPA measures ankle varus and valgus, knee interspace, knee hyperflexion and hyperextension, lordosis, kyphosis, scoliosis S and C curves, rounded shoulders, scapular winging/abduction, shoulder symmetry, and forward head.\textsuperscript{32,33}

During the WMPA, the subject stands on a platform that is 20 cm high, 60 cm long, and 40 cm wide. Adhesive reflective dots are placed on landmarks on the subject. These markers are placed on the left auricle pinna, left axis of the glenohumeral joint, left patellar notch, left greater trochanter, both clavicular heads, both anterior superior iliac spines (ASIS), both tibial tubercles, the center of both patellae, C7, T3, T6, T9, T12, L3, L5, the most prominent spot of the sacrum, and the center of both calcaneus.\textsuperscript{30}

Five photographs of each subject are taken for the WMPA. There is one anterior view photograph, one posterior view photograph, one left lateral view, one at a 45 degree
angle, and one front view photograph with the subject holding their subject number. There are three colored lines on the platform, a red one, blue one, and yellow one. The red one is placed vertically and is used for placement for the anterior and posterior views, the blue one was placed horizontally for the left lateral photograph, and the yellow one was set at a 45° angle from the left back corner to the front right corner of the platform for a posterior left lateral oblique photograph.³⁰

The suggestion for the camera placement for the WMPA is that it is placed 10 ft from the platform and the camera lens be 120 cm from the floor.²⁹

For each of the four photographs the subjects are asked to stand upright with their chins parallel to the ground. It is also asked that they fully extend their elbows and knees for the photographs.²⁹

EMG Technique

Electromyography (EMG) shows the activation of muscles. There are two types of EMG for clinical use. Intramuscular wire electrode EMG is a type where one or two needles are placed into the belly of the muscle. Surface EMG measures the muscle activity if an electrode is placed
on the skin directly above the belly of the muscle. During testing using surface EMG, the surface electrodes are placed directly over the force producing muscle or muscle group. It then measures the amount of muscle action potential as it passes under the surface electrodes.\textsuperscript{31}

To generate the maximum voluntary contractions (MVC) of the pectoralis major, the subject is placed in humeral adduction with the shoulder in $90^\circ$ of flexion and the palms together. The subject then applies the resistance by pressing the palms together. The latissimus dorsi movement to reach a MVC is internal rotation and extension of the humerus with the shoulder in $30^\circ$ of abduction and the elbow is extended. Resistance is then applied at the distal forearm by the clinician.\textsuperscript{32} For the MVC of the serratus anterior the subject’s arm is forward flexed to $130^\circ$. The researcher’s hands are then placed one over the dorsal arm and one on the lateral scapula for stability. The subject then isometrically flexes while the researcher adds resistance.\textsuperscript{33}

Summary

The shoulder complex plays the most crucial role in the freestyle swim stroke, creating 90\% or more of the
propulsive force to carry the swimmer through the water.\textsuperscript{3} Pink et al\textsuperscript{2} described the latissimus dorsi and pectoralis major muscles as being extremely important for the pull-through phase and the serratus anterior as a very active muscle throughout the entire stroke.

With recent popularity in swimming, athletes are working hard to improve their strength which will improve their swimming velocity, stroke length, and stroke rate. The most traditional strength training programs do not concentrate on the dynamic and endurance concepts of swimming and put the athletes at risk for postural distortions, especially in the upper body.\textsuperscript{9}
APPENDIX B

The Problem
THE PROBLEM

Scovazzo, et al\textsuperscript{27} stated that swimmers with painful shoulders had shown a difference in the shoulder muscle activity compared to ‘normal shoulders’. A painful shoulder in this study was one that the subject said he or she was experiencing pain and then evaluated for instability, apprehension, and impingement during an evaluation.\textsuperscript{28} The purpose of this study was to see if different types of postures showed a difference in the shoulder muscle peak activity when compared to ‘normal postures’. EMG testing was done to note any differences in the production of muscle firing patterns and if the timing of peak contractions in the latissimus dorsi, pectoralis major, and serratus anterior were different as well.

Definition of Terms

The following definitions of terms were defined for this study:

1. Maximum Voluntary Contraction: typically portrayed in units of kilograms of Newtons, interval data that shows the greatest muscular contraction that a person can reach.\textsuperscript{32}
2. Muscle Activation: electrical activity of a muscle during an isometric, eccentric, and/or concentric contraction.

3. Posture: the relative arrangement of the parts of the body. Good posture is that state of muscular and skeletal balance which protects the supporting structures of the body against injury or progressive deformity, irrespective of the attitude (erect, lying, squatting, or stooping) in which these structures are working or resting.

4. Forward head: the anterior displacement of the head relative to the thorax.  

5. Rounded Shoulders: shoulders are in front of the upper chest.

6. Shoulder Symmetry: shoulder heights are not equal.

7. Winging Scapula: the medial border of the shoulder is risen abnormally.

8. Ankle Valgus/Varus: increased degree between the Achilles and midline of the heel.

9. Knee Hyperextension: The greater trochanter is forward in relationship to the patellar notch and lateral malleolus.
10. Knee Interspace: testing for genu varum and genu valgum in the knees.

11. Lordosis: excessive extension in the lumbar spine causing excessive lordotic curvature.

12. Kyphosis: the upper thoracic region has a great degree of forward flexion.

13. Scoliosis: The spinous processes do not align, have lateral shifts.

14. Plumb Line: used to provide an absolute vertical line for measuring deviations.

**Basic Assumptions**

The following were basic assumptions of this study:

1. All participants are NCAA athletes so they have received a physical within the last year, are healthy and fully capable of performing the required exercises.

2. There was no evidence that the volunteers would respond differently than random subjects.

3. The subjects answered truthfully on the demographic sheet.

4. The equipment was working correctly and properly calibrated.

5. The subjects gave maximum effort during testing.
6. The Watson-MacDonncha Posture Analysis (WMPA) is a valid and reliable way of measuring posture.

Delimitations of the Study

The following were possible delimitations of the study:

1. The subjects were entirely from Washington and Jefferson College, ages 18-24.
2. The subjects were active on a NCAA division III sports team.

Significance of the Study

A variety of postures can be noted when examining the members of a collegiate swim team. These include, but are not limited to: normal postures, rounded shoulders, forward heads, and sway back postures. There have been studies\textsuperscript{2,28} completed comparing muscle activities in painful shoulders and non painful (or normal) shoulders. This study investigated if different types of postures can cause the muscle firing patterns to change. If there is a significant difference between the peak muscle activation patterns depending on WMPA score that shows that posture can affect the activation of the three muscles tested, certified athletic trainers, coaches, certified strength
and conditioning coaches, etc. may be able to find a way to train the muscles differently and correct postures. Also, if a positive relationship is found, strengthening or stretching certain muscles that can cause the timing of peak muscle activation occurs at the same time for the variety of postures.
APPENDIX C

Additional Methods
Appendix C1

Informed Consent Form
Informed Consent Form

1. RACHEL LOAN, 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 POSTURE AND PEAK SHOULDER MUSCLE ACTIVATION IN COLLEGIATE SWIMMERS.

2. I have been informed that the purpose of this study is to see if there are any differences in muscle activation and timing of peak muscle activation in swimmers with normal postures and swimmers with abnormal postures, such as rounded shoulders, forward head, sway back, etc. 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 other Division II and Division III swimmers who are physically active on their swim team and have no injuries or neurovascular disorders which could interfere with the study.

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 having my posture assessed using the Watson-MacDonncha Posture Analysis (WMPA) which is a series of four photographs and electromyography (EMG) of three of my shoulder muscles during a repeated set of shoulder exercise against resistance. I will only have to go in once for about half an hour.

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. The possible risks and/or discomforts include muscle soreness from doing a shoulder exercise against resistance.

5. I understand that, in case of injury, I can expect to receive treatment or care in Henry Memorial’s Athletic...
Training Facility or Hamer Hall’s Athletic Training Facility. This treatment will be provided by the researcher, RACHEL LOAN, under the supervision of the Washington and Jefferson or 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 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 is see if a difference in peak muscle activation in a functional extension exercise that resembles the pull phase of swimming compared among a variety of Shoulder Posture Scores. If there is a significant difference, athletic trainers, coaches, strength and conditioning coaches, etc. can help train the shoulder muscles so they reach peak at the same time as normal shoulders. This may also help decrease injury rates.

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, RACHEL LOAN, 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:

RACHEL LOAN, ATC
STUDENT/PRIMARY RESEARCHER
LOA5499@CALU.EDU
978-609-0322

Robert H. Kane, Jr., EdD, ATC, PT
RESEARCH ADVISOR
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: 03/04/10 to 03/04/11.

Subject's signature:___________________________________
Date:____________________

Witness signature:______________________________
Date:____________________
Appendix C2
Photographic Release Form
Photographic Release Form

Watson-MacDonncha Posture Analysis

Subject #________

The researcher, Rachel Loan, requests the use of photographic resources for parts of her current study. Photography materials will be used for this research study as the researcher has described in the informed consent form you signed. These materials will be used for this study as well as professional publication, professional conferences, websites and other exhibits related to this study. The appearance of these materials on certain media may require the transfer of copyright of the images. This means that other individuals may use your image. Regarding the use of your likeness in photographs please check one of the following:

I agree ______

I do not agree_______

To give the researcher permission to use photographs of me.

_________________________________  __________
Appendix C3
Demographic Information
Demographic Information

Subject Number: _____________

Age:___________    Sex:    M or F

Sports Team:___________________________

Years in Competitive Sport:__________

Year at W&J:  F   SO   J   SR

Any previous shoulder injury:    Yes    No

If yes, what shoulder:    R    L    Both

Type of Injury:___________________________

(example: tendinitis, impingement, instability, pain, inflammation)

Which shoulder would you like to use for this test:

R     L

Swimmer’s Only:

Major Stroke:  Fr  Br  Bf  Ba

Major Distance in Major Stroke:   50    100    200    500    1000
Appendix C4
WMPA Scoring Guide
1. Ankle Posture (Ankle valgus or varus)

Photograph(s) used: anterior view, posterior view

Scores:
5: the degree of the Achilles tendon is less than 7
3: the degree of the Achilles tendon is between 7-10
1: the degree of the Achilles tendon is greater than 10

2. Knee Interspace

Photograph(s) used: anterior view, posterior view

Scores:
5: the ankles are together and the medial epicondyles are touching
3: 1. the medial epicondyles are touching and the medial malleoli are not touching
    2. the medial malleoli are touching but there is 1-3 mm between the medial epicondyles
1: 1. the medial epicondyles are more than 4 mm apart and the medial malleoli are touching.
    2. the Q angle is measured more than 15 for women and more than 12 for men

3. Knee Hyperflexion or Hyperextension

Photograph(s) used: lateral view

Scores:
5: a line can be drawn straight from the greater trochanter to the lower leg with no marked deviations
3: there is a moderate deviation from the midline either with flexion or extension of the knee
1: there is extreme deviation from the midline from the greater trochanter through the thigh and lower leg with flexion or extension of the knee.

4. Lordosis

Photograph(s) used: lateral view, left oblique view

Scores:
5: a circle with a diameter of 7 cm*
3: a circle with a diameter of 4.5 cm*
1: a circle with a diameter of 3 cm*

*circles of various diameters are used for this assessment on top of the photographs. They are placed against the lordosis curvature.

5. Kyphosis

Photograph(s) used: lateral view, left oblique view

Scores:
5: circle with a diameter of 9 cm*
3: circle with a diameter of 7 cm*
1: circle with a diameter of 6 cm*

*circles of various diameters are used for this assessment on top of the photographs. They are placed against the lordosis curvature.

6. Scoliosis

Photograph(s) used: posterior view

Scores:
5: a vertical line is made down the vertebrae with the reflective dot stickers with no marked deviations
3: a vertical line is made down the vertebrae with the reflective dot stickers and there is
moderate deviation of 1.5-3 degrees from the vertical line

1: a vertical line is made down the vertebrae with the reflective dot stickers and there is an extreme deviation that is greater than 3 degrees from the vertical line

7. Shoulder; Rounded or Forward

Photograph(s) used: lateral view

Scores:
5: the shoulders are behind the upper chest
3: the front of the shoulders is slightly forward of the upper chest
1: The fronts of the shoulders are clearly in front of the upper chest

8. Shoulder abducted/winged scapulae

Photograph(s) used: lateral view, left oblique view

Scores:
5: No deviations
3: the inferior angles and portions of the medial borders of the scapulae are moderately visible
1: the inferior angles and portions of the medial borders of the scapulae are excessively

9. Shoulder symmetry

Photograph(s) used: anterior view, posterior view

Scores:
5: no deviation when comparing the two shoulders
3: a deviation between 1-2.5 mm when comparing the two shoulders
1: a deviation greater than 2.5 mm when comparing the two shoulders

10. Forward Head

Photograph(s) used: lateral view

Scores:
5: the head protraction angle is less than 5 degrees

3: the head protraction angle is between 5-10 degrees

1: the head protraction angle is greater than 10 degrees
APPENDIX C5

Institutional Review Board –

California University of Pennsylvania
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 POSTURE AND SHOULDER MUSCLE ACTIVATION IN COLLEGIATE SWIMMERS
Researcher/Project Director  Rachel Loan
Phone #  978-609-0322  E-mail Address  loa5499@calu.edu
Faculty Sponsor (if required)  Robert Kane
Department  Health Science
Project Dates  Jan 1, 2010 to  Dec 31, 2010
Sponsoring Agent (if applicable)  
Project to be Conducted at  California University of Pennsylvania, Washington and Jefferson College
Project Purpose:  ☒ Thesis  ☐ Research  ☐ Class Project  ☐ Other

Keep a copy of this form for your records.
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(ies) 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 determine if there is a relationship in posture and muscle activation of certain shoulder muscles that are important during the freestyle's swimming stroke. The electromyographical (EMG) activity will be measured to evaluate activation of three shoulder muscles during a functional exercise.

Hypothesis:
There will be a correlation between shoulder posture score and peak muscle activity in the pectoralis major, serratus anterior, and latissimus dorsi during a functional shoulder extension exercise.

Procedure:
Before any descriptive statistics were measured, the researcher applied for and obtained approval from California University of Pennsylvania’s and Washington and Jefferson’s Institutional Review Board. Preliminary research was conducted first so the researcher became proficient in the procedures of the WMPA and the EMG. All subjects signed an informed consent stating the reasoning for the study, how it would be conducted, and that they could withdraw from the study at any time. A photographic release form was also signed. The subjects also filled out a demographic form asking questions such as their years in competitive swimming, hours per week of swimming practices, months per year of the competitive season, and major swimming stroke.

When the subjects arrived for the assessment, they were first set up for the posture analysis. The WMPA is a reliable and valid measure of posture. The subjects were asked to wear non-baggy shorts and tank tops if necessary so that the landmarks, curvatures, and any valgus or varus angles could be photographed.

Five photographs are taken of each subject. The first one is just the subject number photograph for future referencing. For the second photograph, the subjects stood facing the camera and the heels on the red line. Each subject was asked that they keep their chin parallel to the ground, elbows and knees fully extended, and heels in contact with each other.

The third photograph was for the posterior view. The subject faced away from the camera with the heels together on the red line; chin parallel to the ground and the knees and elbows fully extended. The fourth photograph is a left lateral view. Subjects were instructed to stand with their heels touching on the blue line, chin parallel to the ground and knees and elbows extended. The fifth photograph was taken at an oblique angle. The subjects stood on the yellow line which is at a 45 degree angle from the left back corner to the front right corner of the platform.

The procedure of the measuring the WMPA scores is as follows. First, a grid is placed over the top of each photograph of each subject with transparency paper. The grid is lined up with the plumb lines used in the photographs. A second transparency paper is placed on top with circle diameters which is used to determine the degrees of lordosis and kyphosis. A protractor and ruler will be used to measure angles through the adhesive dots. A score of 5 is
given if there is no marked deviation, a 3 is given if there is moderate deviations, and a 1 is
given for extreme deviations

The next part of the process of the study was using the surface EMG to measure the muscle
activation. Electrode pads were placed on the latissimus dorsi, pectoralis major, and serratus
anterior muscle bellies. The subjects then did an upper body warm up using a Theraband®
which helped determine which band would be used for the subject during testing.

After the warm up was completed, the subject’s maximum voluntary contraction was then
tested. For the pectoralis major, the subject was placed in humeral adduction with the
shoulder in 900 of flexion and the palms together. The subject then applied the resistance by
pressing the palms together. The latissimus dorsi movement to reach a maximum voluntary
contraction is internal rotation and extension of the humerus with the shoulder in 30 degrees
of abduction and the elbow is extended. Resistance is then applied at the distal forearm by
the researcher. For the serratus anterior, the subject’s arm is forward flexed to 130 degrees.
The researcher’s hands are then placed one over the dorsal arm and one on the lateral scapula
for stability. The subject then isometrically flexes while the researcher adds resistance.

After the maximal voluntary contraction testing is complete for the three muscles, the subject
will then perform a functional shoulder extension exercise against resistance with a
Theraband® which would mimic the pull through phase of the freestyle stroke.

The subject would determine which of the three choices of Theraband® would have the best
resistance for them. Once established, the subject would then stand with enough room from
the stationary object holding the bands and bend at the waist at about 75 degrees to imitate
being in the water. They would then start in shoulder flexion at about 90 degrees and
impersonate their pull through phase with the resistance of the Theraband® and would do this
10 times. The procedure of the measuring the WMPA scores is as follows. First, a grid is
placed over the top of each photograph of each subject with transparency paper. The grid is
lined up with the plumb lines used in the photographs. A second transparency paper is placed
on top with circle diameters which is used to determine the degrees of lordosis and kyphosis.
A protractor and ruler will is used to measure angles through the adhesive dots.

The procedure of the measuring the WMPA scores is as follows. First, a grid is placed over
the top of each photograph of each subject with transparency paper. The grid is lined up with
the plumb lines used in the photographs. A second transparency paper is placed on top with
circle diameters which is used to determine the degrees of lordosis and kyphosis. Pictures will
be compared to the set of WMPA guidelines to determine if the postures being looked at will
be given a 1,3, or 5. A score of 1 is given if there is a marked deviation. A score of 3 is given
if there is a moderate deviation measured. A score of 5 is given if there are good body
mechanics that ranges from no deviations to a level that is above moderate deviations.

Data Analysis:
Pearson Product Moment Correlation was used to analyze correlation between shoulder
posture score with the peak muscle activity in swimmers, r values will be computed for each
muscle; pectoralis major, serratus anterior, and latissimus dorsi. SPSS version 17.0 for
Windows analyzed all data at p < .05. All EMG scores were reported as a 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.

Every precaution possible will be taken to make sure there are minimal risks during this descriptive study. Subjects include only non-injured and physically active participants which will decrease the likelihood of injury. If at any time the subjects experience any pain or discomfort they will be allowed to discontinue the study. If there is an injury, the research, who is a Certified Athletic Trainer assigned for the year at Washington and Jefferson College, will be present to evaluate and provide treatment for the subject. An Athletic Trainer is certified nationally through the Board of Certification and the responsibilities of an Athletic Trainer encompass the prevention, diagnosis, and intervention of emergency, acute, and chronic medical conditions involving impairment, functional limitations, and disabilities. The risks to the participants are reasonable with respect to the benefits because the risk is very low. This descriptive study can change the way that athletes with a variety of postures train for maximal gains of their sport.

b. How will you insure that the selection of subjects is equitable? Take into account your purpose(s). Be sure you address research problems involving vulnerable populations such as children, prisoners, pregnant women, mentally disabled persons, and economically or educationally disadvantaged persons. If this is an in-class project describe how you will minimize the possibility that students will feel coerced.

The subjects will be volunteer athletes from Washington and Jefferson University. The study will be emailed to the coaches and announced at practices. The potential subject will in no way be forced to participate in this study. There will be no research problems involving vulnerable populations because the subjects will be college aged students that do not include prisoners, pregnant, mentally disabled, or economically or educationally disadvantaged persons.

c. How will you obtain informed consent from each participant or the subject’s legally authorized representative and ensure that all consent forms are appropriately documented? Be sure to attach a copy of your consent form to the project summary.

The copies of informed consent will be distributed to the coaches for the student athletes and copies of the informed consent will be available on days when the study is being done. The paper will inform the participant about their role in the descriptive study and the procedure of the study.

d. Show that the research plan makes provisions to monitor the data collected to insure the safety of all subjects. This includes the privacy of subjects’ responses and provisions for maintaining the security and confidentiality of the data.

The data collection will be in a securely in password protected files on the researcher’s laptop used for collecting data, and the photographs will be kept in the research advisor’s office, both of which only the researcher and research advisor will have access to. The subjects’ names will never appear on the data and they will be assigned a number to keep the results anonymous.
3. Check the appropriate box(as) that describes the subjects you plan to use.

- Adult volunteers
- CAL University Students
- Other Students
- Prisoners
- Pregnant Women
- Physically Handicapped People
- Mentally Disabled People
- Economically Disadvantaged People
- Educationally Disadvantaged People
- Fetuses or fetal material
- Children Under 18
- Neonates

4. Is remuneration involved in your project? □ Yes or ✗ No. If yes, Explain here.

5. Is this project part of a grant? □ Yes or ✗ No    If yes, provide the following information:
   - Title of the Grant Proposal _____
   - Name of the Funding Agency _____
   - Dates of the Project Period _____

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.
This form MUST accompany all IRB review requests

Does your research involve ONLY a survey, interview or questionnaire?

☐ 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/nm/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 ELECTRONIC/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 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)
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

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
Rachel Loan,

Please consider this email as official notification that your proposal titled “Relationship between posture and Shoulder Muscle Activation in Collegiate Swimmers” (Proposal #09-043) has been approved by the California University of Pennsylvania Institutional Review Board as amended.

The effective date of the approval is 3-04-2010 and the expiration date is 3-04-2011. 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 3-04-2011 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,
Robert Skwarecki, Ph.D., CCC-SLP
Chair, Institutional Review Board
Appendix C6
Electrode Placement and MVC
<table>
<thead>
<tr>
<th>Muscle</th>
<th>Electrode Placement</th>
<th>MVC testing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Latissimus Dorsi</td>
<td>Electrodes are positioned obliquely (approx 25 degrees from horizontal in the inferomedial direction) 4cm below the inferior angle of the scapula. The patient is asked to cough while the examiner palpates to feel the latissimus dorsi contract to help locate placement site.</td>
<td>Internal rotation and extension of the humerus with the shoulder in 30 degrees of abduction and the elbow is extended. Resistance is applied at the distal forearm by the researcher.</td>
</tr>
<tr>
<td>Pectoralis Major</td>
<td>Palpating along the line of the clavicle from the medial clavicular head to the acromion, one third along and 3 cms down into the sternal fibers of the pectoralis major</td>
<td>Subject is placed into humeral adduction with the shoulder in 90 degrees of flexion and the palms are facing each other. The subject then applies resistance by pressing the palms together.</td>
</tr>
<tr>
<td>Serratus Anterior</td>
<td>Electrodes place 2 cm apart just below the axilla at the level of the inferior angle of the scapula</td>
<td>Subjects arms are forward flexed to 130 degrees. The researcher’s hands are placed one over the dorsal arm and one on the lateral scapula for stability. Subject then isometrically flexes while the researcher adds resistance.</td>
</tr>
</tbody>
</table>
REFERENCES


ABSTRACT

TITLE: Relationship between posture and peak shoulder muscle activation in collegiate swimmers

Researcher: Rachel Loan

Advisor: Dr. Robert Kane

Date: May 2010

Research Type: Master Thesis

Context: The purpose of the study was to examine the relationship between posture and muscle activity of three separate muscles in NCAA Division III swimmers.

Objective: Few research studies have looked at the relationship among different postures and muscle activity in the major muscles responsible for the freestyle pull-through phase in swimming.

Design: This was a descriptive study using 16 volunteers from a NCAA Division III swim team. Subjects came in for 30 minutes on one day.

Setting: Controlled laboratory setting

Participants: 16 NCAA Division III swimmers including 12 females and 4 males from Washington and Jefferson College.

Interventions: Subjects came in on one day for 30 minutes. The WMPA photographs were taken first. The subject was set up to the EMG and performed MVIC of the three muscles. The subject then performed the functional shoulder extension exercise that mimicked the pull-through phase of the freestyle stroke.
Results: There was no significant relationship among posture scores, using the Watson-MacDonncha Posture Analysis (WMPA), and percentage of peak muscle activity in these shoulder muscles during a resistive functional shoulder extension exercise that mimicked the pull-through phase of the freestyle swim stroke.

Conclusions: This descriptive study showed no significant relationship among posture and peak percentages of muscle activity in three main swimming muscles. It is known through previous studies, that postural distortions can lead to muscle imbalances, pain, and altered biomechanics.

Word Count: 255