The effect of a typical swim training period on forward head and forward shoulder posture in competitive swimmers

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Abstract

REID ELIZABETH JONES: The effect of a typical swim training period on forward head and forward shoulder posture in competitive swimmers
(Under the direction of Joseph Myers)

Forward head, forward shoulder posture is a common postural deviation observed in competitive swimmers. Forward head and forward shoulder posture has been linked to muscular imbalances attributable to the repetitive nature of swimming. Postural changes over the course of a swim training period are unknown. The purpose of this study is to examine the effect of a typical swim training period on forward head and forward shoulder posture in competitive swimmers. Repeated measures of forward head and forward shoulder angles were calculated using Image J software (National Institute of Health, Bethesda, MD). Significant differences were found between swimming and control groups. Significant differences were found within both groups. A small amount of shoulder pain was found to be related to forward shoulder posture. Strength and conditioning and dryland programs performed throughout the training period may have contributed to significant changes in forward head and forward shoulder posture in collegiate swimmers.

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CHAPTER I

INTRODUCTION

THE SPORT OF SWIMMING

Amateur, club/collegiate and master's level swimmers constitute the over one hundred million Americans who classify themselves as swimmers (Johnson, 1988; Stocker, Pink, & Jobe, 1995). Swimming is one of the most popular participation sports as people use it for leisure, cardiovascular fitness and/or competition (Kammer, Young, & Niedfeldt, 1999; Pink & Tibone, 2000; Sein et al., 2010). As organized master's teams, whose ages range from 20 to 95, gain popularity and monetary incentives for elite swimmers become more common swimming continues to be a lifelong sport (Kammer, et al., 1999). In this study we will examine competitive, collegiate swimmers who make up one subset of the swimming population.

TRAINING SCHEDULE

Training time (quantity) and training intensity (quality) along with frequency of training all contribute to the training schedule for competitive swimmers. Competitive swimmers start their intense training between the ages of eight and eleven years old (Bak, 2010). They train three to four hours per day across two training sessions which equates to between ten and twenty thousand yards per day or between five hundred thousand to one million arm cycles per year (Bak, 2010; Costill et al., 1991; Kammer, et al., 1999; W.

McMaster, 1999; Sokolovas, 2003). Swim training uses periodization as the principal means for preparing for competition (Pyne, 2006). Periodization is defined as the division of the annual training plan into smaller, more manageable parts that helps to ensure correct peaking for the main competition of the year (Pyne, 2006). The smaller parts that make up the annual training plan include the mesocycle (long term cycle), the macrocycle (multi-week training cycle), and the microcycle (weekly/daily training cycle) all of which vary depending on individual competition goals (Pyne, 2006). Today, modern, competitive swimming has evolved into a year-round sport where swim yardage is maintained after the collegiate season is over (Kammer, et al., 1999; Wolf, Ebinger, Lawler, & Britton, 2009). Competitive swimmers transition from collegiate training to club training at the end of the collegiate season (mid-March) and continue to swim with their club teams until the collegiate season resumes in September. A week-long break, along with a transition to maintenance yardage, may be the only indicators of the transition from collegiate swimming to club swimming.

The collegiate season for a club swimmer lasts approximately thirty weeks. Beginning in September, with preseason training, the thirty weeks is divided between aerobic, anaerobic, race-specific and competition phases of training (Sterkel, 2001). The preseason, aerobic, anaerobic and race-specific portions are included in what is known as the training period with the competition phase making up what is known as the taper period (Sterkel, 2001). Further division occurs between swimmers categorized as either distance swimmers, where a greater percentage of training is spent in the endurance phase, or sprint swimmers, where a greater percentage of their training is spent in speed work (Sterkel, 2001). The year-long training regiment coupled with the continuous, repetitive nature of competitive swimming may place these swimmers at an increased risk for injury.

SHOULDER PAIN IN SWIMMERS

Forty to ninety percent of complaints by swimmers pertain to issues regarding shoulder pain (Bak, 2010; Weldon & Richardson, 2001). Shoulder pain in swimming is a major cause of missed practice and slower swim times (Weldon & Richardson, 2001) and may develop as a result of the fact that ninety percent of propulsive force in swimming comes from the upper extremity because the athlete must pull the body over the arm through the water (Pink & Tibone, 2000). The term "swimmers shoulder" is used to define any type of shoulder discomfort in the swimmer and it is the most common orthopedic complaint with regard to injuries in swimming (Stocker, et al., 1995; Weldon & Richardson, 2001). "Swimmers shoulder" covers a spectrum of pathologies that are caused by extrinsic and intrinsic factors (Bak, 2010). Swimmers shoulder is a non-descript and ill-defined condition that is widely synonymous with impingement syndrome and rotator cuff tendonitis (W. McMaster, 1999) but may also include labral injury, acromioclavicular joint pathology, long head of biceps pathology or any form of shoulder instability (Allegrucci, Whitney, & Irrgang, 1994; Russ, 1998). In competitive swimming, as the number of training hours increase, the number of arm strokes per year increase, making competitive swimming a demanding activity that places enormous stress on the shoulder. Shoulder pain in swimmers is influenced by the training schedule where distance completed each practice, the number of workouts per week, what is involved in the dryland program and any recent changes in training may all contribute to the development of new injuries (Tovin, 2006). Limited information exists regarding the epidemiology of swimming injury patterns at the collegiate, elite, amateur and master's levels (Wolf, et al., 2009) and this includes injury patterns that are influenced by poor posture.

CONTRIBUTORS TO SHOULDER PAIN IN SWIMMING

The continuous, repetitive nature of swimming increases the stress put on the shoulder joint and leads to injury via repetitive microtrauma with no time to rest and allow the muscles to recover (Pink & Tibone, 2000). There are several factors that contribute to shoulder pain. These include biomechanics, range of motion, muscular imbalances, fatigue, impingement, glenohumeral joint instability and posture. The biomechanics of the freestyle stroke have been studied extensively as 75 to 90 percent of swim-training is completed using the freestyle stroke regardless of stroke specialty (Kammer, et al., 1999). Faulty freestyle biomechanics is thought to contribute to impingement syndrome (Allegrucci, et al., 1994). Sport-specific range-of-motion demands, which include an increase in shoulder range of motion, increased internal rotation and adduction strength and prolonged, fatiguing shoulder-intensive training may improve swimming performance, but these demands have also been shown to cause shoulder instability (Weldon & Richardson, 2001). Muscular imbalances may play an important role in shoulder pain in swimmers due to anterior musculature becoming overactive and tight compared to weak, stretched posterior musculature (Janda, 1987) as a result of three of the four strokes (freestyle, breaststroke, butterfly) being completed prone in the water. The sheer volume and intensity that defines swim training may lead to fatigue throughout the shoulder and scapula musculature (Bak, 2010). Fatigue leads to the disruption of the optimal synchronous firing pattern of the scapular stabilizing muscles (Pink & Tibone, 2000; Weldon & Richardson, 2001) that may predispose a swimmer to shoulder pain and pathology. Glenohumeral joint laxity, defined as an increased translation at the glenohumeral joint, may develop into joint instability when the joint laxity becomes pathologic and begins to cause pain (Pink & Tibone, 2000). Finally, a common posture deviation seen in swimmers involves forward head, forward shoulder posture creating a common "s-configuration" of the back that is seen due to an enlarged thoracic kyphosis and enlarged lumbar lordosis (Bak, 2010). This can be an aggravating factor in the development of scapular dyskinesis which contributes to the reduction of subacromial space (Bak, 2010; Pink & Tibone, 2000). The reduction of subacromial space secondary to poor posture is included as a possible contributor to shoulder pain (W. B. Kibler, 1998). Thoracic kyphosis may alter the bony anatomy surrounding the shoulder and may result in excessive protraction of the scapula, contributing to secondary impingement (Allegrucci, et al., 1994; W. B. Kibler, 1998). Other contributors to shoulder pain, include a high repetition rate of shoulder revolution, taking the shoulder into extreme ranges of motion and the generation of high muscular forces on the shoulder in order to sustain the forward propulsive effort (Stocker, et al., 1995).

POSTURE AND SHOULDER PAIN

Ideal posture is determined by the alignment of significant anatomical landmarks or by general body positions (Griegel-Morris, Larson, Mueller-Klaus, & Oatis, 1992;

Kendall & McCreary, 1983) and is associated with proper skeletal alignment that allows muscles, joints, ligaments, nerves and internal organs to function well (Page, 2005). Forward head and forward shoulder posture is a common deviation from ideal posture and is distinguished by increased thoracic kyphosis, decreased cervical lordosis, protracted scapulae and an internally/anteriorly rotated humeral head (Griegel-Morris, et al., 1992; Tovin, 2006). Forward head and forward shoulder posture are often accompanied by soft tissue findings that indicate restricted and tight anterior shoulder musculature, lengthened and weakened medial scapular stabilizers, posterior capsule tightness of the glenohumeral joint and weak anterior cervical flexors (Janda, 1987; Kendall, McCreary, Provance, Rodgers, & Romani, 2005; W. B. Kibler, 1998; W. McMaster, 1999; Tovin, 2006). Deviations from what is described as normal alignment suggests a system of imbalance or abnormal strain on the musculoskeletal system that may contribute to upper quarter musculoskeletal dysfunction (Page, 2005) including abnormal scapulohumeral rhythm, impingement of the rotator cuff tendons, acromioclavicular joint degeneration, bicipital tendinitis and painful trigger point areas (Griegel-Morris, et al., 1992; Peterson et al., 1997). These posture deviations, which are often seen in the swimming population, are also common deviations in the general population including the collegiate population. Notebook computer use, backpack carrying and study hours all contribute to poor posture in the college-age population (Asundi, Odell, Luce, & Dennerlein, 2010). The competitive swimming population in this study may be influenced by all of these factors as well as the training period during their competitive season.

PURPOSE AND CLINICAL RELEVANCE

Shoulder pain in swimmers is one of the most common complaints of injury (Bak, 2010). Anecdotal evidence exists that swimmers have poor posture and this may be attributable to the amount of training they complete in order to compete at a high level. A gap in the literature exists as to the exact relationship between training volume, training intensity and their effects on forward head and forward shoulder posture commonly observed in swimmers. This study will look at competitive, collegiate swimmers and a control group of non-swimmers or non-overhead athletes. Both groups are influenced by lifestyle factors, such as classroom time, study time, computer use and video game use, which may affect their posture. Forward head posture will be measured using digital photography to capture the angle of inclination between the line extending from C7 to tragus and the horizontal line. Forward shoulder posture will be measured using digital photography to capture the angle of inclination between the line extending from C7 to the shoulder and the horizontal line. This study seeks to demonstrate that the swimming group will experience a greater change in forward head, forward shoulder posture compared to the control group due to the training period they go through as part of swim participation. The swimming group endures the training period in addition to lifestyle factors which is hypothesized to increase forward head and forward shoulder posture compared to the control group. This study may also help to determine when to intervene with rehabilitation exercises during the training period to assist in correcting postural abnormalities before pathology begins. Posture and increased thoracic kyphosis are two intrinsic factors that have been thought to contribute to shoulder pain (Bak, 2010). Determining the extent of the relationship between the training period and changes in forward head and forward shoulder posture in competitive swimmers will help to lay the foundation for future studies to continue exploring the relationship between posture and shoulder pain and the argument that posture is an indirect cause of shoulder pain.

RESEARCH QUESTION

- *RQ1:* What is the effect of a typical swim training period on forward head and forward shoulder posture in collegiate swimmers?
    - *RQ1.1:* What is the effect of a typical swim training period on forward head posture in collegiate swimmers?
    - *RQ1*.2: What is the effect of a typical swim training period on forward shoulder posture in collegiate swimmers?
- *RQ2:* Does forward head and forward shoulder posture differ significantly between the four testing sessions (late August/early September, mid-October, mid-December and late January) in the swimming group?
    - *RQ2.1:* Does forward head posture differ significantly between testing sessions in the swimming group?
    - *RQ2.2:* Does forward shoulder posture differ significantly between testing sessions in the swimming group?
- *RQ3:* Is there a relationship between the change in pain scores between testing sessions and the change in forward head posture in the swimming group?

- *RQ3.1:* Is there a relationship between the change in FASS-TS pain scores between testing sessions and the change in forward head posture in the swimming group?
- *RQ3.2:* Is there a relationship between the change in DASH_SM pain scores between testing sessions and the change in forward head posture in the swimming group?

- *RQ4:* Is there a relationship between the change in pain scores between testing sessions and the change in forward shoulder posture in the swimming group?
    - *RQ4.1:* Is there a relationship between the change in FASS-TS pain scores between testing sessions and the change in forward shoulder posture in the swimming group?
    - *RQ4.2:* Is there a relationship between the change in DASH-SM pain scores between testing sessions and the change in forward shoulder posture in the swimming group?
- *RQ5:* Is there a relationship between yardage completed between testing sessions and the change in posture at testing session?
    - *RQ5.1:* Is there a relationship between yardage completed between testing sessions and the change in forward head posture at each testing session?
    - *RQ5.2:* Is there a relationship between yardage completed between testing sessions and the change in forward shoulder posture at each testing session?
- *RQ6:* Is there a relationship between the change in pain scores at each testing session and yardage completed between testing sessions?

- Is there a relationship between the change in FASS-TS pain scores at each testing session and yardage completed between testing sessions?
- Is there a relationship between the change in DASH-SM pain scores at each testing session and yardage completed between testing sessions?

RESEARCH DESIGN

- Cross sectional design

Variables

- Independent
  - Time
    - Pre-training period (late August/early September)
    - Middle of training period (mid-October, mid-December)
    - Post-training period (late January)
  - Group
    - Swimmers
    - Control (Non-overhead athletes or non-athletes)
- Dependent
  - Forward head angle measurements
  - Forward shoulder angle measurements
  - Pain Scores (FASS-TS, DASH-SM)
  - Yardage

Null Hypothesis

- $H_o 1.1$

- There will be no significant difference in the forward head posture in competitive swimmers compared to the forward head posture in the control group over the course of the typical swim training period
- Differences FHP swimmers = Differences FHP control

- *H_o1.2*
  - There will be no significant difference in the forward shoulder posture in competitive swimmers compared to the forward shoulder posture in the control group over the course of the typical swim training period
  - Differences FSP swimmers = Difference FSP control
- *H_o2.1*
  - The forward head posture in competitive swimmers will not change between testing sessions 1, 2, 3 and 4.
  - $FHP_{swimmers\ T1} = FHP_{swimmers\ T2} = FHP_{swimmers\ T3} = FHP_{swimmers\ T4}$
- H_o2.2
  - The forward shoulder posture in competitive swimmers will not change between testing sessions 1, 2, 3 and 4.
  - $FSP_{swimmers\ T1} = FSP_{swimmers\ T2} = FSP_{swimmers\ T3} = FSP_{swimmers\ T4}$
- H_o3.1
  - There is no relationship between the change in FASS-TS pain scores between testing sessions and the change in forward head posture in the swimming group
- H_o3.**2**

- There is no relationship between the change in DASH-SM pain scores between testing sessions and the change in forward head posture in the swimming group.

- H_o4.**1**
  - There is no relationship between the change in FASS-TS pain scores between testing sessions and the change in forward shoulder posture in the swimming group.
- H_o4.**2**
  - There is no relationship between the change in DASH-SM pain scores between testing sessions and the change in forward shoulder posture in the swimming group.
- H_o5.**1**
  - There is no relationship between yardage completed between testing sessions and the change in forward head posture at each testing session.
- H_o5.**2**
  - There is no relationship between yardage completed between testing sessions and the change in forward shoulder posture at each testing session.
- H_o6.1
  - There is no relationship between the change in FASS-TS pain scores at each testing session and yardage completed between testing sessions.
- H_o6.2

- There is no relationship between the change in DASH-SM pain scores at each testing session and yardage completed between testing sessions.

Research Hypotheses

- *RH1.1*
    - The differences in forward head posture in collegiate swimmers will be greater at the end of the training period compared with the differences in forward head posture in the control group
    - Differences FHP swimmers ≥ Differences FHP control
- *RH1.2*
    - The differences in forward shoulder posture in collegiate swimmers will be greater at the end of the training period compared with the differences in forward head posture in the control group
    - Differences FSP swimmers ≥ Differences FSP control
- *RH2.1*
    - The forward head posture in swimmers will increase at every testing session
    - $FHP_{swimmersT1} < FHP_{swimmersT2} < FHP_{swimmersT3} < FHP_{swimmersT4}$
- *RH2.2*
    - The forward shoulder posture in swimmers will increase at every testing session
    - $FSP_{swimmersT1} < FSP_{swimmersT2} < FSP_{swimmersT3} < FSP_{swimmersT4}$
- *RH3.1*

    - There will be a strong, positive correlation between changes in FASS-TS pain scores and changes in forward head posture in the swimming group at each testing session.
- *RH3.2*
    - There will be a strong positive correlation between changes in DASH-SM pain scores and changes in forward head posture in the swimming group at each testing session.
- *RH4.1*
    - There will be a strong, positive correlation between changes in FASS-TS pain scores and changes in forward shoulder posture in the swimming group at each testing session.
- *RH4.2*
    - There will be a strong, positive correlation between changes in DASH-SM pain scores and changes in forward shoulder posture in the swimming group at each testing session.
- *RH5.1*
    - There will be a strong, positive correlation between yardage completed between testing sessions and the change in forward head posture at each testing session.
- *RH5.**2***
    - There will be a strong, positive correlation between yardage completed between testing sessions and the change in forward shoulder posture at each testing session.

- *RH6.1*
    - There will be a strong, positive correlation between the change in FASS-TS pain scores at each testing session and yardage completed between testing sessions.
- *RH6.2*
    - There will be a strong, positive correlation between the change in DASH-SM pain scores at each testing session and yardage completed between testing sessions.

OPERATIONAL DEFINITIONS

- Collegiate Swimmers
    - Competing on a college swim team during the academic year at the NCAA Division 1 level
- Control Group
    - College-age students not participating in overhead athletics or not participating in athletics
- Training Volume
    - As measured by yardage completed in the pool during practices
- Training Intensity
    - As measured by yardage completed in a given amount of time

ASSUMPTIONS

- Reliable/valid posture measures can be obtained

- Collegiate swimmers used in this study are representative of other collegiate swimmers
- Training volume/training intensity of collegiate swimmers at UNC- Chapel Hill reflects training volume/training intensity of other collegiate swim programs.
- Subjects will assume natural, normal upright posture when measurements are taken

DELIMITATIONS

- Only UNC-Chapel Hill varsity swimmers will be used for the swim group
- Only non-overhead athletes or non-athletes of comparable college age will be used in control group

LIMITATIONS

- An individual may inadvertently correct their “normal” posture during measurements if they know they are being tested for posture.
- Activities outside of swimming cannot be controlled.

CHAPTER II

REVIEW OF THE LITERATURE

INTRODUCTION

More than one hundred million people in the United States classify themselves as swimmers (Johnson, 1988; Stocker, et al., 1995) and many more swimmers may be unreported. Individuals participate in swimming for competition, fitness and recreation (Kammer, et al., 1999; Pink & Tibone, 2000; Sein, et al., 2010). The popularity of the sport can be attributed to the fact that there is no special equipment or rules to participate in the sport (Pink & Tibone, 2000) and there are many community teams that children can begin to participate in early. While some children continue to swim for recreation, a subset of these children will begin competitive swimming careers between the ages of eight and eleven (Bak, 2010; Sokolovas, 2003). These swimmers begin a formal, intensive training that is designed sequentially to produce a stacking effect (Sokolovas, 2003) over eight to ten years in order to allow a competitive swimmer to reach full potential. This stacking style has proven effective based on success at the Olympic trials. (Sokolovas, 2003). Unlike land sports, swimming is a sport in which speed is equated with the forward propulsion of the body over the arm in the water. Successful aquatic athletes are generally lean and tall with long limbs and wide shoulders as swimming is a sport that rewards upper extremity strength (J. Troup, 1999).

There are four competitive strokes in swimming that include freestyle or crawl stroke, backstroke, butterfly stroke and breaststroke. Regardless of a swimmer's level of ability or stroke specialization, eighty percent of training will be spent swimming the freestyle stroke (Allegrucci, et al., 1994; Pink & Tibone, 2000). Due to the large volume of training that occurs using the freestyle stroke, proper stroke biomechanics will aid the swimmer in performing well and pain free. The freestyle stroke can be divided into two parts. The pull-through phase is the portion of the time that the hand is maintained in the water and is often further divided into early pull-through (hand entry and catch phase), mid-pull through (insweep phase) and late pull-through or finish phase (Allegrucci, et al., 1994; J. Troup, 1999). The recovery phase is the time during which the arm is above the water (Allegrucci, et al., 1994) and is often further divided into early and late recovery phases (Allegrucci, et al., 1994). Subdividing the two parts of the freestyle stroke is done to analyze swimming mechanics.

TRAINING SCHEDULE

Training schedules for elite level, competitive swimmers involves several different considerations. This is true of collegiate swimmers who become club swimmers when the collegiate season is over in order to maintain training levels and train year-round. A coach, either club or collegiate, must determine the number of weeks in a season, how much pool time is available on a daily basis for the swimmer to train and how much time outside of the water is devoted to activities such as weight training and dryland training (Hannula & Thornton, 2001). An elite swimmer may log between ten and fourteen thousand yards per day, twenty to thirty hours per week, six to seven days a week as swim training is primarily endurance training (Johnson, 1988; Su, Johnson, Gracely, & Karduna, 2004; Weldon & Richardson, 2001) . Considering a competitive swimmer may swim forty-eight to fifty weeks out of the year, yardage would exceed seven million yards per year. Annual yardage logged throughout the year is not accrued in the same way during every practice or during every phase of the training cycle. Periodization is employed by coaches to split the total annual training into a training period and a taper period around major competitions to assist the swimmer in attaining peak performance as competition arrives.

The Training Period

Club teams are generally made up of college students and hence, the competitive portion of the club season generally incorporates 30 weeks of total training that mirrors the academic year spanning August to late March (Hannula & Thornton, 2001). The training period is loosely described as the period when increases in yardage and intensity are the priority and spans the middle of August to the end of January (Lynch, Thigpen, Mihalik, Prentice, & Padua, 2009; Weldon & Richardson, 2001). Swimming utilizes the principle of overload training to gradually increase workload volumes during the season in order to improve (Sokolovas, 2003). Lynch (2010) pointed out in her study that yardage in September was approximately eight to fourteen thousand yards per day while yardage in December was approximately twenty thousand yards per day which provides an example of how collegiate swimmers use the early part of their competitive season as the intense training period. Following the intensity of the training period, the taper period consists of seven to twenty-one days of reduced training volume designed to enhance swimming performance prior to competition (Trappe, Costill, & Thomas, 2000).

The training period and taper period may be further broken down into phases that include preseason, aerobic development, anaerobic development, race-specific development and competition phases. The training period encompasses the preseason, aerobic development, anaerobic development and race-specific phases (Hannula & Thornton, 2001). The preseason and aerobic development phases focus on building general endurance by gradually increasing yardage and speed work to emphasize muscular strength and a solid cardiovascular base. Generally these two phases occur as swimmers are returning from a brief break where they have been out of regimented training for approximately two to three weeks. The anaerobic and race-specific portions of the training period help to lay the foundation for development leading up to competition (Hannula & Thornton, 2001).

The Taper period

Taper means "preparation to swim fast" and is also referred to as the competition phase (Hannula and Thornton 2001). For collegiate swimmers, taper generally begins around the end of January and continues until the last competition date is reached (Hannula & Thornton, 2001; Trappe, et al., 2000). Taper periods vary between individuals and may last up to three weeks in order to allow swimmers to rest by decreasing training time and increasing the amount of time spent away from the pool (Hannula & Thornton, 2001). The ultimate goal of tapering is to blend reduced training distance with the appropriate workout frequency and swimming speed to produce the fastest possible swim times (Allegrucci, et al., 1994). Over the course of a thirty week competitive season for collegiate swimmers, the training period and the taper period need to be adjusted appropriately for each individual's needs and abilities. When done properly, the training period gradually builds a swimmer's endurance threshold throughout the fall and winter while the taper period, which follows in early spring, allows swimmers to peak in performance as the most important competitions approach.

SWIMMER'S SHOULDER

Swimming is a sport that requires year-round dedication and training in order to continue to build ability and skill. Inherent in this high volume of training, however, is the risk that injury may develop. Shoulder pain is one of the most common reasons for swimmers to miss practice (Weldon & Richardson, 2001). The continuous movement at the shoulder joint during the freestyle stroke puts stress on the shoulders that may lead to repetitive microtrauma (Pink 2000). Bak (2010) asserted that one of the main factors in the development of shoulder pain was high training volumes in the absence of a well-designed and balanced dryland training program. Overuse and repetition alone, however, are not the sole cause of shoulder pain in swimmers. Shoulder pain is generally combined with a second insult that may include supraspinatus avascular tendinitis, biceps avascular tendinosis, impingement syndrome, labral damage, instability secondary to ligamentous laxity and instability secondary to muscle dysfunction (McMaster 1999). Swimmers plagued by debilitating shoulder pain may not progress in training leading to poor competition performance. Rest and interruption from training quickly translates into detraining (W. C. McMaster & Troup, 1993). With the freestyle stroke commonly used for training, certain tissues are at risk during the various phases of this stroke. During the early pull-through phase, the anterior capsulolabral complex and the posterior-superior labrum are at risk for repetitive microtrauma (Bak, 2010). During late pull-through the supraspinatus is at risk for repetitive microtrauma and during the recovery phase, the subacromial bursa, the supraspinatus tendon and the posterior-superior labrum are at risk for repetitive microtrauma (Bak, 2010). This repetitive microtrauma that eventually results in shoulder pain is referred to as “swimmer’s shoulder”.

Swimmer’s shoulder is an ill-defined condition that is widely synonymous with impingement syndrome and rotator cuff tendinitis (W. McMaster, 1999; Russ, 1998) as well as pathology of the acromioclavicular joint, the long head of the biceps, the labrum, tendinopathy or any type of shoulder instability (Allegrucci, et al., 1994; Russ, 1998). According to Bak (2010), extrinsic and intrinsic factors influence the etiology of swimmer’s shoulder. Extrinsic factors include training volume (absolute and sudden increases), technical or biomechanical training errors and the use of hand paddles. Intrinsic factors include excessive laxity and general joint hypermobility, isolated joint hyperlaxity, posture as it relates to core stability and increased thoracic kyphosis, scapular dyskinesis, glenohumeral internal rotation deficit (GIRD), rotator cuff muscle imbalance, poor flexibility (anterior rotator cuff, pectoralis minor) or increased stiffness of the shoulder capsule (posterior/anterior capsule). Swimmer’s shoulder has also been divided into five types, classified as types A through E (Bak, 2010). Type A is defined as isolated external impingement with subacromial bursitis and an increased amount of fluid in the supraspinatus tendon. The morphology of the acromion is normal with the possibility of an enlarged coracoacromial ligament. There is no evidence of hyperlaxity or instability and scapular dyskinesis is present in most cases. Type B is defined as isolated internal impingement without instability. Labral wearing and fraying is apparent along with minor or partial lesions along the articular side of the supraspinatus tendon.

Type C is more complex and involves both extra-articular and intra-articular pathology. There is almost always minor instability and scapular dyskinesis is present with this type of swimmer's shoulder. Type D is defined as minor instability accompanied by bilateral hyperlax shoulders. Pain is rare and scapular dyskinesis is present in all cases. Type E involves other pathologies such as acromioclavicular joint meniscus tears or arthritis. Scapular dyskinesis accompanies this type of swimmer's shoulder. Many factors all contribute to shoulder pain experienced by swimmers. These factors may arise independent of the training volume and repetitive nature of the sport or they may arise secondary to the training volume that is part of swimming.

CONTRIBUTORS TO SHOULDER PAIN

Biomechanics, range of motion, muscular imbalances, fatigue, impingement, glenohumeral joint instability and posture are all contributing factors to shoulder pain. Poor swimming technique and faulty biomechanics may be one factor that contributes to shoulder pain in swimmers.

Biomechanics

The pull-through phase of the freestyle stroke can be subdivided into early, mid and late pull-through (Allegrucci, et al., 1994). During early pull through, which occurs as the fingers are entering the water and ends as the hand becomes perpendicular to the body, the shoulder is internally rotated with the elbow slightly flexed and pointed upward with the palm of the hand facing out. Due to this positioning, the upper trapeziums, rhomboids, supraspinatus and the anterior and middle deltoids are active to abduct the shoulder and upwardly rotate the scapula. The serratus anterior also has peak activity during hand entry as upward rotation of the scapula occurs (Allegrucci, et al., 1994). Mid pull-through begins when the hand becomes perpendicular to the body at the deepest point in the water and ends when the arm is in ninety degrees of abduction and full internal rotation. During this portion of pull-through, the pectoralis major, teres minor, subscapularis and serratus anterior are active allowing the body to be pulled over the arm (Allegrucci, et al., 1994). Late pull-through begins when the arm reaches ninety degrees of abduction and full internal rotation and ends at hand exit with the palm facing the thigh. The latissimus dorsi is active throughout this phase of pull-through (Allegrucci, et al., 1994). As the hand begins its exit from the water at the end of pull through, this simultaneously signifies the beginning of the recovery phase of the freestyle stroke.

The recovery phase of the freestyle stroke may be subdivided into early and late periods. During the early portion of the recovery phase, the shoulder is internally rotating, extending and abducting while the scapula is retracting. With these motions the middle deltoid, supraspinatus, subscapularis and infraspinatus are all active (Allegrucci, et al., 1994). During the late portion of the recovery phase, the shoulder is abducting and internally rotating in order to position the hand for re-entry into the water. The infraspinatus is the primary mover during the late portion of the recovery phase as it works to control internal rotation of the shoulder (Allegrucci, et al., 1994). The biomechanics of the freestyle stroke are important to understand as it is the stroke used for the majority of swim training.

Biomechanical flaws may occur in any of the four stroke types but due to the large amount of training that is completed with the freestyle stroke, the flaws that occur during this stroke will be examined more closely. During the early pull-through phase, the hand placement in the water has been shown to be associated with shoulder pain in swimmers (Allegrucci, et al., 1994). Swimmers with painful shoulders have been observed to have hand placement further from the midline and in a less abducted position upon hand entry into the water (Allegrucci, et al., 1994). A dropped elbow during the late recovery phase and early pull-through phase is another biomechanical error that is commonly seen in swimmers with shoulder pain. This error is understood to be a signal of fatigue (Allegrucci, et al., 1994; Pink & Tibone, 2000). The biomechanics necessary to complete the freestyle stroke naturally places the shoulder in a compromised position (Allegrucci, et al., 1994). When these necessary biomechanics are performed poorly or become poor due to fatigue, the swimmers are at an increased risk of developing shoulder pain.

Range of Motion

Range of motion surrounding the shoulder girdle is another factor that may contribute to shoulder pain in swimmers. Many swimmers have an increased range of motion compared to non-swimmers. Increased range of motion and flexibility around the glenohumeral joint allows a swimmer to generate and increased amount of power through the entire pull-through phase (J. Troup, 1999). Flexibility is largely influenced by the functional anatomy of tendons and ligaments surrounding a joint combined with the size of the supporting musculature (J. Troup, 1999). External rotation range of motion, for example, has been shown to be ten degrees greater and abduction forty degrees greater in swimmers compared to non-swimmers (Beach, Whitney, & Dickoff-Hoffman, 1992). This attribute may actually enhance swimming performance as it allows for increased forward elevation to permit the body and arm to reach a 180 degree angle (Weldon &

Richardson, 2001). This angle allows the body to be parallel to the surface of the water which minimizes the forward axial surface area and reduces drag. Increased shoulder range of motion also allows for greater stroke length which directly increases swimming speed (Weldon & Richardson, 2001). Excessive range of motion, however, may also contribute to the problems of shoulder pain in swimmers. Many times swimmers have an increased amount of external rotation at the glenohumeral joint at the expense of internal rotation (Beach, et al., 1992). This may indicate a tight posterior capsule that may eventually contribute to pain over the posterior aspect of the shoulder (Beach, et al., 1992). Increased shoulder range of motion may also contribute to less glenohumeral joint stability. This leads to an increased amount of capsuloligamentous laxity which may place the rotator cuff muscles in unfavorable positions to maintain the length-tension relationship that allows them to maintain the humeral head centered over the glenoid fossa (Weldon & Richardson, 2001). Joint laxity that becomes pathologic and leads to disability in the form of shoulder pain is also known as instability (W. McMaster, 1999). The increased amount of range of motion that swimmers have surrounding the glenohumeral joint may be advantageous during competition but it can also be a contributing factor to shoulder pain.

Muscular Imbalances

Muscle imbalances around the shoulder girdle also contribute to the development of shoulder pain in swimmers. The majority of the propulsion generated in the water is provided by the upper body with minimal contribution of power from the legs (J. Troup, 1999; Weldon & Richardson, 2001). The force from the upper body is generated by forceful adduction of the shoulders coupled with elbow extension and the pectoralis major, pectoralis minor and latissimus dorsi are the main muscle groups responsible for generating this upper body power (J. Troup, 1999; Weldon & Richardson, 2001). The pectoralis major and the latissimus dorsi are the main muscles responsible for internal rotation and adduction which may lead to increased anterior shoulder strength. This may contribute to muscular imbalances that present as over-active and tight anterior shoulder musculature coupled with weak, stretched posterior shoulder musculature. Muscle imbalances are a result of muscular adaptations that take place as a consequence of the amount of training involved in swimming and have been shown to lead to altered neuromuscular control and abnormal movement patterns associated with elevation of the upper extremity (Greenfield et al., 1995). Adaptive shortening occurs when a muscle is overused in a certain condition that causes it to become tighter and shorter (Kendall, et al., 2005) and is a consequence of muscle imbalances. Opposing muscles develop stretch weakness where they become longer and weaker (Kendall, et al., 2005). This interaction of opposing muscles in the upper extremity that cause muscular imbalance is sometimes referred to as upper cross syndrome (Janda, 1987) which is characterized by weak, deep cervical flexors, lower trapeziums' and serratus anterior due to tight sternocleidomastoid, upper trapeziums and levator scapulae muscles that oppose them. If shoulder pathology develops in swimmers, muscular imbalances must be considered. In the presence of increased shoulder laxity, muscular imbalances may shift the glenohumeral joint which may lead to instability if shoulder pain develops (W. McMaster, 1999). Previous research has also shown that external impingement and scapular protraction may occur as a consequence of over-active and tight anterior shoulder musculature and muscle imbalances (B. Kibler & Sciascia, 2008; Solem-Bertoft, Thuomas, & Westerberg, 1993).

Fatigue

Fatigue is another contributing factor to shoulder pain in swimmers. Muscle activity increases with the onset of fatigue in an attempt to maintain pre-fatigue levels of force and power (J. Troup, 1999; J. T. Troup, S; Crickard, G et al., 1991). The high training volume that swimmers are subject to may lead to muscular fatigue especially when examining the serratus anterior, teres minor, infraspinatus and subscapularis muscles which are active throughout the entire stroke cycle (Pink & Tibone, 2000; Weldon & Richardson, 2001). The serratus anterior acts as a scapular stabilizing muscle and assists in positioning the scapula beneath the humeral head in such a way as to require the minimum amount of concavity compression from the rotator cuff muscles (Weldon & Richardson, 2001). Scapular instability is a result of serratus anterior fatigue. The rhomboid muscles attempt to contract to compensate for the fatigued serratus anterior. The rhomboids, however, are meant to be the antagonist muscle to the serratus anterior and contribute to normal scapular rotation. A fatigued serratus anterior disturbs the synchronous firing pattern that is meant to exist between the serratus anterior and the rhomboids leading to scapular dysfunction that may contribute to shoulder pain (Pink & Tibone, 2000; Weldon & Richardson, 2001).

Impingement

Impingement contributes to shoulder pain in swimmers and is subdivided into primary and secondary impingement. Primary impingement occurs when there is a mechanical obstruction of the rotator cuff tendons. This may occur under the anterior, inferior, lateral 1/3 of the acromion, the coracoacromial ligament or the acromioclavicular joint (Allegrucci, et al., 1994). In swimmers, primary impingement may occur most often during mid pull-through due to the increased adduction and internal rotation of the shoulder (Allegrucci, et al., 1994). Secondary impingement refers to the “relative” decrease in subacromial space as a result of glenohumeral instability which can develop from a disruption in the static stabilizers (ligament, labrum, joint capsule) or fatigue weakness of the dynamic, muscular stabilizers (Allegrucci, et al., 1994). During the recovery phase of the freestyle stroke, there is an increased chance of primary impingement due to the positioning of the shoulder (Allegrucci, et al., 1994). Secondary impingement is influenced by fatigue that may occur at the rotator cuff muscles (subscapularis, infraspinatus, teres minor) or may be influenced by an increased amount of laxity in the static restraints (Allegrucci, et al., 1994). During the recovery phase of the freestyle stroke there is an increased risk for secondary impingement due to anterior laxity and rotator cuff fatigue. Swimmers are most likely to impinge their shoulders in the middle of the pull-through phase and during the recovery phase (Yanai & Hay, 2000). Impingement may also occur when a swimmer reaches forward to “catch” the water during the early pull-through phase. A large moment is created about the shoulder joint due to the fluid force exerted on the hand as it enters and “catches” the water. This is believed to generate a large compressive force on the subacromial structures likely causing shoulder pain due to impingement of these subacromial structures (Yanai & Hay, 2000). Fatigue, range of motion and muscular imbalances, which may all contribute to shoulder pain independently, may also be secondary causes of shoulder pain because of their role in impingement.

Posture

Posture is the final contributing factor to shoulder pain. The accepted definition of normal posture has been defined as a vertical line passing through the lobe of the ear, the seventh cervical vertebrae, the acromion process, the greater trochanter, just anterior to the midline of the knee and slightly anterior to the lateral malleolus (Kendall & McCreary, 1983). This normal or "good" posture is associated with proper skeletal alignment. Bones must be aligned correctly for muscles, joints, ligaments, nerves and internal organs to function well (Page, 2005). The correct posture will contribute to muscular efficiency during the completion of any task. Abnormal posture is generally characterized as an increase in forward head angle, forward shoulder angle and thoracic curve or thoracic kyphosis. Forward head posture is defined as the anterior deviation of the head as observed at the lobe of the ear in relation to a plumb line or imaginary plumb line (Griegel-Morris, et al., 1992). Forward shoulder posture is defined as the anterior displacement of the acromion in relation to a plumb line or an imaginary plumb line and is considered a common deviation from normal posture (Griegel-Morris, et al., 1992). Forward shoulder posture is accompanied by the abduction and elevation of the scapula and a forward position of the shoulders that give the appearance of a hollow chest as well as the scapulae "winging" with medial rotation of the humerus (Peterson, et al., 1997). Thoracic kyphosis is defined as an increase in the convexity of the thoracic spine (Griegel-Morris, et al., 1992). Assuming postures for prolonged periods or completing repetitive motion patterns may lead to muscle imbalances that further perpetuate abnormal posture (Kendall, et al., 2005; Sahrmann, 2002) and put the shoulder at risk for developing shoulder pain.

Poor posture is an observation that may be seen in both collegiate swimmers who are students as well as the general student population who are non-athletes or non-overhead athletes. Poor posture in the general, student population may be seen due to computer/laptop use, video game use, backpack use and study/classroom habits. Over eighty percent of college students today use notebook computers as their personal computers (Chang, 2008). Jacobs et al. (2011) pointed out that from 2006 to 2009, ownership of a notebook computer by university students increased from sixty-six percent to eighty-eight percent with this trend likely to continue as students embrace the portability, lightweight and space-saving features that laptops offer. Time spent in front of a computer continues to increase as more and more as students also use their notebook computers for many different daily tasks, including classroom use. With this increased use of laptops, students are at greater risk for developing what is known as upper extremity musculoskeletal disorders (Jacobs et al., 2011; Straker, 1997). Poor posture in student populations may be attributable to the increased number of hours spent in front of the computer as notebook computers have been shown to increase exposure to risk factors for musculoskeletal disorders due to their compact size, integrated monitor and less than ideal input devices (Chang, 2008). Poor posture is commonly seen in today's student population. This student population includes collegiate swimmers.

Collegiate swimmers, who are student athletes, are subject to the same lifestyle-related postural influences as those students who are non-athletes. The non-athletes, however, are not subjected to the rigors of the swim training schedule. Swimmers spend the majority of their training prone (face down) in the water. It must be considered that posture in swimmers may be influenced by factors that are inherent in swim training.

Normal students who do not participate in athletics or who are not overhead athletes are not subjected to this extra factor. Swimmers who are student athletes, however, are subjected to the same posture-altering factors that normal students are subjected to along with the additional factor of the training period. It is important to understand why postural deviations are occurring in students and student-athletes in order to assist in the proper diagnosis and treatment of shoulder pain as it relates to posture

POSTURE AND SHOULDER PAIN

Typical swimming posture is forward head, forward shoulder posture combined with protracted scapulas that contribute to excessive thoracic kyphosis. Posture, as it relates to shoulder pain, is a relationship that continues to be explored as the two cannot be said to have a cause-effect relationship. The two seemed to be related through muscle length changes, fatigue and muscular imbalances that may exist between agonist and antagonist muscle groups on the anterior and posterior aspects of the shoulder. Muscle length changes in forward shoulder posture may result in abnormal scapulohumeral rhythm, impingement of the rotator cuff tendons, acromioclavicular joint degeneration, bicipital tendinitis and painful trigger areas (Peterson, et al., 1997). Forward head posture generally means that the suboccipital muscles and the upper trapeziums' are overly tight coupled with weak deep neck flexors (Page, 2005). Forward shoulder posture along with an increase in thoracic kyphosis indicates tight pectoral muscles coupled with weak middle and lower trapeziums'.

Muscle length changes that occur in swimming are due to the repetitive nature of the sport and the fact that the majority of training is performed using the freestyle stroke where the swimmer is prone in the water using the anterior musculature, including the pectoral muscles, the serratus anterior and the upper trapeziums', to generate power in the water (Peterson, et al., 1997). The constant use of this anterior musculature causes the muscles to become over-developed, tight and short and pulls the shoulder girdle forward in relation to a plumb line or an imaginary plumb line (Peterson, et al., 1997). Internal rotators and adductor muscles surrounding the shoulder girdle become stronger and hypertrophied relative to antagonist muscles leading to strength imbalances of the anterior shoulder muscles in relation to posterior shoulder muscles. These strength imbalances lead to forward shoulder and protracted scapulae that have been associated with painful shoulders in swimmers (Kluemper, Uhl, & Hazelrigg, 2006; Rupp, Berninger, & Hopf, 1995). The anterior pull on the shoulder girdle by the anterior musculature puts the posterior muscles, involved in pulling the scapulae back towards the spine, on a constant stretch that eventually causes them to lengthen and weaken which contributes to forward shoulder posture (Peterson, et al., 1997). Faulty postural alignment and poor posture over time can lead to abnormal stress on tissues that may contribute to shoulder pain (Page, 2005). Poor posture may be implicated in shoulder pain indirectly through muscle imbalances. These muscle imbalances may alter biomechanics, contribute to secondary impingement, contribute to joint instability and contribute to fatigue.

INSTRUMENTATION FOR POSTURE MEASURES

Posture measures have been attempted using several different techniques. These techniques include the plumb line, standing radiographs, the Baylor Square, the Double

Square, a ruler and a digital inclinometer. Standing radiographs are considered the gold standard for postural analysis (Peterson, et al., 1997). Lateral views are reviewed by a board certified radiologist where a perpendicular line is drawn from the seventh cervical vertebra. The horizontal distance between the perpendicular line and the anterior tip of the left acromion is then measured (Peterson, et al., 1997). Even though this is the gold standard, this is not a method that is very applicable clinically due to its expense and the amount of time required. The plumb line is a visual measurement tool that compares anatomical landmarks to a vertical line/string or an imaginary line. The plumb line is a vertical line passing through the lobe of the ear, the seventh cervical vertebrae, the acromial process, the greater trochanter, just anterior to the midline of the knee and slightly anterior to the lateral malleolus (Kendall & McCreary, 1983). Clinically, the plumb line is very applicable and easy to use to establish a line of reference that coincides with the midline of the body in anterior, posterior and lateral views (Peterson, et al., 1997). The Baylor square is also a method that measures the distance between the tip of the acromion process and the spinous process of the seventh cervical vertebra without the cost and time requirement. It is a method of postural analysis that has the highest correlation with radiographic measurements (Peterson, et al., 1997). This method is appropriate for use in a clinic setting as measurements are taken manually with the subject standing with their back against the wall while the distance between the seventh cervical vertebra and the anterior tip of the acromion are measured. The Double square method has also been used to quantify forward shoulder position by having subjects stand with their back against the wall while a measurement is taken from the wall to the anterior tip of the acromion process (Peterson, et al., 1997). Similar to the Baylor square technique, this is a measurement method that would be applicable to the clinic setting but only has a moderate correlation with the standing radiographic measurements (Peterson, et al., 1997). The final two measurement techniques that have been used to quantify posture measurements for analysis are a ruler combined with a digital inclinometer. Forward head translation was measured with a ruler while forward head angle was measured using a digital inclinometer (Lynch, et al., 2009). Postural analysis has been performed using a variety of techniques. Radiographic measures are the most accurate measure of forward head, forward shoulder posture. This measure is not clinically applicable, however. The Baylor square method, the plumb line method and the ruler coupled with the digital inclinometer are the most reliable measures of posture that are clinically applicable and able to be performed relatively quickly with little expense.

PURPOSE AND CLINICAL RELEVANCE

Abnormal, static postural alignment that includes forward head, forward shoulder posture combined with thoracic kyphosis and protracted scapulae may give rise to muscle imbalances. These imbalances may be due to adaptive shortening of the anterior chest musculature and stretch weakness of the posterior scapulothoracic musculature. Maintaining forward head, forward shoulder posture combined with a protracted scapula for long periods of time could change the orientation of the glenoid fossa and predispose the shoulder to impingement and instability (Lynch, et al., 2009). Swimmers' anterior musculature is continually taxed as a result of performing the majority of their training in the prone position, using the freestyle stroke. In addition, yardage during the training period of the season builds gradually which places an increased demand on those anterior chest and shoulder muscles. As swimmers reach their maximum training yardage and training intensity just prior to the taper period, it is possible, that their forward head, forward shoulder posture is more pronounced than it was prior to the beginning of the training period. In addition to identifying whether the training period increases the forward head, forward shoulder posture in swimmers this study hopes to identify time periods within the training period that show the most change in posture so that proven intervention techniques, that include stretching and strengthening, can be implemented in a timely fashion to prevent further postural changes from occurring. Exercise interventions, over the course of a swim season, have been shown to improve postural deviations that may be associated with shoulder pain (Kluemper, et al., 2006; Lynch, et al., 2009). Posture may only play a minor and indirect role in shoulder pain but if poor posture habits can be identified and corrected, fewer factors are left to be considered as to why a swimmer may be experiencing shoulder pain.

CHAPTER III

METHODOLOGY

INTRODUCTION

This study looked at collegiate swimmers and compared their forward head and forward shoulder posture to a control group of non-swimmers or non-overhead athletes over the course of the training period. Forward head and forward shoulder posture was measured using digital photography to capture the angle of inclination between the line extending from C7 to tragus and the horizontal line and the angle of inclination between the line extending from C7 to the shoulder and the horizontal line respectively.

POPULATION AND RECRUITMENT

Swimming Group

Subjects were recruited for both a swimming group and a control group. Swimming group subjects were recruited from the University of North Carolina at Chapel Hill swim team. Subjects were both males and females between the ages of 18 and 25 years old. An a priori power analysis demonstrated that a minimum of 13 subjects were needed to achieve a power of 0.9 (Harrison, Barry-Greb, & Wojtowicz, 1996; Kluemper, et al., 2006; Shiau & Chai, 1990), however, 42 subjects were used for the swimming group as this was a readily available number of subjects on the UNC-Chapel Hill Swim team who met all inclusion/exclusion criteria.

Inclusion Criteria

Swimming group subjects were included in this study if:

- Members of the UNC-Chapel Hill Swim team
- Able to practice at least 5 times per week, 1-2 hours per practice session
- Minimum of five years of competitive swimming experience (Bak, 2010; Sokolovas, 2003).

Exclusion Criteria

Subjects in the swimming group were excluded from this study if:

- Unable to complete the specified yardage during practice on a daily basis more than two days per week
- Had a history of shoulder surgery (Ramsi, Swanik, Swanik, Straub, & Mattacola, 2004)
- Used an external, correctional posture device
- Performed rehabilitation (strengthening and stretching) to target posture deviations of forward head, forward shoulder posture

Control Group

Control group subjects were recruited from the University of North Carolina at Chapel Hill. Control group subjects were non-overhead athletes or non-athletes between the ages of 18 and 25 years old. 42 control group subjects were age and gender matched to the swimming group based on inclusion/exclusion criteria.

Inclusion Criteria

Control subjects were included in this study if:

- Had not participated in overhead athletics for a minimum of 1 year
- Were enrolled "full time" in college
- Were gender and age-matched to the swimming group (18 to 25 years).

Exclusion Criteria

Control subjects were excluded from this study if:

- Had a history of shoulder surgery (Ramsi, et al., 2004).
- Used any type of external, correctional posture device
- Performed rehabilitation (strengthening and stretching) to target posture deviations associated with forward head, forward shoulder posture.

RESEARCH DESIGN

This study used a cross-sectional, repeated measures research design to evaluate the changes in forward head and forward shoulder posture over time in a swimming group and control group. Both groups were photographed four times over a five month time period. The four measurement time periods were preseason (late August/early September), mid-season (mid-October), prior to training trip (mid-December) and post-training trip (late January). These photographs were used to quantify changes in forward head and forward shoulder posture at each time interval for each group.

MEASUREMENTS AND INSTRUMENTATION

High resolution digital images, using a digital camera, were used for postural assessment of forward head and forward shoulder posture. Images were uploaded and stored on a personal computer for analysis of forward head and forward shoulder angles using Image J software (National Institute of Health, Bethesda, MD). Pain questionnaires, including the DASH-SM (Disabilities of the Arm, Shoulder and Hand Sports Model) and FASS-TS (Functional Arm Scale for Swimmers Total Score), were used to collect informational data regarding shoulder pain at each testing session.

Procedures

Subjects were introduced to the experiment and asked to sign an informed consent form approved by the University of North Carolina at Chapel Hill Institutional Review Board. If the participant had questions regarding the procedures or the study in general, he/she had the opportunity to ask questions of the primary investigator at any point during the consent process. After consent was obtained, the primary investigator ensured that the participant met the inclusion/exclusion criteria by using a screening form designed for either the swimming group or the control group. If inclusion/exclusion criteria were met, each participant underwent the following testing procedures: subjects completed a questionnaire relating to demographics and general physical assessment designed to allow subjects to report any injuries incurred between testing sessions. Swimming group subjects completed demographic questions designed to collect descriptive statistics related to age, gender, current participation level and swimming participation history (previous/current injuries, distance versus sprint group etc.). Control group subjects completed demographic questionnaires designed to collect descriptive statistics related to age, gender and physical activity. Pain questionnaires for each group were administered at each testing session and included the Disabilities of the Arm, Shoulder and Hand Sport Module (DASH-SM) questionnaire and the Functional Arm Scale for Swimmers Total Score (FASS-TS) questionnaire (adapted from the Functional Arm Scale for Throwers©). These questionnaires were used to examine the relationship between shoulder pain and postural changes throughout the research project.

Following completion of the pain questionnaire, reflective markers were placed on the right side of each participant on the following anatomical landmarks: tragus, C7, anterior tip of the acromion (Thigpen, 2006). Subjects received standardized instructions on how to properly perform an overhead squat task followed by a demonstration from the principal investigator of proper technique for an overhead squat task. Subjects were instructed to complete one practice trial of the overhead squat task with an opportunity to receive further instruction and to adjust stance. Subjects were then asked to stand 40 cm in front of a horizontal reference line to be photographed from the side. Subjects were instructed to stand in “a relaxed position” while photographs were taken. Following the initial photograph, subjects were then instructed to complete three overhead squats in a row in order to distract them from the purpose of the study in an attempt to prevent them from making corrections to their standing posture. Following the series of three squats, the subjects were instructed to “relax” and “stand in normal position” while photographs were repeated in the sagittal plane. Subjects completed two additional sets, of three squats per set, “relaxing” and “standing in normal posture” following each set to allow for subsequent photographs to be taken.

Postural analysis was performed using Image J software (National Institute of Health, Bethesda, MD) and the landmarks that were defined by the reflective markers on each participant (tragus, C7, anterior tip of acromion). The landmarks were digitized to calculate the forward head angle (defined as the angle of inclination of the line extending from C7 to tragus and the horizontal line) and the forward shoulder angle (defined as the angle of inclination of the line extending from C7 to the shoulder and the horizontal line) for each participant. Pilot testing conducted prior to this study established intrarater reliability and precision for forward head posture (ICC = 0.99, SEM = 0.11) and forward shoulder posture (ICC = 0.99, SEM = 0.34) using this measurement technique.

DATA REDUCTION

Angles of inclination for forward head and forward shoulder posture will be calculated using Image J software (National Institute of Health, Bethesda, MD). Forward head and forward shoulder posture was averaged (using the three pictures taken following each squat set) for each testing session over the course of the training period (late August/early September to late January).

Total pain scores were calculated for the FASS-TS questionnaire by adding up total responses in all sections. Pain scores for the DASH-SM were calculated using the following formula: {[(sum of n responses)-1]/n}x25. These respective scores were used to correlate pain with forward head and forward shoulder posture in both the swimming group and the control group at each testing session. Yardage totals between each testing session for each swimmer will also be correlated with forward head and forward shoulder posture measures at each testing session. Finally, yardage totals were correlated with FASS-TS and DASH-SM pain scores.

STATISTICAL ANALYSIS

Statistical analyses were run using SPSS version 20.0 software (IBM SPSS, New York, NY). A two by four mixed model ANOVA, one between factor (group) and one within factor (time), was run to evaluate the change in forward head and forward shoulder angles. Post-hoc testing was conducted in the form of t-tests. Protected independent t-tests were used to look at the simple effects of group on forward head and forward shoulder posture. An adjusted alpha level of $p \leq 0.0125$ was set for all comparisons a priori for statistical significance for the between subjects factor. Protected paired sample t-tests were used to look at the simple effects of time on forward head and forward shoulder posture in each group. An adjusted alpha level of $p \leq 0.017$ was set for all comparisons a priori for statistical significance for the within subjects factor. Mauchley's test of sphericity was used to determine whether equal variance was assumed. Huynh-Feldt correction was used if the assumption of sphericity was violated.

An alpha level of $p \leq 0.05$ was set for all comparisons a priori for statistical significance for Pearson *r* correlations run. Pearson *r* correlation coefficients were calculated to analyze the following relationships in the swimming group only: FASS-TS and DASH-SM pain scores and forward head, forward shoulder angle measurements, yardage totals and forward head, forward shoulder angle measurements and yardage totals and FASS-TS and DASM-SM pain scores.

Data Analysis Plan

Research Question	Description	Data Source	Comparison	Method
1	The effect of the training period on forward head posture in collegiate swimmers	Angle of inclination for forward head posture in swimming group versus control group at four different time points	Angle of inclination for FHP in swimming group compared to angle of inclination for FHP in control group at three different time points	2x4 Mixed Model ANOVA
2	The effect of the training period on forward shoulder posture in collegiate swimmers	Angle of inclination for forward shoulder posture in swimming group versus control group at four different time points	Angle of inclination for FSP in swimming group compared to angle of inclination for FSP in control group at three different time points	2x4 Mixed Model ANOVA
3	The differences in forward head posture in the swimming group between testing sessions	Angle of inclination for forward head posture in swimming group versus control group at four different time points	Angle of inclination for FHP in swimming group across four testing session (late Aug./early Sept., mid-Oct., mid-Dec., late Jan.	Paired samples t-tests
4	The differences in the forward shoulder posture in the swimming group between testing sessions	Angle of inclination for forward shoulder posture in swimming group versus control group at four different time points	Angle of inclination for FSP in swimming group across four testing session (late Aug./early Sept., mid-Oct., mid-Dec., late Jan.	Paired samples t-test
5	The relationship between the change pain scores and the change in forward head posture in swimmers between testing sessions.	ΔDASH-SM/ΔFASS-TS pain scores and ΔFHP for swimmers between testing sessions.	Correlation between the change in posture and the change in pain scores in the swimming group between testing sessions.	Pearson *r* Correlation

6	The relationship between the change in pain scores and the change in forward shoulder posture in swimmers between testing sessions.	ΔDASH-SM/ΔFASS-TS pain scores and Δ FSP for swimmers between testing sessions.	Correlation between the change in posture and the change in pain scores in the swimming group between testing sessions.	Pearson *r* Correlation
7	The relationship between yardage completed between testing sessions and the change in forward head posture in the swimmers between testing sessions.	Yardage completed between testing sessions and ΔFHP for swimmers between testing sessions.	Correlation between yardage completed between testing sessions and the change in forward head posture in swimmers between testing sessions.	Pearson *r* Correlation
8	The relationship between yardage completed between testing sessions and the change in forward shoulder posture in the swimmers between testing sessions.	Yardage completed between testing sessions and ΔFSP for swimmers between testing sessions	Correlation between yardage completed between testing sessions and the change in forward shoulder posture in swimmers between testing sessions.	Pearson *r* Correlation
9	The relationship between yardage completed between testing sessions and the change in pain scores at each testing session.	Yardage completed between testing sessions and ΔDASH-SM/ΔFASS-TS pain scores at each testing session.	Correlation between yardage completed between testing sessions and the change in pain scores at each testing session.	Pearson *r* Correlation

CHAPTER IV

RESULTS

SUBJECTS

Forty-seven swimming subjects were screened, met the inclusion criteria and agreed to participate in this study prior to conducting the first testing session (late August/early September). The number of control subjects matched the number of swimming subjects at the beginning of the study. Swimmers and controls were matched by age and gender. Total subjects at the beginning of the study were ninety-four.

Forty-two swimming subjects were still included in the study at the end of the fourth testing session (late January). Three of the swimming subjects (2 female, 1 male) were removed from the study due to shoulder pain/injury and the subsequent implementation of rehabilitation exercises that excluded these subjects from further participation in the study. Two additional swimming subjects (1male, 1 female) were removed from the study as they were no longer swimming as members of the UNC-Chapel Hill Swimming Team. Forty-two control subjects were included in the study at the end of the fourth testing session to match the number of swimmers. Control subjects were removed if their swimming counter-part was removed. Eighty-four subjects (**Table 1**) were included at the end of the study bringing the overall retention rate to 89%.

FORWARD HEAD POSTURE

Four testing sessions of forward head angle measurements (late August/early September, mid-October, mid-December and late January) were used to assess the effect of the training period on forward head posture in collegiate swimmers compared to a control group of non-athletes/non-overhead athletes. A 2x4 mixed model ANOVA was calculated to determine the interaction effect of time and group on forward head posture. Using Huynh-Feldt correction for equal variances not assumed, there was significant time by group interaction of forward head posture across the four time points *($F_{1,82}$ = 4.351, p=0.007).* Simple effects were evaluated due to the significant interaction term. Simple effects were used to determine how the groups differed at each time point and how each group changed over the course of the research study.

Independent t-tests were used to examine the simple effects of group on forward head posture at each of the time points between the swimming group and the control group using an adjusted alpha level of $p \leq 0.0125$. **Table 2** provides the means and standard deviations of forward head posture for both groups at each testing session. Independent t-tests (equal variances not assumed) indicate that there was no significant difference in the mean forward head posture between the swimming group and the control group at time 1 (*t_{82}=-1,449, p=0.152, md=-1.50),* time 2 *(t_{82}=-1.308, p=0.195, md=-1.381),* time 3 *(t_{82}=-0.021, p=0.983, md=-0.022)* or time 4 (t_{82}=-2.358, p=0.021, md=-2.356).

Paired samples t-tests were used to examine the simple effects of time on forward head posture in the swimming group and the control group between each testing session using an adjusted alpha level of $p \leq 0.017$. **Table 2** provides the means and standard deviations of forward head posture for both groups at each testing session. For the swimming group, there was no significant difference found between time 1 and time 2 ($t_{41}=2.041$, $p=0.048$) or time 2 and time 3 ($t_{41}=-0.413$, $p=0.682$) indicating that the mean forward head posture for the swimming group did not change significantly between these testing sessions (**Figure 4**). A significant difference was found between time 3 and time 4 ($t_{41}=3.105$, $p=0.003$) indicating that swimmers were moving into greater forward head posture between these testing sessions (**Figure 4**). For the control group, there was a significant difference found between time 1 and time 2 ($t_{41}=3.734$, $p=0.001$), time 2 and time 3 ($t_{41}=2.886$, $p=0.006$) and time 3 and time 4 ($t_{41}=-2.943$, $p=0.005$). This indicates that the control group was moving into greater forward head posture between times 1 and 2 and times 2 and 3 but that the forward head posture of the control group was improving between times 3 and 4 (**Figure 4**).

FORWARD SHOULDER POSTURE

Four testing sessions of forward shoulder angle measurements (late August/early September, mid-October, mid-December and late January) were taken to assess the effect of the training period on forward shoulder posture in collegiate swimmers compared to a control group of non-athletes/non-overhead athletes. A 2x4 mixed model ANOVA was calculated to determine the interaction effect of time and group on forward shoulder posture. There was a significant time by group interaction of forward shoulder posture across the four time points ($F_{1,82} = 10.605$, $p<0.001$). Simple effects were evaluated due to the significant interaction term. Simple effects were used to determine how the groups differed at each time point and how each group changed over the course of the research study.

Independent t-tests were used to examine the simple effects of group on forward shoulder posture at each of the time points between the swimming group and the control group using an adjusted alpha level of $p \leq 0.0125$. **Table 3** provides the means and standard deviations of forward shoulder posture for both groups at each testing session. Independent t-tests (equal variance assumed) indicate that there was no significant difference in the mean forward shoulder posture between the swimming group and the control group at time 1 $(t_{82}=1.2,\ p=0.233,\ md=2.45)$, time 2 $(t_{82}=2.152,\ p=0.034,\ md=3.842)$ or time 4 $(t_{82}=-1.149,\ p=0.254,\ md=-2.188)$. There was a significant difference in the mean forward shoulder posture between the swimming group and the control group at time 3 $(t_{82}=2.986,\ p=0.004,\ md=5.901)$ indicating that the swimming group had less forward shoulder posture than the control group at time 3.

Paired samples t-tests were used to examine the simple effects of time on forward shoulder posture in the swimming group and the control group between each testing session using an adjusted alpha level of $p \leq 0.017$. **Table 3** provides the means and standard deviations of forward shoulder posture for both groups at each testing session. For the swimming group, there was a significant difference found between time 1 and time 2 $(t_{41}=-4.258,\ p<0.001)$ to indicate that forward shoulder posture was improving between these testing sessions (**Figure 5**). There was also a significant difference found between time 3 and time 4 $(t_{41}=6.773,\ p<0.001)$ indicating that the swimming group was moving into greater forward shoulder posture between these testing sessions (**Figure 5**). There was no significant difference between time 2 and time 3 $(t_{41}=-2.212,\ p=0.033)$

indicating that forward shoulder posture for the swimming group did not change between these testing sessions. For the control group, there was a significant difference found between time 1 and time 2 *(t_{41}=-2.988, p=0.005)* indicating that the forward shoulder posture for the control group was improving between these testing sessions (**Figure 5**). There was no significant difference found between time 2 and time 3 *(t_{41}=-0.095, p=0.925)* and between time 3 and time 4 *(t_{41}=-0.581, p=0.564)* indicating that the forward shoulder posture for the control group was not changing between these testing sessions (**Figure 5**).

CORRELATIONS

Pearson *r* correlations were conducted to examine the relationship between the change in FASS-TS and DASH-SM pain scores between testing sessions and the change in posture at each testing session for the swimming group. These pain scores were also used to examine the relationship between the change in shoulder pain between testing sessions and yardage completed between testing sessions for the swimming group.

A Pearson *r* correlation coefficient was calculated to examine the relationship between the change in FASS-TS pain scores and the change in forward head posture in the swimming group. No significant relationship ($p \leq 0.05$) was found at time 2 *(r_{40}=-0.006, p=0.970)*, time 3 *(r_{40}=0.108, p=0.498)* or time 4 *(r_{40}=0.315, p=0.042)*. Changes in FASS-TS pain scores between testing sessions are not related to changes in forward head posture in the swimming group.

A Pearson *r* correlation coefficient was calculated to examine the relationship between the change in DASH-SM pain scores and the change in forward head posture in the swimming group. No significant relationship ($p \leq 0.05$) was found at time 2 *(r_{40}=-0.216, p=0.170)*, time 3 *(r_{40}=0.073, p=0.644)* or time 4 *(r_{40}=0.275, p=0.078)*. Changes in DASH-SM pain scores between testing sessions are not related to changes in forward head posture in the swimming group.

A Pearson *r* correlation coefficient was calculated to examine the relationship between the change in FASS-TS pain scores and the change in forward shoulder posture in the swimming group. No significant relationship ($p \leq 0.05$) was found at time 2 *(r_{40}=-0.148, p=0.349)* or time 4 *(r_{40}=-0.064, p=0.689)*. A moderate, positive relationship that was significant ($p \leq 0.05$) was found at time 3 *(r_{40}=0.399, p=0.009)*, with an R^2 of 0.156. Changes in FASS-TS pain scores between testing sessions 1 and 2 and testing sessions 3 and 4 are not related to changes in forward shoulder posture at those respective testing sessions in the swimming group. Changes in FASS-TS pain scores between testing session 2 and 3, while significant, may indicate that only a small amount (15.6%) of the change in shoulder pain as reported on the FASS-TS pain questionnaire can be explained by the change in forward shoulder posture at testing session 3.

A Pearson *r* correlation coefficient was calculated to examine the relationship between the change in DASH-SM pain scores and the change in forward shoulder posture in the swimming group. A moderate, positive relationship that was significant ($p \leq 0.05$) was found at time 3 *(r_{40}=0.330, p=0.033)* with an R^2 of 0.109. No significant relationship ($p \leq 0.05$) was found at time 2 *(r_{40}=0.051, p=0.747*) or time 4 *(r_{40}=-0.006, p=0.970)*. Changes in DASH-SM pain scores between testing sessions 1 and 2 and 3 and 4 are not related to changes in forward shoulder posture in the swimming group. Changes in DASH-SM pain scores between testing session 2 and 3, while significant, may indicate only a small amount (10.9%) of the change in shoulder pain as reported on the DASH-SM questionnaire can be explained by the change in forward shoulder posture at testing session 3.

A Pearson *r* correlation coefficient was calculated to examine the relationship between yardage completed between testing sessions and the change in forward head posture in the swimming group. No significant relationship ($p \leq 0.05$) was found at time 2 ($r_{40}=0.176$, $p=0.265$), time 3 ($r_{40}=0.182$, $p=0.249$) or time 4 ($r_{40}=0.145$, $p=0.360$). Yardage completed between each testing session is not related to changes in forward head posture at each testing session in the swimming group.

A Pearson *r* correlation coefficient was calculated to examine the relationship between yardage completed between testing sessions and the change in forward shoulder posture in the swimming group. No significant relationship ($p \leq 0.05$) was found at time 2 ($r_{40}=0.046$, $p=0.770$), time 3 ($r_{40}=0.027$, $p=0.865$) or time 4 ($r_{40}=0.094$, $p=0.553$). Yardage completed between each testing session is not related to changes in forward shoulder posture at each testing session in the swimming group.

A Pearson *r* correlation coefficient was calculated to examine the relationship between yardage completed between testing sessions and the change in FASS-TS pain scores between testing sessions in the swimming group. No significant relationship ($p \leq 0.05$) was found at time 2 ($r_{40}=-0.057$, $p=0.720$), time 3 ($r_{40}=-0.064$, $p=0.688$) or time 4 ($r_{40}=-0.054$, $p=0.733$). Yardage completed between each testing session is not related to the changes in FASS-TS pain scores between testing sessions in the swimming group.

A Pearson *r* correlation coefficient was calculated to examine the relationship between yardage completed between testing sessions and the change in DASH-SM pain scores between testing sessions in the swimming group. No significant relationship ($p \leq 0.05$) was found at time 2 ($r_{40}=-0.157$, $p=0.322$, time 3 ($r_{40}=0.096$, $p=0.544$) or time 4 ($r_{40}=-0.022$, $p=0.890$). Yardage completed between each testing session is not related to the changes in DASH-SM pain scores between testing sessions in the swimming group.

CHAPTER V

DISCUSSION

Forward head and forward shoulder posture are innately linked because many of the muscles responsible for shoulder motion are multi-joint muscles that also cross the cervical spine and head (P. Ludewig & Cook, 1996). Attachments of muscles between the cervical spine, head and scapula such as the upper trapezium and levator scapulae allow cervical and head positions to be possible contributors to alterations in scapular mechanics (Kendall, et al., 2005; P. Ludewig & Cook, 1996). Altered scapular mechanics may predispose swimmers to the occurrence of shoulder pain that may ultimately hinder performance and training time. The purpose of this study was to determine the effects of a typical swim training period on forward head and forward shoulder posture in competitive swimmers. Swimmers were age and gender matched to a control group in order to control for lifestyle factors that may also affect forward head and forward shoulder posture in swimmers. Identifying time points throughout the training period where swimmers may be moving into greater forward head or forward shoulder posture may allow clinicians to identify the best time to intervene with proven intervention programs to counteract the effects and adaptations that occur as a result of the extensive amount of time that swimmers spend training. Determining whether relationships exist between changes in forward head and forward shoulder posture and pain scores or yardage completed contributes to evidence that posture plays a role in shoulder pain or that yardage completed is related to the changes that are seen in forward head and forward shoulder posture. Lastly, determining whether a relationship exists between yardage completed and changes in pain score contributes to evidence that training philosophies may have an effect on shoulder pain experienced by swimmers.

FORWARD SHOULDER POSTURE

There was a significant interaction between group (swimming or control) and testing session. Further analysis revealed that swimmers had significantly less forward shoulder posture at the third testing session, indicating improved posture, compared with controls. Significance seen at the third testing session may be attributable to the strength and conditioning and dryland programs that were completed throughout the fall semester for the swimming group. Strength and conditioning and dryland, in particular, emphasized posterior shoulder strengthening combined with mobility that included targeted stretching for tight, anterior shoulder musculature. The control group did not consist of collegiate athletes. Therefore, they did not participate in an organized, targeted strength and conditioning program to emphasize posterior shoulder musculature strength over the course of these three months. An organized, targeted strength and conditioning program to emphasize posterior shoulder strengthening aids in preventing postural deviations such as forward head and forward shoulders and helps maintain good posture. Had the control group participated in a more regimented strength and conditioning program, the significant interaction between group may not have been present.

Figure 5 represents the changes in forward shoulder posture that occurred in both the swimming group and the control group at each testing session when compared to previous testing sessions within each group. Statistically significant differences indicating improvements, or a decrease in forward shoulder posture, were found in the swimming group between testing sessions one and two. This trend of improved forward shoulder posture continued between testing sessions two and three, though it was not a significant trend. Significant decreases in forward shoulder posture may have been attained between testing sessions one and two because of the aforementioned strength/conditioning and dryland programs implemented at the beginning of the collegiate season. Although researchers did not examine the exact strength/conditioning and dryland protocol that was being implemented during any portion of the training period, it is feasible that no significant decrease in forward shoulder posture was seen between testing sessions two and three because maximum strength gains and improvements in forward shoulder posture were reached between testing sessions one and two. A ceiling effect may have been reached where further improvements in forward shoulder posture may not have been anatomically possible. Alternately, the lack of significant improvement seen between testing sessions two and three may also be attributed to the possibility that yardage was increasing between testing session two and three more quickly than adjustments in the strength/conditioning and dryland programs were being made. Thus, strength/conditioning and dryland programs between those testing sessions could not combat the indirect effects of yardage completed as effectively.

Interestingly, between the third and fourth testing sessions, the forward shoulder posture in the swimming group was no longer improving. Statistically significant differences are apparent between testing sessions three and four, indicating that the forward shoulder posture in the swimming group was increasing. The time between the third and fourth testing sessions for the swimmers was defined by a short period (~1 week), at the beginning of the holiday break, where swimmers were training with their home, club teams. They returned to UNC swim training during the winter training trip that lasted for ten days. Upon returning to campus from the training trip, intense training was maintained through the end of January. Despite the fact that no relationship existed between yardage completed and changes in forward shoulder posture in the swimming group, yardage may be an indirect link to the changes in forward shoulder posture due to fatigue, overuse and muscle imbalances that occur due to the amount of yardage completed. Variations in the strength and conditioning and dryland programs over the course of training trip may also play a secondary role in the increase in forward shoulder posture seen between testing sessions three and four.

Swimmers are subject to early fatigue due to high training volumes (Bak, 2010) because muscle activity increases in an attempt to maintain pre-fatigue levels of force and output (J. Troup, 1999; J. T. Troup, S; Crickard, G et al., 1991). It has been shown that some of the scapular positioning muscles including the serratus anterior, teres minor, infraspinatus and subscapularis are all active throughout the entire stroke cycle in freestyle swimming (Weldon & Richardson, 2001). As these muscles start to fatigue, posterior scapula stabilizing muscles such as the rhomboids attempt to compensate for fatigue occurring through the rotator cuff and serratus anterior muscles (Pink & Tibone, 2000). With the winter training trip, yardage completed daily increased dramatically, compared to the fall semester, with the swimmers completing approximately eighteen to twenty thousand yards, between two practices, for ten straight days. This differs from the practice schedule in the fall where double sessions (two practices per day) were always followed by a session off (single practice the following day). During the course of the training trip, fatigued and overused muscles never had an opportunity for recovery. **Figure 6** indicates average yardage completed over the course of the training period. Cumulative fatigue generated throughout the training period and fatigue following each individual training session while on training trip, likely combine to contribute to the increase in forward shoulder posture seen. Increases in duration and intensity of training sessions during training trip contributed to the role that fatigue plays in perpetuating forward shoulder posture. Fatigued posterior shoulder musculature would be unable to counteract the overactive and tight anterior shoulder musculature, thus perpetuating forward shoulder posture.

Yardage completed may also be an indirect link to changes in forward shoulder posture due to muscular adaptations. Muscular adaptations may occur as a consequence of the training that is involved in swimming (W. McMaster, 1999). Completing large amounts of yardage requires swimmers to use specific postures/positions in the water in repetitive motion patterns for prolonged periods. Both of these factors contribute to the development of muscular imbalances (Kendall, et al., 2005; Sahrmann, 2002) which cause the agonist muscles to become tighter and shorter, leading to what is known as adaptive shortening (Kendall, et al., 2005). This is most apparent when looking at forward shoulder posture because the upper body is providing the force to move the swimmer through the water and pull the body over the arm in the water (Allegrucci, et al., 1994). This upper body force comes primarily from adduction and internal rotation of the shoulder which will contribute to agonist-antagonist muscle imbalances (Kluemper, et al., 2006). Muscle imbalances around the shoulder girdle manifest as overly tight anterior musculature coupled with weak, stretched posterior musculature that results in an anterior pull on the joint. Overdeveloped, tight and shortened pectoralis minor, serratus anterior and upper trapezium muscles, combined with weakened and lengthened lower and middle trapezium muscles that are unable to pull the scapulae toward the spine, all contribute to forward shoulder posture and protracted scapulae (Kluemper, et al., 2006; Page, 2005; Peterson, et al., 1997; Rupp, et al., 1995). It may be inferred that the yardage completed created an increased amount of adaptive shortening and muscular imbalance around the shoulder girdle. The longer that muscular fatigue and imbalance lasts, the harder it is to overcome to correct forward shoulder posture.

The strength and conditioning and dryland programs completed between the third and fourth testing sessions may be a second factor that contributes to the significant increase in forward shoulder posture in the swimming group between the third and fourth testing sessions. Throughout the fall semester, the swimming group completed strength and conditioning exercises three times per week and dryland training two times per week. Mobility, flexibility, postural and core exercises were completed throughout the fall to target posterior shoulder weakness and anterior shoulder tightness. Previous research (Kluemper, et al., 2006; Lynch, et al., 2009) has shown that stretching overly tight shoulder musculature while strengthening stretched/weak posterior shoulder musculature helps to minimize the cascade effect of muscle imbalances leading to adaptive shortening, adaptive shortening leading to postural deviations and postural deviations leading to shoulder pathology. This study supports these findings as forward shoulder posture for the swimming group was actually improving throughout the fall semester despite increases in yardage.

Strength and conditioning and the dryland programs completed over the winter training trip deviated significantly, however, from the program completed with the strength and conditioning coaches throughout the fall semester. This change may have further exacerbated the changes in forward shoulder posture seen in the swimming group between testing sessions three and four. The strength and conditioning and dryland programs were overseen by the swimming coaches over training trip, as opposed to the strength and conditioning coaches. This may have led to differences in or lack of proper form/technique coaching. Plyometric exercises were emphasized during dryland over winter training trip, rather than mobility, flexibility and postural exercises. Swimmers were also left to complete strength training largely on their own during winter training trip. They did not have the benefit of proper supervision for technique and form, which they had received throughout the fall from the strength and conditioning coaches.

These differences in the strength and conditioning program between the fall semester and winter training trip, coupled with the increase in practice session intensity (increased yardage over a shorter period of time) over training trip may account for the significant increase in forward shoulder posture seen in the swimming group between testing sessions three and four. This increase in yardage combined with alterations in the strength and conditioning and dryland programs most likely exacerbated muscular imbalances and adaptive shortening of the anterior shoulder musculature and underlined the inability of the posterior shoulder musculature to effectively respond. If posterior shoulder musculature cannot balance out anterior shoulder musculature, forward shoulder posture may develop and will increase as muscular adaptations and imbalances persist.

Figure 5 also shows the changes in forward shoulder posture for the control group. The control group had significant improvements in forward shoulder posture between testing sessions one and two but then had no change in forward shoulder posture for the remainder of the training period. The fact that there is no significant change in forward shoulder posture in the control group for the remainder of the training period may further substantiate that it is, in fact, the swim training and the concurrent completion of regimented strength and conditioning and dryland programs that influence significant changes in forward shoulder posture for the swimming group.

FORWARD HEAD POSTURE

There were no statistically significant differences between swimmers and controls for forward head posture at any of the four time points, indicating that the load completed during the training period did not have a significant effect on forward head posture in swimmers compared to the controls. This finding may be attributable to the fact that similar lifestyle factors of study time, classroom time, notebook computer use (Chang, 2008; Straker, 1997), video game use and smart device technology affect the forward head posture of both groups equally. Cervical flexors in both groups were likely weak and stretched due to overly tight upper trapezium, levator scapulae and serratus anterior muscles (Kendall, et al., 2005; Lynch, et al., 2009). The strength imbalances between the weak, stretched cervical flexors in comparison to the upper trapezium and levator scapulae muscles (Page, 2005) are examples of the adaptive shortening (Kendall, et al., 2005) that occurs in the presence muscle imbalances (W. McMaster, 1999). The lack of difference in forward head posture in the swimming group implies that the high yardage/intensity training that the swimming group completes during the training period does not contribute towards further changes in forward head posture in the swimming group compared to the control group. No significant effect of the training period on forward head posture in the swimming group is further supported by the lack of relationship between yardage completed between testing sessions and the change in forward head posture between testing sessions.

Figure 4 represents the changes in forward head posture that occurred within the swimming group and the control group at each testing session when compared to previous testing sessions within each group. Though not significant, the swimming group shows trends of moving into increased forward head posture between the first and second testing sessions. Swimmers were returning to regular season practices from summer break and gradually increasing yardage through preseason workouts and early season training. This is the likely explanation for the trend seen. No statistically significant difference was seen for forward head posture in the swimming group between the second and third testing session. As mentioned in the discussion of forward shoulder posture, this may be attributable to the fact that enough strength gains had been attained at this point, due to the strength and conditioning and dryland programs, to counteract the effect of continued yardage increases and cumulative yardage completed to that point. A statistically significant increase in forward head posture for the swimming group was seen between the third and fourth testing sessions which may be attributed to the increases in forward shoulder posture also seen between these two testing sessions.

Forward head posture is generally incorporated into postural discussion due to the possibility that shortened upper trapezium and levator scapulae may alter scapular position, possibly contributing to shoulder pathologies (P. M. Ludewig & Cook, 2000; Lynch, et al., 2009). It may be inferred that the dramatic increase in yardage and training intensity completed over training trip coupled with the difference in the strength and conditioning and dryland programs between the fall semester and winter training trip had an indirect effect on the forward head posture of the swimmers. With strength and conditioning and dryland programs in place through the fall to assist in posterior shoulder strength and anterior shoulder flexibility, overuse of synergistic muscles (upper trapezium and levator scapulae) would be minimized, thus preventing them from becoming shortened and overly tight. Forward head posture data over the fall corresponds with this assumption as there were no significant differences in forward head posture between testing sessions one and two or two and three. Lynch et al. (2009) points out that few studies have investigated an intervention to target forward head posture deviations in isolation. Thus, it might be assumed that forward head posture was influenced secondary to forward shoulder posture due to the interventions targeted at forward shoulder posture. Despite a weak relationship between yardage and the change in forward head posture for the swimming group, forward head posture is likely indirectly affected by yardage through fatigue and muscle imbalances as well as changes in forward shoulder posture.

The upper trapezium and levator scapulae, which work synergistically with the rhomboids and middle trapezium to retract the scapulae, were likely compensating for the rhomboids and middle trapezium muscles between the third and fourth testing sessions when yardage increased substantially and targeted strengthening exercises for these agonist muscles were altered. This increased stress and load caused the upper trapezium and levator scapulae muscles to become overly tight and shortened in relation to weak cervical flexors. Page (2005) described this combination of overly tight agonists coupled with weak, stretched antagonists as the primary scenario for developing forward head posture. If the upper trapezium and levator scapulae were not being overtaxed, forward head posture may not have changed between testing sessions three and four. The lack of focused strengthening for the cervical flexors corresponding with the lack of focused stretching for the upper trapezium and levator scapulae muscles further perpetuated the trend toward increased forward head posture between testing sessions three and four.

The forward head data for the control group further confirms that fatigue and muscle imbalances due to high training yardage combined with a lack of regimented strength and conditioning and dryland programs may be the biggest factor in changes in forward head posture for the swimming group. The control group had significant increases in forward head posture over the fall that corresponds to increased time spent in the classroom, studying or using laptop computers or smart device technology. While the swimmers were also influenced by these factors, it is likely that the regimented strength and conditioning and dryland programs prevented significant increases in forward head posture secondary to improvements in forward shoulder posture. Improvements in forward head posture are seen in the control group between the third and fourth testing session. This corresponds to the holiday break and the likely decrease in time spent in the classroom, studying or using notebook computers and smart device technology. While the swimming group also experienced this same decrease in lifestyle factors affecting their forward head posture due to the holiday break, they continued train, without a regimented strength and conditioning and dryland program, and their forward head posture increased significantly.

PAIN SCORES

A moderately strong, statistically significant relationship between the changes in FASS-TS pain scores and forward shoulder posture as well as DASH-SM pain scores and forward shoulder posture were found in the swimming group at testing session three. This indicates that 15.6% of the change in shoulder pain reported on the FASS-TS pain questionnaire and 10.9% of the change in shoulder pain reported on the DASH0SM pain questionnaire may be explained by the change in forward shoulder posture at testing session three. This makes sense as pain scores were likely decreasing due to trends towards improvement in forward shoulder posture (**Figure 5**). This strengthens the argument that as posture improves, pain levels decrease. This significance is contrary to a study by Richardson et al. (1980) that found that 83% of the subjects in their study reported the greatest problem with shoulder pain during the early and middle portion of the season (Richardson, Jobe, & Collins, 1980; Su, et al., 2004; Weldon & Richardson, 2001). The opposite trend of increasing forward shoulder posture correlating with increases in pain level, was not observed. This prevents us from making a broad assumption that changes in forward shoulder posture, whether increasing or improving, plays a role in shoulder pain reported. No other significant relationships were found between pain scores and posture or pain scores and yardage.

Both the FASS-TS and DASH-SM pain questionnaires ask patients about their pain level over the course of the previous week. Changes in pain scores may have been better represented if the questionnaires had been issued weekly over the course of the training period rather than only during testing sessions. Also, the FASS-TS pain questionnaire sought to address perceptions of shoulder pain outside of athletic participation making it a lengthy questionnaire. Given the demographics of our subjects, full and careful consideration may not have been given to every question in an effort to finish the questionnaire quickly.

Finally, consideration must be given to the type of athlete observed in this study. Swimmers are taught from a very early age to accept a certain amount of pain, especially shoulder pain, as part of their sport and as part of being a swimmer. A study, currently in review by Hibberd & Myers (2013), suggests that swimmers believe shoulder pain is normal and acceptable and that this pain should be tolerated in order to complete practices (Hibberd & Myers, 2013). This may have played a role in the lack of significance seen in our correlation data regarding pain scores. Also, many people have difficulty distinguishing pain from general muscle soreness, often times mistaking muscle soreness for pain. Our swimming sample is most likely on the other end of that spectrum where they may assume that the pain they are feeling is simply muscle soreness. This, again, goes back to the training mentality ingrained in them from very early on that pain is a normal aspect of their sport.

CLINICAL SIGNIFICANCE

This is the first study to track forward head and forward shoulder posture over the course of a typical, collegiate, swim training period. Previous research (Hibberd, 2010; Kluemper, et al., 2006; Lynch, et al., 2009) has shown that improvements in forward head and forward shoulder posture can be made with specific intervention programs that incorporate stretching and strengthening techniques. This study sought to identify whether or not the training period affected forward head and forward shoulder posture and, if so, to isolate the most ideal time to implement proven intervention protocols in an effort to prevent forward head and forward shoulder deviations. Incorporating a control group allowed researchers to control for lifestyle factors that also influence forward head and forward shoulder posture. Despite the lack of relationship between pain scores and forward head and forward shoulder posture and between pain scores and yardage completed, it is apparent that the training and yardage logged throughout the fall semester, especially, has an indirect influence on forward head and forward shoulder posture when comparing the swimming group to the control group. Paired samples t-tests, which served as our post-hoc analysis, indicate that intervention protocols may have the greatest effect just prior to the swimmers leaving for their holiday break. In the instance of this collegiate swim team, this would be the most appropriate time for intervention protocols as little strength training is performed between the beginning of the holiday break and the beginning of the winter training trip. Home exercise programs targeted at strengthening posterior shoulder musculature and stretching anterior musculature may assist in combating detraining effects associated with the lack of regimented strength and conditioning and dryland programs over break prior to the large amount of yardage that is completed during the training trip. Maintaining these home exercises programs throughout the training trip may also assist in counteracting the effects varied strength and conditioning and dryland programs used over the winter training trip. A Certified Athletic Trainer could assist the swimmers in completing targeted stretching and strengthening program over the training trip to combat the effects of fatigue and muscle imbalances brought on by high volume, high intensity yardage. This, in turn, would prevent further postural deviations that may lead to the development of shoulder pain.

LIMITATIONS

There were limitations in the current study. Throughout the testing sessions, all subjects were instructed to "relax arms down and stand normally" at the completion of each of the overhead squat sets. The examiner made an effort not to refer to posture during testing sessions so subjects would not attempt to over-correct their own posture. It is possible, however, that subjects may not have been standing in their "normal" posture while pictures were taken. Previous studies that have included posture measurements have utilized a wall for subjects to stand against to ensure that they move from an over-corrected posture with their back and heels flush to the wall into their "relaxed and normal" posture (Kluemper, et al., 2006). In this current study, subjects were simply asked to return to their "normal" standing position following three sets of overhead squats. While the angle measurements for forward head and forward shoulder posture were averaged across the three pictures at each session, the variability present between each picture measurement were large at times and this may be attributed to differences in "normal" posture assumed by the subject following each overhead squat.

Another limitation may be in the form of reflective marker placement. While pilot testing demonstrated good intrarater reliability, there is always the possibility that reflective marker placement by the examiner at each testing session added some variability into the averaged results at each testing session. Traditional palpation techniques were used for every subject at every testing session to locate and place reflective markers over tragus, the anterior tip of the acromion and the seventh cervical vertebrae. Ideally, the placement of the reflective markers needs to be able to be reproduced exactly at each testing session in order to take out this element of variability between testing sessions.

A third limitation of this study might be the identification of the “middle” of the reflective marker during Image J analysis. The middle of each reflective marker was identified by the examiner and marked with a red adhesive dot. Despite attempting to control where the “middle” of each reflective marker was for use in Image J analysis, minor variations in where the “middle” of each dot was at each testing session would also contribute to the variability in averaged angle measurements at each testing session. The combined variability that is present between the identification of the “middle” of the reflective markers, reflective marker placement and whether or not each subject was assuming “normal” posture for each picture at each testing session may all be limitations in this study.

Another limitation might include the fact that activities outside of the testing sessions were not controlled for in this study. As such, the strength and conditioning and dryland program that were implemented must be considered as a possible limitation. The UNC Swimming team adopted a new approach to dryland training over the course of the 2012-13 season that had not been previously utilized. A mobility program (extensive foam rolling, stretching of both the upper and lower extremities) coupled with posture-focused exercises and core exercises was the foundation of the dryland program this season. These were exercises that all individuals on the swim team completed twice a week with the strength and conditioning coach. This emphasis on stretching and posterior strengthening while engaging the core may have also affected the forward head and forward shoulder measurements that were completed throughout the training period.

Yardage totals were collected throughout the duration of this study. Yardage was totaled between each testing session. Similar to changes made in the strength and conditioning and dryland program this season, the swim coaches were also using a varied approach to their swim training. Rather than remaining in one “training group” (distance, mid-distance, sprint/speed or IM/breaststroke) as had traditionally occurred in the past, many of the swimmers trained with different group coaches at different times during each week depending on the mesocycle being completed at that point in the season. While yardage totals reflect which group each swimmer theoretically trained with on any given day, yardage records received from the coaching staff were incomplete and did not always represent which swimmers actually trained in each group on any given day. Thus, yardage totals for each individual swimmer are a best estimate based on what group they trained with the most. More accurate yardage totals may reveal different results when looking for relationships between the changes in yardage and the changes in forward head and forward shoulder posture as well as the changes in pain scores.

Finally, swimmers are a special type of athlete. Many of them find the presence of shoulder pain to be normal. From a very young age, the swimmers in this study have most likely been told that some degree of shoulder pain is to be expected. Many swimmers opt not to mention shoulder pain until it is preventing them from completing practice. Even then, individual pain thresholds must be considered as this impacts what each individual athlete believes is debilitating pain. These consideration all factor into the results of the FASS-TS and DASH-SM pain scores. While instructions were given to every subject to answer the pain questionnaires in the context of the last ~5-7 weeks (since last testing session), there is the possibility that pain scores varied depending on how the subjects felt that particular day of testing. Individual pain thresholds must be considered here as one individual's low pain score may be another individual's high pain score.

FUTURE RESEARCH

This study was meant to provide further evidence as to the role of posture in shoulder pain seen in swimmers especially during the training period of collegiate swimmers. A similar study design as the current study could be performed to control for activities outside of the testing sessions. This might include controlling for exercises and stretching completed in strength and conditioning and dryland programs. It might be interesting to compare a group of swimmers who complete a regimented strength and conditioning and dryland program with a group of swimmers that do not.

Research examining long-term postural changes in swimmers is also needed. This study examines postural changes within a very short time period of a swimmer’s overall career. In many cases, subjects in this study are near the end of their careers where postural changes may be less noticeable or less apt to occur at this stage of their career. A long-term, longitudinal study may reveal important information. Picture analyses of young swimmers performed from the time they begin swimming (~7years old) until the possible completion of their collegiate swim career would give insight into when postural changes may be occurring the most within swim careers and what factors might be contributing to these postural changes the most.

CONCLUSIONS

This study serves as an important step in recording changes in forward head and forward shoulder posture over time in collegiate swimmers. While this study represents only a small time period in the overall swimming career of the swimmers in this study, it is an important first step in making the argument that further studies need to be conducted to bring more evidence to the idea that posture does play a significant role in shoulder pain in swimmers. This study also highlights the idea that changes to the culture and psychology of swimming and pain may need to be addressed. Finally, reproducing this study to control for the effects of strength and conditioning and dryland programs would be beneficial in further connecting postural deviations with yardage completed and pain scores.

FIGURES

FIGURE 1: Anatomical landmarks

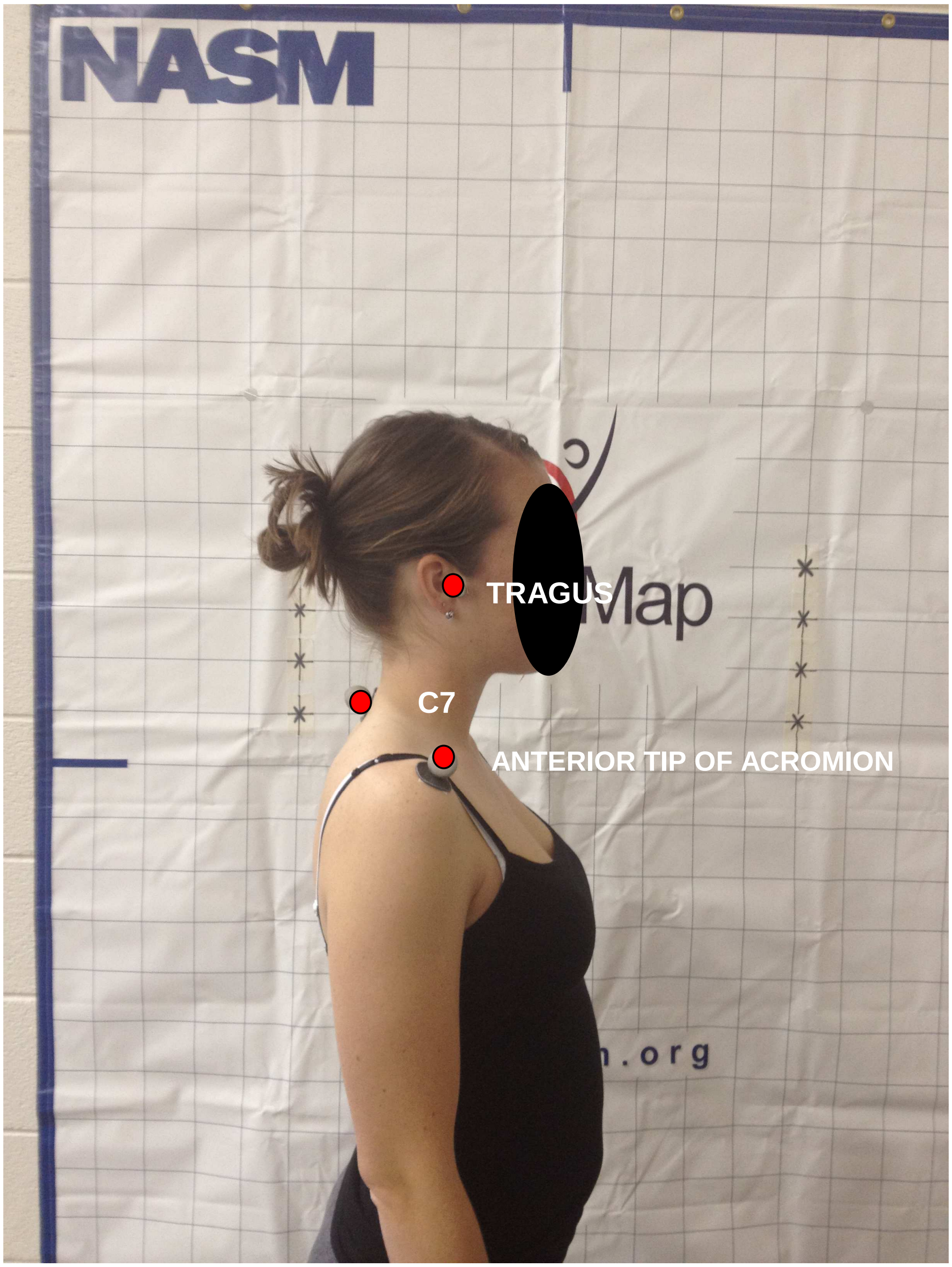


FIGURE 2: Forward Head Angle (FHA)

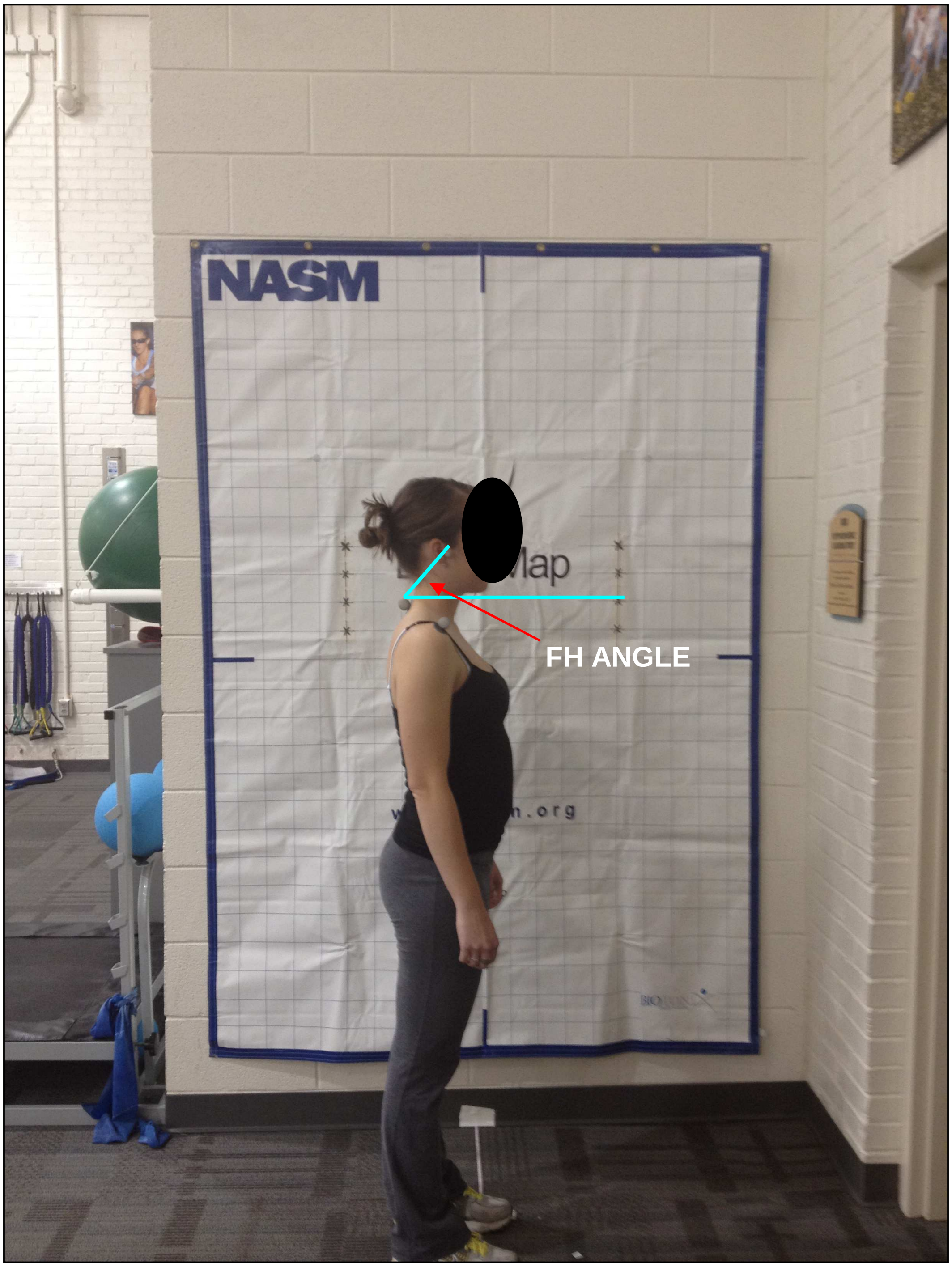


FIGURE 3: Forward Shoulder Angle (FSA)

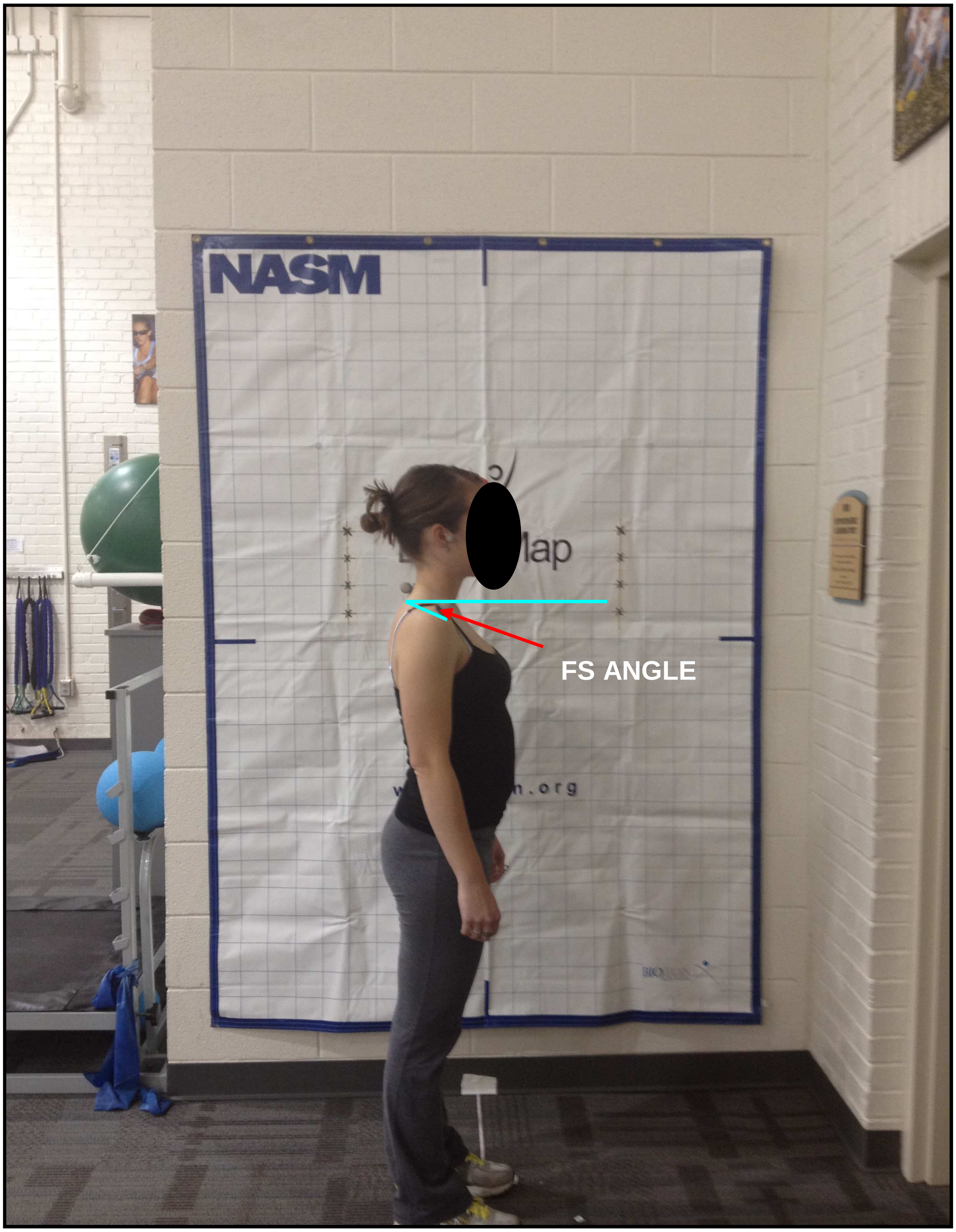
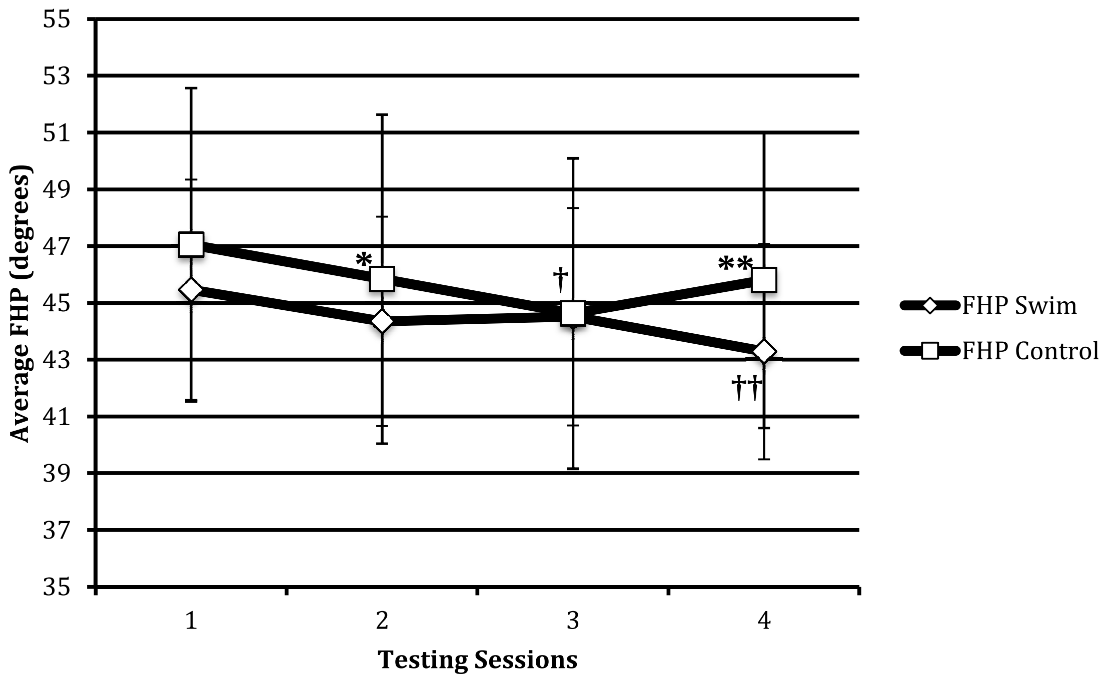


FIGURE 4: Average forward head posture at each testing session by group



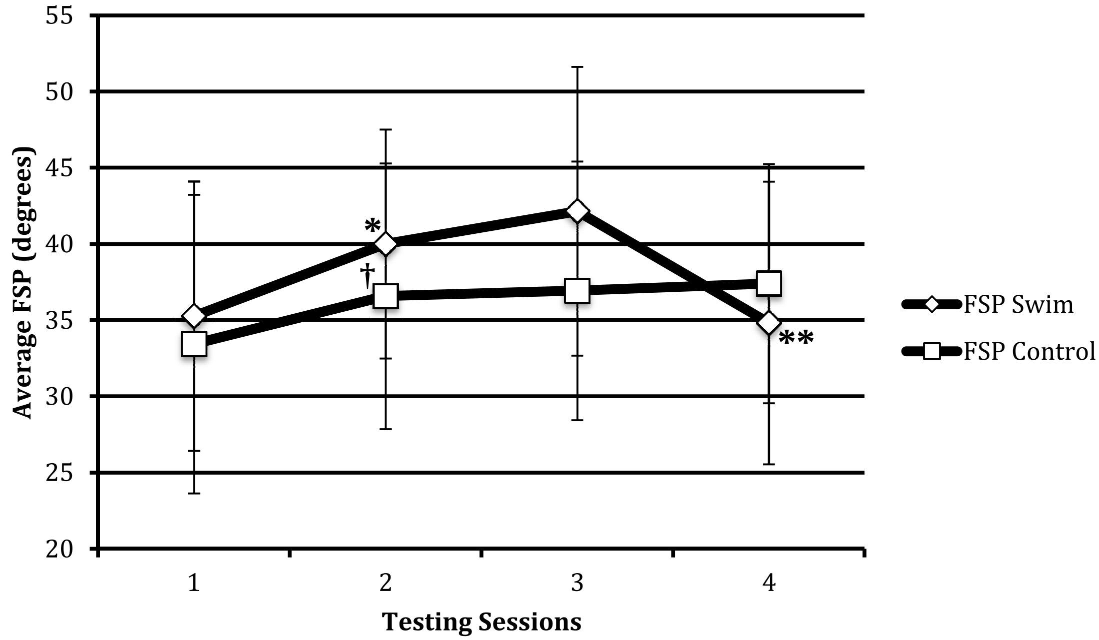
***** Significant (*p*=0.001) increase in forward head posture for control group between testing sessions 1and 2

† Significant (*p*=0.006) increase in forward head posture for control group between testing sessions 2 and 3

****** Significant (*p*=0.005) decrease in forward head posture for control group between testing sessions 3 and 4

†† Significant (*p*=0.003) increase in forward head posture for the swimming group between testing sessions 3 and 4

FIGURE 5: Average forward shoulder posture at each testing session by group

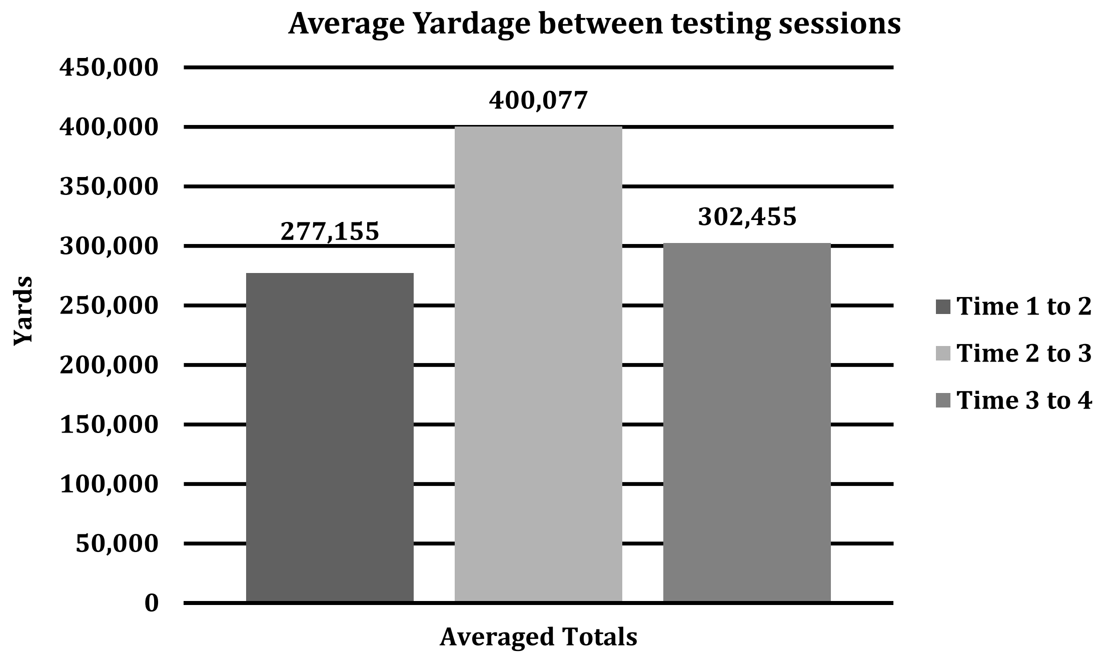


* Significant ($p<0.001$) decrease in forward shoulder posture in the swimming group between testing sessions 1 and 2

† Significant ($p=0.005$) decrease in forward shoulder posture in the control group between testing sessions 1 and 2

** Significant ($p<0.001$) increase in forward shoulder posture in the swimming group between testing sessions 3 and 4

FIGURE 6: Average yardage between testing sessions


Average Yardage between testing sessions
450,000
400,000
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
Yards
277,155
400,077
302,455
Averaged Totals
Time 1 to 2
Time 2 to 3
Time 3 to 4

TABLES

TABLE 1: Participant Demographics

	Swim Group	Control Group
Number of Subjects (n)	42	42
Males/Females	23/19	23/19
Age (years)	19.1±1.2	19.3±1.2
Mass (kg)	72.1±7.0	69.0±12.5
Height (cm)	178.7±7.7	172.8±9.7

TABLE 2: Mean ± Standard Deviation Forward Head Posture by Group

Forward Head Posture (FHP)		
Time	**Swim mean±sd**	**Control mean±sd**
Time 1 (late Aug./early Sept.)	45.5±3.9	47.0±5.5
Time 2 (mid-October)	44.4±3.7	45.7±5.8
Time 3 (mid-December)	44.5±3.8	44.5±5.4
Time 4 (late January)	43.3±3.8	45.6±5.2

TABLE 3: Mean ± Standard Deviation Forward Shoulder Posture by Group

Forward Shoulder Posture (FHP)		
Time	**Swim mean±sd**	**Control mean±sd**
Time 1 (late Aug./early Sept.)	35.6±8.9	33.2±9.8
Time 2 (mid-October)	40.4±7.5	36.5±8.8
Time 3 (mid-December)	42.5±9.5	36.6±8.5
Time 4 (late January)	34.9±9.5	37.1±7.1

APPENDICES

APPENDIX A: The DASH Pain Questionnaire

Sports Module of the Disabilities of the Arm, Shoulder and Hand (DASH-SM)

Please circle the number that best describes your physical ability in the past week where: 1 = No Difficulty (ND), 2 = Mild Difficulty(MD), 3 = Moderate Difficulty (ModD), 4 = Severe Difficulty(SD), 5 = Unable (U).

Did you have difficulty:

	ND	**MD**	**ModD**	**SD**	**U**
Using your usual technique for playing your sport?					
Playing your sport because of arm, shoulder or hand pain?					
Playing your sport as well as you would like?					
Spending the usual amount of time practicing or playing your sport?					

APPENDIX B: Functional Arm Scale for Swimmers (FASS)

Adapted from Functional Arm Scale for Throwers© (Sauers, Dykstra, Bay, Bliven, & Snyder, 2011)

This questionnaire asks about how your arm (shoulder) feels. It asks about how your arm condition affects your ability to swim and to function in sport and daily activities. Instructions: Please answer every question based on your arm condition during the last week by circling the number below the appropriate response. If you did not engage in an activity in the past week, please answer questions based on your estimate of how your arm condition would affect your ability to engage in the activity.

Section 1

Please circle the number that corresponds to your satisfaction level where C = completely, E = extremely, M = moderately, S = slightly, NS = not satisfied at all.

	C	**E**	**M**	**S**	**NS**
How satisfied are you with the way your arm is now functioning?					

Section 2

Please circle the number that corresponds to your pain/discomfort level where N = none, M = mild, MO = moderate, S = severe, E = extreme

	N	**M**	**MO**	**S**	**E**
Following warm-up, how much pain do you have in your injured arm?					
How much pain or discomfort do you have in your arm at night?					
How much strength have you lost in your arm as a result of your arm injury?					

Section3

Please circle the number that best corresponds to each question where N = not at all, SL = slightly, M = moderately, SE = severely, E = extremely

	N	**SL**	**M**	**SE**	**E**
How much has your arm injury limited your ability to advance in your swimming event(s)?					
How much have you modified your behavior to avoid making your arm injury worse?					

Since your arm injury, do you have a more negative outlook on life?					
How much does your arm injury interfere with things that are important, other than sports?					
How stiff is your arm at night?					
How much has your injury interfered with competition at swim meets?					
How much are you limited when lifting your arm overhead to get dressed?					

Section 4

Please circle the number that best corresponds with each question where NN = No, not at all, YSL = Yes, slightly, YM = Yes, moderately, YSE = Yes, severely, YE = Yes, extremely

	N	SL	M	SE	E
Has your enjoyment of life decreased since your arm injury?					
Has your arm injury decreased how long you can continue swimming during a single practice or game?					
Have your sports accomplishments decreased since your arm injury?					
Has your life been more stressful because of your arm injury?					
How much pain or discomfort do you have in your arm with daily activities involving reaching?					
How much pain or discomfort do you have in your arm if you use it for activities that last longer than 30 minutes?					

Section 5

Please circle the number that best corresponds with each question where N = not at all, SL = slightly, M = moderately, SE = severely, U = unable to swim

	N	SL	M	SE	E
How much has your arm injury limited your ability to swim freestyle?					
How much has your arm injury limited your ability to swim butterfly?					
How much has your arm injury limited your ability to swim breaststroke?					
How much has your arm injury limited your ability to swim backstroke?					
How weak does your arm feel during swimming?					
How painful is your arm during “competition speed” swimming?					

How painful is your arm during a 50-75% effort while swimming?					

APPENDIX C: Manuscript formatted for Clinical Journal of Sports Medicine

THE EFFECT OF A TYPICAL SWIM TRAINING PERIOD ON FORWARD HEAD AND FORWARD SHOULDER POSTURE IN COMPETITIVE SWIMMERS

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ABSTRACT

Objective: To determine the effect of a typical swim training period on forward head and forward shoulder posture in competitive swimmers.

Design: Cross-sectional design

Setting: University Research Laboratory, Athletic Training Room

Subjects: Forty-two Division one collegiate swimmers, forty-two age/gender matched college students

Main Outcome Measures: Forward head angle and forward shoulder angle measurements analyzed via Image J software, subjective pain scores (FASS-TS, DASH-SM) collected at each of four testing sessions (late August/early September, mid-October, mid-December, late January) during the training period.

Results: A significant time by group interaction of forward head posture ($F_{1,82} = 4.351, p=0.007$) and forward shoulder posture ($F_{1,82}=10.605, p<0.001$) existed across the four testing sessions. Independent and paired samples t-tests served as post-hoc tests and indicated significant differences between groups for forward shoulder posture only and significant differences within groups for forward head and forward shoulder posture in both the swimming and control group. Correlation results indicated a small amount of shoulder pain may be explained by changes in forward shoulder posture at time three. No other relationships between variables existed.

Conclusions: The results may indicate that strength/conditioning and dryland programs may play an integral role in postural deviations seen in swimmers. Control results re-enforce that lifestyle factors such as laptop use, classroom and study time all contribute to postural deviations that affect both groups equally. The training period and regimented

strength training significantly affect the forward head and forward shoulder posture in the swimming group.

Key Words: swimming, posture, shoulder pain, training period, periodization

Word Count = 249

INTRODUCTION

Competitive swimmers begin their intense training between the ages of eight and eleven years old where they may train three to four hours per day across two training sessions and log between ten and twenty thousand yards per day (Bak, 2010; Costill, et al., 1991; Kammer, et al., 1999; W. McMaster, 1999; Sokolovas, 2003). Training time (quantity) and training intensity (quality), along with frequency of training, all contribute to the training schedule for competitive swimmers. The collegiate season for a competitive swimmer consists of approximately thirty weeks, managed through the principal of periodization, which helps to ensure correct peaking for main competitions throughout the year (Hannula & Thornton, 2001; Pyne, 2006; Sterkel, 2001; Trappe, et al., 2000)

The repetitive nature of swimming places swimmers at an increased risk for injury (W. McMaster, 1999; Weldon & Richardson, 2001). Regardless of stroke specialty, eighty percent of swim training is completed using the freestyle stroke (Allegrucci, et al., 1994; Pink & Tibone, 2000). As training hours increase, arm strokes per year increase, making swimming an incredibly demanding sport that places enormous stress on the shoulder (Bak, 2010; Pink & Tibone, 2000). Forty to ninety percent of complaints by swimmers pertain to issues regarding shoulder pain with shoulder pain listed as a frequent reason for swimmers to miss practice (Bak, 2010; Weldon & Richardson, 2001). Factors that may predispose swimmers to shoulder pain include biomechanics, range of motion, muscular imbalances, fatigue, impingement, glenohumeral joint instability and posture (Allegrucci, et al., 1994; Beach, et al., 1992; Greenfield, et al., 1995; Griegel-Morris, et al., 1992; Janda, 1987; Kendall & McCreary, 1983; Kendall, et al., 2005; W. McMaster, 1999; Page, 2005; Peterson, et al., 1997; Pink & Tibone, 2000; Rupp, et al., 1995; Sahrmann, 2002; J. Troup, 1999; Weldon & Richardson, 2001; Yanai & Hay, 2000). Few studies, however, have examined changes in posture over time in competitive swimmers which may contribute to the development of shoulder pain.

Poor posture may be implicated in shoulder pain indirectly due to muscle imbalances and fatigue (Kluemper, et al., 2006; Page, 2005; Peterson, et al., 1997; Pink & Tibone, 2000; Rupp, et al., 1995; J. Troup, 1999). The purpose of this study was to examine whether a typical swim training period had an effect on forward head and forward shoulder posture. A secondary purpose was to isolate the best time to intervene with proven, intervention exercises (Hibberd, 2010; Kluemper, et al., 2006; Lynch, et al., 2009) so postural deviations are prevented before pathology begins. Lastly, this study examined whether relationships existed between the following variables: postural deviations (FHP, FSP) and pain, postural deviations (FHP, FSP) and yardage completed and pain and yardage completed.

MATERIALS AND METHODS

Subjects

Forty-seven swimmers and controls were screened, met the inclusion criteria and agreed to participate in this study. Forty-two swimming and control (age/gender matched) subjects were retained for the duration of this study. The overall retention rate for the study was 89% with a total of eighty-four subjects participating (**Table 1**). Swimming subjects were included in the study if they were members of the college swim team, if they were able to practice at least five times per week (one to two hours per practice) and if they had a minimum of five years of competitive swimming experience. Swimming subjects were excluded from the study if they were unable to complete the specified yardage during practice on a daily basis more than two days per week, if they had a history of shoulder surgery, if they were using an external, correctional posture device and if they were performing rehabilitation (strengthening and stretching) to target postural deviations associated with forward head and forward shoulder posture.

Control subjects were recruited from a university population. Control subjects were included in this study if they had not participated in overhead athletics for a minimum of one year, if they were currently enrolled "full time" in college and if they could be age and gender matched to a swimmer. Control subjects were excluded if they had a history of shoulder surgery, if they were currently using any type of external, correctional posture device and if they were performing rehabilitation (strengthening and stretching) that targets posture deviations associated with forward head and forward shoulder posture.

Procedures

Subjects were introduced to the study and screened for participation based on inclusion/exclusion criteria. If included, subjects reported for testing to the university research lab or the university athletic training room and completed a demographics/physical assessment questionnaire, the Functional Arm Scale for Swimmers Total Score (FASS-TS) pain questionnaire (adapted from the FAST-TS©) and the Disabilities of the Arm, Shoulder and Hand Sport Model (DASH-SM) pain questionnaire. Reflective markers were then placed on the right side of each participant over the following anatomical landmarks: tragus, C7, anterior tip of the acromion (Thigpen, 2006). Subjects received standardized instructions on how to properly perform an overhead squat task followed by a demonstration from the principal investigator of proper technique for an overhead squat task. Subjects were instructed to complete one practice trial of the overhead squat task with the opportunity to receive further instruction and to adjust stance. Subjects were then asked to stand 40 cm in front of a horizontal reference line while standing in "a relaxed position" while photographs were taken from the side. Subjects completed three overhead squats sets (three squats per set) and then instructed to "relax" and "stand in normal position" while a picture was taken at the end of each squat set. This procedure was repeated four times over a five month period to reflect the span of a typical swim training period for competitive swimmers. Testing sessions were completed during late August/early September, mid-October, mid-December and late January.

Data Reduction

Postural analysis was performed using Image J software (National Institute of Health, Bethesda, MD) and the landmarks defined by the reflective markers on each participant. **Figure 2** and **Figure 3** display the landmarks that were digitized to calculate the forward head angle (defined as the angle of inclination of the line extending from C7 to tragus and the horizontal line) and the forward shoulder angle (defined as the angle of inclination of the line extending from C7 to the shoulder and the horizontal line) for each participant. Forward head and forward shoulder posture measurement angles were averaged for each of the four testing sessions. Pilot testing conducted prior to this study established intrarater reliability and precision for forward head posture (ICC = 0.99, SEM = 0.11) and forward shoulder posture (ICC = 0.99, SEM = 0.34) using this measurement technique.

Total pain scores were calculated for the FASS-TS questionnaire (**Appendix B)** by adding up total responses in all sections. Pain scores for the DASH-SM questionnaire (**Appendix A**) were calculated using the following formula: {[(sum of n responses)-1]/n}x25. These respective scores were used to correlate pain with forward head and forward shoulder posture in the swimming group at each testing session. Yardage totals between each testing session were also correlated with forward head and forward shoulder posture measures at each testing session. Finally, yardage totals were correlated with FASS-TS and DASH-SM pain scores.

Statistical Analysis

Statistical analyses were run using SPSS version 20.0 software (IBM SPSS, New York, NY). A two by four mixed model ANOVA, one between factor (group) and one within factor (time), was run to evaluate the change in forward head and forward shoulder angles. Independent t-tests were used to examine the simple effects of group on forward head and forward shoulder posture with an adjusted alpha level of $p \leq 0.0125$. Paired sample t-tests were used to look at the simple effects of time on forward head and forward shoulder posture in each group with an adjusted alpha level of $p \leq 0.017$.

Mauchley's test of sphericity was used to determine whether equal variance is assumed. Huynh-Feldt correction was used if the assumption of sphericity was violated. An alpha level of $p \leq 0.05$ was set for the Pearson *r* correlations. Pearson *r* correlation coefficients were calculated to analyze the following relationships in the swimming group only: FASS-TS and DASH-SM pain scores and forward head, forward shoulder angle measurements, yardage totals and forward head, forward shoulder angle measurements and yardage totals and FASS-TS and DASM-SM pain scores.

RESULTS

The means and standard deviations of forward head and forward shoulder posture for both the swimming and control groups are presented in **Table 2** and **Table 3**. A significant time by group interaction of forward head posture ($F_{1,82} = 4.351$, $p = 0.007$) and forward shoulder posture ($F_{1,82} = 10.605$, $p < 0.001$) existed across the four testing sessions. Independent t-tests indicated that no significant differences in forward head posture existed between groups at any time point. Paired samples t-tests indicated that within groups, swimmers had a significant increase in forward head posture (**Table 4**) between times three and four ($t_{41} = 3.105$, $p = 0.003$). Controls had a significant increase in forward head posture (**Table 4**) between times one and two ($t_{41} = 3.734$, $p = 0.001$) and between times two and three ($t_{41} = 2.886$, $p = 0.006$) but demonstrated a significant decrease in forward head posture between times three and four ($t_{41} = -2.943$, $p = 0.005$).

Independent t-tests indicated that between groups, swim and control forward shoulder posture differed significantly at time three only. Paired samples t-tests indicated that within groups, swimmers had a significant decrease in forward shoulder posture

(**Table 5**) between times one and two (*t_{41}=-4.258, $p<0.001$*) and a significant increase in forward shoulder posture between times three and four (*t_{41}=6.773*, *$p<0.001$*). Controls had a significant decrease in forward shoulder posture (**Table 5**) between times one and two (*t_{41}=-2.988, p=0.005*).

Pearson *r* correlations were conducted to examine the relationship between the change in pain scores (FASS-TS and DASH-SM) between testing sessions and changes in forward head and forward shoulder posture between testing sessions. A moderate, positive relationship that was significant ($p\leq0.05$) was found between the change in FASS-TS pain scores *(r_{40}=0.399, p=0.009)* and DASH-SM pain scores (r=0.330, p=0.033) and the change in forward shoulder posture in the swimming group at time 3 with R^2 values of 0.156 and 0.109 respectively. This indicates that 15.6% (FASS-TS) and 10.9% (DASH-SM) of the change in shoulder pain can be explained by the change in forward shoulder posture at testing session 3. No other relationships between changes in pain scores (FASS-TS and DASH-SM) and changes in forward head and forward shoulder posture existed.

Pearson *r* correlations were also conducted to examine the relationship between yardage completed between testing sessions and changes in forward head and forward shoulder posture between testing sessions in the swimming group as well as the relationship between yardage completed between testing sessions and the change in pain scores (FASS-TS and DASH-SM) at each testing session. No relationships existed between these variables.

DISCUSSION

Forward head and forward shoulder posture are innately linked because many of the muscles responsible for shoulder motion are multi-joint muscles that also cross the cervical spine and head (P. Ludewig & Cook, 1996). Attachments of muscles between the cervical spine, head and scapula, such as the upper trapezium and levator scapulae, allow cervical and head positions to be possible contributors to alterations in scapular mechanics (Kendall, et al., 2005; P. Ludewig & Cook, 1996). Altered scapular mechanics may predispose swimmers to the occurrence of shoulder pain that may ultimately hinder performance and training time.

Forward shoulder posture decreased (improved) significantly in the swimming group at the third time point compared with the control group. These findings may indicate that the strength/conditioning and dryland program completed throughout the fall by the swimming group may have been beneficial in combating the elements of adaptive shortening, muscle imbalances and fatigue (Kendall, et al., 2005; W. McMaster, 1999; Sahrmann, 2002) that all contribute to postural deviations. Within subjects results further support this belief as swimmers showed significant decreases in forward shoulder posture between testing sessions one and two with this trend continuing, though not significant, between testing sessions two and three. Between the third and fourth testing sessions, the swimmers were moving into significantly greater forward shoulder posture. The changes seen throughout the fall (testing sessions one through three) compared with the different changes observed over the holiday break and early spring (testing sessions three to four) may be attributable to differences in strength/conditioning and dryland programs implemented at these times. The programs implemented over the holiday break were not necessarily being completed (while swimmers were home training with their respective club teams) and they incorporated fewer mobility and strength exercises to target anterior shoulder tightness and posterior shoulder weakness. Also, swimmers did not have the benefit of being properly supervised in the programs over the holiday break by strength and conditioning coaches. Though correlation results proved to be largely weak and not significant, it is believed that yardage does play an indirect role in postural deviations due to fatigue and muscle imbalances which are directly related to yardage completed. The increased training intensity over the winter training trip and the effect of cumulative yardage completed to that point combined with altered strength and conditioning programs likely contributed to the increase in forward shoulder posture observed over the holiday break and early spring compared with the decrease in forward shoulder posture observed during the fall.

No significant difference was present between the swimming group and the control group in regard to forward head posture. This finding may indicate that lifestyle factors such as study time, classroom time and laptop use (Chang, 2008; Straker, 1997) affected forward head posture of both groups equally. Within group results imply that the strength and conditioning and dryland programs that the swimming group completed may also influence forward head posture. The upper trapezium and levator scapulae may become overly tight in order to compensate for weakness throughout scapular stabilizing muscles. Depending on the presence or absence of strength training to target scapular stabilizers, forward head posture will likely be influenced in the same direction as forward shoulder posture. While the swimmers forward head posture did not improve over the fall (testing sessions one through three), the controls were observed to be moving into greater forward head posture indicating that the lack of regimented strength training may be the differentiating factor between the groups. Similarly, within group results indicate that the swimmers moved into significantly greater forward head posture over the holiday break and early spring (testing sessions three to four) while the controls had improved (decreased) forward head posture over the same time. This corresponds with alterations in training intensity, cumulative yardage completed and strength training in the swimming group. This also corresponds with the holiday break for the control group where they likely had less exposure to the aforementioned lifestyle factors that contribute to posture deviations.

This is the first study to track forward head and forward shoulder posture over the course of a typical, swim training period. Previous research (Hibberd, 2010; Kluemper, et al., 2006; Lynch, et al., 2009) has shown that improvements in forward head and forward shoulder posture can be made with specific intervention programs that incorporate stretching and strengthening techniques. This study sought to identify whether or not the training period affected forward head and forward shoulder posture and, if so, to isolate the most ideal time to implement proven intervention protocols in an effort to prevent forward head and forward shoulder deviations. Incorporating a control group allowed researchers to control for lifestyle factors that also influence forward head and forward shoulder posture. Despite the lack of relationship between pain scores and forward head and forward shoulder posture and between pain scores and yardage completed, it is apparent that the training and yardage logged has an indirect influence on forward head and forward shoulder posture when comparing the swimming group to the control group through the direct effect of yardage on such factors as muscle imbalances and fatigue. Intervention protocols may have the greatest effect just prior to the swimmers leaving for their holiday break due to the altered strength training that occurs over the break and during winter training trip. Home exercise programs targeted at strengthening posterior shoulder musculature and stretching anterior musculature may assist in combating detraining effects associated with the lack of regimented strength training performed with home club teams. Maintaining these rehabilitation exercises throughout the training trip, under the supervision of a certified athletic trainer, may also assist in counteracting the effects of varied strength training and dryland completed over the winter training trip. This may assist in preventing further postural deviations that are associated with the development of shoulder pain.

Limitations in this study include the fact that "normal" posture assumed by subjects varied between each picture taken despite efforts to minimize over-correcting of "normal" posture. Small variations in reflective marker placement as well as small variations in determining the "center" of each reflective marker during Image J analysis between testing sessions may have also influenced variability in posture data. Strength training and dryland programs were not controlled for and limitations in collecting yardage data also existed which may have influenced variability in correlation analysis. Finally, swimmers generally consider shoulder pain to be a normal aspect of their sport, which may have influenced pain scores.

Future research needs to address controlling for strength training and dryland activities in the swimming group. A longitudinal study, incorporating a larger portion of swimmers' careers would also provide further information about postural changes in swimmers. Observing posture changes from the start of swimming careers (~7 years old) to the completion of collegiate swimming would provide further insight about when postural deviations occur and what factors might be contributing to these changes the most.

CONCLUSIONS

While this study represents only a small time period in the overall swimming career of the swimmers in this study, it is an important step in recording the changes in forward head and forward shoulder posture in competitive swimmers. Further research is needed, however, to substantiate the role of posture in shoulder pain experienced by swimmers. This study implies that changes surrounding the culture and psychology of swimming and pain may also need to be addressed.

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