2010

This is to certify that the
thesis entitled

THE EFFECTS OF DYNAMIC AND STATIC STRETCHING
ON RANGE OF MOTION AND PERFORMANCE

presented by

KATIE M. RAPKING

has been accepted towards fulfillment
of the requirements for the

M.S. degree in KINESIOLOGY

Tracey Covassin
Major Professor's Signature

4/26/10
Date

THE EFFECTS OF DYNAMIC AND STATIC STRETCHING ON RANGE OF MOTION AND PERFORMANCE

By

Katie M. Rapking

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Kinesiology

2010

TABLE OF CONTENTS

LIST OF TABLES

Table

LIST OF FIGURES

Figure

CHAPTER 1

INTRODUCTION

1.1 OVERVIEW OF THE PROBLEM

Athletic trainers, physical therapists, and coaches are all faced with the dilemma of which type of stretching is more effective - static or dynamic. This decision can be difficult for any coach or clinician because the research is inconclusive. Several researchers claim that static stretching is the key to increasing range of motion and improving athletic performance (Kokkonen, Nelson, Eldredge, & Winchester, 2007) while other researchers suggest that static stretching does not produce long enough lasting gains in range of motion to really make an impact on one's athletic performance (DePino, Webright, & Arnold, 2000). Moreover, dynamic stretching is becoming increasingly popular as recent research suggests dynamic stretching actively stretches and warms the muscle tissue (Fredrick &Szymanski, 2001). To date, few researchers have investigated if static or dynamic stretching is more effective in increasing range of motion and peak torque at the shoulder complex.

Within the shoulder complex there are static and dynamic stabilizers, both which play a large role in stretching and overall flexibility. The static stabilizers include the labrum, capsule, and ligaments. The glenoid labrum is a rim of fibrocartilaginous tissue attached around the margin of the glenoid fossa (Peat, 1986). The labrum's shape adapts for the rotation of the humeral head, adding flexibility to the edges of the glenoid fossa (Terry & Chopp, 2000). The joint capsule surrounds the joint as a whole and does not contribute very much to the stability of the joint by itself. However, if the capsule is stretched too far it can contribute to instability in the shoulder joint. Finally, the shoulder ligaments allow for shoulder flexibility within the bony structures. The shoulder ligaments also contribute to static stability within the complex.

The dynamic stabilizers include the four muscles of the rotator cuff, as well as the deltoid and scapular stabilizers. The rotator cuff is made up of the supraspinatus, infraspinatus, teres minor, and subscapularis. These muscles act as the dynamic steering mechanism for the humeral head. Due to the rotator cuff muscles being closer to the center of rotation on which they act, they are able to provide stability to a dynamic fulcrum during glenohumeral abduction (Terry & Chopp, 2000). These muscles can also limit range of motion and decrease the amount of force available if they are not stretched properly before activity.

Stretching is made possible due to numerous structures interacting with one another. A combination of chemoreceptors, muscle spindles, and golgi tendon organs act in unison to allow for the muscle to stretch without tearing. The chemoreceptors send a message to the central nervous system, and then the golgi tendon organs provide the central nervous system with feedback concerning the tension, while the muscle spindles provide sensory information concerning the relative muscle length (Powers & Howley, 2004). When the muscle spindles detect the stretch of the muscle they send sensory neurons to resist being stretched (Powers & Howley, 2004). When this takes place the golgi tendon organs activate to allow for muscle relaxation. This is known as the golgi tendon reflex (Saladin, 2004). These golgi tendon organs are the safety devices that help moderate muscle contractions before it tears a tendon or pulls it loose from the muscle or bone (Powers & Howley, 2004).

There are four ways to stretch: a) ballistic stretching, b) static stretching, c) propioceptive neuromuscular facilitation (PNF) stretching, and d) dynamic stretching (Bandy & Irion, 1994). Ballistic stretching involves a bouncing movement where repetitive contractions of an agonist muscle (prime mover) work to stretch an antagonist muscle (a muscle that contracts with and limits the action of an agonist with which it is paired) (Bandy & Irion, 1994). Static stretching involves slowly elongating the muscle to tolerance (comfortably with no pain) and holding the position for an extended period of time (Prentice, 2003). PNF is also known as contract-relax or hold-relax; these involve the use of a brief isometric contraction of the muscle prior to a static stretch (Bandy & Irion, 1994). Finally, dynamic stretching method involves an active warming and integration of movement patterns and skills integral to the athlete's sport (Bandy & Irion, 1994).

Static and dynamic stretching are two methods that can be affectively executed by an athlete with no assistance. PNF and ballistic stretching on the other hand should be performed only by a trained individual so that it is not only effective, but does not harm the athlete. Because the overall anatomy and physiology of the shoulder complex does not suggest if static or dynamic stretching is a more effective stretching protocol it is important to investigate which stretching method will produce the greatest range of motion and peak torque.

1.2 SIGNIFICANCE OF THE PROBLEM

The majority of the literature conducted on static and dynamic stretching examines hamstring flexibility and the effects of lower body stretching on performance such as long jump and vertical jump. Researchers have also investigated how long these effects last. However, there is a lack of research on upper extremity stretching and its effect on range of motion and performance. This information is essential to upper extremity athletes such as softball, baseball, and volleyball players who place just as much (or more) strain on their shoulder as their lower extremity.

To date, there has been only one study that has investigated the effects of static stretching on shoulder range of motion. Laudner, Sipes, and Wilson (2008) examined the effect of sleeper stretches (static stretches) on posterior shoulder/capsule tightness, and range of motion in the shoulder complex. The researchers concluded that sleeper stretches (see page 40) increased posterior shoulder motion and internal shoulder rotation. However, external shoulder rotation was not significantly different after athletes performed sleeper stretches (Laudner, et al., 2008). In addition, this study did not examine the effects of dynamic stretching on shoulder range of motion.

There are several other studies that have examined the impact of static stretching on overall flexibility. A study by Bandy and Irion (2007) examined the effect of time and flexibility on static stretching on hamstring muscle flexibility. This study concluded that 30 s was the optimal time to enhance the flexibility of the hamstring muscles (Bandy & Irion, 2007). In 2004, Nelson and Bandy tried to determine if they could improve hamstring flexibility of high-school aged males with either a six week eccentric exercise program or a static stretching protocol. This study concluded that the gains in range of motion with the eccentric training were equal to those made by statically stretching the hamstring muscles (Nelson & Bandy, 2004). Finally, DePino, Webright and Arnold (2000) investigated the duration of maintained hamstring flexibility. These authors concluded that the effects of stretching only lasted 3 min. after the cessation of stretching.

In addition to these studies concentrating solely on the hamstring muscles, none of these authors examined dynamic stretching and its' effect on hamstring range of motion and peak torque.

Dynamic stretching has recently become popular as a stretching protocol for pre-practice activities to improve range of motion. Dynamic stretching is effective due to its ability to elevate core body temperature, enhance excitability of motor units, and develop kinesthetic awareness (Fredrick & Szymanski, 2001). Dynamic stretching has been shown to be just as effective as static stretching in improving flexibility (Winters, et al., 2004). Duncan and Woodfield (2006) showed no significant differences in overall flexibility when comparing dynamic and static stretching protocols. Winters et al. (2004) concluded that passive and active stretching are equally effective for increasing range of motion when investigating their effect in the hip flexors. These studies indicate that there is no significant difference between static and dynamic stretching in improving overall flexibility. Both are effective in increasing range of motion. The only difference at this time is that the length of the effects of dynamic stretching are unknown.

Research has shown that static stretching has both positive and negative effects on performance. Performance has been defined as peak torque (Ryan et al., 2008), speed during a timed run (Taylor, Sheppard, Lee, & Plummer, 2008), and the explosive force during a vertical or standing long jump (Rubini, Costa, & Gomes, 2007). A review of literature by Rubini, et al. (2007) revealed an overall negative effect of static stretching on strength performance. They found decreases in performance ranging anywhere from 4.5% to 28% after static stretching was performed. In another study, researchers looked at the immediate effects of 2, 4, and 8 min. of passive stretching on peak torque and range of motion of the plantarflexors. This study concluded no decrease in torque and temporary improvements in range of motion (Ryan et al., 2008). A study in 2009 revealed a consistent tendency for sprint ability times to be slower after the static stretching interventions. The sprint times were also slower in the change of direction speed tests after static stretching when compared to the control (Beckett, Schneiker, Wallman, Dawson, & Guelfi, 2009). Chronic static stretching, when compared to acute static stretching, was actually shown to improve specific exercise performances. Over the course of 10 weeks those participants who stretched on a consistent basis compared to the control group improved in their standing long jump, vertical jump, and 20 meter sprint (Kokkonen et al., 2007).

Taylor et al. (2008) investigated whether adding a sport specific warm-up component after static stretching would be helpful. They directly compared dynamic stretching and static stretching in this study. When directly compared, static stretching resulted in significantly worse performances compared to dynamic stretching. However, there were no significant differences between static stretching paired with a sport specific warm-up and dynamic stretching (Taylor et al., 2008). There are several other studies that investigate the effects of static stretching on performance. Overall, static stretching seems to be more detrimental than helpful; itt decreases explosive power, force, and jump height (Shrier, 2004). Static stretching seems to help only when paired with a sport specific warm-up or done chronically to improve overall flexibility.

Dynamic stretching has been shown to have a positive impact on performance for high power or explosive actions such as jumping (Saez de Villarreal, Gonzalez-Badillo & Izquierdo, 2007). It uses speed of movement, momentum, and active muscular effort to effectively stretch the muscle tissue (Fredrick & Syzmanski, 2001). One study tested different warm-up protocols and their effects on performance. The results of this study suggest that high intensity dynamic loading as well as sport specific warm-ups can lead to greater acute positive effects on performance (Saez de Villarreal et al., 2007). Herman and Smith (2008) discovered that a 4 week dynamic stretching protocol can produce better results in power, strength, muscular endurance, anaerobic capacity, and agility performance than a static stretching protocol.

Overall, most of the research indicates that dynamic stretching has a more positive effect on performance than static stretching. Several studies concluded that dynamic stretching protocols result in better results in long jump performance, vertical height performance, and peak quad torque. However, there is no research indicating how long the effects of a dynamic stretch last. Furthermore, there is no current research on dynamic stretching for the upper extremity. Therefore, this study is essential to determine whether a static or dynamic stretching protocol should be followed for optimal performance in upper extremity athletes. If one protocol provides significant improvements in range of motion and peak torque over the other, then coaches and clinicians may change their stretching routines for their athletes to the stretching protocol that is most effective.

1.3 PURPOSE OF THE STUDY

The purpose of the study was to investigate whether a static or dynamic stretching protocol is more effective at the shoulder complex as measured by range of motion and peak torque.

1.4 HYPOTHESES:

1. Dynamic stretching will produce greater range of motion at the shoulder complex than static stretching.
2. Dynamic stretching will produce greater peak torque at the shoulder complex than static stretching.

1.5 OPERATIONAL DEFINITIONS OF TERMS

Ballistic stretching - A bouncing movement where repetitive contractions of an agonist muscle (prime mover) work to stretch an antagonist muscle (a muscle that contracts with and limits the action of an agonist with which it is paired) (Bandy & Irion, 1994).

Capsule - The joint capsule surrounds the joint as a whole and is attached medially to the margin of the glenoid fossa beyond the labrum. The capsule is thin and does not contribute very much to the stability of the joint by itself. It relies on the reinforcement by ligaments and the attachment of the rotator cuff muscles (Peat, 1986). The capsule is lined by a synovial membrane attached to the glenoid rim and anatomical neck inside the capsular attachments (Terry & Chopp, 2000).

Dynamic stabilizers - The dynamic stabilizers include the four muscles of the rotator cuff, as well as the deltoid and scapular stabilizers. The rotator cuff is made up of the supraspinatus, infraspinatus, teres minor, and subscapularis (Terry & Chopps, 2000).

Dynamic stretching routine - This method involves an active warming and integration of movement patterns and skills integral to the athlete's sport (Cone, 2007).

Labrum - The glenoid labrum is a rim of fibrocartilaginous tissue attached around the margin of the glenoid fossa (Peat, 1986). Due to its location at the glenoid margin, the labrum extends the articular surfaces, thereby increasing the contact surface area and adding to the stability of the shoulder (Terry & Chopp, 2000). The inner surface of the labrum is covered with synovium, while the outer surface attaches to the capsule and is continuous with the periosteum of the scapular neck (Terry & Chopp, 2000). The labrum's shape adapts for the rotation of the humeral head, adding flexibility to the edges of the glenoid fossa.

Propioceptive neuromuscular facilitation (PNF) – Involves a technique of contract-relax or hold-relax using a brief isometric contraction of the muscle prior to a static stretch (Bandy & Irion, 1994).

Range of motion – Range of motion can be defined as the available movement within a specific joint. In this study, the range of motion tests will identify the athletes' ability to move their shoulder into flexion, extension, internal rotation and external rotation.

Rotator cuff muscles – The rotator cuff is made up of four muscles: a) supraspinatus, b) infraspinatus, c) teres minor, and d) subscapularis (Terry & Chopps, 2000). These muscles act as the dynamic steering mechanism for the humeral head. Due to the rotator cuff muscles being closer to the center of rotation on which they act, they are able to provide stability to a dynamic fulcrum during glenohumeral abduction (Terry & Chopp, 2000).

Shoulder girdle - The shoulder girdle is composed of the scapula, clavicle, and sternum (Terry & Chopp, 2000).

Shoulder joint - The shoulder joint is the connection of the girdle with the humerus (Terry & Chopp, 2000).

Static stabilizers - The static stabilizers include the labrum, capsule, and ligaments (Peat, 1986).

Static stretching – The muscle is slowly elongated to tolerance (comfortably with no pain) and the position is held for an extended period of time (Prentice, 2003).

CHAPTER 2

REVIEW OF LITERATURE

2.1 INTRODUCTION

The review of literature is divided into five major sections. First, an overview of shoulder anatomy including bony anatomy, bony and muscular articulations, static stabilizers and dynamic stabilizers is discussed. Second, an overview is provided of muscle physiology including what happens to the muscle tissue during stretching. Third, the four specific types of stretching that are utilized in athletes are described. The fourth section examines the effects of static stretching on range of motion and performance at the shoulder joint. Finally, this review of literature discusses dynamic stretching and its effect on range of motion and performance at the shoulder joint.

2.2 SHOULDER ANATOMY

The structure of the shoulder complex allows the upper extremity to have a large range of motion (Peat, 1986). However, this unrestricted radius of action leaves the anatomical structures of the shoulder very vulnerable (Terry & Chopp, 2000). There are two components of the shoulder complex: a) the shoulder girdle and b) the shoulder joint. The shoulder girdle is composed of the scapula, clavicle, and sternum. The shoulder joint is the connection of the girdle with the humerus. Due to this anatomical structure, there is more mobility, which results in less stability in the shoulder. The shoulder complex can be broken down into four categories: the bony anatomy, the bony and muscular articulations, the static stabilizers, and the muscles or dynamic stabilizers.

2.2.1 BONY ANATOMY

The humerus is the largest and longest bone of the shoulder joint, with its proximal portion consisting of the half spheroid articulating surface or head, greater tuberosity, bicipital groove, lesser tuberosity and proximal humeral shaft (Terry & Chopp, 2000). The four rotator cuff muscles are the subscapularis, supraspinatus, infraspinatus, and teres minor. The greater tuberosity is the insertion point of the supraspinatus, infraspinatus, and teres minor, while the lesser tuberosity is the insertion point for the subscapularis. The bicipital groove is the insertion point for the long head of the biceps brachii (Terry & Chopp, 2000).

The scapula is a large, thin, triangular bone lying on the posterolateral aspect of the thorax, overlying ribs two through seven, that serves mainly as a site of muscle attachment (Terry & Chopp, 2000). The spine of the scapula separates the supraspinatus muscle from the infraspinatus muscle, and, extends superiorly and laterally to form the base of the acromion. The spine functions as part of the insertion of the trapezius muscle, as well as the origin of the posterior deltoid muscle. The acromion serves as a lever arm for function of the deltoid and articulates with the distal end of the clavicle forming the acromioclavicular joint (Terry & Chopp, 2000). The acromion forms the space for the rotator cuff, and variations in acromial shape can affect contact and wear on the rotator cuff. The coracoid process projects anteriorly and laterally from the upper border of the head of the scapula (Prescher, 2000). The superior surface serves as the origin of the two coracoclavicular ligaments (trapezoid and conoid). The coracoid tip serves as the origin of the coracobrachialis muscle and the short head of the biceps brachii, as well as the insertion of the pectoralis minor muscle. In addition, the coracohumeral and coracoacromial ligaments originate on the coracoid. The scapular notch lies just medial to the base of the coracoid and is spanned by the transverse scapular ligament. The glenoid fossa, or cavity, represents the bony articulating surface for the humerus. Its articular surface is only one third to one fourth that of the humeral head hence providing only a small contribution to glenohumeral stability (Terry & Chopp, 2000).

The clavicle is the sole connector of the trunk to the shoulder girdle via the sternoclavicular joint medially and the acromioclavicular joint laterally (Terry & Chopp, 2000). The clavicle has a double curve along its long axis. The flat outer third serves as an attachment point for muscles and ligaments, whereas the tubular medial third accepts axial loading. The middle third transitional zone is the thinnest portion and weak mechanically (Terry & Chopp, 2000). The clavicle serves as a site for muscle attachments, a barrier to protect underlying neurovascular structures, and stabilizes the shoulder complex by preventing it from displacing medially with activation of the pectoralis and other axiohumeral muscles (Peat, 1986). The clavicle also prevents inferior migration of the shoulder girdle through the strong coraclavicular ligament (Peat, 1986). Finally, the sternum is the connector of the clavicle to the rest of the body.

2.2.2 BONY AND MUSCULAR ARTICULATIONS

The bony and muscular articulations include the glenohumeral joint, the acromioclavicular joint, sternoclavicular joint and the scapulothoracic articulation. The glenohumeral joint is considered a multiaxial ball and socket synovial joint (Peat, 1986). It also considered to be well suited for extreme mobility with its mismatched large humeral head and small glenoid articular surface (Terry & Chopp, 2000). The articular surfaces include the head of the humerus and the glenoid fossa of the scapula (Peat, 1986). The bony architecture of the glenohumeral joint, with its large articulating humeral head and relatively small glenoid surface, relies heavily on the ligament and muscular stabilizers throughout its motion arc (Terry & Chopp, 2000). If any of the static or dynamic stabilizers are injured by trauma or overuse, the shoulder is at an increased risk for injury.

The acromioclavicular joint is a diarthrodial joint between the lateral border of the clavicle and the medial edge of the acromion. The stability of this joint is provided by the static stabilizers (Terry & Chopp, 2000). The curvature of this joint allows the acromion and the scapula to glide forward or backward over the lateral end of the clavicle. This movement of the scapula keeps the glenoid fossa continually facing the humeral head. This joint is important because of its role in the movement of the arm. The acromioclavicular joint allows three degrees of freedom; these movements take place between the acromion and lateral end of the clavicle. They include movement about a vertical axis, around a frontal axis, and about a sagittal axis. The two major movements are a gliding movement as the shoulder joint flexes and extends, and, elevation and depression of the scapula and humerus during abduction (Peat, 1986).

The sternoclavicular joint is the only true articulation between the upper extremity and the axial skeleton (Terry & Chopp, 2000). The medial end of the clavicle is bound to the sternum, the first rib, and its costal cartilage. The movements of the sternoclavicular joint allow elevation and depression of the clavicle, as well as protraction and retraction (Peat, 1986).

The scapulothoracic articulation is not a true joint, but rather a space between the posterior thoracic cage and the concave surface of the anterior scapula. The scapulothoracic articulation allows increased shoulder movement beyond the 120 degrees offered solely by the glenohumeral joint. There are 17 muscles attach to or originate from the scapula; their main function is to stabilize the scapula and provide movement (Terry & Chopp, 2000).

2.2.3 STATIC STABILIZERS

The static stabilizers include the labrum, capsule, and ligaments. The glenoid labrum is a rim of fibrocartilaginous tissue attached around the margin of the glenoid fossa (Peat, 1986). Due to its location at the glenoid margin, the labrum extends the articular surfaces, thereby increasing the contact surface area and adding to the stability of the shoulder (Terry & Chopp, 2000). The inner surface of the labrum is covered with synovium, while the outer surface attaches to the capsule and is continuous with the periosteum of the scapular neck (Terry & Chopp, 2000). The labrum's shape adapts for the rotation of the humeral head, adding flexibility to the edges of the glenoid fossa.

The joint capsule surrounds the joint as a whole and is attached medially to the margin of the glenoid fossa beyond the labrum. The capsule is thin and does not contribute very much to the stability of the joint by itself. It relies on the reinforcement by ligaments and the attachment of the rotator cuff muscles (Peat, 1986). The capsule is lined by a synovial membrane attached to the glenoid rim and anatomical neck inside the capsular attachments (Terry & Chopp, 2000).

The ligaments of the shoulder are the soft tissue structures that connect bone to bone. Within the shoulder complex there are several ligaments, that include the coracohumeral ligament, the glenohumeral ligaments (superior, middle, inferior), the sternoclavicular ligament, coracoclavicular ligament and the acromioclavicular ligament.

The coracohumeral ligament is a thick band of capsular tissue originating from the base of the lateral coracoid and inserting into the lesser and greater tuberosities (Peat, 1986). It is one of the most important ligamentous structures in the shoulder complex (Peat, 1986). The superior glenohumeral ligament extends from the anterosuperior edge of the glenoid to the top of the lesser tuberosity (Terry & Chopp, 2000). The superior glenohumeral ligament assists in preventing downward displacement of the humeral head (Peat, 1986). The middle glenohumeral ligament originates from the supraglenoid tubercle, superior labrum, or scapular neck and inserts on the medial aspect of the lesser tuberosity (Peat, 1986). This ligament limits lateral rotation up to 90 degrees of abduction and is an important anterior stabilizer (Terry & Chopp, 2000). The inferior glenohumeral ligament is the thickest of the glenohumeral structures. This ligament attaches to the anterior, inferior, and posterior margins of the glenoid labrum and passes laterally to the inferior aspects of the anatomical neck of the humerus (Peat, 1986). Its main function is to support the joint in the upper ranges of abduction and prevent anterior subluxation and dislocation (Terry & Chopp, 2000). The sternoclavicular ligament connects the sternum and the clavicle. The coracoclavicular ligament connects the coracoid and the clavicle, while the acromioclavicular ligament connects the acromion and the clavicle.

2.2.4 DYNAMIC STABILIZERS

The dynamic stabilizers include the four muscles of the rotator cuff, as well as the deltoid and scapular stabilizers. The rotator cuff is made up of the supraspinatus, infraspinatus, teres minor, and subscapularis. These muscles act as the dynamic steering mechanism for the humeral head. Due to the rotator cuff muscles being closer to the center of rotation on which they act, they are able to provide stability to a dynamic fulcrum during glenohumeral abduction (Terry & Chopp, 2000). On the other hand, any injury to the rotator cuff can result in considerably less force of elevation in the shoulder joint (Peat, 1986). To palpate the rotator cuff muscles the patients arm must be hanging at their side. The supraspinatus muscle lies just under the acromion. The infraspinatus muscle can be palpated below the spine of the scapula and posterior deltoid muscle. Inferior to the infraspinatus, the teres minor muscle can be palpated along the lateral scapula border. The subscapularis is the one rotator cuff muscle that cannot be palpated as it located on the subscapularis fossa.

The deltoid muscles are made up of three areas: the anterior deltoid originates from the lateral clavicle, the middle deltoid starts at the acromion and a posterior deltoid originates from the spinous process of the scapula. All three areas of the deltoid muscle insert on the deltoid tuberosity of the humerus. The anterior and middle deltoids are responsible for elevation in the scapular plane and assist in forward elevation with help from the pectoralis major and biceps brachii (Terry & Chopp, 2000).

The scapulothoracic muscles include: trapezius, rhomboids major and minor, levator scapulae, serratus anterior and pectoralis minor. The trapezius is a large muscle that begins or originates from the base of the skull to the upper lumbar vertebrae and inserts on the lateral aspect of the clavicle, acromion, and scapular spine. Its main function is to act as a scapular retractor and elevator of the lateral angle of the scapula. It can be palpated from the neck region down to T12. The rhomboid muscles (major and minor) originate from the spinous processes of C7 and T1 and T2 to T5. They insert on the medial aspect of the scapula and retract and elevate the scapula. To palpate, the patient must place arm behind back while resisting rotation. The rhomboids can be found between the scapula and spinous processes. The levator scapulae originates on the transverse processes of the cervical spine and inserts on the superior angle of the scapula. The levator scapulae elevates the superior angle, which results in upward and medial rotation of the scapular body. The serratus anterior is located on the front and lateral side of the chest below ribs five and six. It originates from the bodies of the first nine ribs and anterolateral aspect of the thorax. The serratus anterior inserts from the superior to inferior angle of the scapula. Activating this muscle group causes scapular protraction and upward rotation. The pectoralis minor muscle begins at the anterior portion of the second through fifth ribs and inserts on the base of the coracoid. This muscle protracts and rotates the scapula inferiorly (Terry & Chopp, 2000).

2.2.5 RANGE OF MOTION

As previously mentioned, the shoulder complex is a highly moveable joint. Its range of motion is made possible through all four joints working together as one complex. An Apley's Scratch test is a simple way to measure the available range of motion within the shoulder. This test examines limited range of motion or asymmetry of movements when comparing the affected and unaffected shoulders. The patient is seated or standing and he/she is instructed to simply touch the opposite side shoulder with his/her hand. Any difference in the inability to touch the opposite shoulder shall be considered a positive finding. The normal motion for the shoulder joint is 180 degrees of abduction, 180 degrees of flexion, 55 degrees of internal rotation, 45 degrees of adduction, 45 degrees of extension and 80-100 degrees of external rotation (Terry & Chopp, 2000). The shoulder girdle also includes the following movements: protraction, retraction, upward rotation, downward rotation, elevation, and depression.

The shoulder joint and girdle move together in what is known as "scapulohumeral rhythm." This is the combined movement of the scapula and humerus during elevation. As the arm moves beyond 30 degrees of abduction or 60 degrees of flexion the scapula rotates one degree from every two degrees of humeral movement. And for every three degrees of abduction, two degrees of movement occurs in the glenohumeral joint as one degree occurs at the scapulothoracic joint. The purpose of this combined movement is to increase range of motion while still maintaining stability.

Range of motion within the shoulder is also reliant on bursae; these are small fluid-filled sacs made of white fibrous tissue and lined with synovial membrane (Powers & Howley, 2004). Bursae provide a cushion between bones and tendons and/or muscles around a joint. There are two that are particularly important for total movement within the shoulder complex. These are the subacromial and subscapular bursae. These bursae sacs provide for smoother motion within the shoulder.

2.3 PHYSIOLOGY OF STRETCHING

In order to make gains during a stretching session it is important to know how each of the structures within the muscle interact with one another. Skeletal muscle contains many types of sensory receptors: chemoreceptors, muscle spindles, and golgi tendon organs. A chemoreceptor is a specialized free nerve ending that sends information to the central nervous system (Powers & Howley, 2004). It does this in response to changes in muscle pH, concentrations of extracellular potassium, and changes in O_2 and CO_2 tension (Powers & Howley, 2004). In order for the nervous system to be successful it must receive continuous sensory feedback from the contracting muscle. This sensory feedback includes information concerning the tension developed by a muscle and accounts for the muscle length. Golgi tendon organs provide the central nervous system with feedback concerning the tension, while the muscle spindles provide sensory information concerning the relative muscle length (Powers & Howley, 2004).

Muscle spindles are essential to the stretching process, but they also assist in the regulation of movement and help to maintain posture (Powers & Howley, 2004). They are composed of several thin muscle cells (intrafusal fibers) that are surrounded by a connective tissue sheath. Muscle spindles insert into connective tissue within the muscle and run parallel with muscle fibers (Powers & Howley, 2004). There are two types of sensory nerve endings within a muscle spindle. The primary endings respond to dynamic changes in muscle length and the secondary endings provide the central nervous system with continuous information concerning static muscle length. In addition to sensory neurons, muscle spindles are innervated by gamma motor neurons, which stimulate the intrafusal fibers to contract with the connective tissue sheath (Saladin, 2004). Gamma motor neuron stimulation causes the central region of the intrafusal fibers to shorten, which causes the spindle to tighten. This is more commonly known as the stretch reflex (Powers & Howley, 2004).

During stretching specifically, muscle spindles are responsible for detecting the stretch of the muscle, sending sensory neurons to conduct action potentials to the spinal cord and to synapse with alpha motor neurons (Powers & Howley, 2004). This then causes the stimulation of the alpha motor neurons and the muscle contracts and resists being stretched (Powers & Howley, 2004).

The golgi tendon organs are located within the tendon and are in series with the connective tissue sheath or extrafusal fibers. These organs detect tension applied to a tendon and send sensory neurons to conduct action potentials to the spinal cord and to synapse with inhibitory interneurons that synapse with alpha motor neurons (Powers & Howley, 2004). Inhibition of the alpha motor neurons causes muscle relaxation, relieving the tension applied to the tendon. This is more commonly referred to as the golgi tendon reflex (Saladin, 2004). Golgi tendon organs are considered safety devices that help prevent excessive force during muscle contraction (Powers & Howley, 2004). Therefore, golgi tendons moderate muscle contractions before it tears a tendon or pulls it loose from the muscle or bone (Saladin, 2004).

2.4 FOUR TYPES OF STRETCHES

Good flexibility is essential for successful physical performance; it has long been thought to decrease the incidence of musculotendinous injuries, minimize and alleviate muscle soreness and improve athletic performance (Prentice, 2003). A decreased range of motion can lead to decreased performance capabilities as well as uncoordinated and awkward movements (Prentice, 2003). Athletes who participate in overhead activities such as baseball, softball, and volleyball typically present with posterior shoulder tightness, therefore it is essential to discover an effective way to increase their range of motion in order for these athletes to practice proper kinematics and kinetics (Laudner, Sipes, &Wilson, 2008). Recent research has shown that lesions are commonly associated with posterior shoulder tightness resulting in subacromial impingement (Tyler, Nicholas, Roy, & Gleim, 2000), superior labrum anterior to posterior (SLAP) lesions (Grossman, et al., 2005) and internal impingement (Myers, Laudner, Pasquale, Bradley & Lephart, 2006).

There are four ways to stretch, three of which are very common and well known, while the fourth, dynamic stretching, is becoming more popular in the current athletic population (Bandy & Irion, 1994). The first method is ballistic stretching, which involves a bouncing movement where repetitive contractions of an agonist muscle (prime mover) work to stretch an antagonist muscle (a muscle that contracts with and limits the action of an agonist with which it is paired) (Bandy & Irion, 1994). The muscle spindles tend to tighten during this method instead of relaxing and can lead to possible muscle soreness or injury (Prentice, 2003). This stretching method is not commonly used in athletic populations today as it has been discarded for more effective stretching methods. An example of this type of stretch is a bouncing hamstring stretch. This involves reaching for ones toes in a bouncing, repetitive manner.

The second method is static stretching which involves the muscle slowly elongated to tolerance (comfortably with no pain) and the position is held for an extended period of time (Prentice, 2003). Research has shown that the optimal way to increase flexibility over time is to hold a static stretch for 30 to 45 seconds (Bandy & Irion, 1994). This extended amount of time allows the golgi tendon organs to override impulses from the muscle spindle following its initial reflex resistance (Prentice, 2003). Laudner et al. (2008) concluded that sleeper stretches (static stretches) for the shoulder are effective in increasing shoulder range of motion in the dominant arm of baseball players. Another study suggests that 40 min. of static stretching three times per week for 10 weeks increases flexibility, strength, endurance, and power in the lower extremity (Kokkonen, et al., 2007). When Nelson and Bandy (2004) compared eccentric training (lengthening of the muscle) and static stretching, they discovered that the gains achieved in range of motion in the hamstring muscles during eccentric training were equal to those made by statically stretching the hamstring muscles. The major advantage with static stretching is its convenience because it can be done without the assistance of a partner. An example of a static stretch is a seated hamstring stretch. This is where on reaches for their toes and holds the stretch for an extended time period.

The third common method of stretching is the propioceptive neuromuscular facilitation (PNF) technique of contract-relax or hold-relax; these involve the use of a brief isometric contraction of the muscle prior to a static stretch (Bandy & Irion, 1994). According to clinicians, PNF is the best technique to improve overall flexibility. Both isometric and concentric (shortening) muscle actions completed immediately before the passive stretch (stretch applied by clinician) help to achieve autogenic inhibition (Prentice, 2003). Autogenic inhibition is a reflex relaxation that occurs in the same muscle where the golgi tendon organ is stimulated (Prentice, 2003). Often the isometric contraction is referred to as 'hold' and the concentric muscle contraction is referred to as 'contract' (Bandy & Irion, 1994). A disadvantage to PNF stretching is that an experienced clinician (physical therapist or athletic trainer) is required to administer an effective PNF stretch.

An example of a PNF stretch is a hamstring slow-reversal-hold-relax technique. This is done with the athlete lying supine with the knee extended and the ankle flexed to 90 degrees, the athletic trainer passively flexes the hip joint to the point at which there is a slight discomfort in the muscle. At this point the athlete begins pushing against the athletic trainer's resistance by contracting the hamstring muscle. After pushing for ten seconds, the hamstring muscles are relaxed and the agonist quadriceps muscle in contracted while the athletic trainer applies passive pressure to further stretch the antagonist hamstrings. This action should move the leg so that there is increased hip joint flexion.

The fourth and final stretching method is a dynamic stretching routine. This method involves an active warming and integration of movement patterns and skills integral to the athletes' sports. According to research, the musculoskeletal benefits of active warming is an increase in temperature in exercising muscle, resulting in a general decrease in muscular viscosity, and an increase in muscle pliability (Cone, 2007). According to Cone (2007), movements occur in all planes and ranges of motion, and at both slow and maximal speed. Therefore it is logical for flexibility to progress in three areas: control, speed, and complexity (Cone, 2007). Dynamic stretching begins with simple stretches at a slow speed with controlled movements. As the stretching progresses the movements become faster, more complex, and less controlled. Faigenbaum, McFarland, Ratamess, Kang and Hoffman, (2006) concluded that a dynamic warm-up with a weighted vest may be the most effective warm-up protocol for enhancing jumping performance. An example of a dynamic stretch is overhead arm circles. This mimics the motion of an overhead throw while actively moving the muscle in multiple planes.

In conclusion, both static and dynamic stretching are two methods that can be affectively executed by an athlete with no assistance. PNF and ballistic stretching on the other hand should be performed only by a trained individual so that it is not only affective, but does not harm the athlete.

2.5 STATIC STRETCHING

2.5.1 EFFECT OF STATIC STRETCHING ON RANGE OF MOTION

Most of the current research on static stretching has addressed increasing range of motion or flexibility in the hamstring (Bandy & Irion, 2007). However, only one study has specifically addressed increasing range of motion in the shoulder complex using a form of static stretching. Laudner, Sipes, and Wilson (2008) examined the effect of sleeper stretches on posterior shoulder/capsule tightness, and range of motion in the shoulder complex.

During this study, 33 NCAA Division I baseball players' glenohumeral horizontal adduction motion and internal and external shoulder rotation were measured prior to the stretches. A sleeper stretch is applied in the side lying position, with scapular motion restricted. The shoulder is then internally rotated to isolate the posterior soft tissue restraints. After the sleeper stretch was applied for three 30 s intervals, the measurements were taken again (Laudner, Sipes, &Wilson, 2008). This study had one clinician apply the stretch for each athlete. Although this controlled for internal validity within the study it may not have much external validity. In an athletic setting, it may be more practical to have the athletes apply the stretch on each other due to limited time available before practice for individual stretching by an ATC. The results of this study demonstrated increased posterior shoulder motion and internal shoulder rotation, however, external shoulder rotation was not significantly different after the stretches (Laudner, Sipes, &Wilson, 2008). Further research is needed to determine what other shoulder stretches can successfully result in increased range of motion, the optimal time to hold the stretch and how long the affects of stretching last.

A study conducted by Bandy and Irion (2007) examined the effect of time and flexibility on static stretching on the flexibility of the hamstring muscles. Flexibility was defined as "the range of motion available in a joint or a group of joints that is influenced by muscles, tendons, ligaments, and bones" (Bandy & Irion, 2007). During this study, flexibility of the hamstring muscles was determined by measuring knee extension range of motion with the femur maintained in 90 degrees of hip flexion using a goniometer. Measurements were taken before and after 6 weeks of static stretching. The results of this study suggested that 30 s is an effective time of stretching for enhancing the flexibility of the hamstring muscles (Bandy & Irion, 2007).

Nelson and Bandy (2004) conducted a research study to determine if the hamstring flexibility of high-school aged males would improve with a 6 week eccentric exercise program over a static stretching protocol. The results of this study showed no difference between the eccentric and static-stretching groups. Therefore, the gains in range of motion with eccentric training were equal to those made by statically stretching the hamstring muscles (Nelson & Bandy, 2004).

In another study conducted by DePino et al. (2000) the duration of maintained hamstring flexibility was examined. This study had 30 male subjects with limited hamstring flexibility perform four 30 s static stretches separated by 15 s rests. Their range of motion was measured before and after the stretching protocol by a goniometer. In order to determine how long the gains in flexibility actually lasted, hamstring flexibility was measured at 1, 3, 6, 9, 15, and 30 min. post static stretching. The researchers found that the four consecutive 30 s static stretches enhanced hamstring flexibility, however, the effects only lasted 3 min. after cessation of the stretching protocol (DePino, Webright, & Arnold, 2000). If this is the case, can stretching truly have an impact on performance?

2.5.2 EFFECT OF STATIC STRETCHING ON PERFORMANCE

Static stretching has been shown to have both positive and negative effects on performance. Performance has been defined using numerous measures. Several studies have defined performance as strength by measuring peak torque (Ryan et al., 2008); others have defined it as speed during a timed run (Taylor et al., 2008). Performance has also been defined as the explosive force during a vertical jump or standing long jump (Rubini, Costa, & Gomes, 2007).

A review of literature by Rubini, Costa, and Gomes (2007) revealed a decrease in strength performance ranging anywhere from 4.5% to 28% after static stretching with most of the research being done on the lower body. Although most of the studies they reviewed found acute decreases in strength following stretching, those decreases seemed to be more prominent the longer the stretching protocol and the more exercises and sets performed. The duration and number of these sets tended to exceed the ranges normally recommended in the literature (Rubini et al., 2007). Their review of literature also examined the effect of static stretching on vertical jump performance. The authors concluded conflicting results with some studies demonstrating no decrease in vertical jump after static stretching while others found decreases in performance (Rubini et al., 2007).

Taylor et al. (2008) conducted a research study to investigate if the negative effect of static stretching could be restored when combined with a sport specific warm-up component. Thirteen netball players completed two experimental warm-up conditions. Day 1 warm-up involved a sub-maximal run followed by 15 min of static stretching and a netball specific skill warm-up. Day 2 followed the same procedures as Day 1 except the static stretching was replaced with a 15 min dynamic warm-up. This allowed for a direct comparison between static stretching and dynamic stretching. After the initial warm up (static or dynamic) each participant performed a vertical jump and a 20 meter sprint. Athletes then had their specific skill warm-up and re-performed a vertical jump and a 20 meter sprint. The static stretching condition resulted in significantly worse performance than the dynamic warm-up in both vertical height and 20 meter sprint time. However, there were no significant differences in either performance variable when the skill specific warm-up followed the static or dynamic stretching warm-up routine (Taylor et al., 2008).

In another study, researchers investigated the acute affect of 2, 4, and 8 min. of passive stretching on peak torque and range of motion of the plantarflexors. The study concluded that practical durations of stretching did not decrease peak torque compared with the control, however, caused temporary improvements in range of motion (Ryan, et al., 2008). Another study examined whether a static stretching routine decreased isometric force, muscle activation, and jump power while improving range of motion of the quadriceps (Power, Behm, Cahill, Carroll, & Young, 2004). Their results showed significant decrements in the torque or force of the quadriceps. The force remained significantly decreased for 120 min, although, there were no significant changes in jump performance (Power et al., 2004).

A recent study examined the effects of static stretching on repeated sprint and change of direction performance (Beckett, Schneiker, Wallman, Dawson, & Guelfi, 2009). On four separate occasions 12 male team sport players performed a standardized warm-up followed by a test of either repeated sprint ability or change of direction speed.

Both tests involved three sets of six maximal sprint repetitions, with a 4 minute recovery between sets. During the break, the athletes either completed a static stretching protocol or rested. Results revealed a consistent tendency for repeated sprint ability times to be slower after the static stretching interventions. Sprint times also tended to be slower in the change of direction speed tests after static stretching when compared to the control. These results suggest that an acute bout of static stretching of the lower limbs may compromise repeated sprint ability performance as well as change of direction speed performance (Beckett et al., 2009). Prior research has shown that muscular force and power are lessened after acute bouts of static stretching (Power et al., 2004).

In contrast, chronic static stretching, compared to acute static stretching, may improve specific exercise performance according to a study by Kokkonen and colleagues (2007). These researchers conducted a study in which 38 participants were divided into a stretching group and a control. The stretching group's activity was limited to a 10 week, 40 minutes a day, 3 days a week static stretching routine designed to stretch all the major muscle groups in the lower extremity. The control group included the participants who did not participate in physical activity on a regular basis for 10 weeks. Each participant was measured before and after for flexibility, power (20 meter sprint, standing long jump, vertical jump), strength (knee flexion and knee extension 1 repetition maximum), and strength endurance (number of repetitions at 60% of 1 repetition maximum for both knee flexion and knee extension). The static stretching group had significant improvements for flexibility, standing long jump, vertical jump, 20 meter sprint, knee flexion 1 rep max, knee extension 1 rep max, knee flexion endurance and knee extension endurance. These results suggest that chronic static stretching exercises by themselves can improve specific exercise performances (Kokkonen et al., 2007).

There are two theories why the chronic static stretching improved the participant's performance. One theory is that the chronic stretching caused strength gains. The strength gains can be attributed to increases in muscle length. Increases in muscle length lead to increases in contractile velocities and the forces generated at a given shortening velocity. The other theory is that the improved performance may not be related to the stretching exercises. It is possible that the strength gains in each leg were the result of muscle contractions in the non-stretched leg when it was used to stabilize the body during those stretches (Kokkonen et al., 2007).

Overall, static stretching seems to have more of a negative affect on performance rather than a positive impact. In events that require explosive power, static stretching tends to be a detriment. According to Shrier (2004) an acute bout of stretching does not improve force or jump height. Static stretching as a whole is only successful when paired with a sport specific warm-up or done chronically to improve overall flexibility.

2.6 DYNAMIC STRETCHING

2.6.1 EFFECT OF DYNAMIC STRETCHING ON RANGE OF MOTION

Dynamic stretching or an active warm-up has been shown to be an effective way to stretch due to its ability to elevate core body temperature, enhance excitability of motor units, and develop kinesthetic awareness (Fredrick & Szymanski, 2001). Active warm-ups demonstrate an ability to increase range of motion just as effectively as static stretching (Winters et al., 2004).

Researchers examined the acute effects of a dynamic warm-up protocol on flexibility and vertical jump in children (Duncan & Woodfield, 2006). Forty children participated in three experimental randomized conditions: no warm-up, static warm-up, and dynamic warm-up. Low back and hamstring flexibility was assessed using the sit and reach test while vertical jump height was assessed using a digital jump mat following each condition. The results showed that there were no significant differences in a dynamic warm-up protocol on overall flexibility. But in terms of vertical jump performance, there was a significant increase in scores after a dynamic warm-up (Duncan & Woodfield, 2006). These results indicate that an acute dynamic warm-up may enhance performance in activities that require high power or explosiveness. The results may also be an indication that an acute static warm-up may be detrimental to performance where high power is required.

Another study looked at passive versus active stretching of hip flexor muscles in subjects with limited hip extension (Winters et al., 2004). Thirty-three patients participated in a randomized clinical trial each with decreased range of motion in their hip flexors. Participants were divided into an active stretching group and a passive stretching group. Hip extension range of motion was measured with the subjects at baseline, 3 weeks, and 6 weeks after the start of the study. The results of this study showed that there was an increase in range of motion with the active stretching group as well as the passive stretching group. However, there were no significant differences between the gains in range of motion. The researchers concluded that passive and active stretching are equally effective for increasing range of motion (Winters et al., 2004).

Research done on dynamic stretching has indicated that it is equally effective as static stretching in terms of increasing range of motion (Winters et al, 2004). However, research has not investigated how long the effects of dynamic stretching last. Therefore, additional research should be conducted to examine how long these effects last. A static stretch has been shown to last for as long as six to eight minutes (Bandy & Irion, 1994). However, if gains in range of motion last longer with dynamic stretching it may be the more effective way to stretch before competition or practice.

2.6.2 EFFECT OF DYNAMIC STRETCHING ON PERFORMANCE

Dynamic stretching is defined as quickly moving a joint through its range of motion with little resistance (Fredrick & Szymanski, 2001). It has been shown to have a positive impact on performance for high power or explosive actions such as jumping (Saez de Villarreal et al., 2007). Dynamic stretching uses speed of movement, momentum and active muscular effort to effectively stretch. Physiologically, dynamic stretching raises core body and deep muscle temperature, elongates active muscles (elasticity), decreases the inhibition of antagonist muscles, and stimulates the nervous system (arousal) (Fredrick & Szymanski, 2001). Many strength and conditioning coaches have started to use this type of stretching for daily warm-ups.

Researchers examined the effect of different types of active or dynamic warm-ups as a means to enhance height during vertical jump (Saez de Villarreal et al., 2007). Twelve trained volleyball players performed different types of warm-ups on randomized separate test occasions. Warm-up protocol one (WP1) consisted of three sets of five jumps with extra load. Warm-up protocol two (WP2) consisted of two sets of four reps at 80% of one repetition maximum (RM) parallel squat and two sets of two reps at 85% of one repetition max. The third warm-up protocol (WP3) was two sets of two reps at 90% of one RM and two sets of one rep at 95% of one RM. The fourth warm-up protocol (WP4) was three sets of five drop jumps. A fifth warm-up protocol (WP5) involved specified warm-up for a volleyball match. A sixth warm-up protocol (WP6) was performing three sets of five reps at 30% one RM. The final warm-up protocol (WP7) was an experimental condition of no active warm-up (Saez de Villarreal et al., 2007).

Each athlete in the experimental group gave a baseline vertical jump, 5 min. post warm up vertical jump, and 6 hours post warm-up vertical jump. The results of this study showed improvements in drop jump after WP1, WP2, WP3, and WP5 and countermovement jumps after WP2, WP5, WP3, and WP1. However, specific volleyball warm-up protocol brought about the greatest effects on subsequent neuromuscular explosive responses. The positive effects on jumping performance also lasted after long recovery periods (6 hours) particularly when prior intensity dynamic actions were performed (Saez de Villarreal et al., 2007). The results of this study suggest that high intensity dynamic loading as well as sport specific warm-ups can lead to greater acute positive effects on performance.

Another study examined the effects of active or dynamic warm-ups on performance and force production. Hahn and colleagues (2007) measured force production through torque, range of motion, and muscle activation. Data analysis showed four main results: a) peak torque did not occur at the end of the stretch, but torque at the end of the stretch exceeded the corresponding isometric torque, b) there was no significant force enhancement following muscle stretch, but a small significant passive force enhancement persisted for all stretch conditions, c) forces during and following stretch were independent of stretch amplitude, and d) muscle activation during and following muscle stretch was significantly reduced (Hahn, Seiberl, & Schwirtz, 2007). Although these results showed passive force enhancement, the study could not provide direct evidence of force enhancement with active stretching.

Faigenbaum et al. (2006) explored the acute effects of four warm-up protocols with and without a weighted vest on anaerobic performance in 18 healthy high school female athletes. After five minutes of jogging, athletes performed four randomly ordered warm-up protocols. The first warm-up included five static stretches, each done two times for 30 seconds (SS). The second warm-up was performing nine moderate to high intensity dynamic exercises (DY). A third warm-up included the same nine dynamic exercises performed with a weighted vest with two percent of body mass (DY4). The fourth protocol included the same nine dynamic exercises but performed with a weighted vest that represented six percent of their body mass (DY6). Athletes completing the warm-up protocols followed by vertical jump, long jump, seated medicine ball toss and 10 yard sprint to determine positive or negative effects on performance. The results showed that vertical jump performance was significantly greater after DY and DY2 compared with SS. Long jump performance was significantly greater after DY2 compared with SS. No significant differences between trials were observed for the seated medicine ball toss or 10 yard sprint (Faigenbaum et al., 2006). These results indicate that a dynamic warm-up performed with a vest weighted with two percent of body mass may be the most effective warm-up protocol for enhancing jumping performance.

Another study done by Herman and Smith (2008) indicates that a four week dynamic stretching warm-up intervention elicits long term performance benefits (Herman

& Smith, 2008). In this study 24 NCAA Division 1 wrestlers were randomly assigned to complete either a four week dynamic warm-up (DWU) or a static warm-up (SWU). The measures of performance included peak torque of the quadriceps and hamstrings, medicine ball underhand throw, 300 yard shuttle, pull-ups, push-ups, sit-ups, broad jump, 600 meter run, sit and reach test, and trunk extension test. A four week dynamic stretching protocol showed improvements in several performance areas, including increases in quadriceps peak torque, broad jump, underhand medicine ball throw, sit-ups, and push-ups. On the other hand, the static warm-up resulted in no observed improvements (Herman & Smith, 2008). These findings suggest that a four week protocol including dynamic stretching may help produce better power, strength, muscular endurance, anaerobic capacity, and agility performance enhancements.

A similar study examined dynamic versus static stretching warm-up and their effect on power and agility performance (McMillian, Moore, Hatler, & Taylor, 2006). This study compared the two types of warm-ups using 30 cadets at the United States Military Academy. On three consecutive days, subjects performed one of the two warm-up routines (DWU or SWU) or performed no warm-up (NWU). Following the warm-up the subject performed a t-shuttle run, underhand medicine ball throw for distance and 5-step jump. Results showed better performance scores on all three tests after the dynamic warm-up (McMillian et al., 2006). These results indicate that warm-up routines using only static stretching may need to be reassessed.

Overall, a significant portion of the research indicates that dynamic stretching has a more positive effect on performance than static stretching. Several studies indicate significant improvements in long jump performance, vertical height performance, and peak quad torque after performing a dynamic stretch or active warm-up for an assigned period of time. However, only one study has examined the lasting effects of a dynamic stretch. Therefore, more research is needed to validate the evidence. On the other hand, one study concluded that there was no evidence of force enhancement with dynamic stretching. Therefore it is vital that more research be conducted to truly determine the best stretch for increasing range of motion and performance.

2.7 CONCLUSION

The purpose of this study was to determine an appropriate warm-up or stretching protocol for athletes' participating in an upper extremity sport. Most research on stretching has focused primarily on lower body. A significant amount of the literature primarily examined how to increase flexibility of the hamstring muscles and the effects of lower body stretching on performance such as long jump and vertical jump. Researchers also investigated how long these effects last. Upper extremity athletes such as softball, baseball, and volleyball use their shoulder just as much or more than their lower body. Therefore, research on the impact of stretching on the shoulder joint's range of motion and performance is extremely important. It would be beneficial for coaches and clinicians working with upper extremity athletes to determine if a static or dynamic stretching protocol could provide significant improvements in range of motion and/or performance.

CHAPTER 3

METHODS

3.1 RESEARCH DESIGN

A randomized, counterbalanced, within-subject experimental design was used to compare the two different types of stretching. The independent variable was stretching technique (static, dynamic) and the dependent variables were range of motion and peak torque.

3.2 SAMPLE POPULATION AND PARTICIPANT SELECTION

Thirty subjects from a mid-western university between the ages of 18 and 25 years were asked to volunteer for this study. All participants will be Division I NCAA athletes participating in softball, baseball, or volleyball. Participants were excluded if they had surgery on their dominant arm within the last 6 months. Participants were excluded from the study if they had a previous injury to their dominant arm, elbow, wrist, or hand 1 month prior to the study.

3.3 INSTRUMENTATION

3.3.1 GONIOMETRY

Goniometric measurements are used by physical therapists and athletic trainers to quantify baseline limitations of range of motion, decide on appropriate therapeutic interventions, and document the effectiveness of these interventions. In this study a large plastic goniometer with a 10 in movable arm was used to measure shoulder flexion, extension, internal rotation and external rotation. The scale of the goniometer is marked in 1-degree increments. A study done in 1987 confirmed the reliability of using a goniometer in a clinical setting (Riddle, Rothstein, & Lamb, 1987).

3.3.2 BIODEX SYSTEM 3 DYNAMOMETER

The biodex system 3 dynamometer was used to collect peak torque values for the shoulder during this study. This system is reliable and valid and is specifically used for isolated muscle testing and rehabilitation. A study in 2004 showed that the biodex system 3 dynamometer was capable of producing valid measures of torque (Drouin, Valovich-mcLeod, Shultz, Gansneder, & Perrin, 2004). To assess validity measurement of each variable using the Biodex system 3 dynamometer was compared to a criterion measure of position, torque, and velocity. Position was assessed at 5 degree increments across the available range of motion of the dynamometer. Torque measures were assessed isometrically by hanging six different calibrated weights from the lever arm. Velocity was assessed across a 70 degree arc of motion by manually accelerating the weighted lever arm. The biodex performed with acceptable mechanical reliability and validity on all variables tested (Drouin et al., 2004).

Researchers have also shown that this dynamometer is reliable in measuring glenohumeral medial and lateral rotation (internal and external rotation) concentrically and eccentrically in neutral to slightly abducted positions (Stickley, Hetzler, Freemyer & Kimura, 2008). For this study, peak torque was assessed by the dynamometer with the shoulder in a neutral to slightly abducted position going from external to internal rotation. Isokinetic internal and external rotation peak torque data was measured in Newton*meters for the dominant arm.

3.4 STATIC STRETCHING INTERVENTION

Participants performed four different types of static stretches. Each of the four stretches was performed 3 times for 30 s. Static stretch 1 was a shoulder stretch.

Participants stood tall, feet slightly wider than shoulder-width apart, knees relaxed and slightly bent. They placed their dominant arm parallel with the ground across the front of their chest. Participants bent their non-dominant arm up and used their non-dominant forearm to ease the dominant arm closer to their chest. Participants felt the stretch in their shoulder (See Figure 1).

Static stretch 2 was a shoulder and triceps stretch. Participants stood tall, feet slightly wider than shoulder-width apart, knees relaxed and slightly bent. They placed both hands above their head and then slid their dominant hand down the middle of their spine. Their non-dominant hand pressed down on their dominant elbow to increase the stretch. They felt the stretch in their shoulders and their triceps (see Figure 2).

Static stretch 3 was a biceps stretch. Participants stood tall, feet slightly wider than shoulder-width apart, knees relaxed and slightly bent. They held their arms out to the side, parallel with the ground. Facing forward, participants rotated their hands so their palms faced to the rear. Then they stretched their arms back as far as possible while clasping their hands together. Participants felt the stretch across their chest and in the biceps (see Figure 3).

Static stretch 4 was a sleeper stretch. Participants positioned themselves laying down on their dominant arm side with their dominant arm in front of them so it was perpendicular to their body. They bent their right elbow to 90 degrees so that their forearm was perpendicular to the floor and their fist is pointing up. Participants used their non-dominant hand to gently push their dominant forearm and hand toward the ground alongside their body until a stretch was felt in the back of their shoulder. If participants started to feel a pinch, they eased up on the stretch (see Figure 4).

Figure 1: Shoulder stretch (static stretch 1)

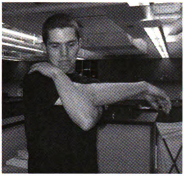


Figure 2: Shoulder and Triceps Stretch (static stretch 2)

Figure 3: Biceps Stretch (static stretch 3)

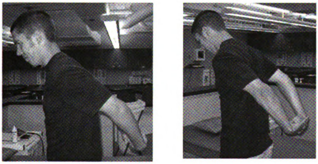


Figure 4: Sleeper Stretch (Posterior Capsule) (static stretch 4)

3.5 DYNAMIC STRETCHING INTERVENTION

Participants performed four different types of dynamic stretches. Each of the four stretches was performed 3 times for 30 s. Dynamic Stretch 1 was shoulder circles. Participants stood tall, feet slightly wider than shoulder-width apart, knees slightly bent. They raised their dominant shoulder towards their dominant ear, took it backwards, down and then up again to the ear in a smooth action (see Figure 5).

Dynamic Stretch 2 was overhead/down and back arm swings. Participants stood tall, feet slightly wider than shoulder-width apart, knees slightly bent. They kept their back straight at all times. They swung both arms continuously to an overhead position and then forward, down, and backwards (see Figure 6).

Dynamic Stretch 3 was side/front crossover arm swings. Participants stood tall, feet slightly wider than shoulder-width apart, knees slightly bent. They again kept their back straight at all times. Participants swung both arms out to their sides then cross them in front of their chest (see Figure 7).

Dynamic Stretch 4 was a wall shoulder girdle stretch. Participants positioned their back against the wall. They placed feet away from wall, slightly bending hips and knees. They bent their elbows to 90 degrees and position back of arms against wall. Participants then pushed shoulders and back of arms and hands into wall and slowly raised their arms as high as possible maintaining contact with the wall. Still pushing shoulders arms, they slowly lowered their arms to starting position (see Figure 8).

Figure 5: Shoulder Circles (dynamic stretch 1)

Figure 6: Overhead/Down and Back Arm Swings (dynamic stretch 2)

Figure 7: Side/Front Crossover Arm Swings (dynamic stretch 3)

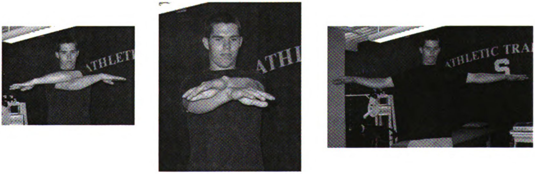
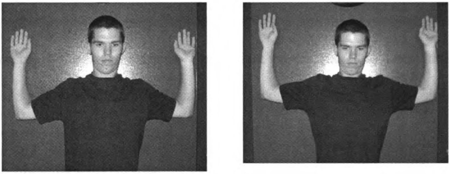


Figure 8: Wall Shoulder Girdle Stretch (dynamic stretch 4)



3.6 PROCEDURES

Prior to data collection, this study was approved from the Institutional Review Board (IRB) at Michigan State University. Each participant was asked to sign an informed consent and complete a health history questionnaire (see Appendix A). Data collection took place in Duffy Daugherty Athletic Training Room at Michigan State University.

Each subject was given a tutorial on static and dynamic stretching prior to completing the study. All participants were required to attend 2 testing sessions each lasting approximately 30 min. Dominant arm was determined by the arm athletes use to throw a baseball/softball or attack a volleyball.

3.6.1 SESSION 1

Participants were randomly assigned to either a static or dynamic group prior to the start of session 1. Baseline testing was done for range of motion (shoulder extension, shoulder flexion, shoulder internal rotation, and shoulder external rotation) and peak torque using a goniometer and the biodex, respectively. In this study, shoulder extension was measured with the patient lying prone, arm at side, and head facing away from the shoulder being tested. The elbow was slightly bent and the palm will be facing towards the body. The goniometer's fulcrum was aligned lateral to the acromion process, the stationary arm was aligned parallel to the table top, and the moving arm was aligned with the midline of the lateral humerus. The patient was instructed to the lift their arm off the table as far as they can. The normal range of motion for shoulder extension is 40 to 60 degrees.

Shoulder external rotation was measured with patient lying supine, elbow flexed to 90 degrees. The goniometer's fulcrum was centered on the olecranon process, the stationary arm perpendicular to the floor or parallel to the table top, and the moving arm was centered over the long axis of the ulna. The patient was instructed to rotate their arm up as far as possible. The normal range of motion for shoulder external rotation is 80 to 100 degrees.

Shoulder flexion was measured with the patient lying supine, arm at side, and palm facing the body. The goniometer's fulcrum was aligned lateral to the acromion process, the stationary arm was aligned parallel to the table top, and the moving arm was aligned with the midline of the lateral humerus. The patient was instructed to the lift their arm over their over, making sure the keep the palm of their hand facing toward their body. The normal range of motion for shoulder flexion is 160 to 180 degrees.

Shoulder internal rotation was measured with patient lying supine, elbow flexed to 90 degrees. The goniometer's fulcrum was centered on the olecranon process, the stationary arm perpendicular to the floor or parallel to the table top, and the moving arm was centered over the long axis of the ulna. The patient was instructed to rotate their arm down as far as possible. The normal range of motion for shoulder internal rotation is 60 to 80 degrees.

Peak torque measurements were taken with the shoulder in internal and external rotation in the modified neutral position (seated). The dynamometer orientation was at 20 degrees, the dynamometer tilt was 50 degrees, the seat orientation was 15 degrees, and the seatback tilt was 55-85 degrees. The axis alignment was longitudinal through the head of the shaft of the humerus in a horizontal plane. The ready position was full external rotation. Following the static or dynamic stretching intervention post-testing measurements was acquired again for range of motion and peak torque.

3.6.2 SESSION 2

Baseline testing was done for range of motion and peak torque as in Session 1 using a goniometer and the biodex, respectively. Following the static or dynamic stretching intervention post-testing measurements was acquired for range of motion and peak torque.

3.6.3 STATISTICAL ANALYSIS

Means and standard deviations was calculated for descriptive statistics. Each dependent variable (i.e., shoulder flexion, shoulder extension) in this study was analyzed separately. Data was analyzed using a 2 stretch condition (static vs. dynamic) x 2 testing occasion (pre vs. post) analysis of variance (ANOVA) with repeated measures on the last factor. The level of significance was set at $p \leq .05$ and all analyses were conducted using SPSS version 17.1 for Windows (SPSS Inc., Chicago, IL).

CHAPTER 4

RESULTS

The primary purpose of this study was to investigate whether a static or dynamic stretching protocol is more effective at the shoulder complex as measured by range of motion and peak torque. The two major hypotheses were: a) dynamic stretching will produce greater range of motion at the shoulder complex than static stretching, and b) dynamic stretching will produce greater peak torque at the shoulder complex than static stretching. For clarity, the results section is separated into subject demographics, flexion range of motion, extension range of motion, internal rotation range of motion, external rotation range of motion, peak torque away (from external rotation to internal rotation) and peak torque towards (from internal rotation to external rotation).

4.1 SUBJECT DEMOGRAPHICS

A total of 60 NCAA Division I athletes volunteered to participate in the study. There were nine male athletes (age =19.56 ± 0.86 years, 72.22 ± 1.66 inches, 196.33 ± 13.75 lbs.) and 21 female athletes (20 ± 0.916 years, 66.86 ± 3.52 inches, 150.31 ± 20.16 lbs.). All were healthy individuals with no self-reported surgery on their dominant arm within the last 6-months or no previous injury to their dominant arm, elbow, wrist, or hand 1 month prior to the study. Athletes had a total of 2.02 ± .81 years experience playing at MSU and 11.92 ± 3.01 years experience playing their respective sport. The majority of athletes were right arm dominant (26/30=86.7%). Over half the athletes participated in softball (n=17, 57%) followed by baseball (n=9, 30%) and volleyball (n=4, 13%). Player positions can be found in Table 4-1.

Table 4-1: Player Positions for Baseball, Softball, and Volleyball

	Softball	*Baseball*	*Volleyball*
Catcher	3	3	
Center Fielder	1		
First Base	1		
Left Fielder	1		
Outfield	4	2	
Pitcher	4	2	
Second Base	1		
Shortstop	1		
Third Base		1	
Utility	1	1	
Libero			1
Right Side			1
Setter			2
Total	**17**	**9**	**4**

4.2 RESULTS FOR SHOULDER RANGE OF MOTION AND PEAK TORQUE

Athletes participated in two sessions that included a static stretching protocol and a dynamic stretching protocol. Baseline range of motion testing was performed using a goniometer for shoulder extension, shoulder flexion, shoulder internal rotation, and shoulder external rotation. In addition to range of motion, athletes also performed a biodex test for peak torque which included measurements for both away (shoulder moving from external rotation to internal rotation) and towards (shoulder moving from internal rotation to external rotation).

4.2.1 SHOULDER FLEXION

The normal range of motion for shoulder flexion is 160 to 180 degrees. A repeated measure ANOVA was conducted to determine flexion range of motion in stretching conditions (static vs dynamic) and testing occasions (pre vs post). Athletes demonstrated significant differences within the testing occasions ($F(1,58) = 110.46$, $p < .00$) (see Tables 4-2, 4-3). Pairwise comparisons revealed significant differences between the pre stretch and post stretch ($p <.00$). Specifically, when athletes performed either the static stretch or the dynamic stretch they significantly increased their flexion range of motion from pre to post test. There were no significant differences between the static and dynamic stretching ($F(1,58) = .28$, $p = .60$) or the interaction between testing and stretching ($F(1,58) = .85$, $p = .36$).

Table 4-2: Descriptive Statistics for Flexion Range of Motion for Stretching Conditions and Testing Occasions

Flexion	N	Mean	Std. Deviation	95% Confidence Interval Lower	95% Confidence Interval Upper
Static					
Pre	30	180.10	±4.326	178.444	181.756
Post	30	184.23	±3.989	182.688	185.799
Dynamic					
Pre	30	181.00	±4.727	179.344	182.656
Post	30	184.47	±4.455	182.921	186.012

Table 4-3: ANOVA Comparing Stretching Conditions and Testing Occasions

Effect	Wilk's Lambda	Df	F	p
Testing	.344	1	110.46	.000*
Testing X Stretching	.986	1	.850	.360

*(significant at the p = .05 level)

4.2.2 SHOULDER EXTENSION

The normal range of motion for shoulder extension is 45 degrees. A repeated measure ANOVA was conducted to determine extension range of motion in stretching conditions (static vs dynamic) and testing occasions (pre vs post). Athletes exhibited significant differences within the testing occasions ($F_{(1,58)} = 9.31$, $p = .003$) (see Tables 4-4, 4-5). Post-hoc pairwise comparisons revealed significant differences between the pre stretch and post stretch ($p = .003$). Regardless of the stretching protocol, athletes significantly increased their extension range of motion from pre to post test. However, there were no significant differences between the static and dynamic stretching ($F_{(1,58)} = .21$, $p = .65$) or the interaction between testing and stretching ($F_{(1,58)} = 1.31$, $p = .26$).

Table 4-4: Descriptive Statistics for Extension Range of Motion for Stretching Conditions and Testing Occasions

Extension	N	Mean	Std. Deviation	95% Confidence Interval Lower	95% Confidence Interval Upper
Static					
Pre	30	69.37	± 6.071	67.035	71.698
Post	30	70.70	± 6.706	68.269	73.131
Dynamic					
Pre	30	67.87	± 6.673	65.535	70.198
Post	30	70.80	± 6.599	68.369	73.231

Table 4-5: ANOVA Comparing Stretching Conditions and Testing Occasions

Effect	Wilk's Lambda	df	F	P
Testing	.862	1	9.313	.003*
Testing X Stretching	.978	1	1.310	.257

*(significant at the p = .05 level)

4.2.3 SHOULDER EXTERNAL ROTATION

The normal range of motion for shoulder external rotation is 80 to 100 degrees for normal non-athletes. Generally, athletes that participate in overhead sports tend to have a higher range of motion for external rotation. A repeated measure ANOVA was conducted to determine external rotation range of motion in stretching conditions (static vs dynamic) and testing occasions (pre vs post). As expected, athletes demonstrated significant differences within the testing occasions ($F_{(1,58)} = 30.24$, $p < .00$) (see Tables 4-6, 4-7). Further, pairwise comparisons revealed athletes significantly increased their external rotation range of motion from pre stretch to post stretch ($p < .00$). There were no significant differences between the static and dynamic stretching ($F_{(1,58)} = .31$, $p = .58$). However, the interaction between testing and stretching was found to be significant for external rotation ($F_{(1,58)} = 4.05$, $p = .049$).

Table 4-6: Descriptive Statistics for External Rotation Range of Motion for Stretching Conditions and Testing Occasions

External Rotation	N	Mean	Std. Deviation	95% Confidence Interval Lower	95% Confidence Interval Upper
Static					
Pre	30	111.23	± 7.394	108.530	113.937
Post	30	112.97	± 8.503	108.597	114.03
Dynamic					
Pre	30	111.30	± 7.401	110.048	115.886
Post	30	115.03	± 7.435	112.114	117.952

Table 4-7: ANOVA Comparing Stretching Conditions and Testing Occasions

Effect	Wilk's Lambda	df	F	P
Testing	.657	1	30.241	.000*
Testing X Stretching	.935	1	4.048	0.049*

*(significant at the p = .05 level)

4.2.4 SHOULDER INTERNAL ROTATION

The normal range of motion for shoulder internal rotation is 55 degrees. Consistent with all other data analysis for range of motion, a repeated measure ANOVA was conducted to determine internal rotation range of motion in stretching conditions (static vs dynamic) and testing occasions (pre vs post). Athletes demonstrated significant differences in internal range of motion ($F_{(1,58)} = 8.96$, $p = .004$) (see Tables 4-8, 4-9).

Post-hoc analysis revealed collegiate athletes significantly increased their internal rotation from pre stretch to post stretch (p =.004). There were no significant differences between the static and dynamic stretching ($F_{(1,58)}$ = .71, p = .40) or the interaction between testing and stretching ($F_{(1,58)}$ = .000, p = .99).

Table 4-8: Descriptive Statistics for Internal Rotation Range of Motion for Stretching Conditions and Testing Occasions

External Rotation	N	Mean	Std. Deviation	95% Confidence Interval Lower	95% Confidence Interval Upper
Static					
Pre	30	47.43	± 10.510	43.680	51.187
Post	30	50.53	± 10.523	45.713	53.220
Dynamic					
Pre	30	49.47	± 10.027	46.901	54.165
Post	30	52.53	± 9.317	48.901	56.165

Table 4-9: ANOVA Comparing Stretching Conditions and Testing Occasions

Effect	Wilk's Lambda	df	F	P
Testing	.866	1	8.955	.004*
Testing X Stretching	1.000	1	.000	0.987

*(significant at the p = .05 level)

4.2.5 SHOULDER PEAK TORQUE AWAY

Collegiate athletes performed a biodex test to measure peak torque away, which is defined as the shoulder moving from external rotation to internal rotation. A repeated measure ANOVA was conducted to determine peak torque away in stretching conditions (static vs dynamic) and testing occasions (pre vs post). No significant differences were noted within the testing occasions ($F(1,58) = 0.05$, $p = 0.82$) (see Tables 4-10, 4-11). In addition, athletes did not exhibit significant differences between the static and dynamic stretching ($F(1,58) = .01$, $p = .92$) or the interaction between testing and stretching ($F(1,58) = 0.02$, $p = .90$).

Table 4-10: Descriptive Statistics for Peak Torque Away for Stretching Conditions and Testing Occasions

Peak Torque Away	N	Mean	Std. Deviation	95% Confidence Interval Lower	95% Confidence Interval Upper
Static					
Pre	30	33.90	$\pm$ 14.378	28.960	38.840
Post	30	33.70	$\pm$ 12.598	28.760	38.640
Dynamic					
Pre	30	34.23	$\pm$ 13.408	29.413	39.054
Post	30	33.80	$\pm$ 12.971	28.979	38.621

Table 4-11: ANOVA Comparing Stretching Conditions and Testing Occasions

Effect	Wilk's Lambda	df	F	P
Testing	.999	1	.051	0.823
Testing X Stretching	1.000	1	.015	0.904

*(significant at the $p = .05$ level)

4.2.6 SHOULDER PEAK TORQUE TOWARDS

Finally, athletes performed a biodex test for peak torque towards which was defined as their shoulder moving from internal rotation to external rotation. A repeated measure ANOVA was conducted to determine peak torque towards in stretching conditions (static vs dynamic) and testing occasions (pre vs post). No significant differences were found for testing occasions ($F_{(1,58)} = 2.07$, $p = .16$) (see Tables 4-12, 4-13), the interaction between testing and stretching ($F_{(1,58)} = .1.89$, $p = .18$), or between static and dynamic stretching ($F_{(1,58)} = .04$, $p = .84$).

Table 4-12: Descriptive Statistics for Peak Torque Towards for Stretching Conditions and Testing Occasions

Peak Torque Towards	N	Mean	Std. Deviation	95% Confidence Interval Lower	95% Confidence Interval Upper
Static					
Pre	30	18.50	$\pm$ 9.609	14.935	22.065
Post	30	19.97	$\pm$ 8.520	16.135	23.265
Dynamic					
Pre	30	19.70	$\pm$ 9.900	16.615	23.319
Post	30	19.73	$\pm$ 9.780	16.381	23.085

Table 4-13: ANOVA Comparing Stretching Conditions and Testing Occasions

Effect	Wilk's Lambda	df	F	P
Testing	.966	1	2.068	0.156
Testing X Stretching	.968	1	1.889	0.175

*(significant at the p = .05 level)

CHAPTER 5

DISCUSSION

The primary purpose of this study was to investigate whether a static or dynamic stretching protocol is more effective at the shoulder complex as measured by range of motion and peak torque. It was hypothesized that dynamic stretching would produce greater range of motion at the shoulder complex than static stretching. In addition, it was also hypothesized that dynamic stretching would produce greater peak torque at the shoulder complex than static stretching. The discussion section is organized into six subsections. These include: a) range of motion at the shoulder complex following static and dynamic stretching, b) peak torque at the shoulder complex following static and dynamic stretching, c) utilization and clinical implications for static and dynamic stretching, d) limitations of current study, e) future research implications, and f) conclusions.

5.1 RANGE OF MOTION AT THE SHOULDER COMPLEX FOLLOWING STATIC AND DYNAMIC STRETCHING

The current study's finding revealed collegiate athletes significantly increased their shoulder flexion range of motion from pre-stretching to post-stretching. However, flexion at the shoulder complex was not differentially influenced by either a dynamic stretching or a static protocol. In other words, one stretching protocol did not produce significantly greater gains over the other stretching protocol. Similar to flexion, extension at the shoulder complex was not influenced any more by using a dynamic stretching protocol versus a static protocol. Although, collegiate athletes did have significant gains in extension range of motion after stretching, neither the static nor dynamic stretching protocol was more effective.

The findings from the current study did reveal an interaction between the stretching protocols and time (i.e., time pre to post stretch) for external rotation. Specifically, collegiate athletes demonstrated significantly greater range of motion on external rotation after performing a dynamic stretching protocol when compared to a static stretching protocol. This finding may be relevant to baseball players who need a greater range of motion when pitching in order to produce greater velocity. According to Crockett et al. (2002) throwing shoulders in pitchers frequently exhibit excessive external rotation. In this study, Crockett and colleagues (2002) examined glenohumeral joint range of motion of the dominant vs. non-dominant shoulder in 25 professional pitchers (throwing group) and 25 non-throwing subjects. External rotation, humeral head retroversion, and glenoid retroversion in the dominant shoulder of the throwing group were significantly greater than the non-dominant shoulder. In the non-throwing group there was no significant difference in external rotation, humeral head retroversion, or glenoid retroversion between dominant and non-dominant shoulders. When comparing the throwing group vs. the non-throwing group, external rotation was also significantly greater (Crockett et al., 2002). This study concluded that increases in external rotation, humeral head retroversion, and glenoid retroversion may provide a competitive edge in pitching, because for the same amount of external rotation (which may relate positively to pitch velocity) the arm with more humeral head retroversion places less stress on the anterior capsule-labral structures (Crockett et al., 2002). Therefore, it can be thought of as not only a protective mechanism but also a performance booster. This indicates that dynamic stretching may be better for pitchers to perform before practice or competition.

The present study found that there were no significant differences between the static and dynamic stretching protocol when collegiate athletes performed internal rotation at the shoulder complex. However, collegiate athletes did significantly increase their shoulder internal range of motion after performing both the static and dynamic stretching protocols. The findings of this study were similar to a study by Laudner and colleagues (2008) who found internal and external rotation were increased after sleeper stretches (e.g. static stretches). This study only examined NCAA Division I baseball players, while the current study used baseball, volleyball, and softball players. In addition, a clinician performed these stretches rather than the athlete themselves.

In contrast to the above study and this study, Reinold and colleagues (2008) found that internal and external rotation were significantly decreased after a pitching session. Reinold et al. concluded that this decrease in range of motion after pitching lasts for 24 hours and may be a result of eccentric muscle contractions causing acute alterations in the musculotendinous junctions at the shoulder complex. These musculotendinous adaptations alter the range of motion available in the shoulder (Reinold, et al., 2008). Therefore, stretching before practice or competition may not be warranted for overhead athletes due to potential decreases in range of motion caused by eccentric activity of the shoulder musculature. However, more research is warranted to determine if stretching is detrimental or facilities range of motion at the shoulder complex.

5.2 PEAK TORQUE AT THE SHOULDER COMPLEX FOLLOWING STATIC AND DYNAMIC STRETCHING

Peak torque away (external to internal rotation) and peak torque towards (internal to external rotation) did not demonstrate significant gains from pre-stretching to post-stretching with either a static or dynamic stretching protocol. The current study did not exhibit any negative effects from the stretching protocols. This is in contrast to prior research, which found that static stretching preceding the main strength activity significantly decreased performance in the lower extremity (Nelson, Kokkonen, & Arnall, 2005). Similarly, Cramer and colleagues (2004) found that after static stretching, peak torque in the leg extensors also significantly decreased. These researchers suggested that the stretching-induced decreases in peak torque may be related to changes in the mechanical properties of the muscle, such as an altered length-tension relationship, or a central nervous system inhibitory mechanism (Cramer, Housh, Johnson, Miller, Coburn, & Beck, 2004; Nelson, Kokkonen, & Arnall, 2005).

Nelson and Kokkonen also found conflicting results with the current study when athletes performed ballistic stretches. These researchers examined the effects of ballistic muscle stretching on maximal strength performance during knee flexion and knee extension. Ballistic stretching is similar to dynamic stretching in terms of it being an active motion to stretch. The ballistic stretching program had a negative influence on one repetition maximum for knee flexion and knee extension (Nelson & Kokkonen, 2001). Although, most of the aforementioned studies utilized the lower extremity, the shoulder complex did not produce any detrimental effects after stretching on peak torque. Moreover, it is difficult to compare and contrast previous studies as no research to date has investigated the effects of static and dynamic stretching on peak torque at the shoulder complex.

In contrast to these aforementioned studies, other studies did not observe any detrimental effects of stretching on strength. A study by Egan and colleagues (2006) found that static stretching had no impact on peak torque or mean power. Eleven female collegiate basketball players performed maximal concentric isokinetic leg extensions on a biodex system 3 dynamometer. After the initial testing, the dominant leg extensors were stretched using static stretches. After completing the stretching protocol, the athletes performed the maximal concentric isokinetic leg extension tests again. There was no significant decrease found in peak torque or mean power. These findings indicate that the static stretching has no impact on peak torque or mean power during maximal, voluntary concentric isokinetic leg extension in collegiate women's basketball players (Egan, Cramer, Massey, Laurie, & Marek, 2006).

In another study the effect of acute stretching performed prior to a strength activity in older adults was investigated. The study examined the effect of stretching on maximal voluntary isokinetic torque production. Participants included 15 young (19-27 yrs) and 14 older adults (62-79 yrs). Maximal voluntary isokinetic torque was measured before and after stretching using a biodex system 3 isokinetic dynamometer. After stretching the participant was allowed to rest 10 minutes before the strength tests were repeated. Results revealed no significant differences between the pre- and post-treatment maximal voluntary torque production values (Garrison, Nelson, Welsch, & Wood, 2002). The two previously mentioned studies are in agreement with the current study that found static stretching has no detrimental effect on peak torque.

Finally, Herda and colleagues (2008) examined the acute effects of static versus dynamic stretching on peak torque, electromyographic, and mechanomyographic amplitude of the biceps femoris during isometric maximal voluntary contractions of the leg flexors. The researchers found that peak torque decreased after the static stretching, but did not change after the dynamic stretching. Therefore, just as the current research study demonstrated, an acute dynamic stretching protocol is not detrimental to muscle strength.

The difference between the previously mentioned studies and Nelson and Cramer's studies showing decrease in strength, was the amount of time the stretch was maintained or performed. The recommended time for stretching is 30 to 45 seconds and it is also optimal to perform each stretch 3 to 4 times (Bandy & Irion, 1994). The studies that found decreases in strength typically performed the stretches for an excessive amount of time (i.e. 1-2 min.) (Rubini, Costa, & Gomes, 2007). In the current study, the athletes performed each stretch 3 times for 30 seconds, which is the optimal amount of time. Therefore, this could be a potential reason for no detrimental effects on peak torque.

5.3 UTILIZATION AND CLINICAL IMPLICATIONS FOR STATIC AND DYNAMIC STRETCHING

The results of this study provide athletic trainers, physical therapists, and coaches with important information regarding overhead athletes and pre-practice or therapeutic stretching protocols. In essence the current study demonstrates that neither stretching protocol is better than the other except for external range of motion. In fact, in terms of range of motion, this study illustrated that both stretching protocols had produced significant gains, External rotation range of motion was the only motion that exhibited greater gains with dynamic stretching over static stretching. In terms of peak torque away and towards, the current findings demonstrated that there were no significant gains in peak torque after stretching.

Coaches can rest easy knowing that whichever stretching protocol they choose their athletes will be ready to throw or spike a ball. Numerous coaches are set on using a static stretching protocol because it is what they are familiar with or have the most experience using. Coaches may also believe that using a static stretching protocol can prevent injuries, because this is what they have grown up learning. The current study shows that it does not matter which protocol is used, except perhaps in regards to baseball pitchers. It may be beneficial to use dynamic stretching with them over static stretching since greater gains in external rotation range of motion were found with the dynamic stretching. And greater external rotation has been shown to give greater velocity to pitches.

Clinicians can use either a dynamic or static stretching protocol when bringing their patient back from injury or surgery to play. Athletic trainers and physical therapists are always looking for cutting edge research on what is best to return athletes to play. Just as coaches are more familiar and more comfortable with static stretching, so are clinicians. Static stretching is something that is taught to increase range of motion after an injury or surgery takes place. The current study indicates that dynamic stretching could also be used. Dynamic stretching may also be more functional for return to play; its constant motion may provide more of a transition to sport specific activities like throwing and spiking. It may also be better to utilize this type of stretching for baseball pitchers that are returning from surgery.

This information also allows the athlete to make the decision for their pre-practice stretching routine for their shoulder. If the athlete feels that one prepares them better for competition it may be better for them to use that stretching protocol. Athletes can be affected by anything that they believe can affect their peak performance. This may be due to familiarity, word of mouth, or repeated use from their childhood. This study shows that either stretching protocol can be utilized with no significant difference between the two.

5.4 LIMITATIONS OF CURRENT STUDY

There are several limitations within this study. First, there were only 30 collegiate athletes that participated in this study. Although this was an adequate sample size for the type of study being conducted, an increase in sample size would also increase the external validity of the study. Second, the sample size only included three collegiate teams (ie., softball, baseball, volleyball) with softball players representing 57% of the participants. As a result, these collegiate teams were not equally represented, and, therefore the results may relate more to softball players than volleyball and baseball. A third limitation to the study is the way peak torque was measured. Peak torque was supposed to represent the power that each athlete uses to either throw or spike a ball. This is not a direct representation of the power used in throwing or spiking, but rather a tool to represent these activities. Finally, only collegiate athletes were used for this study. Future studies could concentrate on high school athletes shoulder range of motion and peak torque.

5.5 FUTURE RESEARCH

The current study has led to the possibility of several future studies. For example, stretching protocols could be compared between males and females. This may determine if males or females are affected differently by various stretching protocols. Another future study could investigate one specific population such as baseball pitchers, rather than overhead athletes in general. Baseball pitchers are known to have increased external rotation range of motion at the shoulder complex when compared to the general population. Therefore, how would various stretching protocols affect their pitching capabilities? It would also be advantageous to examine propioceptive neuromuscular facilitation (PNF) stretching. Unlike dynamic and static stretching, PNF would involve a clinician. PNF has been shown to give large gains in range of motion in a small amount of time. However, it would be important to control for bias between testers (stretching clinicians) in a study like the one suggested. Another possible research study could to investigate sport specific performance rather than measuring peak torque using the biodex. For example, you could measure the speed of a pitch or spike, or examine the accuracy of a throw. Finally, future studies could investigate injury occurrences between various stretching protocols (ie., static, dynamic, PNF).

5.6 CONCLUSIONS

Overall, this study demonstrates that there is no significant difference between static and dynamic stretching protocols at the shoulder complex when performing range of motion or peak torque. The one exception is external rotation range of motion. The dynamic stretching protocol demonstrated significantly greater gains in range of motion than the static stretching protocol for external rotation. This greater significant increase in external rotation with the dynamic stretching protocol is relevant for baseball pitchers who need the greater external rotation to make gains in velocity. Results of this study will allow coaches and clinicians to use either stretching protocol for practice or competition warm-ups and return to play protocols. It will also allow them to consider trying dynamic stretching for baseball pitchers. For athletes, this study indicates that they can use either stretching protocol to increase range of motion and have no significant effect on their torque output.

APPENDIX A

HEALTH HISTORY QUESTIONNAIRE

Health History Questionnaire

Name ________________ Date ___________________

Gender: M F Age ___________________

Height ______________ Weight _________________

Sport __________________ Position _________________

Years you have played current sport ____________________________

Years you have played on MSU's NCAA Team ____________________

Dominant arm used to throw, pitch, or spike a ball ______________________

Have you had surgery on your dominant arm within the last 6 months? Y N

List any injury to your dominant arm, elbow, wrist, or hand one month prior to participating in this study ____

____

APPENDIX B

INFORMED CONSENT FORM

The Effects of Static and Dynamic Stretching on Range of Motion and Performance

Informed Consent

For questions regarding this study, Please contact:
Dr. Tracey Covassin, ATC
Department of Kinesiology
Michigan State University
Phone: 517.353.2010
E-mail: covassin@ath.msu.edu

Katie M. Rapking, ATC
Graduate Assistant
Michigan State University
Phone: 513.218.1828
E-mail: rapkingk@msu.edu

For questions regarding your rights as a research participant, contact:
Michigan State University
Human Research Protection Program
207 Olds Hall
East Lansing, MI 48824
Phone: 517.355.2180
Fax: 517.432.4503
E-mail: irb@msu.edu

The purpose of this study is to investigate whether a static or dynamic stretching protocol is more effective at the shoulder complex as measured by range of motion and peak torque. The study will use a goniometer to measure range of motion and a Biodex system 3 dynamometer to measure peak torque pre and post test.

If you have had surgery on your dominant arm within the last six months you will be excluded from this study. If you have had an injury to your dominant arm, elbow, wrist, or hand within the last month, you will also be excluded from this study.

Your participation in this study will require two testing sessions (approximately 30 minutes each session) on separate days. Upon your first session arrival to the MSU Athletic Training Research Laboratory, you will be presented with an overview of the study, voluntarily sign a consent form, and complete a health history questionnaire. You will then be given a verbal and visual tutorial on either the static stretching protocol or the dynamic stretching protocol being studied for this research. Once you feel comfortable with the protocol, your shoulder range of motion (flexion, extension, internal rotation and external rotation) will be measured as well as your peak torque. Each stretching protocol will consist of four stretches that will be performed 3 times for 30 seconds. Following the stretching protocol post-test measurements will be taken for range of motion and peak torque.

The second session will also be performed at MSU's Athletic Training Research Laboratory. You will be given a verbal and visual tutorial on either the dynamic stretching protocol or the static stretching protocol. When you feel comfortable with the protocol, baseline measurements will again be taken for range of motion and peak torque. You will then perform the stretching protocol. Each of the four stretches will be performed 3 times for 30 seconds. Following the stretching protocol post-test measurements will be taken for range of motion and peak torque.

It is impossible for the risk of injury to be completely eliminated during physical activity. The risk associated with this study may be minimal delayed onset muscle soreness from performing the stretches and measuring of peak torque. Measures will be taken during the test to ensure your safety throughout the research protocol. A certified athletic trainer will be on-site at all times during the testing session. If there is any point during the testing procedures when you feel that you cannot continue, please let the investigator know and the test will be terminated.

The benefits that come from your participation will help further advancements in determining which stretching protocol is more appropriate for upper extremity sports to use prior to practice or competition. This could potentially lead to further advancements in the sports of softball, baseball, and volleyball. The results of this test will be provided to you at the conclusion of the session.

Participation in this research project is completely voluntary. You have the right to say no. You may change your mind at any time and withdraw. You may choose not to answer specific questions or to stop participating at any time. Your identity and information recorded during the study will remain confidential. Confidentiality will be protected by; (a) results will be presented in aggregate form in any presentations and publications; and (b) all data will be stored in a computer that has a password necessary to see confidential data. Data will be stored under double lock and key, whereby only the investigators and their agents will have access. Confidentiality will be protected to the maximum extent allowable by law. Your participation in this research project will not involve any additional costs to you or your health care insurer. You will not receive money or any other form of compensation for participating in this study.

If you are injured as a result of your participation in this research project, Michigan State University will assist you in obtaining emergency care, if necessary, for your research related injuries. If you have insurance for medical care, your insurance carrier will be billed in the ordinary manner. As with any medical insurance, any costs that are not covered or are in excess of what are paid by your insurance, including deductibles, will be your responsibility. The University's policy is not to provide financial compensation for lost wages, disability, pain or discomfort, unless required by law to do so. This does not mean that you are giving up any legal right you may have. You may contact Dr. Tracey Covassin at 517.353.2010 with any questions or to report an injury.

If you have concerns or questions about this study, such as scientific issues, how to do any part of it, or to report an injury, please contact the researcher (Katie M. Rapking, Jenison FieldHouse, East Lansing, MI, 48824, rapkingk@msu.edu, 513.218.1828 or Dr. Tracey Covassin 105 IM Sport Circle, East Lansing MI 48824, covassin@msu.edu, 517.353.2010).

If you have questions or concerns about your role and rights as a research participant, would like to obtain information or offer input, or would like to register a complaint about this study, you may contact, anonymously if you wish, the Michigan State University's Human Research Protection Program at 517-355-2180, Fax 517-432-4503, or e-mail irb@msu.edu or regular mail at 207 Olds Hall, MSU, East Lansing, MI 48824.

Your signature below indicates your voluntary agreement to participate in this study.
I, ____, have read and agree to participate in
(Please Print Your Name)
this study as described above.

___________________________   _____/_____/____
(Please Sign Your Name)   *(Date)*

REFERENCES

REFERENCES

Bandy, W. & Irion, J. (1994). The Effect of Time on Static Stretch on the Flexibility of the Hamstring Muscles. *Physical Therapy*, 74, 54-61.

Beckett, J.R.J., Schneiker, K.T., Wallman, K.E., Dawson, B.T., & Guelfi, K.J. (2009). Effects of Static Stretching on Repeated Sprint and Change of Direction Performance. *Medicine and Science in Sports and Exercise*, 444-450.

Cone, John R. (2007). Warming Up for Intermittent Endurance Sports. *Strength and Conditioning Journal*, 29, 70-77.

Cramer, J.T., Housh, T.J., Johnson, G.O., Miller, J.M, Coburn, J.W., & Beck, T.W. (2004). Acute Effects of Static Stretching on Peak Torque in Women. *Journal of Strength & Conditioning Research*, 18 (2), 235-241.

Crockett, H.C., Gross, L.B., Wilk, K.E., Schwartz, M.L., Reed, J., O'Mara, J., Reilly, M.T., Dugas, J.R., Meister, K., Lyman, S., & Andrews, J.R. (2002). Osseous Adaptation and Range of Motion at the Glenohumeral Joint in Professional Baseball Pitchers. *The American Journal of Sports Medicine*, 30(1), 20-26.

DePino, G.M., Webright, W.G., & Arnold, B.L. (2000). Duration of Hamstring Flexbility After Cessation of an Acute Static Stretching Protocol. *Journal of Athletic Training*, 35(1), 56-59.

Drouin, J.M., Valovich-mcLeod, T.C., Shultz, S.J., Gansneder, B.M., & Perrin, D.H. (2004). Reliability and validity of the Biodex system 3 pro isokinetic dynamometer velocity, torque, and position measurements. *European Journal of Applied Physiology*, 91, 22-29.

Duncan, M.J., & Woodfield, L.A. (2006). Acute Effects of Warm Up Protocol on Flexibility and Vertical Jump in Children. *Journal of Exercise Physiology online*, 9(3), 9-16.

Egan, A.D., Cramer, J.T., Massey, Laurie, L., & Marek, S. (2006). Acute Effects of Static Stretching on Peak Torque and Mean Power Output in National Collegiate Athletic Association Division I Women's Basketball Players. *The Journal of Strength & Conditioning Research*, 20(4), 778-782.

Faigenbaum, A., McFarland, J., Schwerdtman, J., Ratamess, N., Kang, J., & Hoffman, J. (2006). Dynamic Warm-Up Protocols, With and Without a Weighted Vest, and Fitness Performance in High School Female Athletes. *Journal of Athletic Training*, 41, 357-363.

Fredrick, G.A. & Szymanski, D.J. (2001). Baseball: Dynamic Flexibility. *Strength and Conditioning Journal*, 23(1), 21-30.

Garrison, T.T., Nelson, A.G., Welsch, M.A., & Wood, R.M. (2002). The Effect of Acute Muscle Stretching on Maximal Voluntary Isokinetic Torque Production in Older Adults. *Medicine & Science in Sports & Exercise*, 34(5), 178.

Grossman, M., Tibone, J., McGarry, M., Schneider, D., Veneziani, S. & Lee, T. (2005). A cadaveric model of the throwing shoulder: a possible etiology of superior labrum anterior to posterior lesions. *Journal of Joint and Bone Surgery*, 87, 824-831.

Hahn, D., Seiberl, W., & Schwirtz, A. (2007). Force Enhancement During and Following Muscle Stretch of Maximal Voluntarily Activated Human Quadriceps Femoris. *European Journal of Applied Physiology*, 100, 701-709.

Herda, T.J., Cramer, J.T., Ryan, E.D., McHugh, M.P., & Stout, J.R. (2008). Acute Effects of Static Versus Dynamic Stretching on Isometric Peak Torque, Electromyography, and Mechanomyography of the Biceps Femoris Muscle. *Journal of Strength and Conditioning Research*, 22(3), 809-817.

Herman, S.L., & Smith, D.T. (2008). Four Week Dynamic Stretching Warm-up Intervention Elicits Longer-Term Performance Benefits. *Journal of Strength and Conditioning Research*, 22(4), 1286-1297.

Kokkonen, J., Nelson, A., Eldredge, C. & Winchester, J. (2007). Chronic Static Stretching Improves Exercise Performance. *Medicine and Science in Sports and Exercise*, 39, 1825-1831.

Laudner, K., Sipes, R., & Wilson, J. (2008) The Acute Effect of Sleeper Stretches on Shoulder Range of Motion. *Journal of Athletic Training*, 43, 359-363.

McMillian, D.J., Moore, J.H., Hatler, B.S., & Taylor, D.C. (2006). Dynamic vs. Static Stretching Warm Up: The Effect on Power and Agility Performance. *Journal of Strength and Conditioning Research*, 20(3), 492-499.

Myers, J., Laudner, K., Pasquale, M., Bradley, J., & Lephart S. (2006). Glenohumeral range of motion deficits and posterior shoulder tightness in throwers with pathologic internal impingement. *American Journal of Sports Medicine*, 34, 385-391.

Nelson, R. & Bandy, W. (2004). Eccentric Training and Static Stretching Improve Hamstring Flexibility of High School Males. *Journal of Athletic Training*, 39, 254-258.

Nelson, A.G., Kokkonen, J., & Arnall, D. (2005). Acute Muscle Stretching Inhibits Muscle Strength Endurance Performance. *Journal of Strength & Conditioning Research*, 19 (2), 338-343.

Nelson, A.G. & Kokkonen, J. (2001). Acute Ballistic Muscle Stretching Inhibits Maximal Strength Performance. *Research Quarterly for Exercise and Sport*, 72(4), 415-419.

Peat, M. (1986). Functional Anatomy of the Shoulder Complex. *Physical Therapy*, 66(12), 1855-1865.

Power, K., Behm D., Cahill, F., Carroll, M. & Young, W. (2004). An Acute Bout of Static Stretching: Effects on Force and Jumping Performance. Medicine and Science in Sports and Exercise, 36(8), 1389-1396.

Powers, S.K., & Howley, E.T. (2004). Skeletal Muscle Structure and Function. Exercise Physiology: Theory and Application to Fitness and Performance. (p. 157-160). New York, NY: McGraw-Hill.

Prentice, William E. (2003). Training and Conditioning Techniques. *Arnheim's Principles of Athletic Training*. (p. 81-118). New York, NY: McGraw-Hill.

Prescher, A. (2000). Anatomical basics, variations, and degenerative changes of the shoulder joint and shoulder girdle. *European Journal of Radiology,* 35, 88-102.

Riddle, D.L., Rothstein, J.M., & Lamb, R.L. (1987). Goniometric Reliability in a Clinical Setting: Shoulder Measurements. *Physical Therapy*, 67(5), 668-673.

Ryan, E.D., Beck, T.W., Herda, T.J., Hull, H.R., Hartman, M.J., Stout, J.R., & Cramer, J.T. (2008). Do Practical Durations of Stretching Alter Muscle Strength? A Dose Response Study. *Medicine and Science in Sports and Exercise*, 40(8), 1529-1537.

Rubini, E.C., Costa, A.L.L., & Gomes, P.S.C. (2008). The Effects of Stretching on Strength Performance. *Sports Medicine*, 37(3), 213-224.

Saez de Villarreal, E.S., Gonzalez-Badillo, J.J., & Izquierdo, M. (2007). Optimal Warm-Up Stimuli of Muscle Activation to Enhance Short and Long Term Acute Jumping Performance. *European Journal of Applied Physiology*, 100, 393-401.

Saladin, K. (2004). The Spinal Cord, Spinal Nerves, and Somatic Reflexes. *Anatomy & Physiology: The Unity of Form and Function*. (p. 504-508). New York, NY: McGraw-Hill.

Shrier, I. (2004). Does Stretching Improve Performance? A Systematic and Critical Review of Literature. *Clinical Journal of Sports Medicine*, 14(5), 267-273.

Stickley, C.D., Hetzler, R.K., Freemyer, B.G., & Kimura, I.F. (2008). Isokinetic Peak Torque Ratios and Shoulder Injury History in Adolescent Female Volleyball Athletes. *Journal of Athletic Training*, 43(6), 571-577.

Taylor, K.L., Sheppard, J.M., Lee, H., & Plummer, N. (2008). Negative Effect of Static Stretching Restored when Combined with a Sport Specific Warm-Up Component. *Journal of Science and Medicine in Sport*, 336-340.

Terry, G.C. & Chopp, T.M. (2000). Functional Anatomy of the Shoulder. Journal of Athletic Training, 35(3), 248-255.

Tyler, T., Nicholas, S., Roy, T., & Gleim, G. (2000). Quantification of posterior capsule tightness and motion loss in patients with shoulder impingement. *American Journal of Sports Medicine*, 28, 668-673.

Winters, M.V., Blake, C.G., Trost, J.S., Marcello-Brinker, T.B., Lowe, L., Garber, M.B., & Wainner, R.S. (2004). Passive Versus Active Stretching of Hip Flexor Muscles in Subjects With Limited Hip Extension: A Randomized Clinical Trial. Physical Therapy, 84(9), 800-807.