2009

Effects of yoga on physical characteristics on NCAA division I baseball athletes

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EFFECTS OF YOGA ON PHYSICAL CHARACTERISTICS OF NCAA DIVISION I BASEBALL ATHLETES

By

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Thesis

Submitted to the Department of Health Promotion & Human Performance

Eastern Michigan University

in partial fulfillment of the requirements

for the degree of

MASTER OF SCIENCE

in

Exercise Physiology

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May 21, 2009

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DEDICATION

I dedicate this work to my husband, Mike,

for his patience and loving support.

ACKNOWLEDGEMENTS

I would like to express my gratitude to the following professionals for sharing their insights and knowledge. Your contributions have been invaluable.

Anthony Moreno, Ph.D., Eastern Michigan University

Christine Karshin, Ph.D., Eastern Michigan University

James Sweet, M.S. Eastern Michigan University

Steven McGregor, Ph.D., Eastern Michigan University

Steve Nordwall, Head Athletic Trainer, Eastern Michigan University

Michael Szerzsen, Head Strength and Conditioning Coach, Eastern Michigan University

Jacquie Hall, Undergraduate in Athletic Training, Eastern Michigan University

Roger Coryell, Baseball Head Coach, 1987-2007, Eastern Michigan University

Jake Boss, Baseball Head Coach, Michigan State University

Jay Alexander, Baseball Head Coach, Eastern Michigan University

Kyle Rhoad, Center Fielder, Spokane Indians

All Members of The Eastern Michigan University Baseball Team

ABSTRACT

Among baseball athletes, joint range of motion (ROM) is considered an important physical characteristic with respect to injury prevention and performance. Professional and intercollegiate programs employ various methods of flexibility training; however, to date, no literature exists with regard to the effect of a yoga-based training program. The purpose of this investigation was to determine the effects of a sport-specific yoga program among NCAA Division I intercollegiate baseball players. Subjects (N=30, age 19.42 ±1.37 years) were assessed for shoulder joint (SH), hamstring (HS), and groin (GR) ROM and subsequently followed a 12-week, 2x/week yoga intervention. Post-test results indicated significant improvements in SH and HS ($p<0.05$). Future investigations should evaluate the influence of longitudinal yoga interventions on injury incidence and specific performance parameters (e.g., speed, bat acceleration, pitching velocity) important to the game of baseball.

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CHAPTER I: INTRODUCTION AND BACKGROUND

It is reported that the typical National Collegiate Athletic Association (NCAA) Division I baseball athlete will participate in approximately 50 baseball games and 53 practices during a typical 90-day season (Dick, Sauers, et al., 2007). In a review examining the incidence and type of injury among intercollegiate baseball players, it was reported that NCAA Division I athletes experienced 6.64 game injuries per 1000 athlete exposures and 2.34 practice injuries per 1000 athlete exposures (Dick, Sauers, et al., 2007).

Dick, Sauers, et al. (2007) indicate that of the reported injuries sustained, 25% were considered "severe" injuries, resulting in a time loss of greater than 10 days. Furthermore, McFarland and Wasik (1998) found that baseball players with injuries categorized as a "10-day" time loss actually experienced a mean time loss of greater than 21 days, or approximately 25% of the season. In addition, Dick , Sauers, et al. (2007) found that 42% percent of all game injuries were of the non-contact variety, while almost 66% of practice injuries were also non-contact. Although contact injuries, such as a batter being hit by the ball, are difficult to prevent, several papers suggest that some of the most common, non-contact injuries sustained are potentially preventable through specialized forms of physical training (Fleisig, Andrews, Dillman, & Escamilla, 1995; Sauers, August, & Snyder, 2007; Whiteley, 2007).

One suggested form of specialized training is flexibility training. Fleisig et al. (1995) acknowledged one noted osteopathic surgeon who suggested that posterior shoulder stretching is the most effective method of preventing shoulder injuries among overhead throwing athletes. This position is supported by other papers that have also encouraged shoulder flexibility training as prophylactic (Escamilla et al., 2007; Huffman et al., 2006;

Sauers et al., 2007; Whiteley, 2007). Although these articles were based upon expert observation, none of them was an experimental study.

Other authors have linked lack of flexibility to recurrence of various injuries. Croisier (2004) anecdotally found that Australian rugby players with "tight hamstrings" were more likely to suffer from upper-leg muscular tendon injuries than their counterparts with knee flexors that exhibited greater range of motion. Like rugby, baseball players commonly experience non-contact upper-leg muscular tendon injuries at rates of 11% of all practice injuries and 8.3% of all game injuries (Dick, Sauers, et al. 2007). Unfortunately, Crossier's observations were also non-experimental. While flexibility training is often promoted among athletes as a method of preventing injuries, few studies exist that utilize elite athletes as participants.

As unique as it is to see studies among elite athletes, it is even rarer to see peer-review literature on the effects of yoga as a form of flexibility training. Although looking at effects of acute stretching have recently become popular, quality studies on chronic stretching remain in short supply, particularly among specialized populations.

"Yoga" is a training ideology that employs whole body positions with the intent of enhancing segment and joint range of motion (ROM). As a practice it is unique in that it requires participants to conduct these actions in a multi-planar manner, and it combines many different types of stretching, such as active, static, passive, and dynamic, into a unified systematic practice. Although studies utilizing yoga as a flexibility modality are scarce, Boyle, Sayers, Jensen, Headley, and Manos (2004) found that a single bout of yoga training significantly attenuated the symptoms of induced Delayed Onset Muscle Soreness (DOMS) among a group of Kripalu yoga practitioners when compared to a group of control participants who did not practice yoga. It was implied that because the intervention group regularly employed yoga, their enhanced flexibility attenuated the symptoms of DOMS and the resulting muscle damage (Boyle et al.). One limitation of the study was that the investigators did not document the details of the yoga participants' practice routines, allowing for the potential of confounding circumstances. While the study looked promising with respect to DOMS, the participants were predominantly non-recreational middle-aged women, thus making it difficult to extrapolate the results to an elite athletic population.

Hart and Tracy (2008) examined the effects of Bikram-style yoga on strength, balance and steadiness among a slightly younger population (29 ±6 years). Bikram yoga is performed in a room heated between 105-120 degrees Fahrenheit and repeats postures of the same sequence without variation. Hart and Tracy found substantial improvements in balance and modest improvements in strength among their participants. Like many previous investigations, the participants were non-athletic and difficult to compare with recreational and elite athletic populations.

Based upon previous investigations, it is difficult to determine if yoga as a training modality can prevent or attenuate muscle injuries among athletic populations. Currently, there is little information on the longitudinal effects of yoga with respect to injury prevention among non-athletic or elite athletic populations. Finding a preventative training modality for non-contact injuries through practical and safe methods of physical training are areas of vital importance among baseball players, coaches, athletic trainers, and sport medicine physicians.

Because flexibility is often mentioned throughout the literature (Fleisig et al., 1995; Sauers et al., 2007; Whiteley, 2007) as a viable preventative modality, greater research emphasis should be placed on the practice of yoga to determine if there is an association between this practice and the prevention of injury among athletic populations.

Statement of Purpose

The predominant research emphasis with regard to the practice of stretching has 1) focused on an acute bout of stretching prior to an athletic performance; 2) utilized a single bout or short duration design; and 3) investigated untrained participants rather than physically conditioned athletes. Research exploring the effects of stretching at regular intervals for injury prevention among elite athletes is necessary in order to determine if chronic stretching is a viable and effective component of training. This study is designed to examine the longitudinal impact of a sport-specific yoga program on the enhancement of segment range of motion (ROM) and the effect upon non-contact injuries among NCAA Division I baseball athletes.

Research Questions

Does yoga, as a regular component of training, have an effect upon the following:

1. Reduction of non-contact injuries among Division I baseball athletes?
2. Effect on the various types of injuries realized among Division I baseball athletes (contact versus non-contact)?
3. Enhanced segment range of motion (ROM) among Division I baseball athletes?

Assumptions

For this investigation, the following assumptions were made:

1. All participants, as determined by position, followed the same physical training regimen during the course of the study.

2. All participants provided maximum volitional effort at both training and testing sessions.
3. Participants using Non-Steroidal Anti-Inflammatory Drugs (NSAIDs), pain medications, etc. for traumatic injury would report use and dosage to the primary investigator.
4. Participants reported all injuries, severe or otherwise, to the sports medicine staff at Eastern Michigan University.
5. During the course of the study, the athletic training and strength and conditioning staff for the Eastern Michigan University baseball team provided information with regard to all injuries and physical testing conducted on the team.

Limitations

1. The subjects were male, NCAA Division-I baseball players ranging in age from 18-23 years old, and the results may not be generalized to individuals outside this age range, gender, or training status.
2. The sample for this study was restricted to 30 male NCAA Division I baseball players. All were healthy, participated in the same team workouts, and had no pre-existing physical conditions that would interfere with performing yoga or flexibility test procedures.
3. To ensure training and teaching consistency, all yoga training was conducted by the primary investigator and within the scope of the participants' respective physical abilities.
4. The length of the study included only one pre-season period prior to the competitive period.

Significance of the Study

This study examined the effects of a 12-week yoga program on flexibility and injury incidence among NCAA Division I baseball players. The number and types of injuries were compared to those figures collected during the course of an entire baseball season, from pre-season to pre-season.

Through assessment of the data, athletic trainers, conditioning coaches, baseball coaches, and athletes may be able to adjust training routines to reduce the incidence of injury, while enhancing flexibility for potential gains among various performance parameters. For activities like baseball, in which numerous games are played in high frequency, reducing overall injuries and recovery time may enhance performance and collective team outcomes. The results of this study have the potential to help athletes, trainers, and coaches decide if a regular yoga program will help enhance performance and maintain the physical health of baseball players.

Related Definitions

Active Stretch: Muscle lengthening posture that requires strength and balance to maintain.

Acute Stretching: Brief and intense stretching, usually performed as part of a warm-up to an athletic event.

Altered Muscle Recruitment Patterns: Change in use of a muscle or muscle group during a specific motion that route use around a damaged muscle or muscle group.

Ashtanga Vinyasa Yoga: Dynamic stretching program that pairs movements based on The Primary Series of Ashtanga Yoga postures with inhalation or exhalation of breathing.

Autogenic Inhibition: Protective mechanism that works through the Golgi tendon organ to prevent muscles from exerting more force than the bones and tendons can tolerate.

Bikram Yoga: Also known as Hot Yoga and is practiced in a room heated to 105°F (40.5°C) with a humidity of 40% and is guided by memorized dialogue including 26 postures and two breathing exercises.

Chronic Stretching: Usually performed after training exercises, this stretching is performed for longer time periods than acute stretching and is practiced on a consistent basis.

Compliance: Describes the measure of the ease with which muscle tissue may be deformed.

Delayed Onset Muscle Soreness (DOMS): Reduced range of motion, loss of strength, pain and sometimes swelling associated with an unfamiliar exercise or repeated excessive training, which usually peaks 24-48 hours after exercise and dissipates after 5-7 days.

Flexibility: Range of motion exhibition by a joint or series of articulations.

Force: Influence that produces a change in the motion or shape of an object or material.

Glenohumeral Internal Rotation Deficit (GIRD): Angular measurement acquired through bilateral comparison within the subject, with more than 25 degree difference between shoulders total motion at the glenohumeral joint qualifying as GIRD.

Golgi Tendon Organ: Mechanoreceptors in the junction between muscle and tendon that inform the Central Nervous System concerning contraction force of a muscle.

Iyengar Yoga: Characterized by great attention to detail and precise focus on body alignment through the use of "props" such as cushions, benches, blocks, and traps, which function as aids allowing beginners to experience postures more easily than might otherwise be possible without several years of experience.

Kripalu Yoga: Form of yoga that defines itself as therapeutic and spiritually focused, using inner focus and meditation along with standard yoga poses and breathing techniques.

Muscular Endurance: Length of time a muscle or group of muscles can maintain force before becoming fatigued.

Muscle Spindles: Stretch receptors that send information to the CNS with regard to the length of a muscle.

Muscular Strength: Maximum amount of force a muscle or group of muscles can produce.

Neuropathy: Medical term describing disorders of the nerves of the peripheral nervous system and is defined as deranged function and structure of peripheral motor, sensory, and autonomic neurons, involving either the entire neuron or selected levels.

Osseous Adaption: Concept that glenoid fossa adopts a modified bony conformation by increasing its articular surface to enhance anterior stabilization to accommodate the repetitive stress of the throwing motion.

Posterior Band (aka inferior glenohumeral ligament): Main static stabilizer of the shoulder in the abducted or functional position. When the arm is placed into abduction and external rotation, subluxation of the joint is prevented when this broad ligamentous band rotates anteriorly.

Proprioceptors: Specialized sensory receptors on nerve endings found in joints, muscles, tendons, and the inner ear that relay information about motion or position of the body by detecting subtle changes in movement, position, tension, and force.

Range of Motion (ROM): Measured distance a joint can move.

Static Stretch: Muscle lengthening posture held for a minimum of 15 seconds.

Stiffness: Ability of muscle tissue to resist a change in length.

Superior Labrum from Anterior to Posterior (SLAP) lesion: Tear to the Glenoid labrum, a fibrocartilaginous rim attached around the margin of the glenoid cavity.

Torque: Tendency of a force to rotate an object, such as a limb, about an axis.

Transition Movements: Movements between postures in yoga that are paired with inhale and exhale of breathing to smoothly switch postures.

Yoga Posture or Yoga Pose: Arrangement of the body and its limbs.

CHAPTER II

Review of the Literature

Introduction

Among coaches and athletes, many hold the belief that regular stretching can decrease the incidence of injury, and some standard exercise manuals promote this belief. For example, the second edition of *The Essentials of Strength Training and Conditioning* states that stretching, as a component of warm-up, "decreases the risk of injury" (Holcomb, 2000). Despite the widespread belief that stretching may prevent injuries, there are only a few studies that support stretching as an effective injury intervention (De Vries, 1961; McHugh et al., 1999; Pope, Herbert, Kirwan, & Graham, 2000). Even fewer scientific studies have been conducted on the practice of yoga, a form of flexibility training, with respect to injury prevention (Boyles et al., 2004; Hart & Tracy, 2008).

The word *yoga* often conjures many beliefs and images. Among Western culture, yoga is typically embraced as a form of exercise and stress reduction. In India, yoga is one of six essential schools of philosophical thought (Birch, 1995). In this context, yoga refers to a collection of bodily postures based upon Ashtanga Yoga, a series of postures found in an ancient manuscript of unknown origins called the Yoga Korunta, discovered in the 1930s (Birch, 1995). What defines Ashtanga Yoga from other common forms of yoga, such as Iyenger or Bikram, is that its sequencing is logical and progressive and that the postures are linked by transition movements. In Ashtanga yoga, postures are sequenced in relation to one another. For example, upper leg stretches are grouped together, as are balancing postures, as are hip openers. In contrast, in Iyengar yoga, postures may be selected without consideration of their anatomical relationship to one another. Ashtanga yoga also has a progressive sequencing that begins with large, whole body movements, then transitions to large muscle groups, and finally focuses on more defined bodily regions. Because of the logic and precision of the posture sequencing, this form of yoga, used as a stretching program for athletes, may help reduce the number of injuries observed in sport.

This chapter is a review of the relevant literature regarding injury rate and type among collegiate baseball athletes; the relationship between range of motion (ROM) and non-contact injuries in baseball; and finally, mechanisms of injury and stretching and how they pertain specifically to yoga as a viable flexibility conditioning program.

Extent of the Problem

From 1988 to 2004, the NCAA documented intercollegiate baseball injuries with a recorded total of 8,346 injuries of various types and frequency (Dick, Sauers, et al., 2007). During that period, participation in baseball among Division I, II, and III schools increased by 7,592 student-athletes. Predictably, as the number of participants increased, so did the number of injuries (Dick, Sauers, et al.). However, when compared to other NCAA sports such as football, the number of injuries which occur in baseball was low, with an average of 5.78 game injuries per 1000 athletic exposures and 1.85 practice injuries per 1000 athletic exposures compared to 3.80 practice injuries and 35.90 game injuries per 1000 athlete-exposures respectively for football (Dick, Ferrara, et al., 2007) . Despite these relatively low numbers, Dick, Sauers, et al. state that over those sixteen years, 25% of all NCAA baseball injuries were considered severe, with "severe" defined as ten or more consecutive days of lost opportunity to participate. McFarland and Wasik (1998), in a similar study concerning intercollegiate baseball injuries, found that an injury leading to ten days' lost time in fact typically led to an average of 25 consecutive days of lost participation time.

In addition to the increase in lost participation time, the severity of the injuries, especially among pitchers, appears to be on the rise. For example, noted osteopathic surgeon, Dr. James Andrews, performed 350% more Tommy John surgeries from 2004-2007 than in a similar period of time during the late 1990s. Approximately 60% of these patients were intercollegiate or secondary (high) school students. Tommy John surgery is performed on pitchers and other overhead throwing athletes in order to repair a rupture to the ulnar collateral ligament (UCL) (Vitale & Ahmad, 2008). The ulnar collateral ligament (UCL) of the elbow is the primary elbow stabilizer and is vital for the elbow's valgus stability (Vitale & Ahmad, 2008). The acceleration phase of overhead throwing causes the greatest valgus stress to the elbow. Extension can occur at rates of up to 2500 degrees per second (Whiteley, 2007). During the acceleration phase, the forearm is positioned behind the upper arm within the kinetic chain, and valgus stress is generated while the elbow is primarily dependent on the anterior band of the UCL for stability. The valgus force can overcome the tensile strength of the UCL and cause either chronic microscopic tears or acute rupture, which can result in ulnar neuropathy and, without treatment, the end of a pitcher's career. UCL injuries represent only one of many serious injuries on the rise in collegiate baseball. In the text, "Kinetics of Baseball Pitching with Implications about Injury Mechanisms," the authors promote stretching as the best preventative care to relieve throwing-related arm injuries at all levels of baseball (Flesig et al., 1995).

Among collegiate baseball players, serious injury can result in loss of income or perhaps a shortened and less distinguished career for young baseball athletes. Worse, chronic injury may lead to a lifetime of pain, physical limitation, emotional duress, and perhaps affect academic ability among student-athletes. Keeping in mind the host of problems that injuries may generate and considering that the number of serious injuries in collegiate baseball is on the rise, if practicing yoga has the potential to prevent injury or minimize severity, it should be investigated.

NCAA Division I Baseball Injuries

Dick, Sauers, et al. (2007) reported the most common “game” injuries were categorized as upper leg muscle-tendon strain (11%), ankle ligament sprain (7.4%), and shoulder muscle-tendon strain (6.5%). The most frequent “practice” injuries were shoulder muscle-tendon strain (10%), ankle ligament sprain (8.5%), and upper leg muscle-tendon strain (8.3%).

In addition, Dick, Sauers, et al. (2007) also categorized injuries into contact (i.e. player-on-player, ball-to-player, player-to-ground) and non-contact (i.e. running, fielding, and throwing tasks). Forty-two percent of all game injuries were of the non-contact variety, while almost two-thirds of practice injuries were also non-contact. Although contact injuries may be difficult to prevent during competitive circumstances, several studies indicate that some non-contact injuries are potentially preventable through specialized forms of physical training, including stretching (Fleisig et al., 1995; Huffman et al. 2006; Lintner et al., 2007; Sauers, August, & Snyder, 2007; Whiteley, 2007).

With respect to the shoulder complex, one particular ROM deficit, Glenohumeral Internal Rotation Deficit (GIRD), is believed to be the primary cause of labral lesions among overhead throwing athletes (Fleisig et al.,1995; Huffman et al., 2006; Lintner et al., 2007; Sauers et al., 2007; Whiteley, 2007). GIRD is defined as the loss of internal rotation of the throwing arm in comparison to the non-dominant arm; similarly “excessive” external rotation is also measured by comparing the throwing arm’s external rotation to the non-dominant arm's external rotation (Lintner et al.). During the excessive external rotation while throwing, a contracted posterior shoulder band does not shift with the humeral head as it experiences an anterior displacement. This lack of mobility of the posterior band (also known as the inferior glenohumeral ligament) can cause it to peel away from the humeral head, which leads to a tearing of the glenoid labrum (see Figure 1), known as labral lesion (Fleisig et al.).

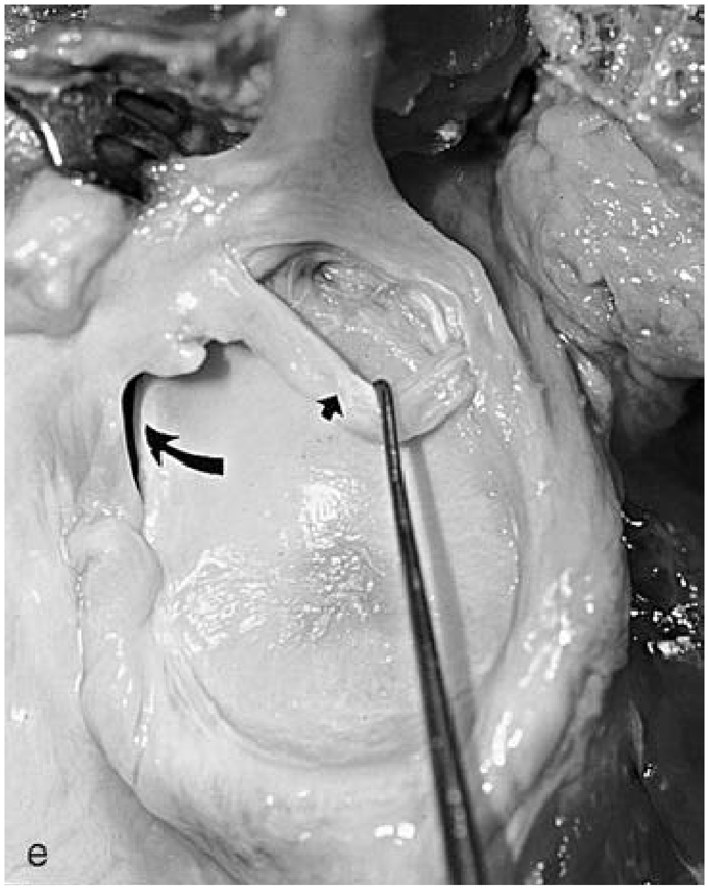

Figure 1. A picture of a superior labrum anterior and posterior lesion.

"Assessment of the Superior Labrum of the Shoulder Joint with CT-Arthrography and MR-Arthrography: Correlation with Anatomical Dissection" by F. Bresler, A. Blum, M. Braun, J.M. Simon, M. Cossin, D. Regent and D. Molé, 1998, *Surgical and Radiologic Anatomy* 20(1), p.57.

Several authors have suggested that by stretching the posterior band of the labrum, injuries generated by GIRD may be prevented (Fleisig et al., 1995; Huffman et al. 2006; Lintner et al., 2007; Sauers et al., 2007; Whiteley, 2007). Whiteley (2007) implies that avoidance of this loss of internal ROM could be preventative or even curative for these injuries, while Huffman et al. state that stretching has been shown to reduce the number of days on the disabled list among Major League Baseball (MLB) players. This same prescription for maintaining shoulder internal ROM for injury reduction or prevention is echoed by Crawford and Sauers (2006), Fleisig et al., and Lintner et al.

The most compelling argument for a consistent stretching program designed to maintain internal rotation comes from a study among professional baseball pitchers (Lintner et al., 2007). Forty-four participants (Group A) who had followed an internal rotation stretching program for three or more years were compared to 41 pitchers (Group B) who had not followed any sort of internal rotation stretching program. Because the participants in Group A had originated from multiple baseball organizations before joining the Houston Astros, they had not been following the same protocol as the Astros, but all had participated in what Lintner at al. described at its equivalent. Group A demonstrated approximately twenty degrees greater internal rotation compared to Group B. Although the study did not include injury information, the purpose was to demonstrate that internal rotation can be maintained, and the authors state that such a program minimizes an important risk factor for shoulder injuries (Lintner et al.). See Figure 2 for an example of internal rotation testing.

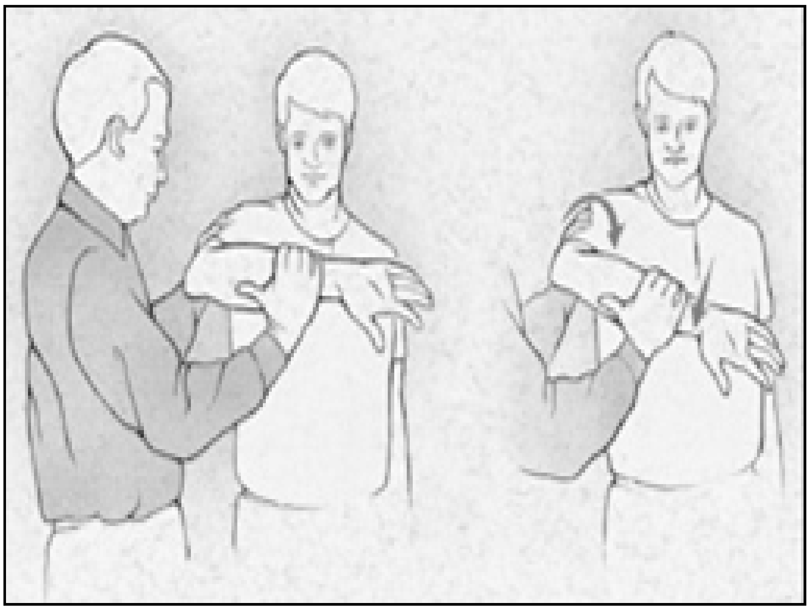

Figure 2. Hawkins' test for subacromial impingement or rotator cuff tendonitis. The arm is forward elevated to 90 degrees, and then gently internally rotated.

Figure from "The Painful Shoulder: Part I. Clinical Evaluation," by Woodward TW and Best TM, 2000, *American Family Physician*, May 15;61(10):3079-88.

Non-contact Injury Mechanisms

When analyzing upper leg muscle-tendon strains, the most common game time injury, several attributing factors are considered, including but not limited to the mode of training, muscle strength anomalies, poor flexibility, and previous injury (Croisier, 2004). While Croisier (2004) implied there are several uncontrollable intrinsic factors, such as hormonal imbalances and age, which may be associated with some hamstring injuries, extrinsic factors such as warm-up, flexibility, and strength imbalances are factors that have the potential to be addressed with specific forms of physical training. A stretching program, such as yoga, which would address injuries linked to poor flexibility, may have the potential to reduce upper leg muscle-tendon strains.

Hamstring injuries fall within the category of upper leg muscle-tendon strains, and among these injuries in particular, strains are reported to occur most often at the proximal muscle tendon junction (Garrett, 1996). The “hamstrings” are composed of the biceps femoris, semitendinosus and semimembranosus muscles, which together act as knee flexors and hip extensors. These muscles attach to the ischial tuberosity (the “sitting bones”) by way of tendons. The junction where muscles and tendons meet is frequently where a hamstring strain occurs, often due to a large eccentric contraction (Garrett, 1996).

During the transition from running to suddenly stopping, as seen in base-running, the hamstrings experience a powerful eccentric contraction during the rapid deceleration phase (Garrett, 1996). Similar run and stop movements are seen in football and soccer, and Witvrouw, Danneels, Asselman, D'Have, and Dirk (2003) found that soccer players who exhibit poor hamstring flexibility possessed an increased risk of developing lesions within that muscle group. In addition, they also noted a similar relationship between flexibility and injuries in players experiencing quadriceps injuries.

With regard to the mechanisms of shoulder injuries, the most common among the practice injuries, Sauers et al. (2007) argue that the mechanism through which labral lesions occur is still unclear as both osseous and soft-tissue changes have been suggested. Labral lesions are preceded by shoulder strains, which not only make up 6.5% of game injuries and 10% of practice injuries, but could be considered the most damaging injury in that, unlike hamstring injuries, which heal over time, labrum tears in many cases can only be repaired through surgical intervention (Sauers et al.).

Lintner et al. (2007) describe glenohumeral internal rotation deficit (GIRD) as a condition that baseball players, particularly pitchers, often experience as internal rotation ROM in their dominant arm decreases when compared to the non-throwing arm. Numerous studies have noted a relationship between G IRD and shoulder injuries among overhead throwing athletes (Flesig et al., 1995; Huffman et al, 2006; Myers, Laudner, Pasuale, Bradley, & Lephart, 2006). In theory, as posterior capsule tightness grows, so does anterior instability, which may result in superior labral anterior posterior (SLAP) lesions. As a result, numerous studies suggest baseball players undergo stretching routines in order to maintain internal rotation and to decrease posterior shoulder tightness (Lintner et al.; Myers et al.; Flesig et al,; Huffman et al.; Sauers et al., 2007; Crawford & Sauers, 2006; Whiteley, 2007).

External rotation during pitching is necessary in order to generate the extreme force demonstrated by elite pitchers, and it is often misconstrued that internal rotation must be lost in order to maintain velocity. Lintner et al. (2007) studied the Houston Astros' stretch routine, which focuses on maintaining internal rotation through passive stretching assisted by an athletic training. They found that of the players who had been participating in that or a similar program had on average 20 degrees more internal rotation than their control counterparts, with both groups having almost identical external rotation. Lintner et al. demonstrated that by participating in a stretching program, it is possible to maintain internal rotation for injury prevention without sacrificing external rotation necessary for high velocity pitching.

Influence of Range of Motion on Non-contact Injuries

Range of motion is an important aspect of many sports because adequate flexibility enables the body to move in multiple planes sequentially in order to complete a complex motor task. Pitching, for example, demands that a player move through many different planes in an ordered and coordinated manner. When a pitcher throws, his front leg moves through the sagittal and transverse planes as he lifts his leg, his arm moves through the frontal plane, then sagittal, then transverse as he ends his throw. By then his trunk has moved through the sagittal plane and finally the transverse plane. See Figure 3 for an illustration of the multi-planar movements during the six stages of pitching. Many training programs used for baseball reflect this need for multi-planar ROM by having athletes mimic movements conducted during game situations during training sessions (Frederick and Szymanski, 2001). Sprinting, batting, and fielding drills have athletes demonstrate similar ROM that they would experience with game situations both to “warm up” the musculature for these movements, as well as increase the athletes’ ROM (see Figures 4 and 5).

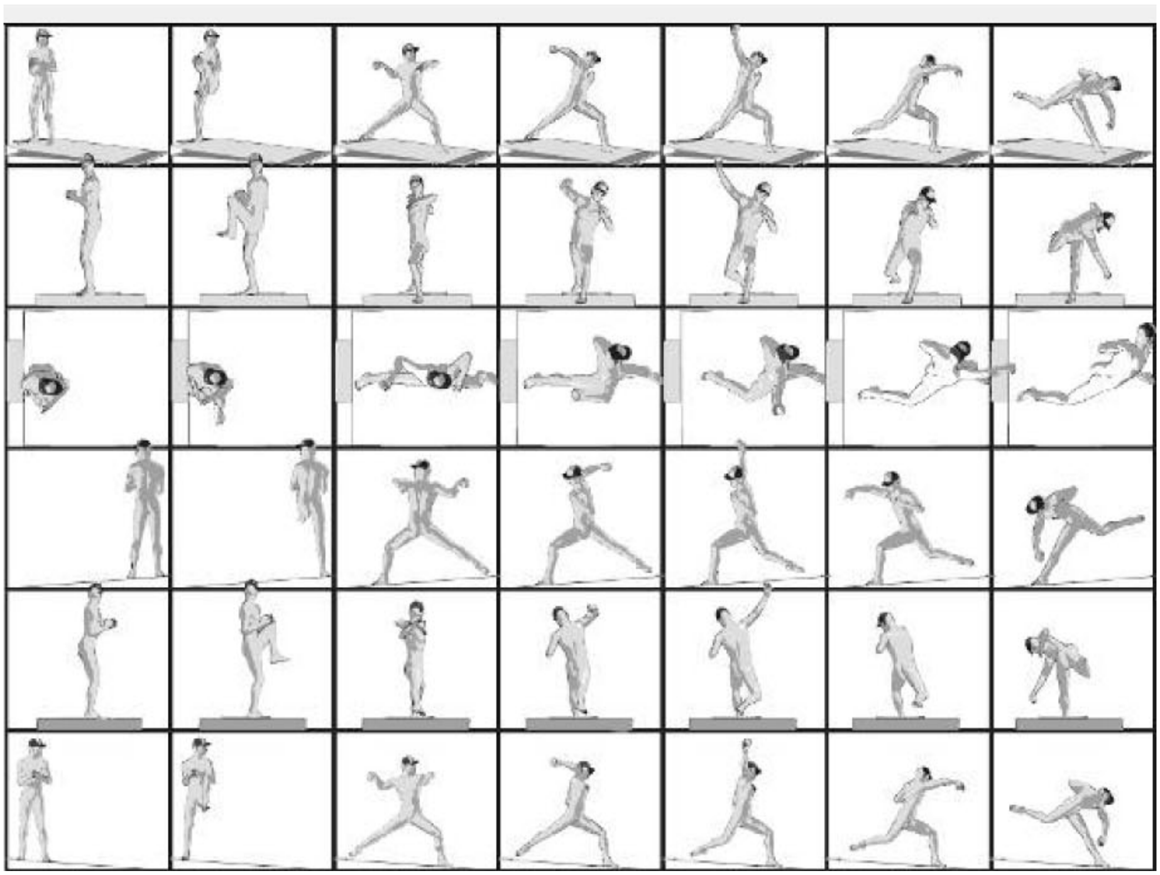

Figure 3. The six stages of pitching, viewed from six different perspectives to show various planes of movement.

Figure from "Baseball Throwing Mechanics as They Relate to Pathology and Performance – A Review," by Rod Whitley, 2007, *Journal of Sports Science and Medicine*, 6, p. 1-20.

Follow through phase of baseball pitching

Figure 4. Athlete participating in dynamic training movement designed to enhance hip, hamstring and trunk flexibility, similar to the follow through in pitching.

Top image from Baseball (Part 1): Dynamic Flexibility by Gregory A. Fredrick and David J. Szymanski, 2001, *National Strength and Conditioning Association*, 23(1), p. 21-30. Bottom image from http://www.clarionledger.com/misc/blogs/mkester/uploaded_images/Baseball_pitching_motion_2004-709207.jpg retrieved 1/29/2009

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Figure 5. Athlete practicing range of motion enhancement for 90 degree transverse hip abduction, similar to initial movement of pitching.

Two images on the left from Baseball (Part 1): Dynamic Flexibility by Gregory A. Fredrick and David J. Szymanski, 2001, *National Strength and Conditioning Association*, 23(1), p. 21-30. Image on the right from http://blog.nj.com/yankees_main/2008/06/medium_yankees-pat-venditte.jpg retrieved 1/18/2009.

Implications of Shoulder Flexibility

In addition to whole body ROM, shoulder flexibility in particular is important for preventing the aforementioned repetitive stress injuries frequently experienced by overhead throwing athletes, particularly baseball pitchers (Fleisig et al., 1995; Fredrick & Szymanski, 2001; Huffman et al., 2006; Sauers et al., 2007). Shoulder injuries represent the most common non-contact practice injury at 10% of all those that occur (Dick, Sauers, et al., 2007). The shoulder complex is arguably the most complicated joint in the human body, and theories on the mechanisms of injury to this area are widely contemplated. Chiefly, the debate falls within two main categories: 1) those who believe that the damage to a pitcher's shoulder is instigated by soft tissue adaptation, and 2) those who believe the underlying cause is related to osseous adaptation. Those who take the soft tissue approach believe that posterior capsular contraction combined with anterior displacement of the humeral head during excessive external rotation cause a "peel back" of the labrum away from the head of the humerus (Fleisig et al., 1995; Huffman et al., 2006; Sauers et al., 2007; Whiteley, 2007). Proponents of osseous origins of shoulder injuries believe that a combination of humeral head retroversion and glenoid retroversion (see Figure 6) in the dominant shoulder compared with the non-dominant shoulder show shoulder injuries are spawned by bony adaptations due to repetitive stress and microtrauma subsequently followed by soft tissue changes in the region of the shoulder (Crockett et al., 2002).

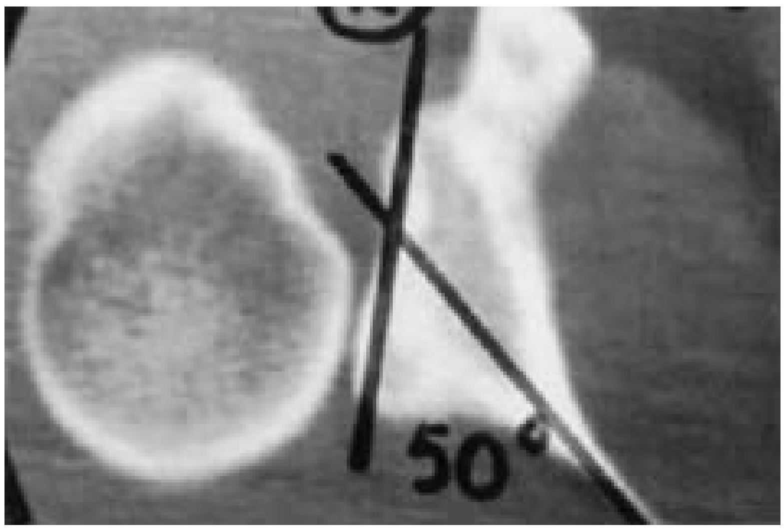

Figure 6. CT scan of a patient with posterior glenoid hypoplasia with increased glenoid retroversion.

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http://www.uphs.upenn.edu/ortho/oj/2001/html/oj14sp01p5.html. Retrieved 05/11/2009 at 9:51am.

Although this debate is current, flexibility appears to be a mechanism of protection that is widely agreed upon among several sport scientists (Fleisig et al., 1995; Huffman et al., 2006; Sauers et al., 2007; Whiteley, 2007). Although Dick, Sauers, et al. (2007) reported that upper leg muscle-tendon strain demonstrated the highest percentage of game injuries (11%) among baseball athletes, shoulder muscle-tendon strains made up the largest percentage of "severe" injuries. Of the injuries leading to ten or more consecutive days on the disabled list, shoulder injuries make up 6.3% of game and 22.1% of practice injuries compared to upper-leg strains at 7.7% of game injuries and less than 1% among practice injuries (Dick, Sauers, et al.). Thus, shoulder flexibility becomes vital for baseball, particularly for non-contact injury prevention.

Several studies have emphasized the connection between humeral head translation and subluxation to lesions in the labrum (Fleisig et al., 1995; Huffman et al., 2006; Sauers et al., 2007; Whitley, 2007). Sauers et al. implied that this displacement of the humeral head comes from a combination of anterior-inferior capsular laxity and posterior-inferior capsular contracture. These combined conditions associated with the shoulder joint can lead to a variety of injuries, including but not limited to SLAP lesions, muscle tears, nerve damage, and ligament rupture (Fleisig et al.).

In a study examining the kinetics of baseball pitching, Fleisig et al. (1995) theorized that overuse injuries observed among pitchers and overhand throwers are caused by large forces and torques produced at the shoulder and elbow joints during the throwing motion. According to Fleisig et al., these large forces and torques are to some degree due to the very nature of pitching itself. The authors report that internal rotation of up to 7510 degrees per second have been recorded, making baseball pitching one of the fastest known human motions (Fleisig et al.). Fleisig normalized pitching stride values both in stride length between starting foot and landing foot as well as position of the landing foot. Based upon Flesig's work, Whiteley (2007) adds that improper pitching mechanics can further increase these already large forces, reporting that for every one centimeter a pitcher's landing foot deviated laterally from normative values described by Fleisig, an additional three Newtons of maximum shoulder anterior force was created during the cocking phase of a pitch. The biomechanical nature of pitching coupled with imperfect mechanics increases the likelihood of translation and subluxation of the humeral head and puts the shoulder labrum at risk for tears (Whiteley).

One limitation of many studies regarding shoulder injury is that while numerous aspects of shoulder flexibility in relation to shoulder injuries have been studied, there is little examination of other aspects of pitching. For example, while increased trunk rotation torque is associated with higher throwing velocity, there appear to be no studies that examine trunk rotation in comparison to shoulder injuries. Thus the question could be posed, "Does producing more trunk torque through greater trunk rotation (flexibility) alleviate some of the damaging torque at the shoulder or elbow?"

Another obvious limitation of the studies cited is that it is impossible to invasively observe the shoulder complex during the pitching motion. Although Magnetic Resonance Imaging (MRI) allow physicians to assess exactly where the damage in the shoulder is, it is not possible to determine the mechanism of injury as it happens; therefore, all of these studies theorize mechanism based upon the available evidence.

Huffman et al. (2006) attempted to acquire a more direct look at shoulder function utilizing a cadaver model. The authors of the study modified eight cadaver shoulders to mimic posterior band contracture through suturing, and then examined the path of glenohumeral articulation, range of motion, glenohumeral forces, and humeral head translation (Huffman et al.). The study confirmed that posterior band contracture had the most profound impact on humeral translation, but the authors also noted their own study's limitation of lacking cadaveric musculature in order to directly see the posterior band (Huffman et al.). Other limitations to note were the respective condition and age of their specimens and the fact that their specimens would lack the years of repetitive motion observed among real-life baseball pitchers. Although many of these studies demonstrate limitations, the trends among the evidence point to the concept that posterior band contracture leads to loss of internal rotation, which in turn leads to the potential for shoulder injury.

Laxity versus Flexibility

One concern among sports medicine staff is that the practice of stretching may cause excessive shoulder laxity, thus, it is necessary to discuss differences between the concepts of laxity versus flexibility. Flexibility is defined as the total ROM of a joint or group of joints, whereas laxity indicates a lack of stability of a joint usually due to the integrity of extra-articular structures such as the joint capsule, ligaments, and muscles. Glenohumeral joint laxity is defined as "the ability of the humeral head to be passively translated about the glenoid fossa" while glenohumeral instability is defined as "a clinical condition in which unwanted translation of the head on the glenoid compromises the comfort and function of the shoulder" (Matsen, Harryman, & Sidles, 1991; Frederick & Symanski, 2001). Whiteley (2007) indicates that glenohumeral joint laxity can be either genetic or attained; however, because it is a condition so common among pitchers, laxity is believed to be acquired by this population. Several studies on glenohumeral displacement and overhead throwing injuries suggest that the physical parameter of flexibility may balance the shoulder joint laxity found among overhead throwing athletes, and further, have emphasized the importance of maintaining flexibility of the shoulder complex as a method of injury prevention (Fleisig et al., 1995; Fredrick & Szymanski; Huffman et al., 2006; Sauers et al., 2007).

Flesig et al. (1995) express that flexibility can help compensate for joint laxity, which is believed to be responsible in part for shoulder injuries among baseball pitchers. Displacement of the humerus via joint laxity is associated with a translation mechanism or the so-called "peel back" of the posterior superior labrum from the glenoid leading to SLAP lesions and internal impingement syndromes (Huffman et al., 2006). While some athletic trainers fear that stretching may amplify joint laxity, Huffman et al. stated that a contracted posterior band of the inferior glenohumeral ligamant furthers anterior displacement of the humeral head, and that professional baseball pitchers that have undergone an extensive posterior capsular stretching regimen incurred fewer shoulder injuries than their counterparts who did not (see Figure 7).

Figure 7. Posterior shoulder stretching as performed in the Houston Astros internal rotation stretching program.

“Glenohumeral Internal Rotation Deficits in Professional Pitchers Enrolled in an Internal Rotation Stretching Program” by D. Lintner, M. Mayol, O. Uzodinma, R. Jones, and D. Labossiere, 2007, *American Journal of Sports Medicine,* 35, p. 17.

One method of maintaining or increasing shoulder flexibility is the Fauls shoulder stretch method. The Fauls protocol was designed by David Fauls in the mid-1980s (Sauers et al., 2007). The protocol provides acute gains in ROM for both external and internal rotation of the shoulder along with decreased posterior capsule tightness (Sauers et al.). Sauers et al. found improvement in external rotation, which includes shoulder complex internal rotation and passive isolated glenohumeral external rotation, measuring seven degrees and five degrees, respectively. They also found improvements in internal rotation, which includes shoulder complex internal rotation and glenohumeral internal rotation, of nine degrees and six degrees, respectively. Sauers et al. found that posterior shoulder tightness decreased by an average to two centimeters. Because posterior capsule contraction is thought to be a component SLAP lesions and, it is hypothesized that improvements in shoulder flexibility concomitant with the reduction of posterior capsule tightness may reduce the incidence of shoulder injuries among baseball athletes. These findings appear to be congruent with similar findings lending support to the fact that among those athletes who perform overhead throwing actions, flexibility training may prevent and reduce shoulder injuries by reducing the strain mechanism on the anterior and posterior joint capsule (Fleisig et al., 1995; Huffman et al. 2006; Sauers et al.; Whitley, 2007).

Based upon the findings by Fleisig et al. (1995), Huffman et al. (2006), Sauers et al. (2007), and Whitley (2007), it appears that preventing shoulder injuries comes from maintaining flexibility, not reducing glenohumeral laxity. Flesig et al. explain that glenohumeral laxity is necessary to pitching itself in order to achieve the extreme external rotation that allows for high velocity in throwing. In other words, glenohumeral laxity is an occupational hazard for pitchers, and flexibility is that means to prevent that laxity from inducing shoulder injury.

Stretching

Stretching is a common and popular practice utilized among many athletic programs in some cases as a "warm-up" or as part of a formal physical conditioning program. Stretching involves the application of a tensile force in order to lengthen muscle and connective tissue with the purpose of enhancing range of motion (ROM) of a segment about a joint, and is often referred to as flexibility (Stone et al., 2006). As stretching is so often a component of athletic programs with the intention of enhancing ROM, there is much interest in its effect on injury rates and performance.

In their 1999 study using 150 military recruits over a 13-week basic training course, Hartig and Henderson found that a stretching program of 3 minutes, 3 times per day over 12 weeks resulted in an average increase in hamstring flexibility in the intervention group of 7%, compared to an improvement of 3% in the control group. More important, they also found 12% fewer lower extremity injuries within the intervention group compared to the control group (Hartig & Henderson, 1999). Similarly, Liddle, Houglum, and Arnold (2001) found that a single static stretch of 30 seconds 2x/day for 5 days /week for 4 weeks improved knee flexor range of motion. Like these stretching programs, yoga involves tensile forces on muscle and connective tissue, and therefore the potential exists for this practice to enhance segment ROM over similar time periods.

It is important to recognize that there are many types of stretching, including but not limited to ballistic, dynamic, active, passive, static, isometric, and proprioceptive neuromuscular facilitation techniques (Stone et al., 2006). Yoga is typically not included among this list, although its main, perceived function is to enhance flexibility (Birch, 1995). Although yoga enhances flexibility, it is more appropriately described as a stretching system because it combines many types of stretching within one discipline (Hart and Tracy, 2008). For example, a protocol could typically begin with a dynamic, whole body sequence designed to raise body temperature. The practice would then move on to active stretching, which includes standing postures that require muscular effort and balance. The next progression is to static stretching, which may be standing or seated, and requires less muscular effort and a longer hold time. And finally, the yoga practice would end with passive stretching, which is done lying down and requires no muscular effort but hold times longer than 2 minutes.

Mechanisms of Stretching

Stone et al. (2006) propose that there are two main methods with which stretching increases ROM: 1) stretching alters properties of soft tissue, such as muscle fibers and tendons, associated with muscle (mechanical hypothesis); and/or 2) stretching increases pain tolerance (neural hypothesis). Ce, Margonato, Casasco, and Veicsteinas (2008) describe the effects of stretching as a combination of both neural and mechanical influences. The authors believe that stretching increases muscle compliance and decreases stiffness and, as a result, alters the interaction of the actin-myosin cross-bridge cycle due to an increase in sarcomeral length and an increase in muscle spindle threshold (Ce et al.). Although muscles have the ability to contract, they also have the ability to elongate. This mechanism is due chiefly to collagen, the most common protein in the body, and the largest component of connective tissue that provides support and structure for the contractile elements. Elastin, another protein component of connective tissue with an elastic quality, provides plasticity, the ability of a tissue to elongate and then return to its typical structural state after the elongating force is removed (Seeley, Stephens, & Tate, 2006).

Viscoelastic behavior, the combination and coordination of muscular viscous and elastic properties are referred to as stiffness and compliance (Alter, 1998). Stone et al. (2006) describe tissue stiffness as "the ability of tissue to resist change in length and is represented by a change in force per change in length ($\Delta F/\Delta L$)." Furthermore, the authors describe compliance as decreased passive stiffness, or a state in which the muscle holds less energy for elastic recoil (see Figure 8). Skeletal muscle cells coordinate muscle stiffness and the elastic limit through selective expression of the protein titin, which connects myosin to the end of the sarcomere (see Figure 9). A portion of the Titin protein within the I-band in the sarcomere acts as a spring and enables the sarcomere to recoil to its normal resting length after being elongated (Seeley, Stevens & Tate, 2006).

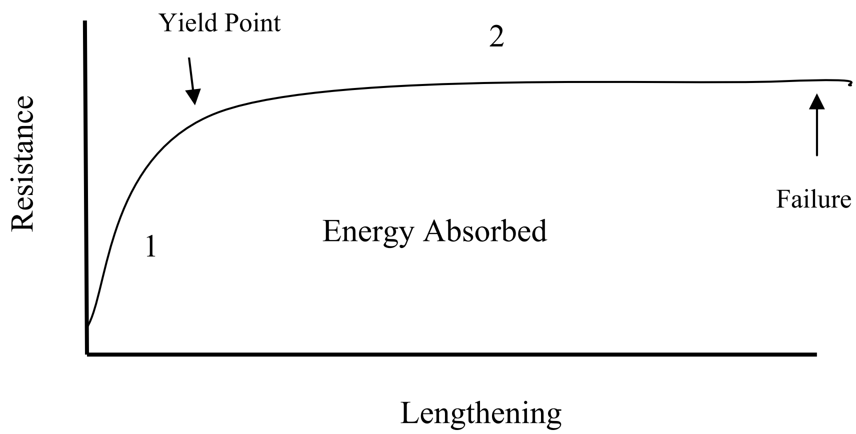

Figure 8. Force-length curve. Region 1 indicates the elastic region where elastic properties increase the force by resisting the stretch. Region 2 indicates the non-elastic region where elastic properties are stretched to their limit and non-elastic properties resist the stretch.

"Stretching: Acute and Chronic? The Potential Consequences," by M. Stone, M.W. Ramsey, A.M. Kinser, H.S. O'Bryant, C. Ayers, and W.A. Sands, 2006, *Journal of Strength and Conditioning Research*, 28(6), p. 66-74.

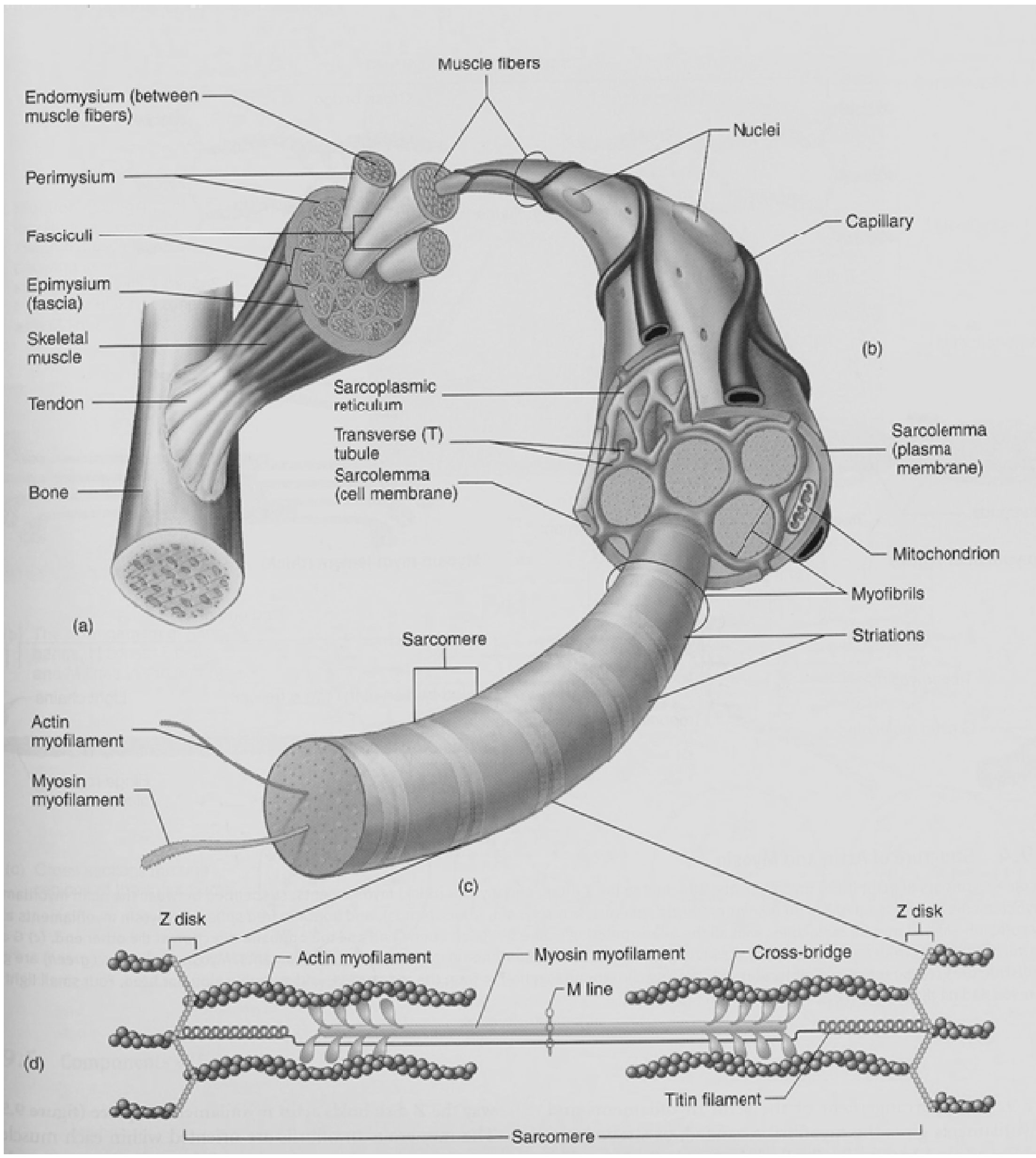

Figure 9. Progressive diagram from muscle to sarcomere, including Titin fibers, graphic taken from *Anatomy and Physiology, 7th edition,* 2006, R.R. Seeley, T.D. Stephens, and P. Tate, McGraw Hill, New York, NY, pg 279.

Muscle Proprioception

Specialized components of the muscle, called proprioceptors, work with the Central Nervous System (CNS) and Autonomic Nervous System (AND) to maintain tone and regulate stretch (Seeley et al., 2006). See Figures 10 and 11 for illustrations of a muscle spindle and Golgi tendon organ. Proprioceptors give and provide feedback to and from joints, tendons, and other connective tissues (Seeley et al.). Muscle spindles are proprioceptors that provide the nervous system with feedback regarding the length of the muscle. As a muscle lengthens, the muscle spindles signal the brain via the gamma motor neurons activating the "stretch reflex," thus increasing both action potentials and tone of the elongated muscles (Seeley et al.). By activating muscle spindles during stretching, pausing briefly, then stretching again, it is possible that the spindles may become less sensitive, thus allowing greater relaxation and, theoretically, less discomfort (Fahey, Paul, & Roth, 1997).

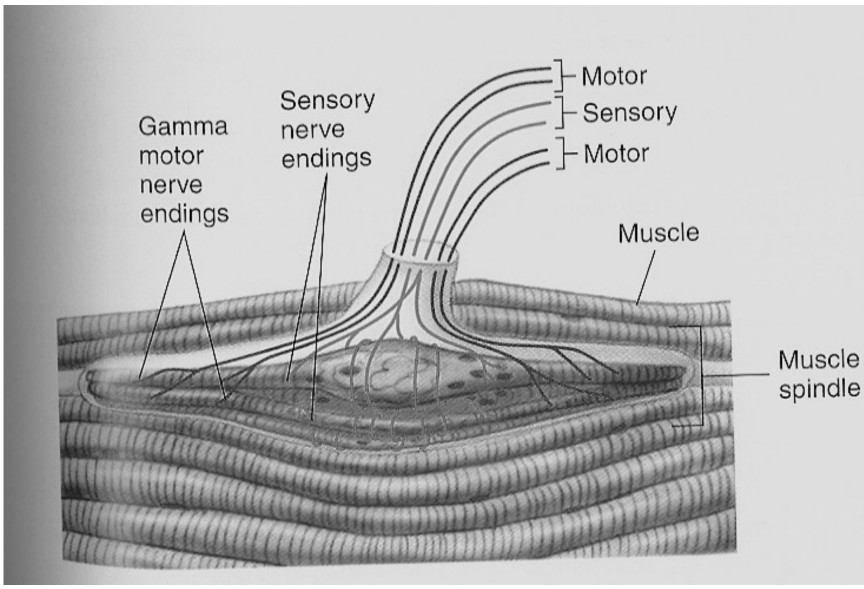

Figure 10. Muscle spindle and gamma motor nerve endings.

Anatomy and Physiology, 7th edition, 2006, R.R. Seeley, T.D. Stephens, and P. Tate, McGraw Hill, New York, NY, pg 479.

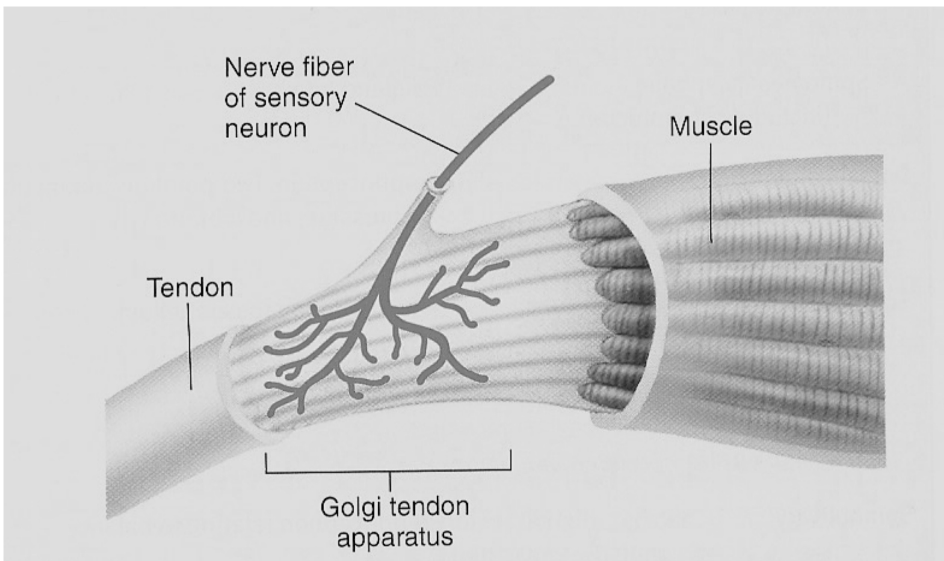

Figure 11. Golgi Tendon Organ.

Anatomy and Physiology, 7th edition, 2006, R.R. Seeley, T.D. Stephens, and P. Tate, McGraw Hill, New York, NY, pg 479.

Another proprioceptor associated with the muscles and the nervous system is the Golgi Tendon Organ. These proprioceptors are located near the junction and in series between the muscle and tendon. GTO's provide feedback concerning muscle tension. During lengthening, GTO's signal the muscle to relax, through a process called autogenic inhibition (Seeley et al., 2006).

Acute Static Stretching

Over the last few years, a position on physical training has emerged that contradicts the long-standing practice of "stretching" prior to athletic performance (Herda, Cramer, Ryan, McHugh, & Stout, 2008; Nelson, Driscoll, Landin, Young, & Schexnayder, 2005; Robbins & Scheuermann, 2008; Torres et al., 2008; Wallmann, Mercer, & Landers, 2008). Numerous studies have indicated that acute static stretching, or brief but intense stretching, can cause a loss of force production and in turn be detrimental to activities involving powerful muscular contractions, such as those during sprinting or vertical jump (Herda, Cramer, Ryan, McHugh, & Stout; Nelson, Driscoll, Landin, Young, & Schexnayder; Robbins & Scheuermann,2008; Torres et al.; Wallmann, Mercer, & Landers).

In a study examining the effect of static stretching just prior to vertical jump performance, Robbins and Scheuermann (2008) found that vertical jump height demonstrated a linear decrease as the length of time of static stretch increased. Brandenburg (2006), in a similar study, found that short durations or static stretch, 15 seconds and 30 seconds, elicited 4.8% and 5.2% decreases in maximum voluntary isometric contraction. The study demonstrated that a decrease in vertical jump performance was not dependent upon length of time of static stretching, but that any amount of static stretch prior to a vertical jump had the same detrimental effect on force production and suggested that all static stretching prior to performance be eliminated (Brandenburg, 2006).

Conversely, Ryan et al. (2008) found that although acute static stretching decreased force production in the plantar flexors immediately after stretching, force production returned to baseline after 10, 20, and 30 minutes. They also found a temporary improvement in ROM, which they concluded was a positive effect of stretching. Ryan et al. (2008) also raised concerns about the relevance of findings among older studies due to impractical protocols noting that some older studies had excessive amounts of stretch involved, such as one might find among animal studies. Such impracticality can be expressed in a study by Fowles et al. examining static stretching and force deficit of plantar flexors, where subjects were asked to stretch one muscle group for 30 minutes, which does not depict a situation normally encountered prior to athletic performance (Fowles et al., 2000).

Ryan et al. (2008) responded to these extreme studies by conducting a study examining practical stretch doses, force deficit, and subsequent recovery time. They found that practical doses of static stretching (2-4 minutes) did reduce force production, but that force production returned to baseline within 10 minutes. Their opinion was that stretching before athletic performance was acceptable as long as enough recovery time was given between the stretching and performance. The most recent studies on this topic have shifted to examining what underlies the effects of stretching.

Mechanisms of Stretch-Induced Force Deficit. The two proposed hypotheses for stretch-induced force deficit caused by static stretching are 1) the neural factors that cause a decrease in motor unit activation and 2) there are mechanical factors related to the length-tension relationship or viscoelastic muscle properties (Ryan et al., 2008). Fowles et al. (2000)

suggested that several neural factors could be the underlying cause either alone or in combination. The authors believed that the temporary inability to recruit all motor units of the stretched muscle could be due to 1) a persistent GTO reflex, 2) pain feedback from nocireceptors or mechanoreceptors, and/or 3) a fatigue-orientated feedback mechanism. Herda et al. (2008) believed that static stretch may function much like vibration effect, in that there is an inhibition of ascending feedback from muscle spindle resulting in an inability to recruit the fast and powerful contracting Type II muscle fibers. Ryan et al. noted that the neuromuscular adaptations experienced by athletes due to training programs may alter their reaction to static stretch and that further studies with athletes need to be conducted in order to determine if stretching prior to athletic performance is appropriate for that population.

There are also arguments that support the mechanical hypothesis (Herda et al., 2008; Ce et al., 2008). These studies propose that by elongating muscle fibers, the increase in resting length of the sarcomeres interferes with the typical length-tension relationship as well as connective tissue deformation. McHugh et al. (1999), in their study of angle-torque ratios during isometric leg flexion, determined that the greatest force deficits were found at the short muscle lengths, which would be consistent with a shifting to the right of the length-tension relationship, which describes the progression of tension development from a muscles shortened length to its longest (see Figure 12). However, Herda et al. noted that a rightward shift in the length-tension relationship would also result with an increase in force production, which McHugh et al. did not find. At this time, there are no definitive conclusions on the underlying mechanisms of stretch-induced force deficit, and the research in this area is apparently ongoing.

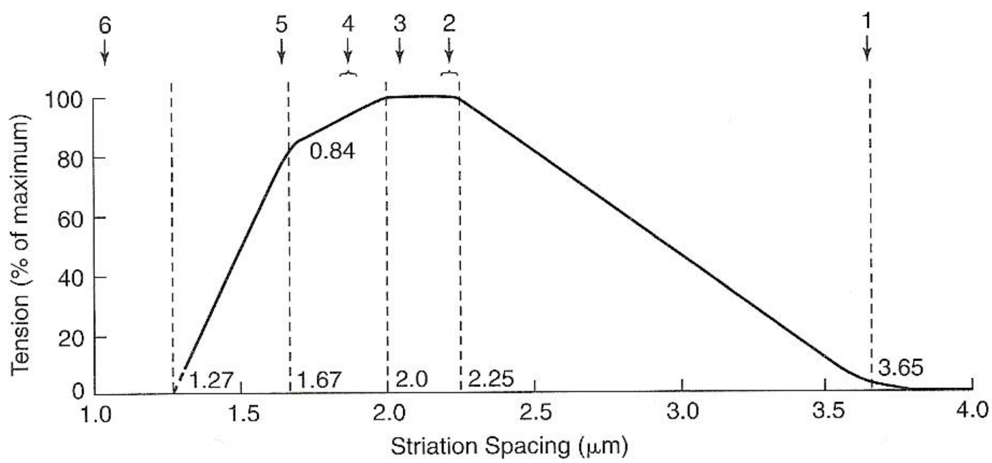

Figure 12. The classic length-tension relationship described in terms of tension development (y-axis) compared to sarcomere length (x-axis). If the relationship experienced a right-ward shift, tension would theoretically peak at greater lengths.

"The Muscular System: Structural and Functional Plasticity," by V. J. Caiozzo and B. Rouke, 2006, *ACSM's Advanced Exercise Physiology,5,* p. 133. Copyright 2006 by the American college of Sports Medicine.

Chronic Stretching

Previously cited investigations within this document have examined acute stretching prior to an athletic event. Chronic stretching, on the other hand, is stretching performed at regular intervals as a component of training, usually after a training session (Stone et al., 2006). Chronic stretching best represents that category with which yoga could be classified. Because chronic stretching is as common in athletic training as acute stretching, many studies have examined the effect of chronic stretching on flexibility, peak torque, injury prevention and that balance between muscle stiffness and muscle compliance (LaRoche et al., 2008; Stone et al., Herman and Smith, 2008). Many coaches and athletes believe that, similar to acute stretching, chronic stretching can enhance performance and prevent injury, with the added effect of reduced muscular soreness and enhanced recovery (Stone et al.).

Investigations that have examined chronic stretching have found considerably different results than those examining acute stretching. For example, while acute stretching creates a force deficit, some chronic stretching studies have found strength enhancement after 3-4 weeks of stretch training (Handle et al, 1997; Worrell et al., 1992; Herman et al., 2008; LaRoche et al., 2008). Although the improvements in strength were small (2-3%), Stone et al. (2006) indicate that at elite levels of performance, the difference between first place and fourth is usually very small in percentages of time, strength, or distance, depending on the event. The mechanisms underlying strength enhancement with stretching appear to be unclear at this time. Stone et al. imply that the improved ROM could have a positive effect in strength activities, such as weightlifting, where positioning of the body influences results. They note that this ROM improvement, like that from acute stretching, could be due to a decrease in muscle stiffness or an increase in stretch pain tolerance. One recent review pertaining to stretching concluded that strength improvements through stretching may be a product of stretch-induced hypertrophy (Shrier, 2004). Others, such as Stone et al., believe that the nature of stretching found to produce hypertrophy in animal studies is unreasonable for humans to perform, as many of these studies required that the animal be stretched with a machine apparatus for up to 12 hours at a time!

Laroche et al. (2008) found little difference in hamstring strength with participants following a 4-week study of static and ballistic stretching 3 times per week. By examining the results of peak torque development, the investigators sought to discover whether changes in ROM were due to a change in force-length relationship of muscle. The authors also found that the subjects maintained their strength and rate of peak torque development and therefore concluded that improvements in ROM were from increased stretch pain tolerance. In a similar study looking at the effects of a 4-week chronic dynamic stretching program, Herman and Smith (2008) found that collegiate wrestlers experienced strength, agility, and speed enhancements and noted that these enhancements were due to the nature of dynamic versus static stretching. Thus, it was proposed that the movement of dynamic stretching created an increase in core temperature that allowed a decrease in muscle and joint stiffness, an increase in transmission rate of nerve impulses, and an increase in various metabolic processes a the cellular level of muscle.

Proposed Mechanisms of Injury Protection

There are two main types of stretch-related injuries and two proposed methods of injury prevention through stretching programs. The first and most-readily understood path of injury prevention is for those injuries in which the subject has moved beyond his or her body's ROM. In this instance, a stretching program that increases the subject's typical ROM will make “over-extension” less likely (Stone et al., 2006). As Stone et al. indicate, an average person forced into the “splits” would likely obtain a muscle injury, but gymnasts, who train to develop that ROM, can jump into the splits without injury. However, the majority of strained muscles are not the result of overextension. The second path of injury prevention relates to injuries associated with high levels of eccentric loading within normal ROM. For example, a sprinter who incurs a hamstring “pull” while running would represent an example of an eccentric load injury (Stone et al.). Stone et al. suggest that these eccentric stretch injuries may be caused by external forces being applied to a less compliant muscle structure not capable of absorbing enough force to prevent cell disruption. They also note that some studies have found that stronger muscles seem to have a reduced risk of injury. In particular, eccentric strength training seems to reduce delayed onset muscle soreness (DOMS) due to physiological adaptation known as repeated bout effect, in which muscle soreness is alleviated by performing a soreness-producing exercise preceded by a similar soreness-producing exercise bout (Stone et al.). This evidence supports the concept that because Ashtanga Vinyasa yoga involves many eccentric contractions, it may help alleviate this variety of muscle injury.

Yoga Studies

“Yoga” entered as a search parameter among many academic search indexes results in a multitude of examples describing its use as a complimentary treatment for disease or as a practice among fitness experts who expound its virtues for athletes. Many Ashatanga Vinyasa yoga postures are utilized to increase ROM about particular segments, but it is noteworthy to indicate that these postures also include eccentric loading. These properties incorporate the suggested mechanisms for injury protection for both “over reach” and the eccentric muscular injuries commonly associated with sport.

With regard to the influence of yoga on injury prevention, there currently exists only one peer-reviewed study by Boyle et al., 2004. Boyle et al. examined how a regular yoga practice delayed the onset of muscles soreness (DOMS), a form of muscle trauma and/or damage at the level of the connective tissue and cell. DOMS usually occurs after participating in a novel physical activity or repeated eccentric contractions, with symptoms including soreness and stiffness that may last from 24 to 72 hours. Although the authors examined the practice of yoga, the type used was Kripalu, different from Ashtanga Vinyasa yoga. Kripalu yoga focused on “perfect alignment” meaning that all students are instructed to perform posture the exact same way despite anthropometric differences, whereas Ashtanga Vinyasa yoga acknowledges the uniqueness of each body physique. The subjects utilized by Boyle et al. were women 38 ±2.6 years of age trained in Kripalu yoga, but the training was not conducted by the authors nor were any particular details of the yoga protocol recorded. They concluded that the yoga trained group had less perceived soreness after strenuous exercise when compared to the control group and that a single yoga session 24 hours after strenuous exercise decreased perceived soreness by 49%, implying that yoga is a viable treatment option for this type of muscle injury. Soreness was measured by a visual analog scale, which can be considered a limitation given that it is a subjective scale.

Another recent study examined the effects of Bikram yoga on strength, balance, and steadiness among a slightly younger population (29 ±6 years). Hart and Tracy (2008) found substantial improvements in one-legged balance and modest improvements in strength among their participants. Bikram yoga is performed in a room heated between 105-120 degrees Fahrenheit and repeats postures of the same sequence without variation. It differs from Kripalu and Ashtanga in that the room is kept very hot, and it contains only one set of postures. Similar to Boyle et al. (2004), Hart and Tracy's participants were also described as non-athletic, although the authors did not define "non-athletic" quantitatively. Although the subjects were younger than those in the study by Boyle et al., there is still a wide gap in physical conditioning between non-athletic subjects and collegiate baseball players. One could argue that 10-20 hours/week of baseball conditioning repeated every year since adolescence will procure profound physiological adaptations that differ even from recreational athletes. The Hart and Tracy also choose Bikram yoga for their experimental design, which is a convenient choice due to its exact and repetitive sequence, but it also does not allow for any progression as participants adapt to the postures. These three types of yoga, Ashtanga Vinyasa, Kripalu, and Bikram, represent only a few of many different styles of yoga. How various yoga protocols relate to muscle injuries and syndromes as a treatment or injury prevention is unknown at the time and warrants further investigation.

CHAPTER III: METHODS

Experimental Design

To address the research questions for this study, a single-group interrupted time-series non-experimental design was used. Pre- and Post-intervention testing assessed several flexibility parameters considered to be relevant or commonly assessed with regard to the sport of baseball. The intervention consisted of a twice-per-week, 45-minute yoga session, with a total of 25 sessions completed during the training period. These sessions were conducted as a component of the team's NCAA regulated "supervised" time, with coaching and athletic training staff in attendance during all sessions.

Participants

Upon approval of the College of Health and Human Services Human Subjects Review Committee at Eastern Michigan University (Appendix A), thirty male baseball athletes from Eastern Michigan University (19.42 ±1.37 years; 84 ±8.04 kg; 183 ±6.33 cm) were recruited during a pre-arranged team meeting with the permission of their Head Coach, Head Athletic Trainer, and Director of Strength and Conditioning. Subject characteristics are presented in Table 1. To ensure the voluntary nature of this research project, no coaches were present during the meeting with the athletes in order to convey the importance of non-coercion.

During the study, both "positional" players and "pitchers" participated in their usual team workouts and practice. It should be noted that positional players (outfielders and infielders) and pitchers participate in their own unique manner that prioritizes the training associated with a set of skills most desirable for their respective positions. For example, infielders require very fast reaction times in response to a hit ball, outfielders require speed when running and powerful throwing arms for long distances, and pitchers require the ability to throw rapidly and precisely in a repetitive manner, in some cases more than 100 times over a period of several innings. Prior to the study, each athlete was examined by the team's physician for physical clearance to participate in the study (Appendix B) and participant and guardian consent was acquired with a completed informed consent document (Appendix C).

Table 1
Subject Anthropometric Characteristics

Subject	Mass (kg)	Height (cm)	age
1	75.0	182.9	18
2	81.8	177.8	21
3	79.5	177.8	21
4	77.3	177.8	21
5	77.3	175.3	20
6	70.5	172.7	19
7	87.7	182.9	20
8	86.4	182.9	19
9	86.4	177.8	20
10	88.6	182.9	19
11	72.7	182.9	18
12	81.8	177.8	18
13	75.0	180.3	21
14	95.5	188.0	17
15	84.1	175.3	18
16	77.3	182.9	19
17	70.5	177.8	18
18	88.6	182.9	22
19	84.1	182.9	19
20	97.7	185.4	20
21	80.0	188.0	18
22	94.5	185.4	21
23	88.6	193.0	18
24	88.6	180.3	18
25	79.5	193.0	18
26	102.3	188.0	20
27	81.8	172.7	18
28	77.3	195.6	19
29	93.2	198.1	21
30	81.8	182.9	19

Testing Protocol

To accommodate the academic schedules of the participants, pre-intervention testing was conducted over a period of two days. Testing included determining range of motion for the following regions and segments of the body: hamstring and lumbo/thoracic during trunk flexion; thigh abduction from a seated position; shoulder hyperflexion from a lying prone position; and left and right transverse trunk rotation about the vertical axis in a standing position.

Prior to testing, a five-minute warm-up was performed by having the athletes squat with body weight in order to increase body temperature and enable participants to achieve full potential ROM during testing without causing injury. These squat movements focused on the lower extremities but also incorporated some shoulder movement (see Figure 13), primarily flexion and abduction.

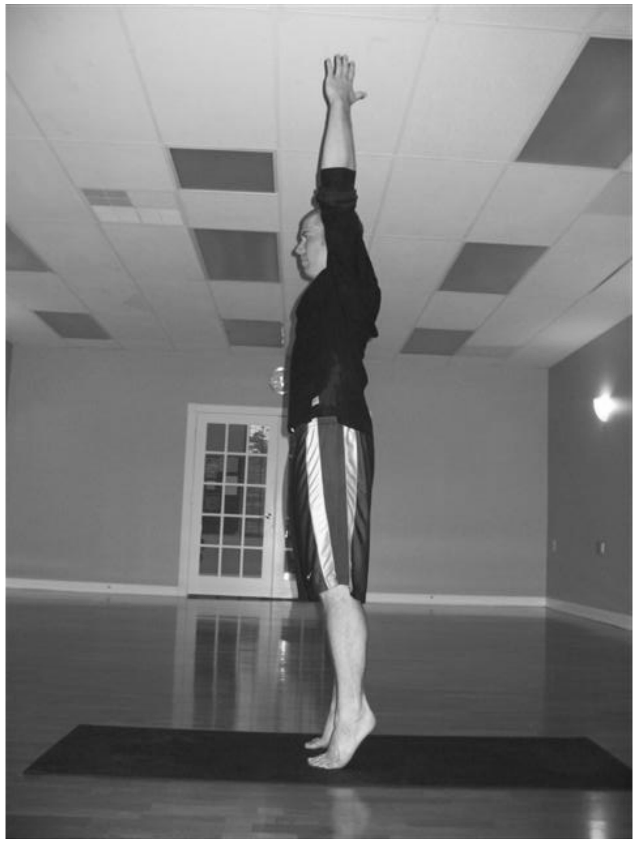

Image A

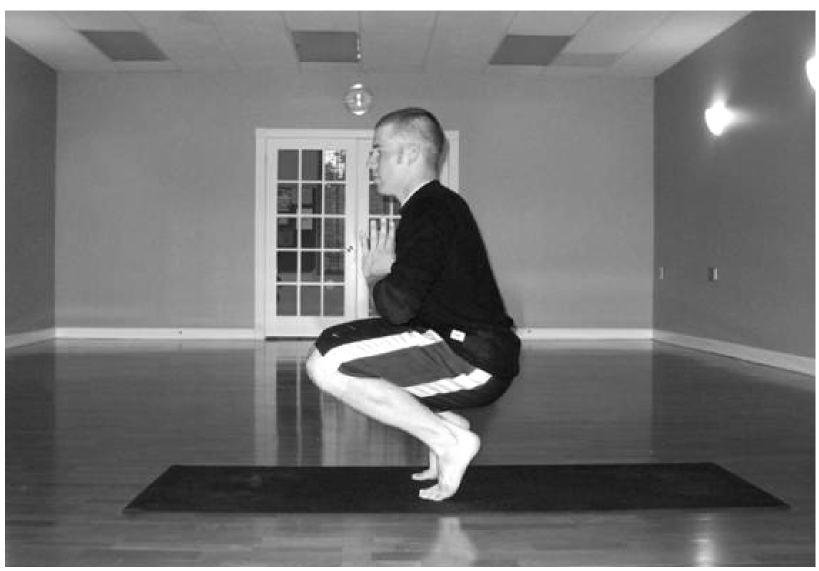

Image B

Figure 13. Body Weight Squat. Up movement paired (a) with participant's inhale, and down movement (b) paired with participant's exhale. Warm-up period lasted five minutes.

Sit and Reach Test

The Sit and Reach Test assesses flexibility of the knee flexors, hip extensors, and lumbo-thoracic musculature during trunk flexion parallel to the sagittal plane. It is a popular and often documented flexibility test (Hui & Yuen, 2000, Minkler & Patterson, 1994). To initiate assessment, participants were asked to sit on the floor with knees extended and upper thigh in 90˚ flexion with respect to the trunk as the soles of the feet were positioned against the Sit and Reach Box (M-F Athletic, Cranston, RI, USA). Participants were then asked to dorsiflex both ankles until perpendicular (heels on the floor and toes superior to the heels) with respect to the floor. Upon pressing the soles of feet against the foot plate of the Sit and Reach Box, participants positioned the middle fingers (digitus medius) of both hands on top of one another, then flexed trunk forward while reaching with the hands toward the feet as positioned on the box (See Figure 14). Participants were then asked to push the slide bar of the Sit and Reach Box forward until obtaining maximal lumbar thoracic flexion, with fingers maintaining contact with the slide bar for a full breath (inhale and exhale). The measurement of the scale at maximum flexion was recorded to the closest centimeter. The procedure was then repeated, with the greater of the two readings utilized as the final result in the data.

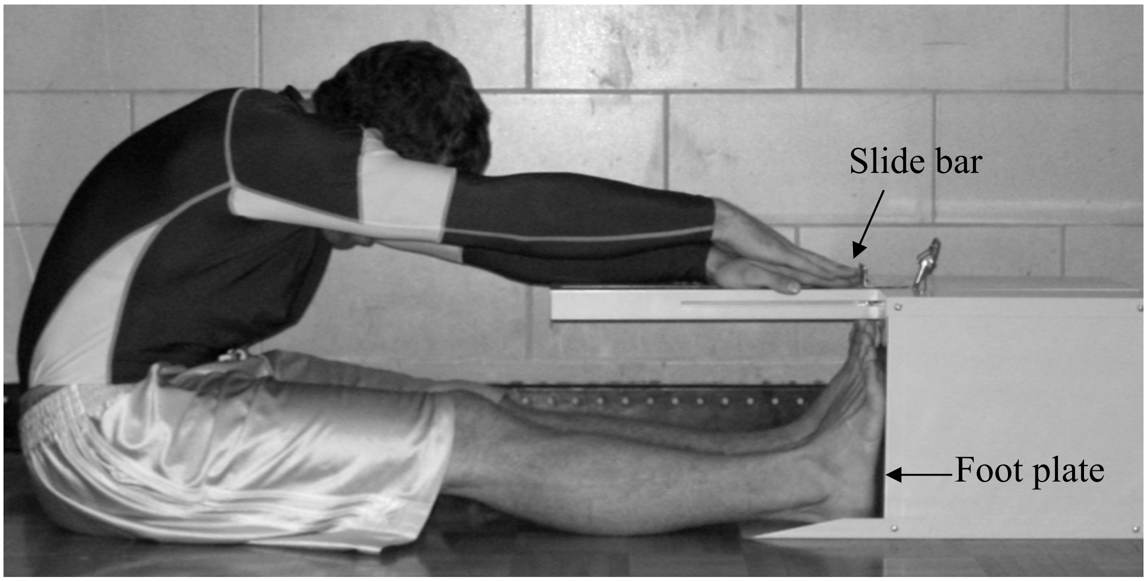

Image A

Image B

Figure 14. An assessment of knee flexor, hip extensors and lumbar thoracic flexibility using a Sit and Reach Box (a) with a close-up of hand positioning (b).

Shoulder Flexibility

This inexpensive and simple-to-administer test examines posterior-inferior shoulder flexibility, an important component of overhead throwing, and requires no expensive equipment. Participants were asked to lie prone on the floor and hold a 152.4 cm polyvinyl chloride (PVC) pipe superior to the head with a pronated grip and elbows completely extended (see Figure 15). Hands were positioned approximately shoulders-distance apart. Participants were then asked to perform shoulder hyper-flexion and the PVC pipe was raised off the floor while the forehead maintained contact with the floor. The distance between the floor and the bottom of the PVC pipe was determined using a ruler secured to a wall directly in front of the participant. This procedure was then repeated, and the greater of the two values was recorded.

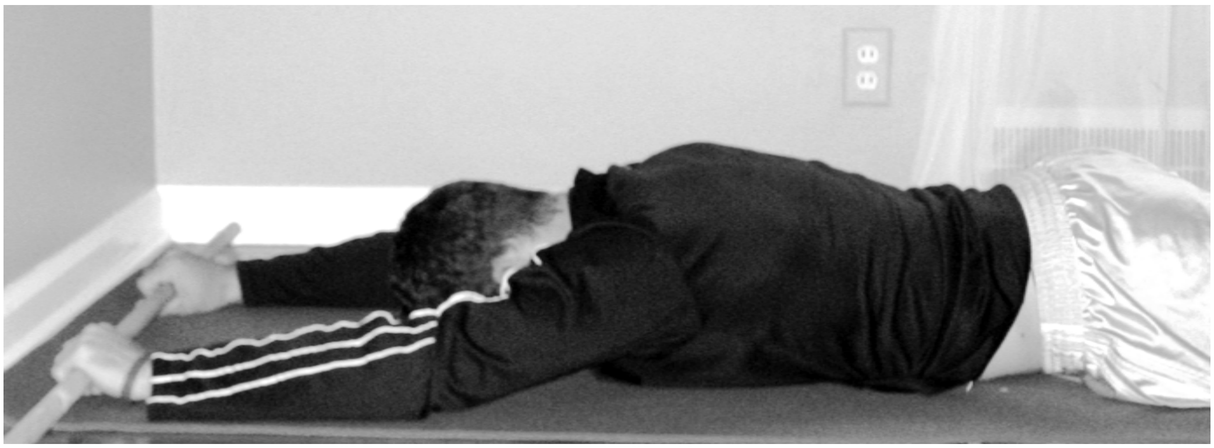

Image A

Image B

Figure 15. An assessment of shoulder flexibility using PVC pipe. Participant begins prone on the floor (a), then lifts from shoulders (b).

Leg Adductor Flexibility

This test assesses the flexibility of the leg adductors, which are an area of common injury for athletes (Verrall, Slavotinek, Fon, & Barnes, 2007). To assess adductor flexibility, participants were asked to sit upright on a Functional Training Grid (Novel Products, Rockton, IL., USA), with spine perpendicular to the floor and centered over the center of the FTG, legs together with 90˚ hip flexion in relation to the trunk, and knees in complete extension. Participants were then asked to abduct the right leg as far to the right as possible without the trunk deviating from the initial assessment position. When the participant's spine remained perpendicular over the center of the FTG, the angle made between the legs was dependent mostly upon leg adductor flexibility. If the participant moved off the center, he would be able to achieve falsely a large angle, and therefore, maintaining the initial trunk position was vital to this test's accuracy. To assess the angle, a yardstick was positioned on the medial side of the right heel, and the corresponding angle from the outer circle of the training grid was recorded. The procedure was then repeated. The greater of the two assessments was then recorded (see Figure 16).

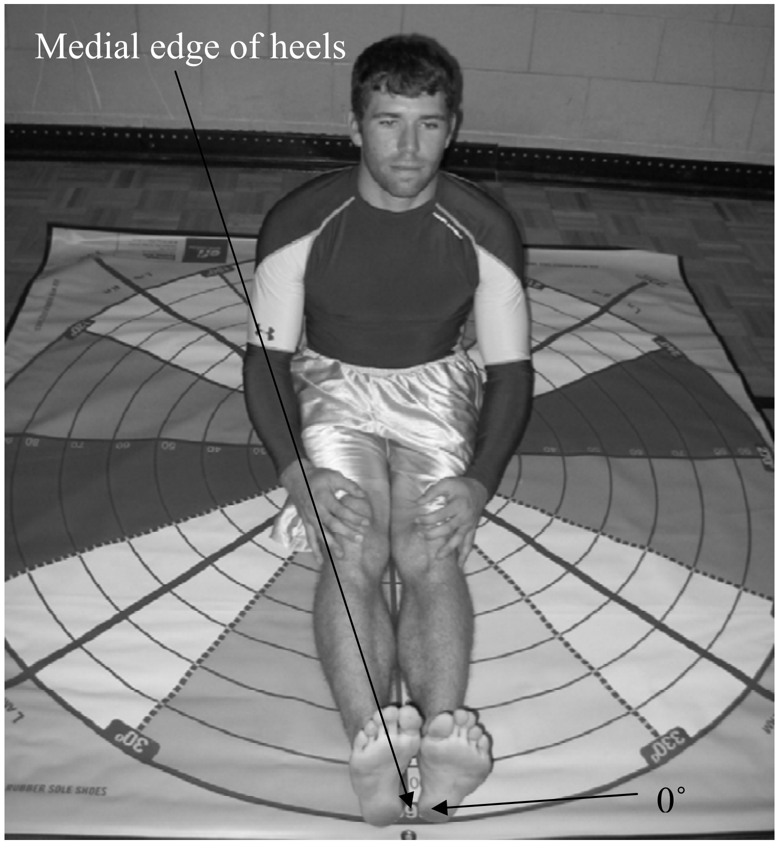

Image A

Image B

Figure 16. An assessment of leg adductor flexibility using Functional Training Grid. Participant begins with heels at 0˚ (a), then abducts right leg to the right until maximum abduction has been reached (b).

Standing Torso ROM

This test measures transverse lumbo-thoracic and hip rotation along the vertical axis with the hips in a mobile position. Because transverse hip rotation can be evaluated in combination with lumbo-thoracic mobility, this assessment may be useful to better understand how hip rotation along the vertical axis works in combination with the trunk in producing power during batting or throwing tasks, thus potentially an assessment tool of performance enhancement (Ebben, Fotsch, and Hartz, 2006).

To determine transverse lumbo-thoracic and hip rotation right in the standing position, participants were asked to stand in the anatomical position on the FTG with the posterior aspect of both heels placed along the initial reference line (90°-270° line) of the FTG. Participants were asked to face 0° with respect to the FTG with spine positioned perpendicular to the center of the grid. Participants were then asked to abduct both arms to position wrists parallel to the acromioclavicular joint, with the hand in a prone position and fingers extended. Participants were then asked to rotate the trunk as far as possible to the right about the vertical axis, while also enabling hip to rotation. A 226.8 gram plumb line was affixed to the distal aspect of the right radius and placed superior to the FTG. To determine the angular displacement, a yard stick was used to form the angle formed by the initial reference position and the maximum lumbo-thoracic rotation value. This procedure was repeated to determine standing transverse lumbo-thoracic and hip rotation right. Each procedure was performed twice in both the right and left directions, with the greater of the two measures recorded as the assessed value (see Figure 17).

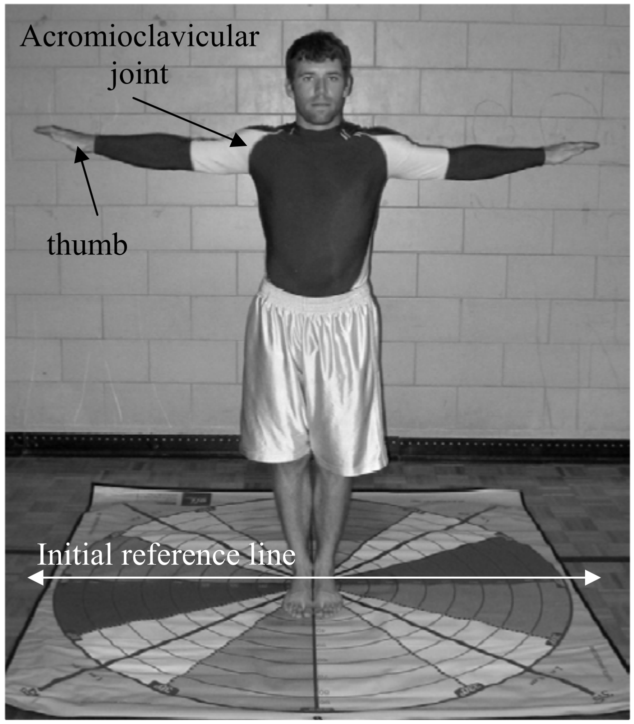

Image A

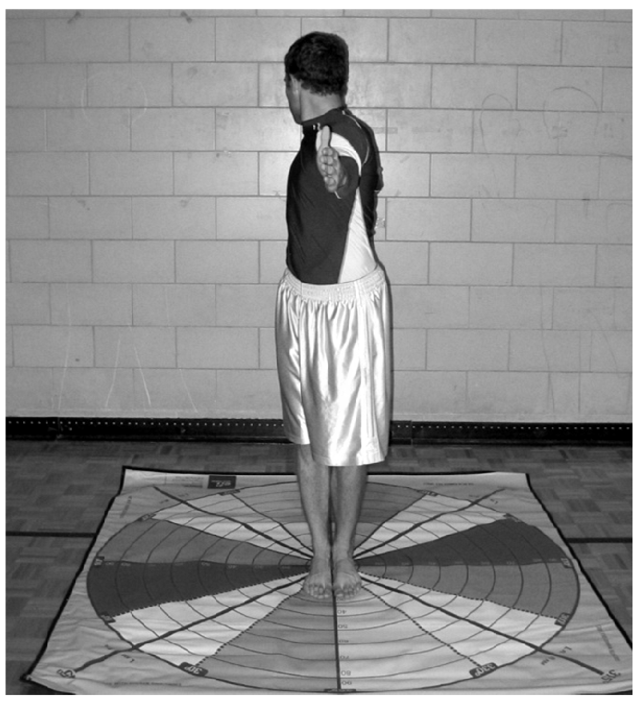

Image B

Figure 17. Assessment of standing transverse trunk and hip range of motion using the Functional Training Grid. Participant begins facing 0˚ (a), then rotates in one direction until maximum rotation has been reached (b).

Intervention

All yoga sessions were led by the primary investigator, a Yoga Alliance certified, and highly experienced individual verse in Ashtanga-style yoga. Participants performed a forty-five minute, twice-per-week, twelve-week protocol. The sessions were initiated during baseball's fall scrimmage season and continued during the off-season in preparation for the spring season. A total of twenty-five sessions were conducted during this period. Flexibility pre-and post-intervention testing were performed respectively in September and December, 2007.

Yoga Protocol

From September through December 2007, participants performed two yoga sessions per week for 12 weeks unless excused by the sports medicine staff due to illness or injury. Yoga sessions utilized varying anatomical focus and progressed in difficulty as participants became familiar with the postures. Sessions were held in a large, warm room in The Warner Building on Eastern Michigan University's campus.

The athletes arrived at the room after completing their other conditioning, bringing yoga mats that were provided for them by a donor. The participants lined up approximately in three rows of ten, all facing the same direction, with enough room in between individuals to allow for lateral arm movement. Sessions began by having the participants perform a slow dynamic sequence, which varied day to day, in order to warm up. Yoga practices were taught "coaching style" rather than by demonstration, meaning that the participants were given verbal cues to move in and out of postures with little or no visual examples. This method of teaching was used so that the instructor could watch the athletes, assuring that postures were performed correctly. (See Figure 18.)

Figure 18. Typical yoga session with instructor correcting postures among baseball athletes.

After the warm-up, the participants were led through the postures series for the day, which varied from practice to practice. The series was determined by the participants' other conditioning for the day as well as their progress in postures. Each series consisted of standing static postures linked by dynamic transition movements. After standing postures, seated postures were performed once the athletes were completely warmed up and had been through some preliminary postures. Seated postures acted as a cool-down period, and after these postures were complete, the participants were instructed to lie on their backs, close their eyes, and relax for 2-4 minutes at the end of each session. See Table 2 for posture information and Figure 19 for the posture sequence.

Table 2

Yoga Postures: Sequencing and Instructions

Warrior II

- Feet are positioned 3 1/2 to 4 feet apart.
- Abduct arms parallel to the floor, palms down, and contract arms isometrically.
- Turn right foot 30 degrees to the left and left foot 90 degrees to left.
- Align the left heel with the right heel as you isometrically contract quadriceps and rotate left thigh so that the center of the patella is in line with the center of the left ankle.
- Exhale and bend left knee over the left ankle, so that the shin is perpendicular to the floor, bringing left thigh parallel to the floor, if possible.
- Straighten right leg and press outer right heel to the floor. Don't lean torso over the left thigh: Keep the sides of the torso equally long and shoulders superior to hips. Turn the head 90 degrees to the left and look out over the fingers.

Hold for 30 seconds to 1 minute.

Extended Side Angle

From Warrior II:

- Flex torso to the left.
- Place the center of forearm on left thigh, just above knee.
- Extend right arm over head with palm facing the floor, creating a straight line from fingers through side of right ankle.

Hold for 30 seconds to 1 minute.

Warrior II

From Extended Side Angle:

- Hinge torso back to upright position.
- Return to Warrior II.

Hold for one inhale, and move to Triangle

Triangle

From Warrior II:

- Straighten left leg.
- Bring feet 6-9 inches closer together.
- Abduct arms parallel to the floor, palms down.
- Contract arms isometrically.
- Turn left foot out to the left 90 degrees.
- Align the left heel with the right heel.
- Isometrically contract quadriceps and turn your left thigh outward, so that the center of the left patella is in line with the center of the left ankle.
- Exhale and flex ribcage to the left directly over the plane of left leg.
- Press through the inner edge of the left foot and outer heel of the right foot.
- Rest left hand on shin, ankle, or the floor.
- Abduct right arm toward the ceiling, in line with shoulders.
- Head rotates toward ceiling.

Hold for 30 seconds to 1 minute.

Twisted Triangle

From Triangle:

- Place right hand either to the floor (inside or outside the foot) or onto left leg.
- Turn right foot in 45 to 60 degrees to the left and maintain the position of left foot (left 90 degrees).
- Keep both knees in extension.
- Square hips as much as possible with the front edge of sticky mat while firmly pressing into right heel.
- Head is either in neutral position or rotated towards ceiling.

Hold from 30 seconds to one minute.

Basic Lunge

From Twisted Triangle:

- Bring both hands to the ground on either side of front foot, with finger tips in line with toes.
- Step right foot back toward the back edge of mat, with the ball of the foot on the floor and left knee forming a right angle.
- Torso lengthens over front thigh.
- Look forward.
- Right knee stays in extension.
- Isometrically contract right leg.
- Stretch your right heel toward the floor.

Hold for 30 seconds to one minute.

Lunge with Twist

From Basic Lunge:

- Leave right hand on the ground.
- Abduct left hand toward ceiling so that the hand is superior to the shoulders.
- Push right hand into floor.
- Twist left chest toward ceiling.
- Head can either be in neutral or looking toward ceiling.

Hold for one minute.

Basic Lunge

From Lunge with Twist:

- Place left hand on the ground.
- Return to basic lunge.

Hold for one inhale, and move to Downward Facing Dog.

Downward Facing Dog

From Basic Lunge:

- Step left foot back in line with right foot.
- Set feet apart slightly wider than shoulders.
- Lift hips toward ceiling.
- Spread palms, index fingers parallel.
- Press into entire surface of hands.
- Extend knees.
- Press heels onto or down toward the floor.

Hold for 1 minute.

Change sides

From Downward Facing Dog, step back to the front of your mat, return to an upright position, and begin again on the opposite side.

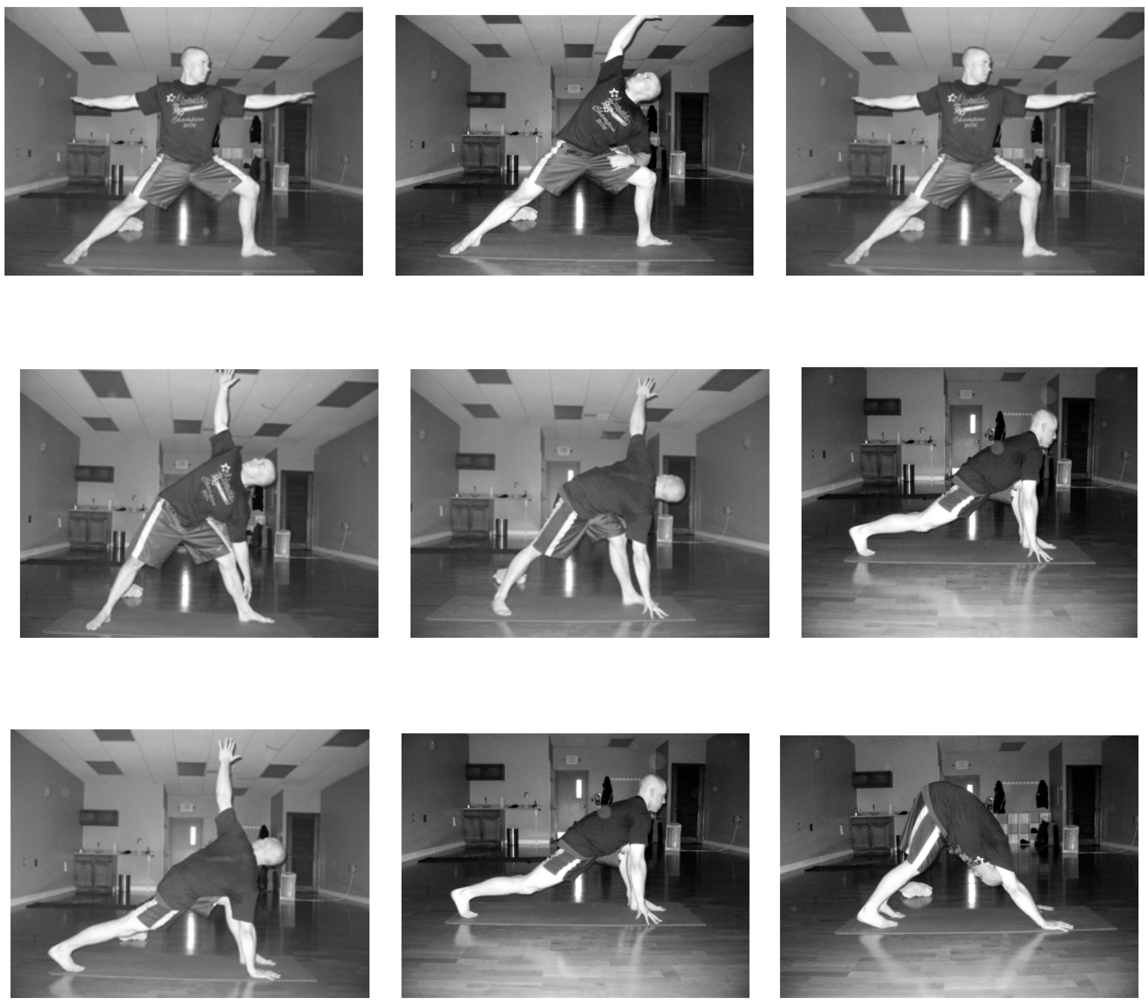

Figure 19. Progression of postures seen in Table 2 seen together as a yoga sequence.

Post-Intervention Testing

In order to determine the effects of the intervention, the same set of tests used in pre-intervention testing were performed after 25 sessions over 12 weeks had been completed. The same protocol was followed in order to assure reliability. The post-intervention testing was performed in the same room as pre-intervention, with the participants beginning with a five minute body weight squat warm up, and then each participant completing all flexibility tests. Unlike pre-intervention testing, which was scheduled over two days, post-intervention testing was performed on all participants on the same day due end of the semester requirements by the NCAA, which stipulates that all mandatory team activity must stop one week before semester final exams begin.

Statistical Analysis

In order to determine if the yoga intervention at post-intervention generated statistical significance compared to the pre-intervention conditions, a paired samples t-test was performed for each flexibility assessment: the Sit and Reach, Leg Adductor Flexibility, Shoulder Flexibility, and Standing Trunk Rotation – right and left. Statistical analysis was performed using the statistical package, SPSS 16.0 (SPSS Inc., Chicago, IL) with significance set at $p \leq 0.05$.

CHAPTER IV: RESULTS

Pre-intervention and Post-intervention flexibility testing was performed to determine if an Ashtanga Vinyasa yoga program would enhance range of motion (ROM) among NCAA Division I baseball athletes. To determine if the yoga program successfully increased ROM, the following flexibility tests were performed: Sit and Reach, Leg Adductor Flexibility, Shoulder Flexibility, Standing Trunk Rotation Right and Standing Trunk Rotation Left. Raw individual scores for each of these tests are presented in Tables 3-7. Due to an injury, one subject was excluded from the post-intervention testing for shoulder flexibility due to an injury.

The Sit and Reach Test was performed pre- and post-intervention to determine if ROM of the knee flexors, hip extensors, and lumbo-thoracic musculature changed among the subjects. For the Sit and Reach Test (cm), pre-intervention testing resulted in $M = 29.01$, $SD \pm 7.41$, $t(58) = -1.52$, and $p \leq .233$ compared to Post-intervention, which resulted in $M = 36.0$, $SD \pm 5.16$, $t(58) = -1.52$. Results of the statistical analysis reveal no significance from pre- to post-intervention. See Table 3 for each subject's raw scores.

Table 3

Individual Raw Scores for Sit and Reach Test

Subject	Pre-Intervention	Post-Intervention	Difference cm
1	53.3	23.5	-29.8
2	33.0	30.5	-2.5
3	17.8	46.4	28.6
4	36.8	49.5	12.7
5	43.2	49.5	6.4
6	15.2	29.2	14.0
7	38.1	39.4	1.3
8	38.1	40.6	2.5
9	12.7	26.7	14.0
10	30.5	30.5	0.0
11	15.2	45.7	30.5
12	55.9	50.8	-5.1
13	22.9	17.8	-5.1
14	50.8	43.2	-7.6
15	27.9	44.5	16.5
16	25.4	34.9	9.5
17	-7.6	16.5	24.1
18	30.5	30.5	0.0
19	7.6	20.3	12.7
20	45.7	47.0	1.3
21	27.9	29.2	1.3
22	72.4	69.9	-2.5
23	-10.2	10.2	20.3
24	33.0	28.6	-4.4
25	35.6	40.6	5.1
26	22.9	33.0	10.2
27	27.9	31.1	3.2
28	48.3	21.6	-26.7
29	29.2	45.7	16.5
30	58.4	52.1	-6.4

To determine what influence the Ashtanga Vinyasa yoga program had on results in increasing ROM in the inguinal region of the leg, the Leg Adductor Flexibility Test was performed pre- and post-intervention. For the Leg Adductor Flexibility Test (degrees), pre-intervention testing resulted in M =107.13, SD ± 10.82, $t(58) = -.369$, and $p \leq .908$ compared to post-intervention results in which M =108.13, SD ±10.18, $t(58) = -.369$, and $p \leq .908$. Results of the statistical analysis reveal no significance from pre- to post-intervention for the Leg Adductor Flexibility Test. See Table 4 for each subject's raw score.

Table 4

Individual Raw Scores for Leg Adduction Flexibility

Subject	Pre-Intervention (˚)	Post-intervention (˚)	Difference (˚)
1	99	98	-1
2	104	116	12
3	98	98	1
4	95	97	2
5	109	116	7
6	102	94	-8
7	102	101	-1
8	110	117	8
9	104	115	11
10	96	94	-2
11	103	104	1
12	113	108	-5
13	91	105	14
14	133	119	-14
15	124	126	2
16	106	113	7
17	104	97	-7
18	112	120	8
19	102	101	-1
20	120	104	-16
21	96	106	10
22	136	128	-8
23	105	101	-4
24	111	109	-2
25	107	112	6
26	113	105	-8
27	115	107	-8
28	103	109	6
29	90	94	4
30	111	130	19

To determine what influence the Ashtanga Vinyasa yoga program had on results in increasing shoulder ROM, the Shoulder Flexibility Test was performed pre- and post-intervention. For the Shoulder Flexibility test (cm), pre-intervention testing resulted in M = 29.7, $SD \pm 7.9$, $t(57) = -2.21$, and $p \leq .209$ compared to post-intervention, which resulted in M =34.9, $SD \pm 9.9$, $t(57)$, $p \leq .209$. Results of the statistical analysis reveal no significance from pre to post intervention for Shoulder Flexibility. See Table 5 for individual raw Shoulder Flexibility results.

Table 5

Individual Raw Scores for Shoulder Flexibility

Subject	Pre-intervention (cm)	Post-intervention(cm)	Difference (cm)
1	34.3	35.6	1.3
2	39.4	40.6	1.3
3	27.9	30.5	2.5
4	27.9	15.2	-12.7
5	38.1	40.6	2.5
6	22.9	27.9	5.1
7	38.1	53.3	15.2
8	25.4	27.9	2.5
9	22.9	38.1	15.2
10	30.5	33.0	2.5
11	17.8	27.9	10.2
12	35.6	40.6	5.1
13	12.7	19.1	6.4
14	25.4	33.0	7.6
15	26.7	27.9	1.3
16	24.1	38.1	14.0
17	27.9	24.1	-3.8
18	20.3	20.3	0.0
19	35.6	27.9	-7.6
20	43.2	53.3	10.2
21	30.5	--	--
22	45.7	53.3	7.6
23	34.3	41.9	7.6
24	36.8	40.6	3.8
25	22.9	38.1	15.2
26	27.9	38.1	10.2
27	21.6	27.9	6.4
28	35.6	40.6	5.1
29	20.3	27.9	7.6
30	30.5	48.3	17.8

Note. Subject 23 was eliminated from post-intervention testing due to an injury.

To determine what influence the Ashtanga Vinyasa yoga program had on results in increasing standing trunk rotation ROM, the Standing Trunk Rotation Right Test was performed pre- and post-intervention. For the Standing Rotation Right (degrees), pre-intervention testing resulted in M =195.47, SD ±16.48, $t(58) = -2.26$, and $p \leq .477$ compared to post-intervention, which resulted in M = 205.93, SD ± 19.26, , $t(58) = -2.26$, and $p \leq .477$ Results of the statistical analysis reveal no significance from pre- to post-intervention. See Table 6 for individual raw scores for each subject.

Table 6

Raw Individual Scores for Standing Trunk Rotation to the Right

Subject	Pre-intervention (˚)	Post-intervention (˚)	Difference (˚)
1	180	180	0
2	205	207	2
3	195	195	0
4	177	222	45
5	223	228	5
6	181	190	9
7	181	220	39
8	185	190	5
9	187	199	12
10	189	185	-4
11	190	235	45
12	190	210	20
13	223	220	-3
14	215	215	0
15	182	208	26
16	185	210	25
17	174	177	3
18	170	208	38
19	195	195	0
20	212	245	33
21	209	207	-2
22	184	189	5
23	209	225	17
24	195	188	-7
25	187	160	-27
26	196	205	9
27	212	215	3
28	241	240	-1
29	199	210	11
30	193	200	7

To determine whether the Ashtanga Vinyasa yoga program provided significant results in increasing standing trunk rotation ROM, the Standing Trunk Rotation Left Test was performed pre- and post-intervention. For the Standing Rotation Left (degrees), pre-intervention testing resulted in $M = 201.47$, $SD \pm 12.85$, $t(58) = -1.58$ and $p \leq .342$, compared to post-intervention, which resulted in $M = 207.47$, $SD \pm 16.29$, $t(58) = -1.58$ and $p \leq .342$. Results of the statistical analysis reveal no significance from pre- to post-intervention for the Standing Trunk Rotation Left. See Table 7 for each subject's individual raw score.

Table 7

Raw Individual Scores for Standing Trunk Rotation to the Left

Subject	Pre-intervention (˚)	Post-intervention (˚)	Difference (˚)
1	218	194	-24
2	203	197	-6
3	207	204	-3
4	187	204	17
5	223	223	0
6	201	188	-13
7	191	214	23
8	186	203	17
9	185	205	20
10	188	185	-3
11	221	240	19
12	207	210	3
13	191	202	12
14	220	214	-6
15	187	200	14
16	190	207	17
17	201	185	-16
18	189	202	13
19	196	180	-16
20	203	225	22
21	214	225	11
22	199	188	-11
23	201	225	24
24	204	207	3
25	211	208	-3
26	195	206	11
27	236	245	9
28	201	237	36
29	191	197	6
30	198	204	6

CHAPTER V: DISCUSSION

As the number of NCAA baseball participants has increased, so have the number of injuries and the percentage of those injuries considered to be severe (Dick, Sauers, et al., 2007). Of these severe injuries (considered ten or more consecutive days of lost participation time), many are also categorized as non-contact injuries. Non-contact injuries may include “pulled” hamstrings or quadriceps, “rolled” ankles, back or oblique strains, and various shoulder and elbow injuries. Some experts in the area of baseball injury believe that some of these non-contact injuries may be preventable by following an appropriate flexibility program (Fleisig, Andrews, Dillman, & Escamilla, 1995; Sauers, August, & Snyder, 2007; Whiteley, 2007).

Currently, the predominant research on flexibility has focused on an acute bout of stretching prior to athletic performance, with a single bout of stretching or a short duration design. In addition, most research has utilized untrained participants rather than physically conditioned athletes. Research exploring the effects of stretching at regular intervals for injury prevention among athletic populations is necessary in order to determine if chronic stretching is a viable and an effective component of training. This study was designed to examine the longitudinal impact of a sport-specific yoga program on the enhancement of segment ROM and its effect upon the incidence of non-contact injuries among NCAA Division I baseball players.

The frequency and types of injuries during the study were compared to those figures collected during the course of an entire baseball season, pre-season to pre-season. In order to examine the overall trends in injuries, data were also collected pre-intervention in Fall of

2006, through the intervention period in Fall 2007, and until the post-intervention in Fall 2008.

All injury data for the participants were grouped into the following categories: upper extremity injuries, lower extremity injuries, and lower back injuries. Upper extremity injuries included, but were not limited to, the following: elbow strain, infraspinatus strain, medial elbow strain, biceps tendonitis, teres minor strain, biceps tendon strain, triceps strain, biceps short head tendonitis, shoulder rotator cuff strain, supraspinatus impingement, shoulder subluxation, ulnar collateral ligament (UCL) sprain, proximal trapezius strain, biceps tendonitis, upper trapezius strain, shoulder soreness (when it led to missed participation), and common flexor tendon strain.

Lower extremity injuries included, but were not limited to, the following: ankle sprain, groin strain, hamstring strain, dorisflexor tendon strain, plantar fasciitis, biceps femoris strain, ACL, and mid foot sprain. Lower back injuries included, but were not limited to, mid-back spasm and chronic low back pain.

Range of Motion Tests

Sit and Reach. Although results for the sit and reach assessment were found to be statistically non-significant, an improvement with a mean value of 7 cm was seen from pre-invention (M = 29.01 cm, SD ±7.41) to post-intervention (M =36.0 cm, SD ± 5.16). This represents an approximate 24% improvement in the mean. The sit and reach test measures the flexibility of the knee flexors, hip extensors, and lumbo-thoracic musculature during forward trunk flexion. Based upon the observations of Witvrouw et al. (2003), who found that soccer players who exhibit poor hamstring flexibility possessed an increased risk of developing lesions within that muscle group, the results of the Sit and Reach test may indicate those baseball players at highest risk for hamstring injuries. Knee flexor flexibility is vital for several movements in the game of baseball for all positions. For example, flexible hamstrings are necessary for sprinting actions, the follow-through phase of pitching, and fielding ground balls. While the emphasis of this flexibility program was on preventing injuries, there are also performance or skill-enhancing factors that may be improved by increasing knee flexor ROM.

Leg Adductor Flexibility Test. While the t-test results were statistically non-significant, a modest improvement with an average mean of one degree was demonstrated with pre-intervention testing results (*M* =107.13 degrees, *SD* ± 10.82), compared to post-intervention results in which (*M* =108.13 degrees, *SD* ±10.18). A large increase in leg adductor flexibility was not anticipated at the outset as groin stretching was already a strong component of the team's typical flexibility training.

Shoulder Flexibility Test. The t-test results were statistically non-significant, but an improvement in average mean of 5 cm was observed from pre-intervention (*M* = 29.7 cm, *SD* ± 7.9) to post-intervention, (*M* =34.9 cm, *SD* ± 9.9). This improvement equates to a mean 14.49% improvement during the course of the intervention. As discussed extensively in earlier chapters, maintaining or improving shoulder flexibility is seen as an important injury prevention technique among coaches and athletes. It has also been shown that a decrease in shoulder flexibility can lead to a loss in throwing velocity among pitchers, while enhancing shoulder ROM leads to increased external rotation during the late-cocking phase, early acceleration, and increased throwing velocity (Huffman et al., 2006). For all overhead throwing athletes, particularly baseball pitchers, shoulder flexibility represents perhaps one of the most important aspects of injury prevention and performance enhancement.

Standing Trunk Rotation Right and Left. The t-test results for both right and left sides were statistically non-significant. However, in the Standing Rotation Right, there was an improvement in average mean of 10 degrees from pre-intervention (*M* =195.47 degrees, *SD* ±16.48), compared to post-intervention (*M* = 205.93 degrees, *SD* ± 19.26). For the Standing Rotation Left, there was a more modest improvement in average mean of 6 degrees, from pre-intervention testing (*M* = 201.47 degrees, *SD* ±12.85) to post-intervention (*M* =207.47 degrees, *SD* ±16.29). The disparity on the left side may be due to the fact that the left side average was 6 degrees greater at pre-intervention. Aside from potential protection against oblique and lower back strains, trunk rotation is an important component of both pitching and batting, and rotary trunk flexibility may have some bearing on performance.

Injury Data

Lower Extremities. During the Winter/Spring Season 2007, groin strain was listed among the types of injuries seen among positions players, but it was the only mention of any groin injuries in all pre-and post- intervention data. The lack of overall improvement in leg adductor flexibility along with the minor incidence of groin injuries among the participants may suggest that they were already at the maximum level of leg adductor flexibility at the beginning of the yoga intervention. When examining the decrease in lower extremity injuries at post-intervention, a more likely source for decreasing injuries was the decrease in hamstring injuries. Hartig and Henderson (1999) found that a stretching program of three minutes, three times per day over thirteen weeks resulted in an average increase in hamstring flexibility of 7% as well as a decrease of 12% in lower extremity injuries. The average mean of hamstring flexibility in the current study improved by 24%. Although data for specific injuries were not provided, based on the findings of Hartig and Henderson along with the sharp decline in lower extremity injuries, it appears that increased hamstring flexibility among the participants may have had a profound effect upon injury rate.

During the 2007 Winter/Spring Baseball Season (pre-intervention), lower extremity injuries were responsible for 3 missed practices, 54 limited practices, and 4 missed events (see Table 8). During the 2008 Winter/Spring Baseball Season (post-intervention), lower extremity injuries were responsible for 9 missed practices, 3 limited practices, and 14 missed events. As indicated in Table 8, post-intervention testing shows less variety in injuries than pre-intervention, suggesting that the intervention may have eliminated some types of injury. During the 2008 season, all 9 missed practices and 12 of 14 missed events came from among the pitching staff exclusively. In fact, although the official injury data from the sports medicine staff were not separated into missed events and missed practices by each subject, it was revealed that most of the missed practices and events came from just one subject alone. Therefore, as most of the lower extremity injuries occurred among very few players, the majority of the team experienced an overall decrease in lower extremity injuries. The overall trend shows a sharp decline in lower extremity injuries when the one subject responsible for a majority of the missed events and practices is excluded. For future considerations, it would be interesting to track injuries, limited practices, and missed opportunities to each subject in order to examine which injuries were responsible for the predominance of missed time.

Table 8

Lower extremity injuries – All Seasons

Intervention Period	Season	Players	Practices Missed	Practiced Limited	Events Missed
Pre-intervention	Fall 2006	Pitchers	0	0	0
		PP	4	19	1
Pre-intervention	Winter/Spring 2007	Pitchers	0	0	0
		PP	3	54	4
During Intervention	Fall 2007	Pitchers	0	2	0
		PP	0	2	0
Post-intervention	Spring/Winter 2008	Pitchers	9	0	12
		PP	0	3	2
Post-intervention	Fall 2008	Pitchers	0	0	0
		PP	0	0	0

Note. PP designates all players other than pitchers

Upper Extremity Injuries. From the 2007 pre-intervention Winter/Spring Season to the post-intervention 2008 Winter/Spring Season, the number of missed practices decreased by 51%, the number of limited practices increased by 31%, and missed events decreased by 76% (see Table 9). Although there was an increase in the number of limited practices due to upper extremity injuries, the substantial decrease in missed practices and missed events may infer that the severity of the injuries decreased, thus allowing more practices/events that were simply limited rather than missed altogether. Less severe injuries allow players to return to participation sooner or take part in limited participation, unlike severe injuries. The linear progression of all of the data taken together shows an overall trend in which upper extremity injuries were declining. As shown in Table 9, upper extremity injuries among these participants primarily affected members of the pitching staff. Successful pitching rotation often determines the outcome of a team's season, and the importance of maintaining the health of these athletes cannot be underestimated within the game of baseball.

Table 9

Upper extremity injuries

Intervention Period	Season	Players	Practices Missed	Practiced Limited	Events Missed
Pre-intervention	Fall 2006	Pitchers	0	17	0
		PP	0	12	0
Pre-intervention	Spring 2007	Pitchers	39	15	50
		PP	0	1	0
Intervention	Fall 2007	Pitchers	41	17	0
		PP	10	20	0
Post-intervention	Spring 2008	Pitchers	19	21	12
		PP	0	0	0
Post-intervention	Fall 2008	Pitchers	3	18	0
		PP	22	0	0

Note. PP designates all players other than pitchers

Lower Back Injuries. One of the categories of injury designated by the athletic training staff included lower back injuries, but as seen in Table 10, the incidence of lower back injuries was quite low at both pre-intervention and post-intervention; thus, it cannot be determined what effect, if any, this stretching program had on lower back injuries. However, while the incidence of missed events due to lower back injuries was rare, complaints of lower back discomfort among the subjects was common. Although the yoga program may not have provided any impact on mitigating lower back pain, it may have relieved discomfort, allowing the subjects to participate in practices and games with an enhanced sense of physical well-being, which in turn may influence performance.

Table 10

Lower Back injuries

Intervention Period	Season	Practices Missed	Practiced Limited	Events Missed
Pre-intervention	Fall 2006	0	5	0
Pre-intervention	Winter/Spring 2007	0	0	0
During intervention	Fall 2007	0	0	0
Post-intervention	Spring/Winter 2008	0	0	0
Post-intervention	Fall 2008	0	1	0

Matters of Concern

When working with untrained participants, the researcher can request that subjects refrain from other physical activity, and communication takes place directly between researcher and subjects. Working with NCAA athletes as participants, however, requires communication and cooperation with coaching staff, strength and conditioning staff, athletic trainers, as well as compliance with NCAA regulated mandatory team activity time. Utilizing NCAA student-athletes as participants can introduce a complex network of time schedules and regulations, which can significantly affect the results of a study.

One such limitation of this study regarding the NCAA system was working with regulated mandatory time for team activities. Under NCAA regulations, student-athletes are allowed to participate in only a set number of hours of practice and competition hours each week, specifically 20 hours during the playing season and eight hours off-season. Coaches must also allow players one day off during the season and two days off during the off-season. Within these set hours, coaches need to schedule all practice, conditioning, and game-playing time. The yoga program for this study counted towards conditioning time and required that time otherwise allotted to skills practice or strength training be shifted to stretch conditioning. Not only did this time allotment require the cooperation of the strength and conditioning coaches, but it also limited the time that could be devoted to stretch conditioning to 1.5 hours each week. Under these circumstances, sessions were spaced three days apart, which allowed too much time for the participants' muscles to recoil to their original length. Under ideal circumstances, stretch conditioning would have been at least three times per week for forty-five minutes, or a total of 2.25 hours each week, in order to maintain some of the muscle length accrued during the yoga sessions.

Another limitation of this study pertains to schedule coordination with technical (skill) and strength training. Ideally, yoga should be performed when the athletes have finished with their other physical conditioning so that their muscle temperature and heart rate are elevated and muscles have increased blood flow. It can also be argued that stretch conditioning should be performed after other conditioning because it may have a temporary adverse effect on force production as mentioned in Chapter 2 in the section regarding stretch-induced force deficit (Ce et al., 2008; Herda et al., 2008; McHugh et al., 1999; Ryan et al., 2008). During the intervention period, all yoga practices were scheduled immediately after other conditioning sessions, which meant that sometimes yoga practices were performed later into the evening. By 9:30pm, the athletes were usually tired and did not always give their fullest participation to the yoga practice. The yoga practices were also always held in one particular building, which sometimes meant the athletes were in that building for skills work, but other times meant that the athletes had to drive to the building from strength conditioning, which allowed too much time for the athletes to cool down and lose motivation. Under these circumstances, it is possible that the study's results were affected by lack of complete effort on the part of the participants.

Along with possible effects from scheduling challenges, another factor that likely had a great impact on the post-intervention testing was an end-of-the-semester scheduling conflict with strength and conditioning. Unknown to the researcher, strength and conditioning had scheduled their end of the semester "one rep max" tests the day before the yoga study's post-intervention ROM testing. One rep max testing measures the athlete's strength by having them left as much weight as they can for one repetition. This maximum lift is performed after a warm-up in which an athlete would lift a large percentage of that goal weight. For example, an athlete might start with warming up with 85% of his previous maximum weight in a back squat, then attempt his previous maximum weight, and then add weight 5 or ten pounds at time until he can lift no more. As this type of testing is extremely strenuous, it often causes DOMS. DOMS is often accompanied by muscle edema, which can limit ROM (Boyle et al., 2004). Post-intervention testing the day after one rep max testing may have been adversely affected due to DOMS. Better communication with the Strength and Conditioning coaches might have prevented this result.

The relationship with the practice of yoga and performance testing was confirmed serendipitously. After examining the data to look for a possible relationship between the athletes who missed the most yoga sessions (usually due to class schedule conflict) and those athletes who experienced a decrease in ROM in post-intervention testing, it was discovered that the athletes who lost ground were some of the most consistent and hardest-working athletes in the group. At first glance, this fact may seem confusing, but when considering that the hardest-working athletes in yoga sessions were also usually the hardest-working athletes in the weight room, and given the fact that they had performed their one rep max testing the day before post-intervention testing, it becomes clear that the data may reflect their efforts in the weight room. Although the weight room data were not an official component of this study, the athletes who lost ROM made up most of the highest performers in the one rep max testing, with one of the them setting the team record in the back squat. In future research, understanding the timing of other conditioning sessions and testing may have a tremendous impact on study results. This point cannot be overemphasized.

Ideal Yoga Session Schedule and Environment

In light of the possible effects on results from the circumstances of this study, the parameters for creating a more ideal yoga practice protocol for athletes has become clear. Scheduling would be similar to this protocol in that all sessions would be scheduled after conditioning, except that the ideal location would always be in the same building as conditioning so that there would not be enough time to cool down or lose motivation.

Yoga would be scheduled after strength conditioning, which is usually scheduled during the day or early evening, leaving room for a yoga practice afterwards before the athletes are too tired or distracted. There would be a twenty-minute break between strength conditioning and yoga in which the athletes would be encouraged to drink a glass of water and eat a small amount of food (a banana or half a granola bar) to help them maintain energy for yoga. Sessions would take place in a warm, but not hot, private room. Locker rooms that can accommodate the entire team work well. Strength and Conditioning coaches would be consulted to coordinate body region emphasis and to schedule any necessary ROM testing.

Under ideal circumstances, the yoga program would not only be sport-specific but also position-specific. It would address both the performance needs and most common injuries associated with each of the sport's positions. For example, the yoga posture Parivrtta Ardha Chandrasana, which was referred to as Pitcher's Twist in this program, mimics the movement seen during the follow-through stage of baseball pitching (see Figure 19). While much attention is paid to the initial phase of pitching in conditioning sessions, it is important to remember that the entire process of pitching represents a dynamic kinetic chain movement. The initial force generated in the first stages of pitching are generated through ROM of the throwing shoulder and elbow, while during the final stage of pitching, force is generated through forward acceleration and transverse rotation of the trunk. This forward acceleration must be halted once the ball is released, which is accomplished by transferring the force into the “landing” or “breaking” leg. In order for a high velocity ball release to occur at the same time as breaking forward acceleration, there must be ROM compatibility between the breaking leg’s hip musculature, hamstrings, and trunk rotation, which makes the Pitcher’s Twist a highly position-specific posture. By separating the team into position-specific groups, it is possible that the overall results for both performance enhancement and injury prevention would be improved.

Pitcher’s Twist

Final phase of pitching

Figure20. Position specific yoga posture compared to the final phase of pitching in a game situation.

First image retrieved from http://www.yogaartandscience.com/poses/Standing%20Poses/parchand/parchand.html retrieved 4/29/09. Bottom image from http://www.clarionledger.com/misc/blogs/mkester/uploaded_images/ Baseball_pitching_motion_2004-709207.jpg retrieved 1/29/2009

Compared to Other Works in the Area

This study adds to what is currently a very small body of knowledge. Peer-reviewed studies on yoga are scarce: searches in multiple data bases found only two studies on yoga applicable to the field of exercise science. As it has become popular, it is not unusual to read articles in various magazines and newspapers that mention athletes and teams using yoga as part of their conditioning program. However, no study to date utilizes elite athletes as subjects, thus the potential benefits or risks of a yoga-based stretching program for athletes have been based upon anecdotal evidence.

An examination of these two peer-reviewed studies in detail results in several interesting differences from the present study. The most notable difference between these three studies is that they each utilized a different style of yoga. For people unfamiliar with yoga, there are vast differences between styles. Similar to resistance training, in which there can be considerable different philosophies that fall under one category, the same concept applies to yoga.

Boyle et al. (2004). In their study of the effect of yoga on DOMS, Boyle et al. (2004) utilized Kripalu style yoga. Kripalu yoga focuses on "perfect alignment" meaning that all students are instructed to perform yoga postures the same way despite anthropometric differences. Along with utilizing a different style of yoga, the other main difference between the Kripalu study and the current study is the subject population.

One of the limitations of this study was that the subjects were all women 38 ±2.6 years of age. The subjects were divided into those previously trained in Kripalu yoga and those who were untrained. All subjects were considered physically active, although the details of what constituted "physically active" were left unclear. Another limitation is that the subjects who had been previously trained in Kripalu yoga were not trained by the researchers, which leaves many variables concerning their training unanswered. And, although the study by Boyle et al. (2004) gave explicit details of their DOMS-inducing protocol, their one-time yoga protocol for reducing soreness was not detailed. Although their results showed promise, the dissimilarities between the Kripalu subjects and elite athletes makes extrapolating their results to an athletic population unlikely.

One similarity between the current study and that of Boyle et al. (2004) is that they both address a form of injury prevention. DOMS is a form of muscle trauma and/or damage at the level of the connective tissue and cell and is a type of injury. Boyle et al. examined how a regular yoga practice affected this type of injury, although not through an intervention protocol. The Kripalu study sought to answer whether yoga alleviated symptoms of muscle damage after it had been induced, whereas the present study sought to examine if a regular yoga program could halt injuries before they occurred.

Hart and Tracy (2008). The purpose of Hart and Tracy's 2008 study examined the effects of Bikram yoga on strength, balance, and steadiness. Hart and Tracy found substantial improvements in one-legged balance and modest improvements in strength among their participants. Hart and Tracy utilized Bikram yoga, which repeats the same twenty-six postures in the same sequence without variation and is performed in a room heated between 105-120 degrees Fahrenheit. Similar to Kripalu, Bikram encourages participants to follow an alignment based philosophy which dismissed anthropometric differences.

Hart and Tracy's (2008) study on Bikram yoga had younger subjects than the Kripalu study, but their youngest subjects were still older than a collegiate population. Their subjects were 10 men and 11 women, 29 ±6 years. One major limitation of this study was that the subjects were described as non-athletic, with only 2 of 21 reporting any regular physical activity for the three months previous to the study. While these subjects may better reflect the general population, they do not reflect the physical attributes of trained athletes, and, therefore, applying their results to an athletic population may be tenuous at best.

The Current Study. Ashtanga Vinyasa yoga differs from both Kripalu and Bikram yoga in that it acknowledges the uniqueness of each body's physique, is performed in a warm, but not hot, room, and utilizes a multitude of postures that may be changed in sequencing, time held, and which postures are included in a given practice. The overall difference is the capacity for adaption to its practitioners. Every human body is different: We are defined not only by age and gender, but also by individual musculature and bone structure, past injuries, body fat composition, and ways in which we use our bodies in our daily lives. Athletes in particular are distinct from the general population in that they require from their bodies relatively extreme levels of force production, muscular endurance, ROM and repetitive stress. Because Ashtanga Yoga can be adapted to these individual needs, it represents the best means of promoting flexibility for athletic populations.

The current study's participants were all male baseball athletes, 19.42 ±1.37 years. Their training included strength, speed, and agility training as well as specific skill work associated with the sport of baseball. The study presents a unique population in that, as student athletes, these subjects' training schedule and protocols were recorded, removing some of the vagueness of what constitutes "physically active" seen in the other studies. As trained athletes, these subjects' results are more applicable to other athletes than results from the untrained subjects from the other studies.

Although each of these three studies utilizes yoga, when looking at them together, it becomes clear that this is an area of research in its infancy. There are interesting and promising trends: a yoga-based stretching program may have the ability to enhance ROM, balance, and strength; decrease DOMS symptoms, and even prevent injury. The three studies together also cause questions to arise: do all styles have the capacity to prevent injuries, how do the ages of the subjects affect results, and are athletes more adaptable to the benefits than non-athletes? Given the beneficial relationship between a yoga practice and various forms of physical enhancement seen in these three studies, an argument can be made for more detailed and longitudinal studies in this area.

Future Research

The use of yoga in sport conditioning is a novel area of research, and there are many possible directions for future research. Adhering to the research questions of this particular study, further investigations may want to begin by adding a control group to create a true experimental design. Although it is difficult to promote this concept among players on the same team, the importance of the research on injury prevention makes an attempt worth the effort. If were unlikely to maintain a control group on one team, perhaps having a control group from another institution within the same division is viable. It would be important to have a control group consisted of the same caliber of athletes that ensure that any differences in outcome was not the results of inequities in physical conditioning rather than the outcome of the intervention.

As suggested earlier, another adaptation would be to make the ROM testing and subsequent yoga protocols position-specific within the sport. For example, pitchers, outfielders, and infielders often have different strength training and conditioning drills from one another. Making the stretch program more specifically designed by position may have an impact on results. Although the current study examined posterior shoulder flexibility, adding external and internal rotation assessments would be of great value considering the emphasis placed on these movements for both injury prevention and performance enhancement by experts in the field (Lintner et al.; Myers et al.; Flesig et al,; Huffman et al.; Sauers et al., 2007; Crawford & Sauers, 2006; Whiteley, 2007). Although all of these studies suggest that maintaining shoulder ROM, particularly internal rotation, can help prevent shoulder injuries, there is no study to date that directly examines that relationship. In future research, an experimental approach to the line of thinking could prove extremely beneficial for all levels of overhead throwing athletes.

If engaging in a longitudinal study, looking not only at the number of injuries, but also the duration of days on the Disabled List for both contact and non-contact injuries would be interesting to see if yoga helps decrease the severity of injuries or even accelerates the healing process. One could also examine the length of participation in a yoga program to see if duration effects rate of injuries or rate of recovery. If, for example, you had a program at the collegiate level that lasted three years, the players who have been participating for three years (Juniors and Seniors) could be compared to the two-year participants (Sophomores) to the one-year participants (Freshmen) to a control group to look for a longitudinal interaction.

Summary

Upon completion of this study, a pattern emerged that potentially demonstrates the dual importance of flexibility training. There was an improvement in player performance, leading to a Mid-American Conference 2008 championship that was matched by a substantial decrease in injuries. Although the improvement in performance cannot be directly linked to the decrease in injuries, it stands to reason that when players are injured, they cannot perform as well as they can when healthy or not at all if they are on the Disabled List (DL). Beyond injury statistics, what cannot be quantified is the sense of physical well-being and ease of movement that this yoga program induced among the players and the potential impact those elusive factors had on the players' performances. Perhaps it is becoming clear that flexibility training for injury prevention is in fact performance enhancement, and that this component of physical training needs more emphasis.

Through assessment of these data, athletic trainers, conditioning coaches, baseball coaches, and athletes may be able to adjust training routines to reduce the incidence of injury, while enhancing flexibility for potential gains among various performance parameters. For activities like baseball, in which numerous games are played in close succession, reducing overall injuries and recovery time may enhance performance and collective team outcomes. The results of this study have the potential to help athletes, trainers, and coaches decide if a regular yoga program will help enhance performance and maintain the physical health of baseball players.

This study sought to answer whether a sport-specific yoga program as a regular component of training affects enhancing baseball relevant ROM among Division I baseball athletes with the purpose of preventing non-contact injuries. In this preliminary study, trends seen in both non-contact upper and lower extremity injuries suggest that the intervention did have a beneficial effect in reducing the number of injuries and possibly severity of injuries. Future research is needed to better assess the relationship between a consistent sport-specific stretch program and prevention of non-contact injuries, but these initial results are promising.

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APPENDICES

Appendix A

IRB Approval

EASTERN MICHIGAN UNIVERSITY

10 October, 2007

Julie Biernat McLean
Anthony Moreno, Ph.D.
School of Health Sciences
Eastern Michigan University
Ypsilanti, MI 48197

Dear Ms. McLean

The CHHS Human Subject Review Committee has reviewed your request for approval of the study entitled "The Influence of Yoga on Physical Performance Characteristics of NCAA Division I Baseball Athletes". The committee unanimously approved the study with the following changes. The Informed Consent Form needs to clarify why this study is being done and the length of time the study will be conducted and the frequency of the yoga treatment.

Sincerely,

George U. Liepa Ph.D.
Co-Chair, CHHS Human Subjects Review Committee

Appendix B

NCAA Physical Exam

Student Name: ______________________ Sport: ______________ Date: ______

E ID #: ______________ SSN: ______________ Age: ______ Date of Birth: ______

Family Physician: ______________________ Physician's Phone: ______________________

EASTERN MICHIGAN UNIVERSITY
Sports Medicine

Pre-Participation Physical Evaluation

CONFIDENTIAL INFORMATION

EMU Certified Athletic Trainers, under the direction of the Team Physicians withhold the right to allow for full participation in intercollegiate athletics at any time. Any diagnostic testing necessary to determine your fitness to participate fully will be your own financial responsibility.

Revised may 08

Eastern Michigan University - Annual Medical Review for Athletic Participation Clearance

Student-Athlete's Name: ______________________ Student #: ____________ Sport(s): ____________

Participation in sport requires an acceptance of risk of injury. Athletes rightfully assume that those who are responsible for the conduct of sport have taken reasonable precautions to minimize such risk and that their peers participating in the sport will not intentionally inflict injury upon them.

Periodic analysis of injury patterns lead to refinements in the rules and other safety decisions. However, to legislate safety via a rule book and equipment standards, while often necessary, seldom is effective by itself, and to rely on officials to enforce compliance with the rule book is as insufficient as to rely on warning labels to produce compliance with safety guidelines. "Compliance" means respect on everyone's part for the intent and purpose of a rule or guideline.

Health Questionnaire

This annual form must be completed and returned before the student-athlete will be permitted to practice or compete. The National Collegiate Athletic Association's (NCAA) policies recommend that all student-athletes have a qualifying medical evaluation upon initial entrance into an institution's intercollegiate athletic program, and an annual "health-status" review. Eastern Michigan University supports this NCAA policy. Further medical evaluations may be required for specific matters.

Date of initial medical (physical) evaluation: ______________________

Date of most recent medical review (for upper class): ______________________

1. Have you been hospitalized or have been seen by a physician for a major/minor illness since the most recent above medical evaluation? Explain: ______________________ YES / NO
2. Are you currently injured or ill in any way? Do you currently have any incompletely healed Injury(s)? Explain ______________________ YES / NO
3. Have you had a major injury (including head/neck injury) since the most recent above medical evaluation? Explain: ______________________ YES / NO
4. Are you currently taking any dietary/nutritional supplements, or vitamins? (ie: creatine, Protein supplements, energy enhancement, etc) Explain: ______________________ YES / NO
5. Are you taking any medication on a regular or continuing basis? Explain: ______________________ YES / NO
6. Are you currently taking any short-course medication for specific current illness/injury/conditions? (ie: Asthma, ADHD, Epilepsy, etc.) Explain: ______________________ YES / NO
7. Do you know of, or do you believe that there is any health reason why you should <u>not</u> participate in the Eastern Michigan University Intercollegiate Athletic Program at this time? Explain: ______________________ YES / NO
8. Do you need to meet with a team physician for any reason at this time? Explain: ______________________ YES / NO

I ______________________ understand that I must refrain from practice/participation while ill or injured, whether
Student-Athlete's name (print)
or not receiving medical treatment, and during medical treatment until I am discharged from treatment or am given permission by the clinical practitioner to restart participation despite continuing treatment. I also understand that having passed the physical examination does not necessarily mean that I am physically qualified to engage in athletics, but only that the evaluator did not find a medical reason to disqualify me at the time of examination.

I certify that the answers to the above questions are accurate and true.

Student-Athlete's Signature: ______________________ Date: ____________

Blood Pressure: _____/_____ **Pulse:** ________ **Height:** ________ **Weight:** ________

Female Student-Athletes Only

At what age was your first menstrual cycle? _______years
How many days does your cycle last? _______days
How many days between cycles? _______days
How many periods have you had in the past 12 months?
Have you ever had "irregular" cycles? .... YES / NO
Have you ever had heavy bleeding? .... YES / NO
Have you ever stopped having a period? .... YES / NO
When was your last pelvic exam? .... YES / NO
Have you ever had an abnormal pelvic exam or PAP smear? .... YES / NO
Do you or have you taken Birth Control Pills or Hormones? .... YES / NO
Has a physician ever told you that you had anemia (low hematocrit or iron)? .... YES / NO
Have you ever tried to control your weight by:
Dieting/Fasting? _______ Diet Pills? _______
Diuretics? _______ Laxatives? _______
Vomiting? _______ Excessive Exercise? _______
Does your weight fluctuate? .... YES / NO
Highest weight: _________lbs.
Lowest weight: _________lbs.
What is your ideal weight for participation? _________lbs.
Are you happy with your present weight? .... YES / NO
Do you diet regularly? .... YES / NO

Explain any "Yes" answers (please indicate which corresponding question):

____
____
____
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____
____
____
____
____
____
____
____

Note: Pre-participation physical evaluation does not substitute, in any way, for a comprehensive medical examination.

I hereby state that, to the best of my knowledge, my answers to the above questions are correct. I understand that this information will be used by the Sports Medicine Staff at Eastern Michigan University to determine physical fitness to athletic participation.

Signature of Student Athlete:_______________________________ Date:____________________

Cell Phone Number:____________________ Home Phone Number: ____________________

Revised may 08

Pre-Participation Physical Evaluation

Student Athlete: ______________________________ Sport(s): ________________ Date: ____________________

Height: ________ Weight: ___________ BP: _____/_____ Pulse: ________ Vision: R ___/____ , L ___/____

	Normal	Abnormal Findings	Initials
Cardiopulmonary			
Pulses			
Heart			
Lungs			
Skin			
Abdominal			
Genitalia			
Musculoskeletal			
Neck			
Shoulder			
Elbow			
Wrist			
Hand			
Back			
Knee			
Ankle			
Foot			
Ears/Nose/Throat			
Other			

Clearance:

☐ **Cleared** For Participation Date: __________

Note: ____

____

☐ **Not Cleared** For Participation

Note: ____

____

Recommendations ____

____

____

(Print) Name of Physician: ____ Date: ____________________

Signature of Physician: ____

Revised may 08

Annual Medical Review for Athletic Participation Clearance

Student Athlete: ______________________________ Sport(s): ________________ Date: ______________

BP Re-Check: ____/____ ______ ____/____ ______ ____/____ ______
Date Date Date

	Normal	Abnormal Findings	Initials
Cardiopulmonary			
Pulses			
Heart			
Lungs			
Skin			
Abdominal			
Genitalia			
Musculoskeletal			
Neck			
Shoulder			
Elbow			
Wrist			
Hand			
Back			
Knee			
Ankle			
Foot			
Ears/Nose/Throat			
Other			

Clearance:

□ **Cleared** For Participation Date: __________

Note: ____

____

____

□ **Not Cleared** For Participation

Note: ____

____

____

Recommendations ____

____

____

(Print) Name of Physician: ____ Date: ____________________

Signature of Physician: ____

Appendix C

Information of Risk
and
Informed Consent

Eastern Michigan University
Department of Health Promotion and Human Performance

INFORMATION OF RISK

Description of the Study:
This study is being conduction by researchers in Eastern Michigan University's Department of Health Promotion and Human Performance in order to test the effects of a regular sport specific yoga practice on performance characteristics in NCAA Division I baseball athletes. In particular, we are interested in using yoga to prevent common muscular non-contact injuries among this group of athletes. You can us by participating in these yoga sessions regularly in a schedule that has been approved by your coach and trainers. Yoga sessions will take place twice a week for thirty minutes per session and all testing procedures for range of motion, flexibility and agility will be scheduled within your team's preexisting testing times.

Yoga is a series of dynamic and static stretches designed to increase flexibility, lengthen muscles, increase balance and balance muscular tension with the intention of preventing muscular injury. The yoga protocols being taught in this study are designed specifically for the sport of baseball.

Benefits and Risks:
As a participant in this study, you will benefit personally by learning a stretching protocol that may prevent injuries and enhance performance. In addition, you will be providing valuable information to future athletes. The risks are minimal as you can only participate in the study if you have been cleared by the team's medical staff. You may experience some soreness as you adjust to the protocol, but no more so than you would normally experience from team practices or workouts. If, for any reason, you experience any type of physical or mental distress that concerns you during the course of the study, please contact the researcher.

Right to Withdraw:
You have the right to refuse to participate and withdraw from the study at any time. No penalties, team related or academic, will result from your withdrawal or refusal.

Confidentiality:
All data collected during this study will be held in the strictest of confidence. Your name will not appear in the data results and will be in no way associated with this study.

Dissemination of Information:
The results of this study will be published and presented at appropriate professional conferences and peer reviewed journals.

If you have any questions related to this study, please contact:
Julie McLean

Please keep this copy for your future reference.

INFORMED CONSENT AGREEMENT

Your signature below indicated that you have read and understand the information provided about the research study and have decided to voluntarily participate in the study. Again, if you have any questions, feel free to contract the administrator of this study.

I understand that the primary purpose of this research study is to examine the effects of a regular sport specific yoga practice on performance characteristics in NCAA Division I baseball athletes. I understand that yoga practice is designed to prevent injuries commonly seen in the sport of baseball. I understand that as I participate in the study, I may learn training techniques that help prevent injury and enhance performance. I understand that while the risks of participating are minimal, I may experience physical sensations while participating.

I understand that this study will begin in September 2007 and end in May 2008 and that yoga sessions will be held two or three times a week in agreement with Athletic Compliance and the Baseball practice/game schedule.

I understand that my participation is voluntary. I understand that I am free to ask questions at any time during the course of the program. I understand that I will not be credited or compensated in any way for my participation.

I understand that I have the right to refuse participation and withdraw from the study at any time. I understand that I have the right to refuse to perform any physical posture that I feel my harm me. I understand that no penalties or negative consequences will result from my withdrawal or refusal.

I understand that the data collected will be held in the strictest confidence. All information will be kept in a secure file in the office of the Principal Investigator. I understand that my name will in no way be associated with this study.

______________________________ __________________________

Signature of Participant Date

Please return this form to the administrator of the research project.

Eastern Michigan University
Department of Health Promotion and Human Performance

INFORMATION OF RISK
(Parent Consent)

ABOUT THE STUDY:

- The study that we are asking your child to a part will help to test the effects of a regular sport specific yoga practice on performance characteristics in NCAA Division I baseball athletes. In particular, we are interested in using yoga to prevent common muscular non-contact injuries among this group of athletes.

- Yoga is a series of dynamic and static stretches designed to increase flexibility, lengthen muscles, increase balance and balance muscular tension with the intention of preventing muscular injury. The yoga protocols being taught in this study are designed specifically for the sport of baseball.

WHAT WILL HAPPEN?

If you approve of your child's participation in this study:

- He will by participating in these yoga sessions regularly in a schedule that has been approved by the coach and trainers.

- Yoga sessions will take place twice a week for thirty minutes per session.

- All testing procedures for range of motion, flexibility and agility will be scheduled within the baseball team's preexisting testing times.

WILL ANYONE KNOW MY CHILD WAS IN THE STUDY?

- All data collected during this study will be held in the strictest of confidence. Your child's name will not appear in the data results and will be in no way associated with this study.

ARE THERE ANY RISKS FOR PARTICIPATION IN THE STUDY?

- The risks are minimal as your child can only participate in the study if he has been cleared by the team's medical staff.

- Your child may experience some soreness as he adjusts to the protocol, but no more so than he would normally experience from team practices or workouts.

- All data collected during this study will be held in the strictest of confidence. Your child's name will not appear in the data results and will be in no way associated with this study.

ARE THERE ANY RISKS FOR PARTICIPATION IN THE STUDY?

- The risks are minimal as your child can only participate in the study if he has been cleared by the team's medical staff.

- Your child may experience some soreness as he adjusts to the protocol, but no more so than he would normally experience from team practices or workouts.

IS MY CHILD REQUIRED TO PARTICIPATE IN THE STUDY?

- NO. Your child has the right to refuse to participate and withdraw from the study at any time.

- No penalties, team related or academic, will result from your child's withdrawal or refusal.

ABOUT THE RESULTS OF THE STUDY:

- The results of this study will be published and presented at appropriate professional conferences and peer reviewed journals.

WHAT SHOULD I DO IF I WANT MY CHILD TO PARTICIPATE IN THIS STUDY?

Please indicate below whether or not you agree to have your child participate in this study and return this form to the researchers immediately.

☐ **I AGREE** to have my child participate in the study described above which is part of an authorized program at Eastern Michigan University. I understand the purpose of the yoga protocol and my questions, if any, have been answered.

☐ **I DO NOT PERMIT** my child to participate in the study described above and understand that he will no be penalized in any way for refusal to participate.

IS MY CHILD REQUIRED TO PARTICIPATE IN THE STUDY?

- NO. Your child has the right to refuse to participate and withdraw from the study at any time.

- No penalties, team related or academic, will result from your child's withdrawal or refusal.

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☐ **I DO NOT PERMIT** my child to participate in the study described above and understand that he will no be penalized in any way for refusal to participate.

______________________	______________________	__________
Parent/Guardian Signature	Print Name	Date

____
Print Child's Name

____
Julie McLean
Graduate Student
Eastern Michigan University
Ypsilanti, Mi. 48197

WHO CAN I ASK IF I HAVE ANY QUESTIONS?

If you have any questions at a later time you can call: Julie McLean

This research protocol has been reviewed and approved by the Eastern Michigan Human Subjects Review Committee and if you have any questions on the process, please contact Julie McLean.

Please Save A Copy For Your Records