ABSTRACT

Acute Effects of Dynamic and Static Stretch on the Peak Torque and ROM of the Shoulder Internal and External Rotators

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Purpose: The primary purpose was to determine whether or not static and/or dynamic stretch techniques affect the peak torque and average power of the shoulder rotators. A secondary purpose was to assess and compare range of motion after the two stretching techniques. Methods: Using a cross-over design, 16 recreationally active females (18-35 yrs) participated in three sessions (baseline, static stretch, dynamic stretch) separated by at least 48 hours. Each subject warmed-up for five minutes before being tested for peak torque and power measurements, using Biodex System 3 Isokinetic dynamometer with 5 repetitions at 60°/second and 180°/second, and range of motion with a standard universal goniometer was also measured. In sessions two and three, the participant performed either 3x15 repetitions of five dynamic stretches or 3x25 second holds of five static stretches between warm-up and testing. Subjects were randomized as to the order of stretch sessions. Results: No significant differences were found between stretch protocols.

Acute Effects of Dynamic and Static Stretch on the Peak Torque and ROM of the Shoulder Internal and External Rotators

by

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A Thesis

Approved by the Department of Health, Human Performance and Recreation

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CHAPTER ONE

Introduction and Rationale

Background

Warm-up before physical activity is a universally accepted practice to physically and mentally prepare athletes for optimal performance. Warm-ups usually consist of low-intensity aerobics to increase core and muscle temperature and improve neuromuscular function. Stretching of the specific muscles to be used in the subsequent activities are used to achieve a short-term increase in the ROM at a joint or induce muscle relaxation and decrease the stiffness of the muscle-tendon system. Rehearsal of the skill about to be performed is incorporated into the warm-up at increasing intensities so that the specific muscle fibers and neural pathways are activated and recruited for optimum performance. While the use of a warm-up before performance is rarely questioned (Young & Behm, 2002) and the "active" component has been shown to benefit performance by increasing core temperature, blood flow, and preparing the body for exercises, less is known about the use of passive stretches as a part of the warm-up process (Fletcher & Jones, 2004). Many times warm-ups are based on the trial and error experience of the athlete or coach instead of scientific evidence (Bishop, 2003).

Static stretches are commonly used and recommended before athletic performance to increase the joint range of motion, decrease muscle soreness, and prevent the risk of injury (Siatras, Papadopoulos, Mameletzi, Gerodimos, & Kellis, 2008). Acute increases in shoulder external and internal rotation may decrease injury potential by reducing the amount of strain on the glenohumeral joint capsule (Sauers, August, & Snyder, 2007) and increasing muscle-tendon unit length and flexibility (Weerapong, Hume & Kolt, 2004). However, research appears to show that static stretching acutely impairs muscular performance by reducing successive strength and power production (Torres, Kraemer, Vigren, Volek, Hatfield et al., 2008).

The majority of research evaluating the effects of stretching on performance and power is based on the lower body (Torres at al. 2008). In 2006, Little & William found significantly improved performance in the flying 20 meter sprint, 10 meter acceleration, and zig-zag agility after the dynamic stretch protocol vs. no stretch. The flying 20 meter sprint times were also significantly improved after static stretch vs. no stretch. The researchers found no significant difference in performance after dynamic vs. static stretch or between any of the protocols for the vertical jump (Little & William, 2006). Fletcher & Anness found a decrease in 50-m sprint performance after the combination of static and dynamic stretching compared to only dynamic (Fletcher & Anness, 2007). Nelson, Guillory, Cornwell & Kokkonen (2001) reported static stretch-induced decreases in isokinetic peak torque of the leg extensors at low speeds, but no changes at fast speed. In 2005, Nelson, Dristoll, Landin, Young, & Schexnayder found a significant difference in the pre and post peak torque in both limbs even though only one limb was statically stretched. However, other studies, such as Beedle, Rytter, Healy & Ward (2008), who looked at looked 1 RM in the bench and leg presses after dynamic, static, and no stretch protocols, have come to the conclusion that moderate-intensity stretching does not seem to adversely affect power.

Due to these findings some researchers have recommended that static stretching be omitted from warm-ups or replaced by dynamic stretching (Little & Williams, 2006). The majority of studies have only examined the effects of stretching on lower-body performance. To our knowledge only five previously published studies have investigated the effects of stretching on upper-body muscular performance (Haag, Wright, Gillette & Greany, 2010; Katz, Jabara, Sumlet, Swanson & Manske, 2009; Torres et al., 2008; Knudson, Noffal, Bahamande, Bauer, & Blackwell, 2004; Evetovich, Nauman, Conley, & Todd, 2003). Of these, only Torres et al. (2008) and Katz et al. (2009) compared dynamic and static stretching. Torres et al. found no significant difference between dynamic and static stretch protocols in isometric bench press, bench throws, or lateral medicine ball throws. The authors suggested this may be due to the five minutes of rest given between the last stretch and the test. It should also be noted that the subjects performed two sets of fifteen dynamic stretch repetition and two sets of fifteen second static stretches which is the minimum amount of stretching recommended by the American College of Sports Medicine. The subjects in the present study performed three sets of twenty-five seconds for static stretches which falls in the midrange of ACSM recommendations (Whaley, Brubaker, Otto, &Armstrong, 2006). The amount of fifteen repetitions for dynamic stretches allows an equal amount of time to be spent on each stretch protocol.

The Biodex was used to measure peak torque since it has been found to have a high validity for shoulder internal and external rotation values. Meeteren, Roebroeck, & Stam (2004) found intraclass correlation coefficients of 0.74 and 0.87 for external rotation and 0.81 and 0.92 for internal rotation values for female and male patients, respectively.

To date, no study has examined and compared the acute effects of dynamic and static stretch protocols on both peak torque and range of motion of the internal and external rotators of the shoulder. The purpose of this study was to determine whether or not static stretching or dynamic stretching protocols acutely influence the range of motion, isokinetic peak torque and/or isokinetic average power of the internal and external rotators of the shoulder. This information will assist athletic trainers, coaches, strength coaches, and athletes in making decision related to the stretch component of warm-ups.

Purpose of the Study

The purpose of this study was to investigate and compare the effect of dynamic and static stretch techniques on the peak torque, average power and acute range of motion of shoulder internal and external rotation using a Biodex Isokinetic Dynamometer.

Statement of the Problem

Most published research on dynamic and static stretching focuses on lower body performance. For sports, such as softball and baseball, upper body performance also plays a critical role. Due to the different anatomical structure and complexity of the shoulder joint, specific research needs to be done to find the effect pre-performance stretching has on this joint.

Introduction to the Hypothesis

Due to the lack of research on the effects of static and dynamic stretching on upper body performance, the null hypothesis was chosen for this study.

Hypotheses

Previous research does not clearly support or refute the following effects/relationships, therefore, only the null hypothesis was stated in the following cases:

$H0_1$ There will be no statistically significant difference in ROM between the static stretching and the dynamic stretching sessions.

$H0_2$ There will be no statistically significant difference in isokinetic average power between the static stretching and the dynamic sessions.

$H0_3$ There will be no statistically significant difference in isokinetic peak torque between the static stretching and the dynamic sessions.

Delimitations

This study was completed using the following guidelines:

1. Apparently healthy females between the ages of 18-35 years old participated in this study according to the guidelines approved by the Baylor University Institutional Review Board for human research.
2. Study participants were recruited from the student population at Baylor University and in the Waco community by flyers posted throughout campus and on the HHPR department website.
3. Participant were tested in the Exercise Biochemistry & Nutrition Lab (EBNL)
4. Participants reported to Baylor University on three non-consecutive days to complete baseline, static stretch, and dynamic stretch protocols.
5. Each participant was randomly assigned to the order of stretch protocol procedures.

6. Familiarization to the Biodex was done prior to testing procedures with trial repetitions.
7. Each patient was tested with the same three protocols, with the exception of the stretch component, on different days with at least 48 hours between testing sessions. Test results were not be given until the completion of the study.
8. Participants were asked to abstain from strenuous exercise at least 24 hours prior to testing and upper body exercise within 48 hours prior to testing.

Limitations

1. The sample size was limited to those who came forward to participate in the study which may limit the degree to which inferences can be made to a larger population.
2. The sensitivity of the technologies and protocols that were used to identify quantifiable changes in criterion variables.
3. Each participant's willingness to exert maximal effort on each repetition for each isokinetic test.
4. The daily schedules of each participant and inherent circadian rhythms that exist for all humans as a result of slightly different testing times, stresses, etc.

Assumptions

1. Participants were physically active, but refrained from upper body exercise for 48 hours and strenuous exercise for 24 hours prior to each of the three sessions.
2. Participants gave maximum effort with each test.
3. All instrumentation used was calibrated and reliable in the quantification of the criterion variables.

4. All methods were previously established and are accurate and reliable methods for determination of the criterion variables.

Definition of Terms

1. Active Range of motion- The arc of motion attained by a subject during unassisted voluntary joint motion (Norkin & White, 2003).
2. Dynamic stretch- Slow movement of a joint as a result of antagonist muscle contraction throughout the range of movement (Weerapong et al., 2004)
3. Isokinetics- A form of exercise where a person provides a maximum muscle contraction against a resistance or lever arm, (isokinetic dynamometer) at a fixed speed through a given range of motion. This type of muscle action can be done either concentrically or eccentrically at the given joint (Kowalski, 2003).
4. Peak Torque- Is the greatest amount of force produced by a muscle. This can be determined within each repetition or the entire set. Peak torque indicates the muscle's maximum capability of developing force. This is also equivalent to a 1-repition maximum isotonic strength test. Peak torque is an absolute value (Kowalski, 2003).
5. Static Stretch- The technique of lengthening a muscle group by slowly moving a joint to its maximal range of motion and maintaining the position for a period of time (Guissard & Duchateau, 2006).

CHAPTER TWO

Review of Literature

Effects of Stretching

While the "active" component of warm-ups has been shown to benefit performance by increasing core temperature, blood flow, and preparing the body for exercises, less is known about the use of passive stretches as a part of the warm-up process (Fletcher & Jones, 2004). Weerapong et al. (2004) defined stretching as movement applied by an external and/or internal force in order to increase flexibility and/or joint range of motion and stated that the aim of stretching before exercise is to increase muscle-tendon unit length and flexibility. This increase in flexibility is theorized to enhance athletic performance and decrease the risk of injury from exercise. Recent research has shown that passive stretching may inhibit performance by reducing power output (Fletcher & Jones, 2004). Some researchers hypothesize that stretching reduces muscle stiffness and places the contractile filaments at a less-than-optimal length for the development of maximal tension. They also proposed that stretching causes signals from neural structures, such as muscle spindles, to work more slowly and reduce the number of activated muscle fibers (Beedle et al., 2008).

Nearly all of the studies reporting significant decreases in maximal muscle strength used higher stretch durations and intensities than most competitive and recreational athletes usually do and some even placed joints in vulnerable positions during the stretch protocols (Beedle et al., 2008). Some of these studies used stretches lasting from 90 seconds to one hour (Fletcher & Jones, 2004), while typical stretch routines usually use 10-30 seconds per muscle group (Torres et al., 2008). The alternative theory is that decreasing muscle stiffness through stretching actually decreases the amount of energy needed to move the limb and so the force/speed of contraction may be increased (Shrier, 2004). Most studies have only looked at the effects of stretching on lower-body performance (Torres et al., 2008). According to Sauers et al. (2007), acute improvements in shoulder ROM prior to throwing may reduce injury occurrence during throwing. Techniques that acutely increase external and internal rotation may decrease injury potential by reducing the amount of strain on the anterior and posterior glenohumeral joint capsule.

Dynamic Stretching

Fletcher & Jones (2004) defined dynamic stretching as controlled movement through the active range of motion for each joint. Unlike ballistic stretching, dynamic stretching does not increase the risk of injury and the joint of the limb is stretched with a movement that resembles part of a sport skill (Beedle et al., 2008). Dynamic stretching is said to raise core body and deep muscle tissue temperatures, stimulate the nervous system, decrease the inhibition of antagonist muscle, increase post-activation potentiation, and possibly reduce the risk of injury. As a result, it is theorized to enhance force and power development and vertical jump performance (Jaggers, Swank, Frost & Lee, 2008). However, few studies have been conducted on whether or not dynamic stretching can aid in athletic performance (Beedle et al., 2008).

Static Stretching

Static stretching is frequently used to increase flexibility due to safety and ease of use (Torres et al., 2008). This technique is scientifically based and effective in enhancing range of motion. The key qualities of static stretching are maximum control, little or no movement, and minimal to no velocity of movement. The usefulness of static stretching has commonly been attributed as aiding in warm-up, aiding in cool down, relieving post-exercise delayed onset muscle soreness, helping enhance athletic performance and/or preventing injury. However, it does not increase core or peripheral temperature and so does not aid warm-up and does not facilitate the redirection of the blood flow away from the exercised muscles and so does not aid in cool-down (Alter, 2004). Also, research does not support the theory that passive stretching can decrease delayed onset muscle soreness (LaRoche & Connolly, 2006; Lund, Vestergaard-Poulsen, Kanstrup & Serjrsen, 2007; Andersen, 2005).

In a 2007 literature review by Woods, Bishop & Jones, four of the five articles that evaluated the effects of stretching on injury prevention found a significant decrease in the amount of injuries in the stretch vs. no stretch groups. Woods et al. reported that the reason Pope et al. did not find a significant decrease in injury might be due to the definitions for “injuries” and “soft tissue injuries” the researchers used. Pope et al. defined injuries as lower body injuries that kept the military recruit from performing full duty for three days. Injuries were initially reported to medical assistants or nurses and then to the regimental medical officer for further diagnosis if the recruit was unable to perform normal activities without signs or symptoms within three days. Injuries were only reported to the researchers if they were severe enough to make it to the regimental medical officer. “Soft-tissue” injuries in this study included joint, ligament, meniscus, muscular and ‘other’ injuries (Woods et al., 2007). This is important because stretching is proposed to decrease the incidence, intensity, or duration of the musculotendinous injury by making the muscle more compliant so it can be stretched further and to a higher ultimate strain during activity (Alter, 2004). Three of the four studies in the Woods et al. literature review found a significant decrease in injuries in the stretching groups when looking at muscular injuries only and the fourth study looked exclusively at overuse injuries. The authors concluded that stretching should be implemented prior to activity to specifically decrease musculatendinous injuries (Woods et al., 2007).

Effects of Stretching on Strength and Performance

Findings on direct comparisons of different lower-body stretching modalities are inconclusive as to the effect stretching has on performance. The majority of studies show that static stretching has either no effect or decreases performance whereas dynamic stretching has either no effect or improved performance. These findings indicate that sports relying on high lower-body power output may benefit from dynamic stretching instead of static stretching prior to activity.

Both neural and mechanical factors have been proposed for stretching-induced decreases. Many different peripheral mechanisms have been proposed to explain reduced muscle activation after stretching. These include the autogenic inhibition of the Golgi tendon reflex, mechanoreceptor and nociceptor afferent inhibition, fatigue-induced inhibition, joint pressure feedback inhibition due to excessive ranges of motion during stretching, and stretch reflex inhibition originating from the muscle spindles. A central nervous system mechanism, such as “supraspinal fatigue”, has also been suggested as a potential mechanism. The mechanical factors involve the viscoelastic properties of the muscle affecting the muscle's length tension relationship (Cramer, Housh, Johnson, Miller, Coburn & Beck, 2004) and decreasing the amount of elastic energy that can be stored in the musculotendinous unit. However, some studies have found that dynamic stretching has the opposite effect of enhancing performance. This phenomenon has been linked to the rehearsal of specific movement patterns, helping proprioception and preactivation, and allowing an optimum switch from the eccentric to concentric muscle contraction required to generate high running speeds (Fletcher & Annness, 2007).

In a repeated measures study of fifty-one moderately to very active subjects, no significant difference was found between the three treatments of static or dynamic stretching and no stretching in 1 repetition maximum for bench and leg presses. The study concluded that if the stretching routine is not intense and long, then pretesting stretching probably will not adversely affect strength tests. In this study, three sets of fifteen seconds were performed for the static stretching and 15 repetitions were performed for the dynamic stretch protocol (Beedle et al., 2008). Belm, Cahil, & Power (2004) found impairments in balance, reaction time and movement time post-stretch when they used a static stretching protocol involving the quadriceps, hamstrings, and plantar flexion at three sets of forty-five second stretches each.

Egan, Cramer, Massey & Marek (2006) measured the peak torque and mean power output of maximal concentric isokinetic leg extensions at 60° and 300° after a bout of static stretching of eleven NCAA DI Women's Basketball players. Four leg extensor stretches were performed four times and held for thirty seconds. This stretch protocol was the same used in studies that found a strength deficit from pre-exercise static stretching, but the results showed that isokinetic peak torque and mean power were not reduced. Egan et al. concluded that strength in these trained athletes may not be affected by an intense static stretching protocol.

Little & Williams (2006) evaluated how different stretching protocols during warm-ups effect high speed motor capacities in professional soccer players. Eighteen professional soccer players were tested for countermovement vertical jump, stationary 10-m sprint, flying 20-m sprint and agility performance after each stretch protocol. The three protocols of static, dynamic and no stretch were performed on three non-consecutive days. Four different static stretches were performed with a 30 second hold and twenty seconds of rest between stretches. Dynamic stretches were performed on alternating legs for 60 seconds with approximately one stretch cycle every 2 seconds or unilaterally for thirty seconds with approximately one stretch cycle every second. The total time spent on stretching was 6 minutes and 20 seconds. All tests were performed in the same order for each protocol with twenty seconds between each test. There was no significant difference among the different stretch protocols for the vertical jump. Both static and dynamic produced significantly better performance than no stretch in the flying 20m Max speed, but only dynamic was significantly faster than no stretch in the 10m acceleration. Dynamic was significantly faster than the static and no stretch protocols in the zig-zag agility. In summary, dynamic stretching produced better performance than static in 1 of the two tests used (agility) and showed a tendency for being more beneficial in 2 of the three other tests. From these results, the authors suggested that the decrements that other studies have seen following static stretching may have been avoided in this study due to the shorter stretch duration. The authors also concluded that dynamic stretching, as opposed to static stretching or no stretching, is probably most effective at preparation for the high-speed performances required in sports such as soccer and that, if static stretching is used, it should be limited to short durations and be followed by further activity to minimize decrements to power-based performance.

Siatras et al. (2003) evaluated vaulting speed in gymnasts after static and dynamic stretching. Eleven healthy prepubescent boys participated in the study. On non-consecutive days, the athletes performed a general warm-up only, a general warm-up and static stretching exercises, and a general warm-up and dynamic stretching exercises. Two 30 second stretches were performed with each stretch protocol. The static stretches were each held for 30 seconds and the dynamic stretch motions were performed as quickly as possible for 30 seconds. Vault speed was significantly slower in the static stretching and warm-up compared to warm-up only ($P<0.01$). No significant differences were found between the dynamic and static or the dynamic and warm-up protocol. The researchers suggested that, even though stretching is necessary for flexibility, it is not advisable to perform static stretching prior to activities like vaulting.

Zakas, Doganis, Papakonstandinou, Sentelidis & Vamakoudis E (2006) used a Cybex NORM dynamometer at angular velocities of 60, 90, 150, 210 and 270º/seconds to evaluate the peak torque of fourteen semiprofessional soccer players after static stretching sessions.   Each player completed each of the three sessions within a week of the previous. Static stretching of the quadriceps muscle group was used in all three protocols with the only difference being the number of stretches: 1x 30 seconds, 10 x 30 seconds and 16 x 30 seconds. All three stretch protocols significantly increased knee flexion from pre to post stretch. There was no significant difference in between group range of motion. Isokinetic peak torque was also measured pre and post stretch. No significant difference was found after the single 30 second stretch protocol, but significant decreases in peak torque were found after the 10 x 30 second and 16 x 30 second protocols. The first four velocities (60, 90, 150, 210°) in the 10 x 30 second and the first two of the 16 x 30 second had a P value of < 0.01 while the 270° for the 10 x 30s and the last four speeds of the 15 x 30 seconds had a P value < 0.001. The authors reported that no data collected in this study could suggest a specific mechanism explaining the results, but that neural inhibition and tissue damage could possibly explain the decrements caused by the prolonged static stretching.

Marek, Cramer, Fincher, Massey, Dangelmier et al.(2005) compared the acute effects of static and proprioceptive neuromuscular facilitation stretching on muscle strength, mean power output, active range of motion, passive range of motion, electromyography amplitude, and mechanomyographic amplitude of the vastus lateralis and rectus femorus muscles during concentric isokinetic leg extensions at 60 and 300º/second. Ten female and nine male apparently healthy and recreationally active volunteers participated in the study. Four repetitions of each stretching exercise were held for 30 seconds with a 20 second rest between each stretch. PNF and static protocols were performed in two different visits. Both protocols increased active and passive range of motion and caused similar deficits in strength, power output, and muscle activation at both slow and fast velocities. The authors pointed out that the effect sizes for these changes were small and that practitioners need to consider a risk-to-benefit ratio when incorporating static or PNF stretching.

Cramer et al. (2004) used a Cybex 6000 dynamometer to evaluate the acute effects of static stretching on leg extensor peak torque at 60 and 240º/ second. The fourteen female subjects were statically stretched only on the dominant side but peak torque was assessed both pre and post on both sides. Each subject performed an unassisted stretch followed by three assisted stretches. Each stretch was held for thirty seconds and performed four times. Significant decreases were found following the static stretch in both limbs at both velocities. The researchers concluded that these finding support the theory that a central nervous system mechanism, such as "supraspinal fatigue", may be responsible for the decreases in force following an acute bout of static stretching.

Torres et al. (2008) used the 30% of one repetition bench throw, isometric bench press, and overhead and lateral medicine ball throws to measure the peak power, peak force, peak acceleration, peak velocity, and peak displacement for eleven Division I track and field athletes to evaluate the effects of static and dynamic stretching on upper-body muscular performance. Each of the four protocols (no-stretch, static stretch, dynamic stretch, combined static and dynamic stretch) were separated by at least 48 hours. Two sets of fifteen second holds were performed for each of the seven static stretches: head side to side, overhead reach, deltoid side press, triceps square, finger interlock, side bends, and twist and hold. Thirty repetitions were performed for each dynamic stretch: head side to side, overhead reach, crossover arm swings, triceps pyramids, overhead arm swings, side bends, and hip twists. The only statistically significant finding was the improvement in the peak displacement of the lateral throw after static and dynamic stretching compared to static stretching only ($p \leq 0.05$). The results did not support the hypothesis of a decrease in upper-body performance following static stretching or the hypothesis of an increase in upper-body performance following dynamic stretching.

Katz et al. (2009) evaluated the effects of dynamic and static stretching on the functional capacity of the upper extremity. Subjects were 1st and 2nd year physical therapy students between the ages of 21 and 35 years. Subjects served as their own control. Tests used to evaluate functional performance of the upper extremity were: concentric IR and ER isokinetic strength testing, proprioception, distance of softball throw and a closed-kinetic chain upper extremity stability test. All stretches were performed once with a 30-second hold. The isokinetic testing used in this study was concentric internal and external strength measured supine on LIDO isokinetic dynamometer with the shoulder abducted to 90° and elbow flexed to 90°. Subjects performed an interval warm-up of 25%, 50%, 75%, and 100% of maximal internal and external rotation against 180° per/seconds before performing 10 consecutive internal and external rotation maximal repetitions. Each subject then repeated the protocol at 300° per/second. Average peak torque and work were calculated. A week was given between stretch protocols. Paired t-tests revealed no significant difference between proprioception, isokinetic, and softball throw tests, but did reveal a significant improvement in the dynamic vs. static stretch results in the closed kinetic chain upper extremity stability test.

Daphyn (2009) performed a similar study using sixteen healthy university students between 18 and 30 years old. Eleven female and five male subjects qualified for the study. Pre- and post-tests of five concentric-concentric repetitions at 60°/second were performed on a Biodex System 2 Dynamometer each session. Each subject went through the three sessions. Each session consisted of a different stretch duration. The stretch protocols consisted of three sets of 10, 30 or 60 second holds for one internal rotation and two external rotation stretches. There were no statistically significant differences among any of the protocols. The authors concluded that static stretching protocols utilizing stretch durations typical of those used in a pre-exercise warm-up was not sufficient to impair or enhance muscle strength performance in this study and that further research is warranted.

Haag et al. (2010) evaluated the effects of acute static stretching of the throwing shoulder on the pitching performance of National Collegiate Athletic Association Division III baseball players. Twelve players participated in the study: 6 pitchers and 6 field players. Each participant completed two separate testing protocols over a span of 4-6 days. In the experimental condition, six static stretches were applied to the throwing shoulder after an active warm-up. The static stretching routine consisted of shoulder horizontal abduction, horizontal adduction, external rotation, internal rotation, flexion, and extension stretches performed once each and held for 30 seconds "at the point of mild discomfort" with a rest period of 10 seconds between each stretch. The players were then given a rest period of 5-10 minutes before throwing 5 warm-up pitches followed by 10 pitches measured for velocity and accuracy. Pitching velocity was measured with a cordless radar gun. No significant differences were found in average velocity, maximum velocity, or accuracy measures when comparing the SS and NS conditions. The authors concluded that acute static stretching of the throwing shoulder does not have a significant impact on baseball pitching performance.

In contrast, Evetovich et al. (2003) demonstrated that static stretching immediately prior to activity reduced muscular performance of the Biceps Brachaii.

Eighteen adult subjects were tested with EMG static stretch and no-stretch protocols with at least 48 hours between test sessions. The static stretch protocol was composed of 3 different static stretches performed 4 times and held for 30 seconds each. Subjects were tested isokinetically using a Cybex II dynamometer at velocities of 30°/second and 270°/second while EMG and MMG amplitude were recorded. The authors stated that MMG has been suggested as a means to monitor muscle stiffness and that greater MMG amplitude is inversely related to muscle stiffness. EMG amplitude was used in an attempt to measure possible autogenic inhibition. The results revealed significantly decreased torque and increased MMG amplitude at both speeds, but no significant difference in EMG amplitude. These results support the hypothesis that stretching negatively impacts torque and that this decrease is related to increased musculotendinous stiffness.

Biomechanics and Anatomical Adaptations of the Overhead Throw

Baseball pitchers, tennis and handball players have repeatedly been found to have an increased range of external rotation with a corresponding decreased range of internal rotation in their throwing shoulder compared with the contra-lateral shoulder when assessed at 90 degrees of abduction. This increased range of external rotation is commonly referred to as external rotation gain (ERG) and the decreased range of internal rotation is commonly referred to as internal rotation deficit (GIRD) (Borsa, Laudner & Sauers, 2008).The total arc of rotational ROM (external + internal rotation) is not significantly different bilaterally. Instead, the total arc of rotation in the overhead-throwing shoulder appears to adapt by shifting “backwards”, favoring more external rotation at the expense of internal rotation. Wilk et al. (1992) has referred to this rotational arc shift phenomenon as the "total motion concept".

The greater range of external rotation allows for increased arm cocking which is correlated with a greater ball velocity during the acceleration to the ball release phase of the throw along with increases in angular velocity of the humerus during follow-through and ball release (Borsa et al., 2008). However, Miyashita, Urabe, Kobayashi, Yokoe, & Koshida et al. (2007) report that the amount of stress on the shoulder and elbow appears to be directly correlated with the degree of maximum shoulder internal and external rotation during the throwing motion and that scientific evidence indicates that avoiding excessive maximal external rotation is an effective approach for rehabilitation and prevention of throwing related injuries. According to Sauers et al. (2007), it is unclear whether this adaptation in range of motion results from soft tissue changes, osseous changes, or from a combination of both.

Jobe et al. (1996) advocated the theory of micro-instability of the throwing shoulder. This theory states that as a result of repetitive strain on the anterior inferior capsuloligamentous structures in the later cocking position of abduction and external rotation, there is a reduction of anterior stabilizing structure and corresponding increase in humeral head translation. This humeral head translation contributes to secondary impingement of the rotator cuff tendons in the subacromial space of internal impingement resulting from hyper-angulation. This theory proposes that stretching of the anterior-inferior capsuloligamental structures results in increased anterior glenohumeral joint laxity and associated decease in anterior glenohumeral joint stiffness. The increase in external rotation range of motion is cited as supportive evidence for this theory.

However, anatomically, the antero-inferior capsule and inferior glenohumeral ligament has been depicted as the thickest, strongest portion of the glenohumeral joint and the posterior capsule as the thinnest portion. In the functional test position of abduction and external rotation, Ellenbecker et al. (2000), Borsa et al. (2008), and Crawford & Sauers (2006), all found minimal anterior translation in several populations of overhead athletes. These studies suggest that anterior-inferior restraints are in place and stable in non-pathological overhead-throwing shoulders, and are not stretched out as theorized by Jobe et al. (Borsa et al., 2008). After comparing the range of motion and glenohumeral translation of professional baseball pitchers, the Borsa et al (2008) concluded that no significant difference in glenohumeral translation exists between the throwing and non-throwing shoulders of asymptomatic baseball pitchers, posterior translation is significantly greater than is anterior translation in the throwing shoulders of professional baseball pitchers in abduction and 90 degrees of external rotation, and the angle of humeral translation is not related to passive rotational range of motion in the throwing shoulders of asymptomatic professional baseball players. Another important adaptation factor is that increases in posterior shoulder tightness and decreases in shoulder internal rotation have been clinically and empirically linked to several conditions, including subacromial impingement, superior labrum anterior-posterior (SLAP) lesions, and internal impingement (Laudner et al., 2006). This posterior capsule tightness develops from repetitive throwing (Lorenz, 2005).

Kibler et al. (1998) proposed the idea that lack of posterior shoulder flexibility affects smooth motion of the shoulder and causes the scapula to be pulled forward and inferior prematurely. Tyler, Nicholas, Roy & Gilbert (2000) reported that the tightness causes the humeral head to migrate anterior and superiorly and that for every 4 degrees of internal rotation loss there is a 1 centimeter loss of posterior capsule extensibility. It is inconclusive as to whether this change is caused by tightness of the posterior capsule, changes in the rotator cuff, or simply a shift in motion (Lorenz, 2005). Recent investigators have reported no side-to-side differences in anterior or posterior GH translation in professional baseball pitchers indicating that contracture of posterior soft tissue structures rather than the capsule may be causing these rotational differences and pathologic characteristics. Regardless of which soft tissue structures are contracted, this loss of motion is strongly associated with the development of shoulder injury (Laudner et al., 2006). Lorenz et al. (2005) stated that athletes need to stretch the posterior shoulder regardless of what causes the problematic adaptation.

Isokinetic Testing of the Upper Extremity

Isokinetic testing has been shown to be valid and reliable for measuring the strength of the shoulder internal and external rotators. The 90º-90º position shows better correlation to overhead sport activities while providing greater stabilization than other test positions (Ellenbecker & Davies, 2000). The position of 90 º of abduction with 90 º of elbow flexion is considered the “position of function” (Newsham et al., 1998) and has been used to evaluate strength in a variety of sports with upper body involvement, such as tennis, baseball, swimming, and volleyball (Chandler, Kibler, Stracener, Ziegler, & Pace, 1992; Nocera, Rubley, Holcomb, & Guadagnoli, 2006; Wilkin et al., 2006; Newsham et al., 1998; Ramsi, Swanik, Swanik, Straub & Mattacola, 2004, Noffal, 2003, Forthomme, Croisier, Ciccarone, Creilaard & Cloes, 2005).

In comparison to closed chain isokinetic testing, open chain isokinetic testing for the shoulder provides increased control over range of motion, speed, translational stresses, and rotational forces while with closed kinetic chain testing the control decreases. This causes increased muscular compensation and risk of injury with the use of closed kinetic chain testing and the test may not show true existing weakness (Ellenbecker & Davies, 2000).

According to Elsner et al. (1983), speeds of 60º or less were a possible cause of inaccurate testing due to lack of stabilization of the subject and dynamometer. Subjects in their study described a fear of injury during slow speed testing, and slow speed testing may actually cause injuries. However, high speed testing also has limitations, such as overshoot, that are usually less pronounced at lower speeds.

A study by Arrigo, Wilks & Andrew (1994) evaluated the number of repetitions needed to adequately evaluate peak torque for shoulder internal and external rotation. Using 191 professional baseball players, the authors concluded that as few as five isokinetic repetitions may be used unless the assessment of endurance is imperative.

Meeteren et al. (2002) found good to excellent reliability of isokinetic testing with the Biodex for research on groups. Specifically, intraclass correlation coefficients in their female participants were 0.74 and 0.81 for external rotation and internal rotation, respectively. Reliability values for male participants were higher. In a pilot study, the researchers found that preset angular velocities higher than 180° /seconds in external/internal rotation could not be exceeded by healthy subjects who were all active sportsman. At the low angular velocity, five repetitions were made and at the high angular velocity 10 repetitions were made. The maximal peak torque of these repetitions was determined, because this is reported to be the most used parameter in isokinetic dynamometry.

Summary

The literature shows that more research needs to be done to compare static and dynamic stretching, especially with the upper extremity. Since the throwing motion involves maximal to near-maximal internal, external rotation and abduction, numerous muscles are involved in the throwing motion. Research shows that stretches should be carefully selected so that the movements assist in decreasing posterior tightness, decreasing stress on the capsule and musculature, and encouraging smooth joint motion.

With isokinetic testing of the shoulder, the 90-90 position provides more stability, more closely resembles overhead sport movement, and is frequently used to evaluate the strength of a variety of sports involving the upper body. Opened-chained isokinetic testing gives clinicians more control over testing. Research involving isokinetic testing of athletes uses a variety of isokinetic speeds. A few studies have reported an increased fear and risk of injury involved with low angular speeds, but that higher speeds also have limitations. The protocol of five repetitions has proven to be adequate in measuring the peak torque for internal and external rotation. ROM stops have also shown to increase result quality.

CHAPTER THREE

Methods

Participants

Sixteen female subjects between the ages of 18 – 35 who were moderately active and regularly performed upper body exercise were recruited for this study. Apparently healthy individuals were considered to be eligible using the qualifications stated by American College of Sports Medicine (ACSM), which states that subjects must be < 40 years of age and have no symptoms of or known presence of heart disease or major coronary risk factors. To meet the criteria for being a moderately active individual, subjects needed to engage in moderate exercise ≥ 3 times per week (2000). At least a portion of this weekly exercise had to involve the upper extremity. The subject also needed to have participated in an upper body sport (i.e. tennis, softball, volleyball) within the last year. Subjects were considered ineligible for the study if they had a history of unresolved pain, injury or surgery to the neck and/or upper extremity, a history of pulmonary disease, hypertension, hepatorenal disease, musculoskeletal disorders, neuromuscular/neurological diseases, autoimmune disease, cancer, peptic ulcers, anemia, or chronic infection (e.g., HIV), or were taking any heart, pulmonary, thyroid, anti-hyperlipidemic, hypoglycemic, anti-hypertensive, endocrinologic (e.g, thyroid, insulin, etc), psychotropic, neuromuscular/neurological, or androgenic medications. Any subject who reported any unusual adverse events in association with this study that in consultation with the supervising physician recommended removal from the study would have become ineligible. This event did not occur. During the familiarization session, ROM measurements were taken to ensure participants were within the normal limits for ROM and those who were not within these ranges were disqualified. The normal ranges for internal and external rotation were based on the American Academy of Orthopaedic Surgeons (1965) and Berryman, Reese & Bandy (2002), which list normal active internal rotation as less than 70° and normal active external range of motion as less than 90°. All eligible participants were in both the dynamic and static stretching groups with adequate time between testing. This cross-over approach was utilized to create a more homogeneous sample. All eligible subjects signed university-approved informed consent documents and approval was granted by the Institutional Review Board for Human Subjects. Additionally, all experimental procedures involved in the study conformed to the ethical consideration of the Helsinki Code.

Study Design

All tests that were conducted in this study were performed in the Exercise Biochemisty & Nutrition Lab (EBNL) of the Marrs McLane Gymnasium at Baylor University in Waco, Texas. Table 1 illustrates the general research design administered in this study.

Independent Variables

The independent variables were the two stretching protocols (dynamic and static). The static and dynamic stretch protocols are listed in Table 2 and Table 3, respectively.

Dependent Variables

Dependent variables included range of motion, isokinetic peak torque and isokinetic average power for internal and external rotation of the shoulder as measured by the Biodex Isokinetic Dynamometer.

Entry and Familiarization Session

Participants expressing interest in participating in this study were interviewed on the phone to determine whether they appear to qualify to participate in this study. Participants believed to meet eligibility criteria were invited to attend an entry/familiarization session. Once reporting to the lab, participants signed informed consent documents, completed a medical history questionnaire along with an exercise and supplement history/activity questionnaire form, Participants meeting entry criteria were familiarized to the study protocol via a verbal and written explanation outlining the study design and practiced the stretching and Biodex protocols used in the study. Within the exercise and supplement history/activity questionnaire form, the participant was asked to identify which arm was their dominant arm/shoulder during sporting activity (i.e. throwing arm). This was the arm used for all tests and measurements. The subject underwent range of motion testing using a standard universal goniometer and performed 5 repetitions at 60º/second and 180º/second on the Biodex to familiarize them to isokinetic testing and in order to document their set up position which would be utilized for all further testing. At this time, subjects were given an appointment time to perform baseline assessments and were instructed not to perform any vigorous exercise within 24 hours or upper body exercise within 48 hours of sessions.

Study Protocols

After the entry and familiarization session, subjects were randomly assigned to a sequence of testing for the static stretch and dynamic stretch protocols. This study utilized a cross-over design which means all subjects participated in a baseline session and both stretching sessions. These three testing sessions are outlined in Table 1 along with the familiarization session. Both stretching sessions were identical with the exception of the stretch protocol utilized. Each test session included a standardized 5 minute warm-up on an upper body ergometer at 50 revolutions per minute with no additional resistance, a stretch protocol lasting approximately 5-7 minutes, range of motion testing using a standard universal goniometer, followed by isokinetic testing on the Biodex. Baseline testing was identical with the exception of a stretch protocol. Subjects were reminded not to engage in any strenuous exercise within 24 hours prior to testing sessions or upper extremity exercise within 48 hours prior to testing sessions.

All test sessions were separated by at least 48 hours and the order in which subjects perform static and dynamic stretch protocols was randomized to minimize any carry over effects. Forty-eight hours was selected based on Weijer, Shamus, & Gorniak's (2003) findings that the effects of stretching remain up to 24 hours even though the greatest decline occurs in the first 15 minutes post-stretch. Other studies evaluating the effects of stretching on performance also used this time frame to separate test protocols (Torres et al., 2008; Evetovich et al., 2003; Little & Williams, 2006).

Range of Motion Testing Procedures

Participants underwent range of motion testing 48 hours prior to the first stretch session for baseline measurements and two more times following dynamic stretch and

Table 1. *General Research Protocol*

Familiarization & Entry	Baseline Testing	Test session 1	Test Session 2
Phone Interview	Warm-up	Warm-up	Warm-up
Informed Consent Form	ROM measurements	Stretch protocol	Stretch Protocol
Demographic Form	Trial repetitions	ROM measurements	ROM measurements
Randomization into	60° Isokinetic test	Trial repetitions	Trail Repetitions
stretch protocol order	Trial repetitions	60° Isokinetic test	60° Isokinetic test
Warm-up	180° Isokinetic test	Trial repetitions	Trial repetitions
ROM measurements		180° Isokinetic test	180° Isokinetic test
Trial/Practice repetitions			
60° Isokinetic test			
Trial/Practice repetitions			
180° Isokinetic test			
Schedule Baseline session			
45 Minutes	20 Minutes	25 Minutes	25 Minutes

static stretching bouts. Range of motion was assessed using a standard universal goniometer. Subjects were positioned supine on a table with hips and knees bent and feet flat on the table to prevent the back from arching. The shoulder was abducted to 90º and elbow flexed to 90º. The full length of the humerus, but not the elbow, was supported by the table. The forearm was placed perpendicular to the table and in 0 degrees of supination and pronation. A towel was placed under the humerus so that it was level with the acromion process. The center of the fulcrum was placed over the olecranon process. The proximal arm was aligned so that it was parallel with the floor and the distal arm so that it was aligned with the ulna using the pre-marked olecranon process and ulnar styloid for reference. Participants were asked to externally rotate the arm to the end of the range of motion by moving the palm of the hand towards the floor until an end point was reached without compensation or discomfort. The investigator felt for compensation at the lateral border of the scapula. The ROM was taken in this position. This process was repeated in internal rotation except that compensation was felt as the spine of the scapula lifting off the table (Norkin & White, 2003; Barnes, Van Steyn, & Fischer, 2001). Following range of motion measurements, isokinetic peak torque and average measurements were assessed.

Performance Testing Procedures

Isokinetic peak torque and isokinetic average power measurements were also tested during baseline, dynamic stretch and static stretch sessions. Subjects were positioned on the Biodex using a standard protocol for assessment of shoulder internal and external rotation in a seated 90-90 position. The chair was rotated to 0 degrees and the dynamometer to 0 degrees with a 5 degree tilt. The elbow/shoulder attachment was attached with the shaft dot aligned to R or L, depending on the patient's dominant arm, and secured with the locking knob. The dynamometer was raised so that it was aligned with the subject's axis of rotation and the chair adjusted or raised to accommodate various patient sizes. The shoulder was abducted to 90° with the elbow flexed to 90°. The patient was stabilized with shoulder, waist and thigh straps (Biodex Medical Systems, Inc. 2001). Range of motion settings limited the motion to 55° of internal rotation and 40° of external rotation since these settings are within the normal reported range for adult females between the ages of 20 and 39 (Norkin & White, 2003) and the Biodex System 3 Application/Operation Manual recommended ROM settings for internal and external rotation at 90° of abduction (Biodex Medical Systems, Inc., 2001).

Each strength assessment session consisted of participants performing three submaximal repetitions at an estimated effort of 25%, 50%, and 75%, followed by 5 maximal (100% effort) (Arrigo, Wilks & Andrew, 1994) concentric repetitions at 60° and 180°/second (Elsner, Pedegana, & Lang, 1983). Sixty seconds of rest were given between each test speed since Parcel, Sawyer, Tricoli, & Chinevere (2002) found no difference in peak torque measurements between 60 seconds of rest and 180 or 300 seconds of rest between sets of isokinetic test velocities of 60°/second and 180°/second. Peak torque and average power were recorded during the five maximal isokinetic repetitions.

Stretch Protocols

Each subject participated in two separate stretch protocols. Both dynamic and static stretch sessions followed identical protocols with five stretches being performed three times. Static stretches are explained in Table 2 and dynamic stretches are explained in Table 3. "Holds" for the static stretch were 25 seconds long. In order to make the stretch protocols approximately the same length, 15 repetitions of the dynamic stretches were performed per set. All stretch protocols and testing were performed on the participant's dominant arm which was defined as the arm the subject reported on the activity questionnaire that they use to throw. The stretches were demonstrated to the participant and then performed by the participant. Participants were instructed to stretch the muscles to the point of tightness without invoking discomfort. Each static stretch was performed 3 times and held for 25 seconds each time, which is within the 2-4 sets of 15-30 seconds recommended by the American College of Sports Medicine (Whaley et al., 2006). Dynamic stretches were performed with 3 sets of fifteen repetitions. Fifteen repetitions took subjects approximately 25 seconds to perform. Torres et al (2008) used 25 dynamic repetitions to match the 25 second hold for static stretching. The amount of fifteen repetitions for dynamic stretches in the current study allowed an equal amount of time to be spent on each stretch protocol.

Table 2. *Static Stretch Protocol: 3x 25 seconds each*

Stretch	Procedure
Deltoid Side Press	Bring arm across chest level with the top of the sternum. Use opposite arm to assist during terminal range of motion by placing the palm of hand above elbow and pulling the arm towards chest. Hold this position for 25 seconds.
Diagonal 1 Chest Press	Bring arm across chest in an upward diagonal until elbow is level with chin, place palm of opposite arm above elbow and pull towards chin. Hold this position for 25 seconds.
Diagonal 2 Chest Press	Bring arm across chest in a downward pattern until elbow is level with the bottom of the sternum, place palm of opposite arm above elbow and pull towards chest. Hold this position for 25 seconds.
Internal Rotation Stretch	Hold dowel rod behind back and with wide grip so that the upper arms are shoulder level (abducted 90°) with the elbows flexed at 90°. Internally rotate until a stretch is felt. Upper arms should remain level with the shoulders and the elbows flexed to 90°. Hold this position for 25 seconds.
External Rotation Stretch	Hold dowel rod parallel to the floor and with wide grip so that the upper arms are shoulder level (abducted 90°) with the elbows flexed at 90°. Externally rotate so that arms/dowel rod go over and behind head and stretch is felt. Upper arms should remain level with the shoulders and the elbows flexed to 90°. Hold this position for 25 seconds.

Evetovich et al (2003) found that static stretching hindered the full capabilities of biceps brachii torque production at both slow (30°/second) and fast (270°/second) velocity (2003). The stretches were held for 30 seconds and repeated four times with fifteen seconds between sets. For the current study, five seconds separated each set as this more closely imitates the amount of time used for team warm-ups. There was also a short break between stretching and test procedure due to set-up. This lasted no less than 3 and no longer than 5 minutes so that all subjects had a similar amount of recovery time.

Statistical Analysis

Statistical analysis was performed utilizing a 2 x 2 [group (static, dynamic) x time (pre-test, post-test)] mixed ANOVA with baseline as the covariate to analyze the dependent variables of ROM for external rotators and internal rotators, isokinetic peak torque at 60º/second and 180º/second, and isokinetic average power at 60º/second and 180º/second. Mauchly's test was used to test for sphericity. If violated, Huynh-Feldt test was used to determine significance. All statistical procedures were performed using SPSS 17 software (SPSS Inc., Chicago, IL) and a probability level of <0.05 was adopted throughout.

Table 3. *Dynamic Stretch Protocol: 3x 15 repetitions each*

Stretch	Procedure
Deltoid Side Press	Swing arm across chest level with the top of the sternum. Opposite arm assists during terminal range of motion by placing the palm of hand above elbow and pulling the arm towards chest as terminal motion is reached. Immediately swing arm horizontally away from the body. Repeat 15x.
Diagonal 1 Chest Press	Bring arm across chest in an upward diagonal until elbow is level with chin. Opposite arm assists during terminal range of motion by placing the palm of hand above elbow and pulling arm towards chest as terminal motion is reached. Immediately swing arm in downward diagonal. Repeat 15x.
Diagonal 2 Chest Press	Swing arm across chest in a downward pattern until elbow is level with the bottom of the sternum. Opposite arm assists during terminal range of motion by placing the palm of hand above elbow and pulling the arm towards chest as terminal motion is reached. Immediately swing arm in an upward diagonal away from the body. Repeat 15x.
Internal Rotation Stretch	Hold dowel rod behind back and with wide grip so that the upper arms are shoulder level (abducted 90°) with the elbows flexed at 90°. Internally rotate so until a stretch is felt. Upper arms should remain level with the shoulders and the elbows flexed to 90°. Repeat 15x.
External Rotation Stretch	Hold dowel rod parallel to the floor and with wide grip so that the upper arms are shoulder level (abducted 90°) with the elbows flexed at 90°. Externally rotate so that arms/dowel rod go over and behind head and stretch is felt. Upper arms should remain level with the shoulders and the elbows flexed to 90°. Return to starting position and repeat. Repeat 15x

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CHAPTER FOUR

Results

Participants

Twenty-four female participants volunteered for this study. Seven of these participants were disqualified due to external range of motion not being within normal limits during the familiarization session. One subject was not able to complete the last two sessions due to illness unrelated to the study. Sixteen participants qualified and completed the study. The demographic information is presented in Table 4. Since a cross-over design was used, each subject completed all three testing sessions (Baseline, Static, Dynamic) and essentially acted as their own control. Participants were randomized to the order of the stretch protocols (static or dynamic).

Table 4. *Study Participant Demographics*

Demographics	Mean ± SD
Age (years)	20.38 ± 1.93
Height (in)	63.75 ± 2.29
Body Mass (lbs)	135.0 ± 14.18

Glenohumeral Internal and External Rotation Range of Motion

Glenohumeral internal rotation was measured with a standard universal goniometer at baseline, after the static stretch protocol, and after the dynamic stretch protocol. The means and standard deviations for these measurements are shown in Table

5 and Figure 1. The analysis showed no group effect for internal rotation ($F=0.107$, $p= 0.748$, $n_p^2 =0.008$) with baseline as the covariate.

Table 5. *Range of Motion*

Session		Mean ± SD in degrees
Baseline		
	IR	59.12 ± 5.88
	ER	82.89 ± 5.18
Static		
	IR	57.91 ± 5.53
	ER	86.88 ± 3.44
Dynamic		
	IR	57.54 ± 5.66
	ER	86.59 ± 3.78

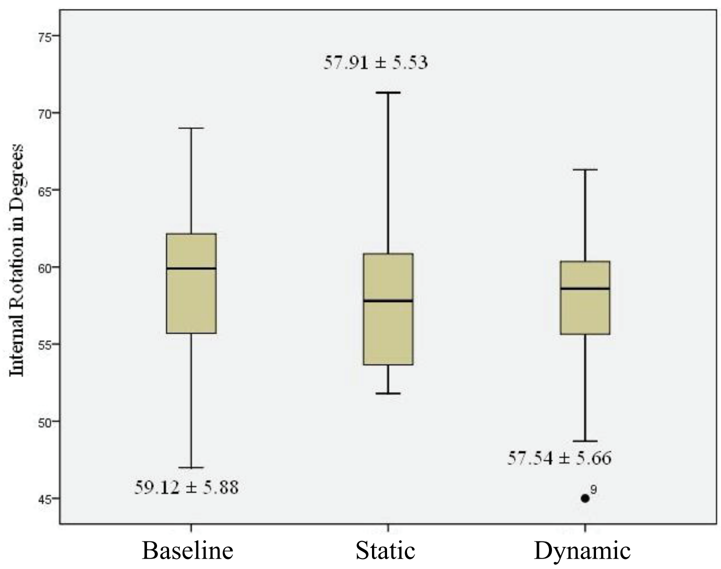

Figure 1. Means ± standard deviations for internal rotation range of motion. •9 Signifies outlier for the sample.

Glenohumeral external rotation was also measured with a standard universal goniometer at baseline, after the static stretch protocol, and after the dynamic stretch protocol. These means and standard deviations were shown in Table 5 above along with the internal rotation values. The means and standard deviations are shown in Figure 2.

The analysis showed no group effect for external rotation (F=0.304, p= 0.590, n_p^2 =0.021) with baseline as the covariate.

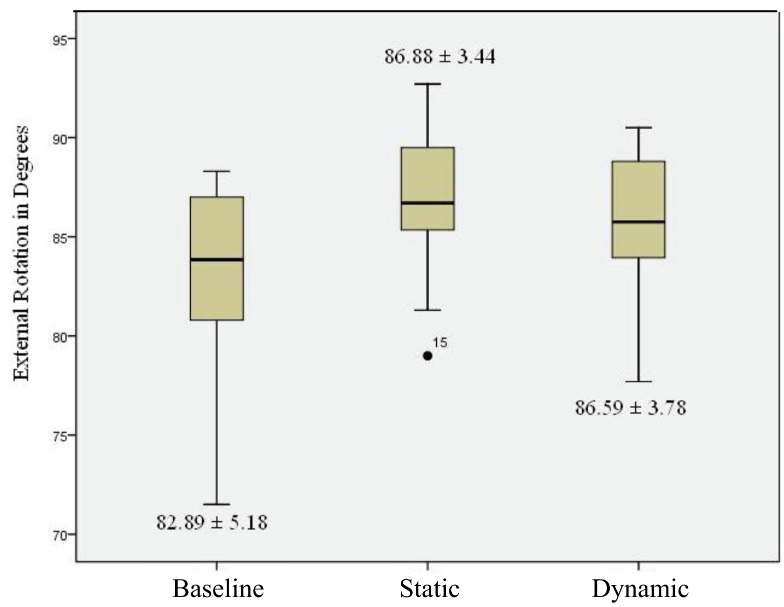

Figure 2. Means ± standard deviations for external rotation range of motion

Hypothesis one stated that there will be no statistically significant difference in glenohumeral range of motion between the static stretching and the dynamic stretching sessions. Thus, the hypothesis failed to be rejected.

Isokinetic Power at 60º/second and 180º/second

Isokinetic power of glenohumeral internal rotation was measured at 60º/ second and 180º/second at baseline, after the static stretch protocol, and after the dynamic stretch protocol. The means and standard deviations are shown in Table 6 and Figure 3. The analysis demonstrated there was no group effect for isokinetic power for glenohumeral internal rotation at 60º/second (F=0.841, p= 0.375, n_p^2 =0.057) or 180º/second (F=0.159, p= 0.696, n_p^2 =0.011) with baseline as the covariate.

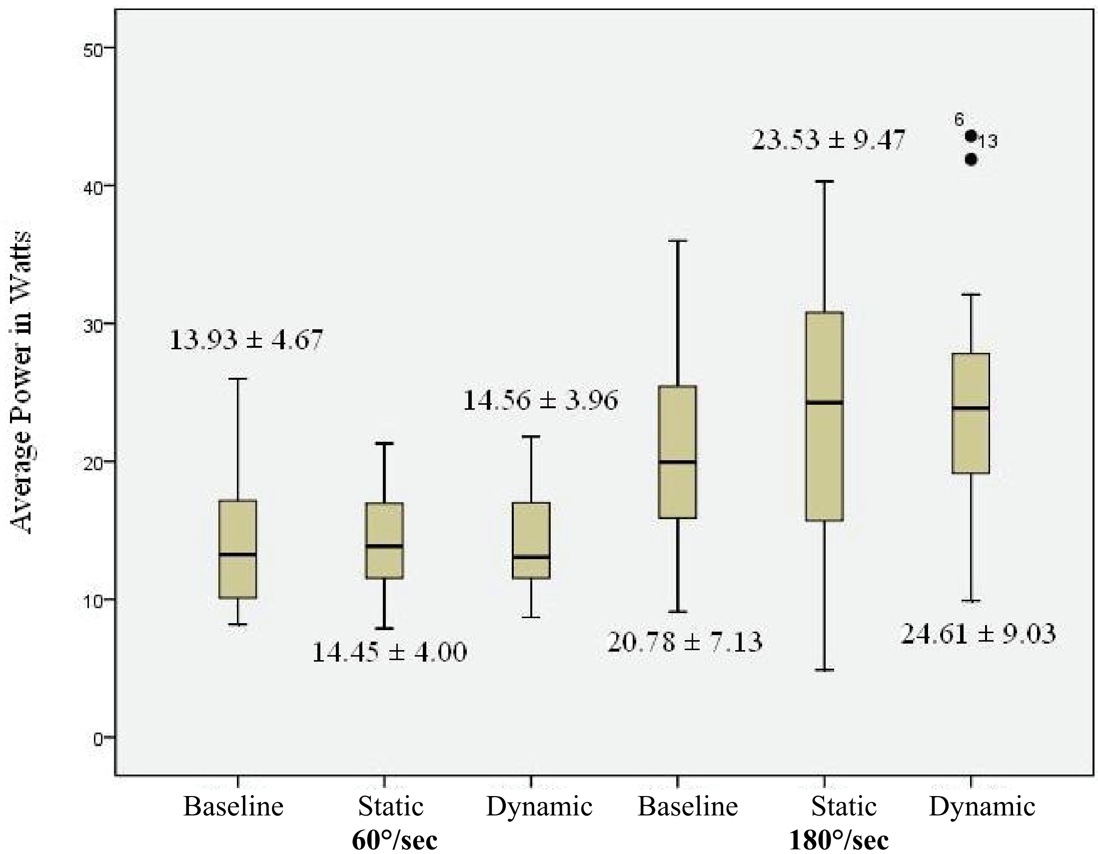

Figure 3. Means ± standard deviations for isokinetic internal rotation average power

Isokinetic power for glenohumeral external rotation was measured at 60º/second and 180º/second at baseline, after the static stretch protocol, and after the dynamic stretch protocol. The means and standard deviations for glenohumeral isokinetic glenohumeral external rotation average power are shown in Table 6 and Figure 4. The analysis demonstrated there was no group effect for external rotation power at 60º/second (F=0.911, p= 0.356, n_p^2 =0.061) or 180º/second (F=0.069, p= 0.797, n_p^2 =0.005) with baseline as the covariate.

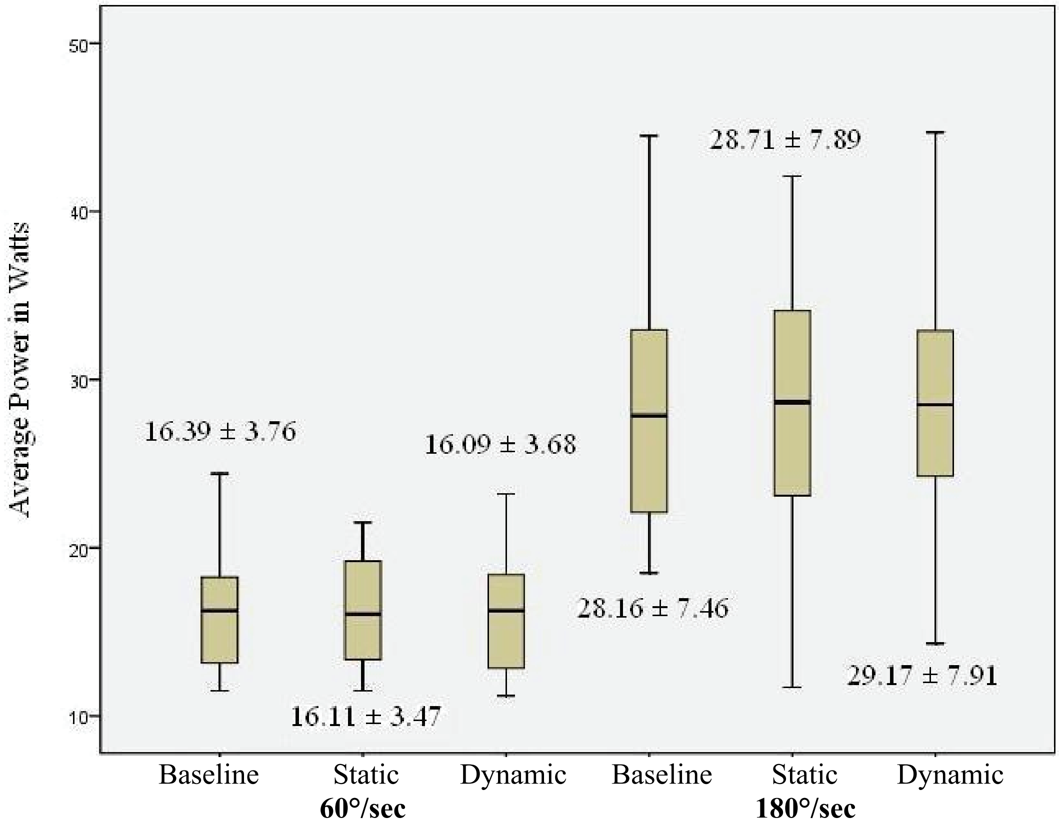

Figure 4. Means ± standard deviations for isokinetic external rotation average power

Hypothesis two stated that there will be no statistically significant difference in glenohumeral isokinetic power between the static stretching and the dynamic stretching sessions. Thus, the hypothesis failed to be rejected.

Isokinetic Peak Torque at 60º/second and 180º/second

Glenohumeral peak torque with internal rotation was measured at 60º/ second and 180º/second at baseline, after the static stretch protocol, and after the dynamic stretch protocol. See Table 7 and Figure 5 for means and standard deviations for glenohumeral isokinetic peak torque at 60º/ second and 180º/second. The analysis demonstrated there was no group effect for internal rotation at 60º/second (F=0.220, p= 0.646, n_p^2 =0.015) or 180º/second (F=0.014, p= 0.909, n_p^2 =0.001) with baseline as the covariate.

Table 6. *Isokinetic Average Power Output*

Session	Mean ± SD in Watts
Baseline	
IR 60°/sec	13.93 ± 4.67
IR 180°/sec	20.78 ± 7.13
ER 60°/sec	16.39 ± 3.76
ER 180°/sec	28.16 ± 7.46
Static	
IR 60°/sec	14.45 ± 4.00
IR 180°/sec	23.53 ± 9.47
ER 60° /sec	16.11 ± 3.47
ER 180°/sec	28.71 ± 7.89
Dynamic	
IR 60°/sec	14.56 ± 3.96
IR 180°/sec	24.61 ± 9.03
ER 60° /sec	16.09 ± 3.68
ER 180°/sec	29.17 ± 7.91

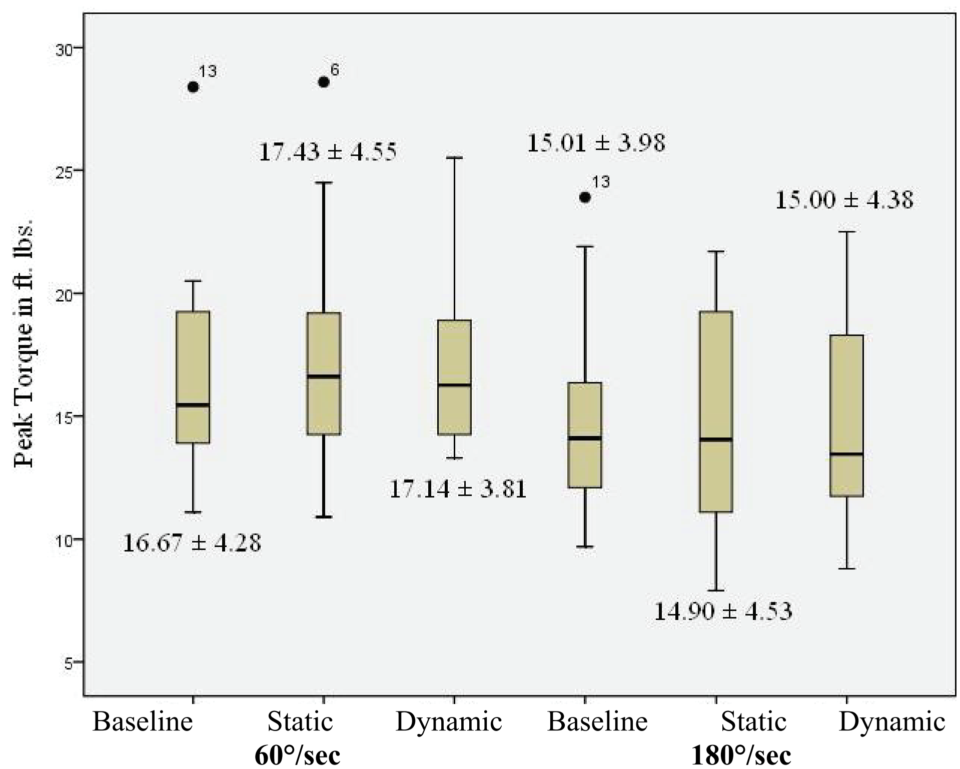

Figure 5. Means ± standard Deviations for isokinetic internal rotation peak torque

Glenohumeral peak torque with external rotation was measured at 60º/second and 180º/second at baseline, after the static stretch protocol, and after the dynamic stretch protocol. The analysis demonstrated there was no group effect for glenohumeral external rotation peak torque at 60º/second ($F=1.527$, $p= 0.237$, $n_p^2=0.098$) or 180º/second ($F=0.047$, $p= 0.831$, $n_p^2=0.003$) with baseline as the covariate. Means and standard deviations for glenohumeral isokinetic peak torque measurements across all sessions are depicted in Table 7 and Figure 6.

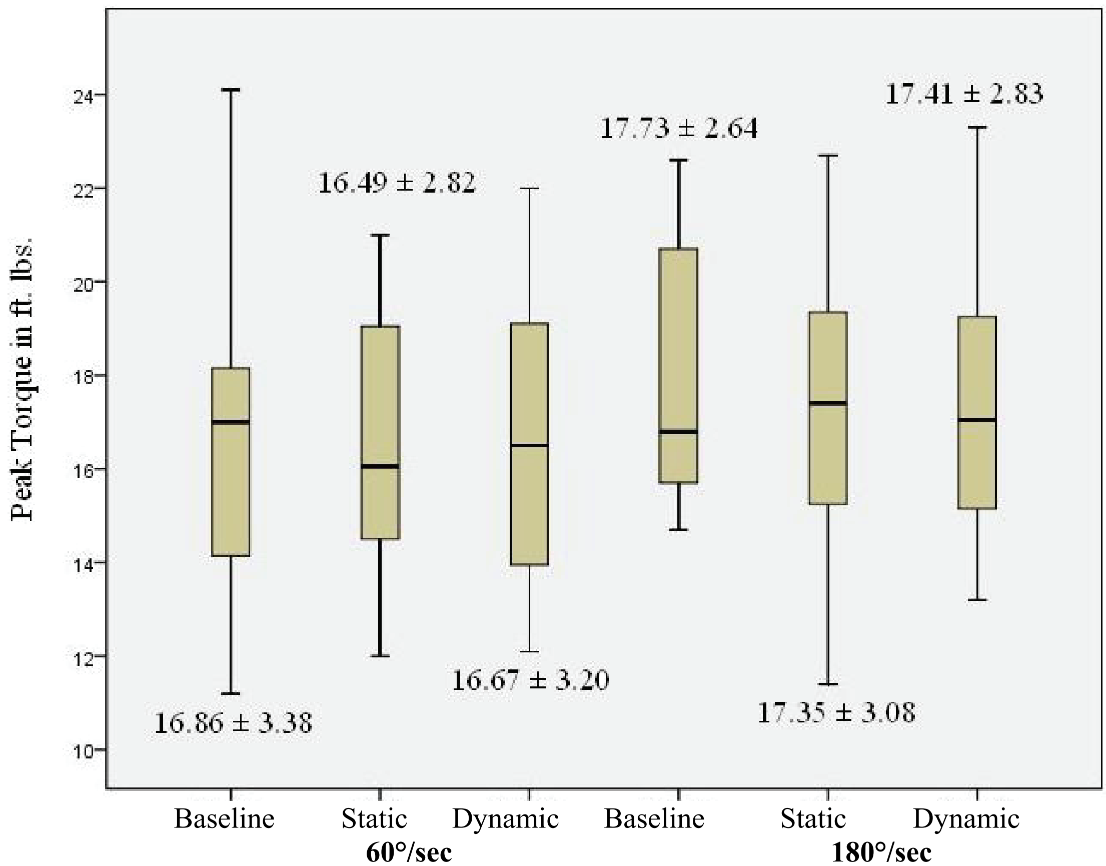

Figure 6. Means ± standard deviations for isokinetic external rotation peak torque

Hypothesis three stated that there will be no statistically significant difference in glenohumeral isokinetic peak torque between the static stretching and the dynamic stretching sessions. Thus, the hypothesis failed to be rejected.

Table 7. *Isokinetic Peak Torque Output*

Session	Mean ± SD in ft.lbs.
Baseline	
IR 60° /sec	16.67 ± 4.28
IR 180°/sec	15.01 ± 3.98
ER 60° /sec	16.86 ± 3.38
ER 180°/sec	17.73 ± 2.64
Static	
IR 60° /sec	17.43 ± 4.55
IR 180°/sec	14.90 ± 4.53
ER 60° /sec	16.49 ± 2.82
ER 180°/sec	17.35 ± 3.08
Dynamic	
IR 60° /sec	17.14 ± 3.81
IR 180°/sec	15.00 ± 4.38
ER 60° /sec	16.67 ± 3.20
ER 180°/sec	17.41 ± 2.83

CHAPTER FIVE

Discussion

The purpose of this study was to assess the effects of static and dynamic stretching on isokinetic power and peak torque production of the shoulder internal and external rotators. The results indicated that there were no statistically significant differences between the stretching conditions. This is in agreement with the results of Torres et al. (2009) and Katz et al. (2009), who reported no significant differences in upper extremity performance after dynamic or static stretching, and Haag et al. (2010) and Daphen et al. (2009), who reported no significant differences in upper body performance after static stretching. Some of the current research has found no significant impact of static or dynamic stretching on the lower extremity either (Handrakis, Southard, Abreu, Alois, Doyen et al.; Winke, Jones, Berger & Yates, 2010). However, other researchers, including Evetovich et al. (2003) who evaluated the effects of static stretching of the biceps muscle (2003), and many studies evaluating lower extremity performance after stretching have found significant differences in performance between dynamic, static and no stretch protocols (Little & William, 2006; Fletcher & Anness, 2007; Nelson et al., 2001; Nelson et al., 2005; Khorasni et al., 2010; Chaouachi et al., 2009; Wilson, Hornbuckle, Kim, Ugrinowitch, Lee et al., 2009).

Internal and External Rotation Range of Motion

With the variety of upper body stretches being used in the literature, it may be beneficial to determine whether or not an acute increase in range of motion correlates with the theory that stretching puts the muscle fibers at a less-than-optimal length for firing. The current study measured range of motion at baseline and after both the static stretch and dynamic stretch protocols. By measuring both range of motion and performance, it may be possible to establish whether or not a correlation between a significant increase in range of motion and a significant decrease in performance exists. The upper body performance measurement used in the current study was isokinetic peak torque and power. Evetovich et al. (2003), Daplyn (2009), Katz et al. (2009) also used isokinetic testing. In other studies, Haag et al. (2010) used pitching velocity and accuracy, Torres et al. (2009) used medicine ball throws, and Knudson et al. (2004) used tennis serve velocity.

The baseline results for internal and external rotation range of motion in this study were within “normal” limits as stated by the American Academy of Orthopedic Surgeons (AAOS) (1965). According to the AAOS the normal active range of motion for internal rotation is <70° and the normal active range of motion for external rotation is <90° in healthy adults. In the current study, the end range of motion for internal rotation measurements ranged from (47.0°-69.0°) and the end range of motion for external rotation was from (71.5°-88.3°).

Even though Sauers et al. (2007) and Laudner et al. (2008) both found significant differences in range of motion after static stretching of the shoulder, the current study did not find significant differences between either of the stretch protocols and baseline values. The referenced studies used experienced clinicians to stretch participants while subjects in this study stretched themselves under the supervision of a clinician since this is what typically occurs in team warm-ups. Another difference is that Sauers et al. had participants in the supine position during the internal and external rotation stretches. The current study used a similar position when range of motion was measured, but participants were standing while performing stretches which is again most typical during team warm-ups. This difference could have affected results because, even though the scapula was closely monitored for compensation during ROM measurements in the current study, the scapula was free to move during stretching. Also in the study by Sauers et al., the table limited scapular motion and consequentially stretched the internal and external rotators differently. Additionally, ten other stretches were performed on the thirty collegiate baseball players. These included: shoulder rolls, pectoral stretch, extension stretch, flexion stretch, shoulder circles, the pump stretch, shoulder flexion stretch, elbow circles, wrist circles, and arm waves. This protocol is called the Fauls' modified passive shoulder stretching routine and each stretch was performed with five 7 second holds or 10 repetitions each.

In the study by Launder et al. (2008), 33 National Collegiate Athletic Association Division I baseball players (15 pitchers, 18 position players) and 33 physically active male college students participated. The sleeper stretches they used also limited scapular motion and were performed by experienced clinicians. The stretch was performed with the participant in a side-lying position and the dominant shoulder and elbow positioned in 90° of flexion. After the investigator passively internally rotated the shoulder by grasping the distal forearm and moving the arm toward the table, the pressure was held constant at the end range of motion for 30 seconds. This was performed three times with 30 seconds of rest between each stretch. Increases in internal rotation ROM after these stretches were significant, but no significant difference was found in external rotation.

The gender difference between these two studies and the present study may have contributed to the variation in results since females typically have a greater range of motion than males so there may be less range of motion to gain (Norkin & White, 2003). Also, the differences in competitive level of study participants in the referenced studies compared to the present study could have increased the effects of glenohumeral internal rotation deficit (GIRD) causing an increased tightness of the external rotators. If this is the case, then the participants in the studies with collegiate baseball players would have more internal rotation to gain than participants in this study who were recreationally active females (Borsa et al., 2008). The amount of stretching in the current study also differed slightly from the studies by Launder et al (2008) and Sauer et al. (2007) with the current study using three sets of 25 second holds per stretch which was slightly less than Launder et al. but more than Sauers et al.

In regard to studies evaluating the effect of stretching on athletic performance, the stretches used in the current study were similar to those of Haag et al. (2010) and Torres et al. (2009). The "deltoid press" static stretches used in this study were comparable to Haag et al.'s horizontal adduction stretch and Torres et al.'s deltoid press stretch. The "deltoid press" dynamic stretches used in this study resembled the cross over arm swings used in Torres et al.'s dynamic protocol. The static internal rotation and external rotation stretches were also similar to Haag et al.'s internal and external rotation stretches except that Haag et al. had athletic training students assist with these stretches. Similar to the current study, stretches were performed in the standing position in both of these studies.

Isokinetic Peak Torque and Average Power at 60°/second and 180°/second

The range of peak torque values at 60°/second in this study were similar to the results of Tis & Maxwell (1996) who also tested recreationally active females in a similar 90-90 seated position as was used in this study. Peak torque at baseline in the current study was (11.1-28.4 ft lbs.) for internal rotation and (11.2-24.1 ft lbs) for external rotation compared to (13.0-23.4 ft lbs) and (10.8-26.94 ft lbs), respectively, in Tis & Maxwell's study. No studies that reported isokinetic peak torque at 180°/second or isokinetic average power of the shoulder internal or external rotators were found for comparison.

In the current study, no significant differences were found for isokinetic peak torque measurements at 60°/second after stretching. This is in agreement with the results of Daphen et al. (2009) who investigated the effects of static stretching on isokinetic peak torque of the internal and external rotators at 60°/second after three different stretch times. Healthy university students (M=5, F=11) between the ages of 18 and 30 were used in the study. The same internal rotation stretch and external rotation stretch were used three times in each protocol, but were held for either 10, 30 or 60 seconds each time. This is in contrast to the current study which used five different static stretches performed three times each and held for 25 seconds each time. Daphen et al. also used a 60°/second concentric-concentric isokinetic test with the only difference in isokinetic testing being that the subjects were placed in the scapular instead of a 90-90 position like the current study. Additionally, pre and post stretch isokinetic measurements were performed for each of their 3 static stretch protocols instead of comparing them to a no stretch or dynamic stretch protocol performed on a separate test day as was done in this study.

As was the case for isokinetic peak torque at 60°/second, no significant differences were found for the peak torque measurements at 180°/second in this study. The results are similar to Katz et al. (2009) who looked at the effect of static and dynamic warm-up in upper extremity functional activities. Participants were physical therapy students between the ages of 21 and 35 years. Upper extremity testing included: proprioception, softball throw, isokinetic testing of internal and external rotation at 180° and 300°/second, and Closed Kinetic Chain Upper Extremity Stability. All stretches were performed once with a 30-second hold. No description or number of stretches or differentiation between dynamic or static protocols was given in the article. Ten maximal test repetitions, as opposed to the five used in the current study, were used to calculate average peak torque and work. A week was allowed between the dynamic and static test sessions. The current study used a 48 to 72 hour recovery period between testing, and the two studies also differ in the amount of testing performed per session. Katz et al. performed twice as many isokinetic test repetitions and it was unclear whether each of the other upper body performance tests were performed on the same day or separate days

Dynamic stretching is theorized to enhance force and power development by raising core body and deep muscle tissue temperatures, stimulating the nervous system, decreasing the inhibition of antagonist muscle, and increasing post-activation potentiation (Jaggers et al., 2008). It is also said to assist with the rehearsal of specific movement patterns, help proprioception and preactivation, and allow an optimum switch from the eccentric to concentric muscle contraction required to generate high running speeds (Fletcher & Annness, 2007). The proposed benefits of an optimal switch from eccentric to concentric muscle contraction at high speeds may not have affected results since isokinetic testing was performed with concentric-concentric motions in a limited range of motion at a set speed. Several of the studies that found significant increases in performance after dynamic stretching evaluated performance based on the speed of running, agility or vaulting as their primary measurement (Little & Williams, 2006; Siatras et al., 2003, Khorsani et al., 2010). This is unlike the testing in the current study in which repetitions were performed at set velocities, 60°/second and 180°/second, and isokinetic peak torque and average power were measured at those same velocities.

Since the stretching in this study was performed at a steady, controlled pace, which was less than the isokinetic test speed, the carry over effects may have limited the rehearsal of specific movement patterns and nervous system stimulation. However, the pace used in this study was similar to the "one stretch cycle per 2 seconds" pace used by Little & Williams (2006) who found significantly improved sprinting and agility times after dynamic stretching. The patterns of the dynamic stretches in the current study may have also limited the potential benefits of rehearsing specific movement patterns. The arc of internal rotation used for the internal stretch started behind the back with the elbow flexed to 90° with the forearm pointed down perpendicular to the floor and finished at the terminal range of motion, but the arc of internal rotation used for testing started with the elbow flexed to 90° with forearm pointing up perpendicular to the floor and finished internally rotated 55° from the starting point. However, the external rotation stretch did go through the whole test range of motion with some additional degrees of both internal and external range of motion. If the study was limited to dynamic warm-up, internal range of motion could have been performed in front of the body and closer to the testing range of motion but, since the goal was to make dynamic and static stretches comparable and to reach terminal range of motion, stretching the internal rotators behind the back was chosen.

Some researchers hypothesize that stretching reduces muscle stiffness and places the contractile filaments at a less-than-optimal length for the development of maximal tension (Beedle et al., 2008). Since no significant increases in range of motion were noted after stretching, the stretches in the current study may not have significantly affected the length of the contractile filaments. The amount of stretching in this study may not have been enough to activate the mechanisms proposed in the theory that stretching causes signals from neural structures, such as muscle spindles, to work more slowly and reduce the number of activated muscle fibers (Beedle et al., 2008). Haag et al. (2010) and Katz et al. (2010) used one set held for 30 seconds for each of their stretches while Torres et al. (2008) and Knudson et al. (2004) both used two sets of 15 seconds per stretch. Knudson et al., who tested performance using the tennis serve, and Torres et al., who tested performance testing using medicine ball throws, used upper and lower body stretches since their performance testing involved both the upper and lower body. Knudson et al. used three stretches for the lower extremity, three for the shoulder, and one for the forearm. Torres et al. used two stretches for the hips and core, one stretch for the neck, and four stretches for the shoulder. There was no mention of lower body stretching in Haag et al.'s study even though the performance test, pitching, involved both the upper and lower body. Haag et al.'s study included 6 shoulder-specific stretches. All of these studies had a total duration of 30 seconds of stretching and no significant differences. Evetovich et al. (2003) had a much higher total duration of stretch, targeted the elbow joint instead of the glenohumeral joint, and found significant differences during isokinetic and mechanomyography measurements. The primary investigators applied three different static stretches to target the forearm flexor muscle group. Each stretch was performed four times with 30 second holds and 15 seconds in-between for a total of 2 minutes per stretch. In the current study, each stretch was performed three times with 25 second holds for a total of one minute and fifteen seconds per stretch. More research needs to be conducted to determine if the 4 x 30 seconds of stretching performed is the minimal amount of static stretching that will elicit the decrease in performance that Evetovich et al. found and if this quantity has the same effect on the glenohumeral joint.

Uniqueness and Limitations

To the author's knowledge, this is the only study that exclusively evaluated the effects of stretching on the performance of female participants. Torres et al. (2008) used 11 male track and field runners, Evetovich et al. (2003) had 18 college-age men (10) and women (8) who met the American College of Sports Medicine Association's minimal requirements for moderate aerobic activity (2000), Haag et al. used 12 college baseball players (2010), and Katz et al. (2009) used an unspecified number of physical therapy students (2009). Knudson et al. (2004) had 83 tennis players from the beginning level to advanced with 39 men with a mean age of 39.1 ± 16.7 and 43 women with a mean age of 35.5 ± 17.5. All subjects in the current study had within normal range of motion prior to stretching, were female, were moderately active according to the ACSM, were regularly involved in upper body exercise, and had been actively participating in an upper body sport within the last year. These requirements helped to create a more homogeneous sample, but limited power of the study by decreasing the number of volunteers who qualified. Sixteen volunteers qualified for the study and an analysis of power was performed a priori. The effect size for power was found to be (0.25). A sample size of 24 would have been needed to bring the effects size for power above (0.80). The actual effect size for power with 24 subjects would have been (0.86).

Future Directions & Conclusions

In summary, the results of this study were not statistically significant, but they do add to the growing literature on the effects of static and dynamic stretching on the upper extremity. Future research needs to evaluate the claim that there are detrimental effects of static stretching, and if so, at what stretch duration are they manifested. In light of the results of this study and the current research, it appears that static and dynamic stretches do not affect performance of the upper extremity if the total duration of stretching each muscle group is kept below 30 seconds or at least below 1 minute and 15 seconds. It appears that 30 seconds of total duration per stretch is not enough to elicit a detrimental effect on medicine ball throws (Torres et al., 2008), baseball pitching velocity (Haag et al., 2010), and isokinetic testing at 180° or 300°/second (Katz et al., 2009). Seventy-five seconds per stretch was not enough to elicit detrimental effects with isokinetic testing at 60° or 180°/second in this study. However, a total duration of 2 minutes per stretch was enough to cause a significant effect on the biceps brachii when three stretches targeted the same muscle group (Evetovich et al., 2003).

In the current literature, a variety of stretches has been used for the upper body. This is especially important with the evaluation of the upper extremity due to the complexity of the glenohumeral joint. Diversity among stretches makes it more difficult for cross-study comparison of stretch duration, intensity, and results. Future studies should include detailed descriptions of performed stretches so that studies can be better replicated and results can be built on. Reporting other factors, such as whether or not subjects stretch themselves, is the intensity of each stretch, how many stretches are performed, and whether or not the lower extremity is used in the performance test, can also help in expanding the research on this topic.

Future research should include more specific inclusion and exclusion criteria so that results can be applied to a precise population. For example, results on athletes involved in baseball, tennis, and swimming, are likely to fluctuate since the various demands of each sport result in different muscle groups becoming stronger or tighter. Also, some researchers have suggested the effects of stretching on performance of the lower extremity may differ between trained and untrained athletes (Egan et al., 2006). Much of the current upper extremity research mixes both male and female participants (Katz et al., 2010, Torres et al., 2008; Knudson et al., 2004). Since females are typically more flexible, this could affect outcomes (Norkin & White, 2003). Consequently, future research should consider gender, training level and sport when determining inclusion criteria.

Since there are still a limited number of studies on the upper extremity and the results among lower extremity studies are mixed, athletes and coaches may elect to withhold athletes from static stretching immediately prior to competitions requiring speed and power or at least give five minutes between stretching and the performance (Torres et al, 2008). Dynamic stretching appears to have no effect on the upper body and no effect or improved performance on the lower extremity. Athletes may want to add dynamic stretching prior to competition to prepare the muscles for performance and use static stretching at the end of competition to maintain or improve flexibility, however, at this time best practice has not been established.

APPENDICES

APPENDIX A

Basic Information Questionnaire

Baylor University

Exercise and Sport Nutrition Laboratory

Personal Information

Name:

Address:

City: _________________________ State: ______ Zip Code
SS#______________________

Home Phone: (___) __________ Work Phone: (___)

Beeper: (___) _____________ Cellular (___)

Fax: (___) _____________ email address: ____________________

Birth date: _____ / _____ / _____ Age: ______ Height: ______ Weight: _____

APPENDIX B

BAYLOR UNIVERSITY
DEPT. OF HHPR

Medical History/Activity Questionnaire

<u>Directions</u>. The purpose of this questionnaire is to enable the researchers to evaluate your health and activity status. Please answer the following questions to the best of your knowledge. All information given is **CONFIDENTIAL** as described in the **Informed Consent Statement**.

Name: ____________________________________ Age _____Date of Birth_______________

MEDICAL HISTORY

1. If you have a prior history of unresolved pain, injury or surgery to any of the following body parts, please place a check by any that apply.

☐ Shoulder
☐ Elbow
☐ Neck/spine

Please provide information regarding the type and extent of the injury or injuries that you checked.

____
______
____
______

2. Are you currently taking prescription or over-the-counter medication for pain or inflammation? YES_____NO_____

If yes, what medication(s) are you taking?
____

3. Are you currently taking or have taken within the last 3 months any nutritional supplement except for
multivitamins? YES _____ NO_____

If yes, please explain ____

Recommendation for Participation

____ No exclusion criteria presented. Subject is ***cleared*** to participate in the study.
____ Exclusion criteria is/are present. Subject is ***not cleared*** to participate in the study.

Signed: __________________________________ Date: _______________________

APPENDIX C

Exercise & Supplement History/Activity Questionnaire

1. Describe your typical occupational activities.

2. Describe your typical recreational activities

3. Describe any exercise training that you routinely participate.

4. How many days per week do you exercise/participate in these activities?

5. How many hours per week do you train/play?

6. How long (years/months) have you been consistently training?

7. Which sport(s) are you involved in?

8. What position(s) do you usually play?

9. Which is your dominant arm/shoulder during sporting activity (i.e. throwing arm)? Right / Left

10. When was the last time you ingested an anti-inflammatory product?

11. What was the reason you were taking an anti-inflammatory product?

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