STATIC STRETCHING VERSUS DYNAMIC STRETCHING IN ATHLETICS

A Paper
Submitted to the Graduate Faculty
of the
North Dakota State University
of Agriculture and Applied Science

By

Dewayne Nathaniel Dale Jr.

In Partial Fulfillment of the Requirements
for the Degree of
MASTER OF ATHLETIC TRAINING

Major Department:
Health, Nutrition, and Exercise Sciences

March 2010

Fargo, North Dakota

North Dakota State University
Graduate School

Title

STATIC STRETCHING VERSUS DYNAMIC STRETCHING IN ATHLETICS

By

Dewayne Nathaniel Dale, Jr

The Supervisory Committee certifies that this ***disquisition*** complies with North Dakota State University's regulations and meets the accepted standards for the degree of

MASTER OF ATHLETIC TRAINING

ABSTRACT

Dale, Dewayne Nathaniel, MATrg, Department of Health, Nutrition, and Exercise Sciences, College of Human Development and Education, North Dakota State University, March 2010. Static Stretching versus Dynamic Stretching in Athletics. Major Professor: Dr. Pamela Hansen.

Athletes in a variety of sports will perform a stretching routine before each workout or competition. This is why coaches, strength and conditioning specialists, and athletic trainers are always in search of new ways to increase performance and reduce injuries. As there are different types of flexibility, there are a variety of types of stretching techniques, and all have their purpose in the athletic world. Static stretching has been the traditional way of physically preparing the body prior to exercise, and recent research is bending toward another stretching technique, dynamic stretching. Static stretching is an easy to learn technique that increases static flexibility, relaxes muscles, and realigns muscle fibers, but it may not be the best way to "warm" the body up before a workout or competition. Performing a dynamic stretching routine can provide athletes with opportunities to perform sports specific movements and to increase blood flow and temperature, which is a true way to "warm" up the body beforehand. These two different techniques can be utilized effectively within an athlete's workout regimen. However, the differences in the athletes, gender, and the type and level of the sport are important factors to consider in the evaluation of the two stretching techniques. By understanding these main areas, it will be easier to develop a well-designed warm-up prior to a competition.

ACKNOWLEDGEMENTS

I would like to thank my awesome wife for supporting me and cooking tasty food for me so that I could finish my research and continue my education. I want to thank my families, from the southwest to the great white north, for making me put forth my best effort in everything I do. I would also like to thank Dr. Pamela Hansen for her patience and support throughout the process.

TABLE OF CONTENTS

LIST OF FIGURES

CHAPTER I. INTRODUCTION

Overview of Topic

Athletes, coaches, and athletic trainers traditionally include stretching as part of a pre-activity warm-up in order to improve performance and decrease the risk of injury. Static stretching, the most common method, involves slowly moving a joint to the endpoint of its range of motion and holding that stretch position (Weerapong, Hume, & Kolt, 2004). Dynamic stretching is another method that consists of functional based exercises, incorporating sport-specific movements which prepare the body for a workout (Behm & Kieble, 2007). The static stretching method is well-known for several reasons: it is simple to learn, can be performed individually, and it is effective at increasing joint range of motion (Kovacs, 2006). Static stretching has been thought to improve performance by maximizing joint range of motion, leading to increased elasticity of the musculotendinous unit (MTU), and improving coordination (Preedy & Peters, 2002; Shellock & Prentice, 1985). Regardless of this common stretching practice, there is no conclusive evidence supporting the theory that static stretching prior to exercise reduces the risk of injury (Shrier, 2004).

Static stretching has recently been shown to decrease performance in measures of maximal force production sprinting speed, jump height, and reaction time and balance (Cramer, Housh, Johnson, Miller, Coburn, & Beck, 2004). The performance reductions that follow a static stretching routine were explained by mechanical and neurological factors. The mechanical factor is increased elasticity of the MTU as a result of static stretching. As the MTU lengthens and becomes more flexible, the conctractile elements will contract over a bigger distance, and more forcefully, which results in a reduced peak torque and slower rate of force development (McMillan, Moore, Hatler, & Taylor, 2006). A stiffer muscle or MTU would facilitate rapid changes in tension and lead to a faster joint motion response (Preedy & Peters, 2002). These characteristics of a stiffer muscle can potentially improve performance. Neurologically, static stretching may decrease the activation of motor units, which produces negative effects of muscle force production. Cramer et al. (2004) and Cramer, Housch, Weir, Johnson, Coburn, and Beck (2005) state that static stretching performed on the dominant leg can only result in decreases in motor unit activation and peak torque in both the stretched and unstretched limbs. This only provides more support to the performance decreases due to neurological factors.

Over the years this growing body of evidence has changed athletic trainers, coaches, and strength and conditioning professionals' warm-up routines. They began to shift away from static stretching in favor of a functional dynamic warm-up prior to practices and games (Kovacs, 2006). Dynamic stretching routines combine skipping, shuffling, directional running, and various calisthenics of increasing intensity that mimic movement patterns necessary for success in a particular sport. Young and Behm (2003) suggest that dynamic stretching routines prior to activity may improve sport performance. It does so by increasing joint range of motion and core body temperature, resulting in increased blood flow to the muscles and faster nerve-impulse conduction. The stimulation of movement of patterns used in a sport may also improve coordination by providing an opportunity for sport specific skill rehearsal (Mann & Whedon, 2001). Improvement in performance after dynamic stretching has been recorded in sprinting, jumping, and peak force generating capacity (McMillan et al., 2006).In the research movement drills and ballistic stretching can be compared and related to dynamic stretching. For that reason, further research clearly defining dynamic stretching is substantial, as well compare the effects of both static and dynamic stretching on sport performance.

Statement of Purpose

The purpose of this comprehensive paper was to review the literature that explores the effects static stretching and dynamic stretching had in athletics and document current research as it related to sport performance and injury prevention.

Specific Objectives

1. Reviewed current literature on static and dynamic stretching techniques routines.
2. Compared and contrasted static stretching and dynamic stretching techniques among athletics.
3. Described how current literature on static and dynamic stretching affected sport performance and sports injury.

Steps of Review Process

The review of the literature was researched using North Dakota State University Library for books and referred research articles from the library databases Science Direct, SPORTDiscus, EBSCO host, and PubMed. The keywords used to search included static stretching, dynamic stretching, flexibility, stretching and sport performance. Also, the reference sections from research articles that were found in the previously mentioned databases were thoroughly reviewed and additional references will be taken from them.

Definitions

Static Stretch – Slowly moving a joint to the end point of its range of motion and holding that position for a period of time with little to no movement. (Yamaguchi & Ishii, 2005).

Dynamic Stretch – Controlled movements that gently take an individual(s) to his or her end range of motion (Yamaguchi & Ishii, 2005).

Flexibility – The intrinsic property of body tissues that determines the range of motion achievable without injury (Anderson, Hall, & Martin, 2005).

Range of Motion – the end point ranges that can be moved about a joint. (Anderson,Hall, & Martin, 2005).

Musculotendinous Unit – The link between the skeletal system and the contractile component of the muscles. (Preedy & Peters, 2002).

Postactivation Potentiation – A mechanism that occurs in the fast-twitch muscles which increases the efficiency of a muscular contraction by lowering the threshold for recruitment of motor units (McMillan et al., 2006).

Electromyography (EMG) – A technique for evaluating and recording the activation signal of muscles (Cramer et al., 2005)

Mechanomyography (MMG) – A technique used for determining muscle contractile properties through the lateral expansion of muscle fibers (Cramer et al., 2005).

Twitch Interpolation – A technique used to study the degree of motor unit activation during voluntary muscle contraction (Herbert & Gandevia, 1999).

Significance of Paper

It is important to educate athletes, coaches, and allied health professionals about the differences between stretching techniques, decrease the risk of sports injury, and increase sport performance. This will allow coaches and athletes to evaluate their current warm-up/stretching routine and evaluate it and possibly improve it so that it is beneficial before or after a competition.

Organization of Remaining Chapters

Chapter I contains an overview of the topic, statement of purpose, brief review of literature, review process, definitions and limitations. Chapter II includes the brief review of literature and further discusses static and dynamic stretching effects on anatomical structures and sport performance. A discussion will conclude chapter II. Chapter III includes static and dynamic stretching effects on injury prevention as well as a dynamic warm-up protocol.

CHAPTER II. REVIEW OF LITERATURE

Stretching and Anatomy

Skeletal muscle is a form of striated muscle tissue linked to the bones by bundles of collagen called tendons, which regulate body movement. It is one of the three major muscle types, the others being cardiac muscle and smooth muscle. The skeletal muscle has a musculotendinous unit (MTU), which is the connection point between the muscle and its tendon. Skeletal muscle is made up of individual components known as muscle fibers or myofibers. These myofibers are long, cylindrical, multinucleated cells composed of actin and myosin myofibrils. The sarcomere is the segment of actin and myosin myofibrils and the contractile unit of a skeletal muscle. The term muscle refers to multiple bands of muscle fibers held together by connective tissue (Martini, Ober, Garrison, Welch, Hutchings, & Kathleen, 2004).

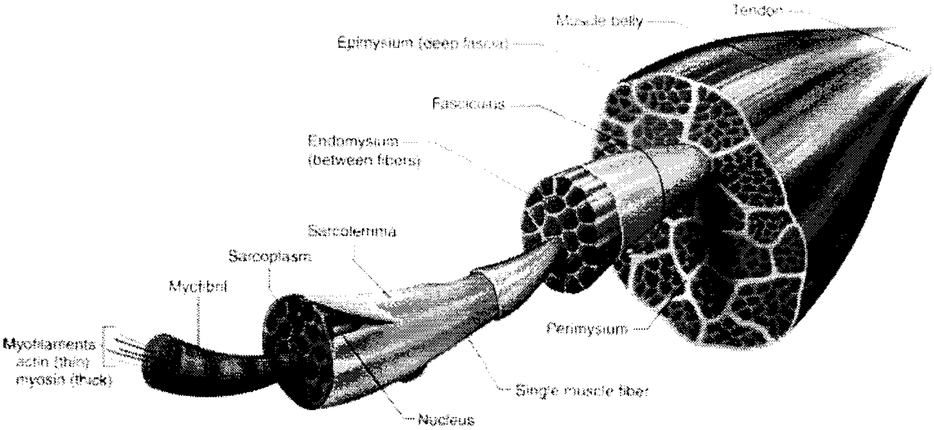

Figure 1. The elements of a muscle. (Reprinted, with permission, from National Strength and Conditioning Association, 2008, Essentials of strength training and conditioning, 3rd ed. (Champaign, IL: Human Kinetics), 5.)

For years, the athletic/active population has been advised to stretch prior to physical activity to improve performance and to decrease risk of injury. Several reasons leading to improved performance were, including maximizing joint range of motion (Shellock & Prentice, 1985). For example, a baseball pitcher that is lacking sufficient flexibility in the upper body and lower body may not be able to maintain an optimal throwing mechanism, therefore his speed is reduced and performance is negatively affected. In addition, different sports require different amounts of flexibility to maximize performance. More specific sports such as gymnastics, diving, and certain events in track-and-field require a large degree of flexibility around specific joints. Behm, Button, and Butt (2001) also state that a lack of flexibility may result in movements that are awkward or uncoordinated. Peak performance in any sport requires an individual to maintain specific biomechanics to maximize speed, efficiency, or power. Therefore, a change in biomechanics may affect performance negatively.

Stretching has been advised as a means to decrease post-exercise muscle soreness and prevent injury to muscles, specifically the MTU (Preedy & Peters, 2002). The MTU includes both active contractile elements (muscle fibers) and passive elements (tendons). When a joint moves through a greater range of motion or when large forces are placed on the MTU, a more compliant tendon can absorb a greater amount of energy. The more energy absorbed allows for more protection of the active contractile elements, reducing risk of injury to the muscle fibers (Preedy & Peters, 2002). A muscle strain injury is cited as the most frequent sporting injury characterized by a partial or complete tear of the MTU. Muscle strains occur when a muscle is stretched to a critical tensile force (Anderson, Hall, & Martin, 2005). Therefore, it would seem reasonable that a more compliant MTU would be able to withstand a greater tensile force, which would be beneficial at injury reduction. Weldon and Hill (2003) have also indicated that individuals with very little flexibility are more likely to experience injury in the form of muscle strains. Stretching as a way to increase the compliance of the MTU is a logical way to reduce risk of injury (Thacker, Gilchrist, Stroup, & Kimsey, 2004).

Mechanical and neurological factors may play a vital role in the decreased force production after static stretching. Preedy and Peters (2002) suggest that static stretching may result in increased compliance or elasticity in the MTU, which allows the tendon to absorb more energy that is placed on it. Witvrouw, Mahieu, Danecls, and McNair (2004) argue that in some sporting activities, particularly those involving movements that transfer considerable force to the MTU, a stiff tendon might be advantageous as it would allow for faster joint motion response. When the MTU stretches it is more compliant and contractile elements must contract over a greater distance to "pick up the slack", leading to reduced peak torque and slower rate of force development (Witvrouvw et al., 2004).

Decreases in motor unit activation have been reported on several occasions (Cramer et al., 2005) through decreases in electromyography (EMG) amplitude after a static stretching routine. Weerapong, Hume, and Kolt (2004) suggested that static stretching may decrease performance in repetitive power-based movements, which was due to motor unit activation. Mechanically, increased elasticity of the MTU can cause slow joint movement and at the same time the neural changes such as, decreased motor unit activation, play a role in performance reduction.

Static Stretching and Sport Performance

Among the various methods of stretching that effectively increase range of motion the most common type is static stretching (Weerapong, Hume, & Kolt, 2004). It involves slowly moving a joint to the endpoint of the range of motion, usually to the point just before onset of pain. According to The National Strength and Conditioning Association (NSCA), a static stretch should be held for 30 seconds (Baechle & Earle, 2000; NSCA, 2008). The American College of Sports Medicine (ACSM) recommends holding a stretch for 15 to 30 seconds, and acknowledges that no further improvement in flexibility is seen past 30 seconds (ACSM, 2005). The static stretching method is advantageous for increasing flexibility, which is defined as the intrinsic property of body tissues which determines the range of motion achievable without injury at a joint or group of joints (Knudson, 1999). Anderson, Hall, & Martin, (2005) define flexibility as the intrinsic property of body tissues that determines the range of motion achievable without injury. According to Kovacs (2006) increasing static flexibility during a pre-exercise warm-up may be detrimental to performance.

In the sports performance world, stretching forms an integral part of any conditioning program because it prepares athletes physiologically and mentally before a competition. In the research reviewed, the effects of static stretching on athletic performance were evaluated. In a study examining stretching and sports performance, Shrier (2004) stated that the majority of studies he reviewed suggested that individuals who are not highly trained, static stretching can decrease performance in tests of lower-body strength and power.

Three studies researched the effect static stretching had on National Collegiate

Athletic Association (NCAA) athletes. First, Unick, Kieffer, Cheesman, & Feeney (2005) examined the acute effects of static and ballistic stretching on vertical jump performance and investigated whether power was altered. The subjects evaluated were actively trained NCAA Division-III women's basketball players and performed a series of vertical jumps after bouts of no stretching, static stretching, or ballistic stretching. The results concluded that there were no differences in vertical jump scores and stretching did not hinder performance. A second study investigated the performance of vertical jump tests following static stretching and proprioceptive neuromuscular facilitation (PNF) stretching. The participants were NCAA Division-I athletes in a variety of sports. The results showed no change in vertical jump performance following a static stretching routine, but revealed a significant decrease in performance following a PNF stretching routine (Church, Wiggins, Moode, & Crist, 2001). The third study examined the effects static stretching had on peak torque and mean power output in NCAA Division-I women's basketball players. The participants had to perform a series of leg extensions on a Biodex system following a bout of static stretching. Much the same as the previous study, the results showed no changes in peak torque or mean power output of the leg extensors (Egan, Cramer, Massey, & Marek, 2006).

Two more studies that involved athletes from different sports contributed to the results of unchanged sport performance measures. Little and Williams (2006) examined the effects of different modes of stretching within a pre-exercise warm-up in professional soccer players. They were tested on a countermovement vertical jump (CMJ), stationary jump, 10 meter sprint, flying 20 meter sprint, and an agility test after different warm-ups. These warm-ups consisted of static stretching, dynamic stretching, or no stretching, and reported that the bout of static stretches prior had no effect on CMJ height or 10 meter sprint time. Similar to the previous study, Knudson, Noffal, Bahamondde, Bauer, and Blackwell (2004) examined static stretching and the effects on a tennis serve. Tennis players, ranging from beginning to expert level, performed a warm-up and a static stretching routine before performing a tennis serve. The service speed and service percentage (accuracy) of each subject was measured. The researchers found no change in tennis serve performance at any skill level, age, and gender after a bout of static stretching.

In the research reviewed, very few studies reveal that static stretching does in fact increase sport performance. In a study involving competitive athletes from the United States Military Academy (USMA), researchers examined effects of dynamic and static stretching warm ups (McMillan et al., 2006). Athletes performed either a dynamic stretching warm-up, static stretching warm-up or no warm-up at all, and were tested on performance measures of power and agility. The researchers determined that static stretching actually increased performance on the 5-step jump test (McMillan et al., 2006). Little and Williams (2006) revealed that static stretching for professional soccer players had no effect on most performance tests, however static stretching actually improved the times on a flying 20-meter sprint.

Static stretching also poses results that reveal a decrease in sport performance. Fletcher & Anness (2007) examined the effects of static and dynamic stretch protocols on sprint performance in elite track-and-field sprinters. The athletes were tested on one performance measure, which was the 50 meter sprint, following a static or dynamic stretch warm up. The researchers revealed that the static stretching protocol yielded a slower 50 meter sprint time. In addition, a study by Siatras, Papadoulos, Mamaletzi, Gerodimos, and

Kellis (2003) examined the effect of different protocols, static and dynamic, on speed during vaulting in gymnastics. Eleven boys were asked to perform three different protocols: a warm-up, warm-up and static stretching, and a warm-up and dynamic stretching. These protocols were all performed on three consecutive days. Each gymnast performed a "handspring" vault after each protocol. The results showed a significant difference among the different protocols, with a decrease in the gymnasts' sprint speed following the static stretching protocol. These findings supported the notion that static stretching has inhibitory effects on speed and power development (Knudson, Bennett, Corn, Leick, & Smith, 2001).

Another factor of static stretching focuses on the duration of the effects. A study by Fowles, Sale, & MacDougall (2000) examined the duration of the effects of static stretching focused on young highly active individuals, measuring muscle activation of their plantar flexors. The muscle activation was measured using electromyography and a twitch interpolation technique after a stretch ranging from 5, 15, 30, 45, and 60 minutes post stretching. The results displayed a decrease in maximum voluntary contraction of the plantar flexors and there was a significant decrease immediately following stretching. According to the study, the force reductions of the plantar flexors persisted up to 60 minutes post stretching. The participants who were tested over 30 minutes post stretch showed signs of muscle stiffness, which was a result of not moving for an amount of time. It seemed static stretching created a lasting effect on sport performance and was explained in a study by Pearce, Kidgell, Zois, and Carlson (2009). This study examined a static stretching routine which was followed by a dynamic stretching warm-up. The purpose of this study is to see if adding a secondary warm-up (dynamic) after static stretching would alter the effects on a countermovement vertical jump (CMJ). The athletes' baseline CMJ height was recorded, then again after static stretching, and again after the dynamic warm-up. The results revealed a decrease in CMJ height even after a secondary warm-up was incorporated. This suggests that when static stretching is incorporated into a warm-up routine that included dynamic stretching, the outcomes can still impact performance.

In the literature, the majority of performance measures were based on maximal force and explosive power. Examples of these movements are quick bursts of speed and movements that utilize major muscle groups, such as sprinting and vertical jumping. In addition, the athletic population train and mimic movements to obtain high levels of force and power making them essential aspects to sports performance (Perrier & Hoffman, 2009). Although there were differences among the research, the combined results suggest that static stretching negatively impacted athletic sports performance in measures of maximal force production and explosive power. Holt and Lambourne (2008) examined the relationship of lower body muscular strength and several explosive performance measures on male and female collegiate athletes in a variety of sports. All participants were tested to determine: lower-body muscular strength, countermovement vertical jump, repetition maximum barbell back squat, standing broad jump, agility, sprint acceleration, and spring velocity. The researchers found that there were significant differences among gender in each performance measure. More importantly, the researchers revealed that muscular strength, vertical jumping ability, and peak power output are highly related to the performance measures of speed, agility, and acceleration (Holt & Lambourne, 2008). This study commends the concept that if static stretching can have a negative impact on performance measures in explosive power and maximal force output, it is presumable that measures in agility, speed, and acceleration would be affected. Along with force and power, which are important to sports, speed, balance, and coordination are required by an athlete to achieve a high level of performance as well. In addition, the minimal changes made in an athlete's ability to shift balance quickly or change direction quickly may be able to alter the outcome of an athletic competition. The performance measures of agility, balance, and reaction time are just as important as explosive power and maximal force measures when it comes to improving sports performance (Mann & Whedon, 2001; Perrier & Hoffman, 2009). Additionally, it is understood why measures of agility, balance, and reaction time should be considered along the lines of studies that concern explosive power and maximal performance.

Although agility, balance, and reaction time are important to sports performance, there was little research that examined those specific areas of performance. In the literature reviewed on balance, reaction time, and movement time there was some studies that speculated about static stretching effects on athletic performance. In a previous study involving professional soccer players, the athletes were tested in a zig-zag agility drill against different stretching protocols. Little and Williams (2006) revealed that static stretching didn't affect the zig-zag drill peformance in the professional soccer players. Similarly, McMillan et al. (2006) in another previously mentioned study on athletes in the USMA, found that static stretching had no effect on a T-drill peformance test or a medicine ball throw. In contrast, a third study investigated the effects of an acute bout of lower-body static stretching on balance, proprioception, reaction, and movement time. In this study by Behm, Bambury, Cahill, & Power, (2004), athletes were tested before and after a static stretching routine that stretched the quads, hamstrings, and plantar flexors. This routine involved a warm-up followed by three stretch exercises held to the point of discomfort for 45 seconds. The result revealed that static stretching of the three structures resulted in impaired balance, increased reaction time, and increased movement time in the athlete population (Behm et al., 2004). Studies that examined the performance measures of agility, balance, and reaction time was limited. Although there was limited research and static stretching didn't hinder performances, it is clear that a static stretching warm-up routine didn't increase performance as well.

Chiefly, static stretching posed results in the studies mentioned to decrease performance in a variety of performance measures, which include vertical jumping ability, balance, reaction time, sprint speed, movement time, and peak torque. Although the decreased performance is displayed among athletes, the literature still portrays mixed results on whether athletes are less susceptible to performance decrease after static stretching. In addition, the research didn't specify if either genders or just one were used during the studies involving elite track-and-field, USMA, and tennis athletes.

Dynamic Stretching and Sport Performance

Dynamic stretching involves actively moving a joint through its range of motion without holding the movement at its endpoint, may increase flexibility without reducing neuromuscular activity (Mann & Whedon, 2001). Exercises such as high knee pulls, skipping, walking lunges, carioca, and jumping exercises are examples of dynamic stretching exercises. Behm et al. (2004) suggested that a progression from moderate to high intensity dynamic movements may improve balance, coordination, and enhance neuromuscular function. The study by Behm et al. (2004) reported that just five minutes of moderate intensity of cycling, without any stretching exercises, resulted in improved performance in balance, decreased reaction time, and decreased movement time. Another study by Young and Behm (2003) it showed improved jump height when exercises included a general warm-up, dynamic stretching, or practice jumps. These studies support the importance of including a general component to the warm-up that increases the heart rate and muscle temperature in order to prepare the body for more intense exercise.

In almost all sports, a preliminary jog is usually the first activity in a pre-practice or pre-competition warm-up, which usually lasts from 5 - 10 minutes. The jog performed at the beginning of a warm-up causes dilated blood vessels, ensuring that adequate oxygen is supplied to the muscles being utilized, such as the quadriceps, hamstrings, gastrocnemius, deltoids, abdominal muscles, and pectoral muscles. In addition, muscle temperature will be increased to the optimal level for flexibility and an efficient, powerful muscle contraction (Mann & Whedon, 2001). When an athlete sits down or stands to complete a static stretching protocol, any temperature increases gained during the preliminary jog may be reduced. In contrast, the characteristics of a dynamic stretching protocol require an athlete to perform active movements throughout the warm-up. Muscle temperature remains elevated in a dynamic stretching protocol, because the athletes will continue to perform at a low to moderate intensity (Thacker et al., 2004).

In contrast with static stretching, dynamic stretching has a different effect on sport performance. A previous study by Fletcher and Jones (2004) examined the effects of dynamic and static stretch treatments on rugby union players. After the mandatory 10 minute jog warm-up they performed two 20 meter sprints prior to the stretch protocols, and then two 20 meter sprints after. The types of stretching protocols consisted of passive static stretching, active static stretching, active dynamic stretching, and static dynamic stretching.

Players were tested on 20 meter sprints after completing a static stretching session or a dynamic stretching session. The players who participated in the static stretch treatment displayed slower sprint times. In contrast, the players in the dynamic stretch group displayed faster sprint times or decreased their sprint time (Fletcher & Jones, 2004). In addition, Fletcher and Anness (2007) investigated the effects of static and dynamic stretch components in a track-and-field warm-up, which yielded similar results. After a mandatory warm-up jog, athletes performed a dynamic or static stretch protocol, followed by 50 meter sprints. The group of trained sprinters' sprint time improved after a warm-up that included dynamic stretching components. Fletcher and Anness (2007) proposed that the improvements seen after dynamic stretching may be due to the rehearsal of specific movement patterns found in dynamic stretching exercises. They also hypothesized that dynamic stretching may allow for a more optimal switch from eccentric to concentric muscle action which will improve explosive force production (Fletcher & Anness, 2007).

Little and Williams (2006) provide further confirmation that dynamic stretching as a pre-exercise warm-up increases performance. The authors concluded that four lower-body dynamic stretches, each performed for 60 seconds, resulted in improved performance in both a stationary-start 10 meter sprint and the flying-start 20 meter sprint, as well as improved performance in the zig-zag drill measuring agility. McMillan et al. (2006) revealed that a dynamic warm-up was beneficial in performance measures of power and agility performed by USMA athletes. McMillan et al. (2006) revealed that a dynamic warm-up, which was performed before the measures of performance, resulted in improved performance. The performance measures included were the five-step jump, T-drill, and medicine ball throw, which measured lower body explosive power, agility, and whole body power. The results of Little and Williams (2006) research and McMillan et al. (2006) propose that dynamic stretching exercises may be effective at improving sport performance.

There are several factors that may contribute to performance improvements, such as movement rehearsal, increased muscle temperature, and post-activation potentiation (PAP) (Fletcher & Anness, 2007; Thacker et al., 2004). More specifically, dynamic stretching results in increased heart rate leading to increased blood flow to muscles, muscle temperature, energy substrate delivery to muscle, speed of nerve impulses, and waste product removal, all of which can contribute to improving performance (Thacker et al., 2004).

It is also possible that PAP may contribute to the increase in sport performance. PAP occurs only in fast-twitch muscle fibers that cause enhanced and immediate muscle output in explosive movements following submaximal to maximal muscle contractions. PAP results in increased crossbridge formation and this quicker rate of crossbridge formation would affect the rate of force development, possibly improving sport performance. In sports, every movement an athlete makes is a simultaneous reaction of different muscles to complete the action (Young & Behm, 2003). For example, the quicker an athlete can go from side shuffling to a forward sprint will increase that athlete's advantage in sport, which ultimately increases sport performance. Behm et al. (2004) speculated that PAP would benefit balance and reaction time by decreasing response time to shifts in body posture. Dynamic stretching, depending on intensity level, will cause submaximal or maximal contractions and therefore activate PAP.

An important aspect of a dynamic stretching routine is the freedom to incorporate sport-specific movement patterns, which may contribute to performance improvements. In a study using rugby athletes, the rehearsal of specific movement patterns in a sprint cycle with submaximal muscle contraction is attributed to the improved sprint performance by enhancing movement pattern coordination (Fletcher & Jones, 2004). Furthermore, the rehearsal of movements such as carioca, shuffling, and short agility drills may be beneficial to sports that require high-speed movements, like soccer (Little & Williams, 2006).

Along with dynamic stretches, an aerobic component, like jogging, should be a part of any pre-exercise warm-up prior to stretching (Knudson et al., 2001). The aerobic component is a main reason for increased blood flow and muscle temperature, creating efficient substrate delivery to muscles, and increased neural impulse conduction. The next element of the warm-up will be the dynamic stretching routine. Dynamic stretching will keep an elevated muscle temperature, making it easy enough to increase range of motion without compromising neural input to muscles, and rehearsal of sport-specific movements.

Stretching and Injury Prevention

Generally, the sports population accepts the idea that increasing the flexibility of a muscle-tendon unit will promote better performances and decrease the number of injuries. However, there is little concrete evidence supporting this common perception that stretching prior to activity will reduce an individual's risk of injury. It was described in a systematic review by Weldon and Hill (2003) that most muscle strains occur within normal limits of range of motion, and occur during the eccentric phase of muscle contraction. The eccentric phase of an exercise is when the muscle will develop tension while lengthening. Flexibility is an intrinsic property of the body tissues and a continuous progression that determines the range of motion achievable without injury at a joint or group of joints

(Thacker et al., 2004). Two review articles that examined stretching and its effects on injury prevention revealed that athletes who exhibit drastically reduced flexibility (i.e., muscle tightness) or extreme flexibility will have a greater risk of injury (Thacker et al., 2004; Witvrouw et al., 2004). Static stretches are the easiest to learn and most frequently used stretching method to increase flexibility, which it does effectively. This would result in an athlete increasing static flexibility which might improve performance for some sports that require an increased range of motion, like gymnastics or swimming (Thacker et al., 2004). Weldon and Hill reveal that a lack of flexibility is also the cause to many of the gradual onset injuries, like low back pain and patella-femoral syndrome, which hinder athletes and their performance.

The reviewed literature affirmed that the role of static stretching in injury prevention includes a broad range of sport activities, each with different musculoskeletal demands. In a systematic review by Weldon and Hill (2003), most of the confusion dealing with stretching and injury prevention is derived from an available body of literature that examined sports with different movement patterns. In addition to their review, they argue that different sports require different levels of MTU flexibility, which may dictate the type of warm-up. Therefore, the sport activities were separated into two broad categories: sports that involved low-intensity muscle stretch-shortening cycle (SSC) movements and sports with high-intensity muscle (SSC) movements (Witvrouvw et al., 2004). It would seem relevant that the sports containing lower-intensity SSCs might actually benefit more from a stiffer MTU. As previously noted, a stiffer MTU (less flexible) would have the ability to transmit force faster across a joint, which results in quicker movements by the athlete. Therefore, sports such as swimming and cycling may benefit from a stiffer MTU unit due to the intensity level. In terms of injury prevention, lower-intensity SSC activities did not place excessive tensile stress on the MTU to cause injury, which means that it is unconvincing that performing static stretching to increase flexibility would greatly impact the rate of injury.

In contrast, a more compliant or flexible MTU needs more energy to "pick up the slack" in muscle contraction during active movements, which has an opposite effect than a stiffer MTU. A compliant MTU has the ability to store and release adequate elastic energy which results in a more forceful contraction or explosive movement without causing damage to the muscle. Sports that involve quick bursts of speed, reaction time, changes in direction, and other high intensity movements might benefit from a more compliant MTU unit. Therefore, activities with such characteristics may benefit in terms of injury prevention by having a more compliant MTU, allowing more energy to be absorbed by the MTU without rupturing. Finally, in the literature reviewed it is important to remember, however, that achieving increased MTU flexibility does not necessarily need to involve static stretching before activity (Witvrouvw et al., 2004).

Furthermore, dynamic stretching has become a broad category in the direction of injury prevention, mainly because it is built around active movements, and that in itself is endless. Thacker et al. (2004) revealed that prevention of injuries is a process that encompasses many aspects, including flexibility, prior to activity. Thacker et al. (2004) also revealed that a recent direction for injury prevention appears to be a multifaceted model, which will include a proper warm-up, compounded with proprioceptive, plyometric, and strength training. Due to the nature of a muscle strain injury it is unclear how increasing a joint(s) range of motion only by performing static stretching would be effective at preventing muscle strains (Thacker et al., 2004). Within the literature it has been suggested that the general component of an aerobic warm-up is more effective than static stretching at increasing blood flow to the muscles. When there is an increase in blood flow it results in increased delivery efficiency of energy substrate and oxygen to working muscles, removing waste products, and increasing the speed of nerve impulses (Thacker et al., 2004; Witvrouw et al., 2004). In terms of muscle tissue and oxygen supply, the Bohr shift revealed that as muscle temperature increases, there is an increase in the amount of oxygen released from hemoglobin, released into the working muscles. Thacker et al. (2004) stated that the Bohr shift was the reason for an increase in oxygen to muscles during the warm-up. This increase in oxygen and energy substrate will delay the process of the muscles becoming fatigued and weak. This further compliments an active warm-up to be beneficial for sport performance, but it may also be effective in inury prevention because the gradual progression of varying intensities prepare an athlete's muscles for the strenuous demands of competition.

In the sports world there is a diverse population of unique athletes. Similarly, every sport produces unique body movements that are important for success in that particular sport. Static stretching may provide positive results in sport performance for some athletes or sports, but it may prove detrimental for performance. The evidence reveals that dynamic stretching is beneficial for preparing athletes and improving sport performance, in some sports. After reviewing the literature there were mixed results to support static or dynamic, as a sole method of preventing injuries.

CHAPTER III. PRE-EXERCISE WARM-UP AND DISCUSSION

Dynamic Warm-up

In the past, parents, physical education teachers, coaches, and athletic trainers have been teaching the importance of a warm-up routine before activity. It is likely the traditional warm-up exercises used then are the same exercises athletes use today. When it comes to prescribing a conditioning program to athletes physical educators will seek out scientific research and the results may seem conflicting or insufficient. Results of this literature review revealed that a dynamic stretching warm-up provided more positive results than negative as it affected sports performance.

Furthermore, from the past to the present people are still being told to stretch during warm-up routines. Although this is true to an extent, performing static stretches may not be the best way to prepare for a competition or practice. Unlike the traditional way of warming up, science has provided new research on why performing static stretches before exercise may detrimental for athletes. In the current literature reviewed, there was little scientific evidence that supported the advantages of static stretching as an effective pre-exercise warm-up. It only seemed suitable if the sports required the athletes to move beyond normal ranges of motion such as, gymnastics, diving, and certain track and field events. According to the literature athletes benefited very little from performing static stretches before a workout. Also, physiologically static stretches weakened the muscles, which decreased the motor unit activation leading to a decrease in performance (Knudson, 2000). Knudson, Magnusson, and McHugh (2000) revealed when muscles are statically stretched it causes a neuromuscular inhibitory response, causing muscles to become weakened from 15 to 60 minutes after the stretch. Given the scientific evidence on static stretching, this may not be how athletes want to start their workout or competition.

Dynamic stretching before exercise has become more and more popular with strength and conditioning specialists, coaches, and athletic trainers. The scientific evidence on this technique introduced it as an essential aspect in a warm-up protocol. Studies performed on professional soccer players, rugby players, and United States Military Academy athletes reveal that dynamic stretching is beneficial in performance areas of power and agility. This improvement in performance is due to the physiological and psychological effects of dynamic stretching. Examples include the rehearsal of sport-specific movement patterns, increased nerve impulse speed, waste product removal, blood flow, which leads to increased muscle temperature. Dynamic stretching can be viewed as a technique that primes the muscles for a workout or it prepares the athletes' bodies for further higher intensity work. The physiological effects of dynamic stretching can assist with delaying muscle fatigue and in turn the muscle becomes accustomed to training and injuries can be prevented. Moreover, muscle fatigue is one cause of injury and most injuries usually occur within normal ranges of motion, which is why it is unclear why increasing an athlete's range of motion will assist in injury prevention. The trend of scientific evidence suggests that static stretching before practice or competition actually shows no difference on injury rate.

The pre-game or pre-practice warm-up should include three things. First, through active movements it should ease muscles and tendons which will allow for a greater joint range of motion (Knudson et al., 2000). Second, it will provide athletes an opportunity to practice sports-specific movements prior to a competition and lastly, it will do as the name implies and warm up the body.

To begin, the warm-up should start with light aerobic activity, such as a jog, which lasts from 5 to 10 minutes. Knudson (2000) and Mann and Whedon (2001)advises to start with a warm-up jog at approximately 40 percent of the maximum heart rate, a very easy pace, then slowly increasing intensity, proceeding to 60 percent. This aerobic activity should not cause fatigue, but instead produce a light sweat at the end of the jog. Generally, the dynamic stretches are performed immediately after aerobic activity, but not all athletes are the same or play the same sport. With that in mind, the duration of a dynamic warm-up may vary depending on the level of performance. For example, sprinters may require more warm-up time because of the extreme loads and stresses on the muscles (Knudson et al., 2000). In retrospect, it is important to remember that the intensity and duration of aerobic activity will affect the results. It was revealed that an intense aerobic warm-up naturally raised body temperatures and blood flow, but made the athletes tired in the end. On the other hand, many athletes performed a warm-up too early and rested for 30 minutes which caused their muscles to become stiff (Fowles, Sale, & Macdougall, 2000).

The next stage of a proper warm-up will be the most important stage and will include some irregular movements. It is important to remember that dynamic stretches are not held like static stretches, but are instead performed through active movements. Unlike static stretching, where muscles receive a neuromuscular inhibitory response, the continuation of muscle motion allows athletes to receive "an excitatory message" preparing athletes for sport performance (Knudson et al, 2000). There are many dynamic stretches already created and available to use in any warm-up routine, but there are also many sports played. The availability of dynamic stretches can be universal among sports and some that are more sport-specific, but dynamic stretches are capacious and limited by creativity.

Dynamic stretches should last from 10-15 minutes or as long as it takes athletes to finish suitable dynamic stretches, keeping in mind the intensity level and duration. In sports such as basketball, volleyball, tennis, and soccer where the athletes are required to move rapidly in different directions, the dynamic stretches should involve many parts of the body. In other sports, like golf where rapid change of direction is not as apparent, dynamic stretches don't have to involve many body parts at once. For example, the dynamic stretches can be separated into upper and lower body. More importantly, performing a warm-up that is sports-specific makes dynamic stretching more effective.

When designing a dynamic warm-up for the first time, try to incorporate stretches that will target the body's muscle's groups: quadriceps, hamstings, hip flexors, calves-soleus complex, Pectoralis Major, and lumbo-pelvic hip complex (core) muscles. Perform the exercises immediately after the aerobic warm-up and before a workout or competition. Each exercise should be performed for about 10 yards one way and back, allowing for about 20-30 feet of total distance. Also, performing dynamic stretches for about 30 feet straight and jogging back to starting line is also another example of how a warm-up routine can be carried out. Similar to learning a new sports drill, it is crucial to start dynamic stretches in a slow and controlled manner until the athletes begin to master the routine. Again, during the warm-up it is important to make sure athletes are not standing still for longer than a minute and they are actively moving to guarantee the warm-up effect is not lost. Four to six dynamic stretches is considered a good start to beginning a dynamic warm-up. The number of dynamic stretches will increase as the performance level of the athletes increase (Knudson, 2000). Variety and creativity of a dynamic warm-up will keep athletes interested and prevent them from being content during the warm-up. A well-designed dynamic warm-up also prepares athletes mentally for the workout or competition ahead.

Static Stretching: Before or After?

Reviewing static stretching and sports performance, it seems many dislike static stretching because of the decrease in power outputs in sport performance. Although there are a number of studies that display static stretching as a poor way to warm-up, it is also prevalent that there was not enough evidence to prove that those same effects affected athletes at all levels of training. After reviewing a variety of scientific evidence it seems plausible to conjecture that athletes need a combination of dynamic and static stretching. Static stretching can be applied before a workout, if the stretching occurs before an aerobic warm-up and an hour before the workout. If used properly static stretching can increase sport performance by making an athlete more flexible, which will have a positive effect on an athlete's range of motion and reducing gradual onset injuries. While static stretching can be performed prior to exercise, it also can be performed after. The difference is, after a workout, athletes should perform a 5-10 minute light aerobic activity with static stretching performed immediately after. The stretching session should last about 10-15 minutes with each stretch held for 10-15 seconds. Again, no further flexibility is gained after 30 seconds of holding the stretch.

McNair, Dombroski, Hewson, Stanley, and Stephen (2001) examined two types of stretching, static holds, and continuous passive motion and its effects on the viscoelastic properties of the ankle joint. A dynamometer was used to measure muscle stiffness and force relaxation response around the ankle after a plantar flexor stretch was applied. In the end, it was revealed that to decrease muscle stiffness, a continuous passive motion was more effective than a static hold. In contrast, a static hold was more effective at relaxing the muscles at peak tension. Static stretching seems more appropriate as a part of the cool down phase, because it helps muscles to relax, realign muscle fibers, and re-establish the normal range of movement (Weldon & Hill, 2003).

Discussion

In spite of the accustomed recommendations to include static stretching as a part of a pre-game warm-up routine, the current literature proposes that static stretching can be detrimental to athletic sport performance (Behm & Kieble, 2007; Church et al., 2001; Fletcher & Anness, 2007; Fletcher & Jones, 2004; Knudson, 2001; Kovacs, 2006; Little & Williams, 2006; McMillan et al., 2006; Perrier & Hoffman, 2009; Shrier, 2004). Performance reductions have been reported in measures of sprint performance to jump height in a variety of sports. However, the American College of Sports Medicine (2005) and National Strength and Conditioning Association (2008) revealed that static stretching is a great way to increase static flexibility, relax muscle tension, and realign muscle fibers which gives reason as to why it can be incorporated into a pre/post-exercise routine. The evidence revealed static stretching lacked positive results in sport performance, but the evidence didn't account for all types of sports, all types of athletes, or gender specific. Furthermore, the limited evidence contributed to the need of further research in areas of agility, balance, reaction, time, injury prevention, specific sports, gender differences, and experience level of sports.

In terms of dynamic stretching, researchers have speculated on creating a more comprehensive warm-up model of injury reduction (Perrier & Hoffman, 2009). This new model emerging will include a general warm-up combined with strength training, plyometric and proprioceptive techniques. As mentioned, dynamic stretching can increase muscle temperature and blood flow while improving nerve conduction speed and waste product removal. Additionally, dynamic stretching provided an opportunity for skill rehearsal, which can be modified to be sport-specific, further improving performance. However, being that a dynamic warm-up resulted in positive changes to performance, there should be more research that specifies some negatives on dynamic stretching.

The world of competitive sports is huge and in that realm the sports and athletes are unique. Different sports require different musculskeletal movements or patterns, at the same time the way an athlete naturally performs those movements are different as well. As a result, it leads to the conclusion that a dynamic stretching technique is not greater than static stretching, instead they both play important roles in increasing sport performance. When the outcome of a competition is down to a fraction of a second, it is vital that coaches, athletic trainers, and strength and conditioning personnel have current information to design the best warm-up routine to increase performance.

REFERENCES

American College of Sports Medicine., (2005). *Guidelines for exercise testing and prescription: 7th edition*. Baltimore, MD: Lipincott Williams and Wilkins.

Anderson, M. K., Hall, S. J., & Martin, M., (2005). *Foundations of athletic training:prevention, assessment, and management*. Baltimore, MD: Lipincott Williams and Wilkins.

Baechle, T. R., & Earle, R. W. (2000). *Essentials of Strength Training and Conditioning*. Champaign, IL: Human Kinetics.

Baechle, T. R., & Earle, R. W. (2008). *Essentials of Strength Training and Conditioning*. Champaign, IL: Human Kinetics.

Behm, D. G., Bambury, A., Cahill, F., & Power, K. (2004). Effect of acute static stretching on force, balance, reaction time, and movement time. *Medical Science and Sports Exercise, 36*, 1397-1402.

Behm, D. G., Button, D .C., & Butt, J. C. (2001). Factors affecting force loss with prolonged stretching. *Canadian Journal of Applied Physiology, 26*, 261-272.

Behm, D. G. & Kieble, A. (2007). Effects of differing intensities of static stretching on jump performance. *European Journal of Applied Physiology, 101*, 587-594.

Church, J. B., Wiggins, M. S., Moode, M. F., & Crist, R. (2001). Effect of warm-up and flexibility treatments on vertical jump performance. *The Journal of Strength and Conditioning Research*, *15*, 332-336.

Cramer, J. T., Housh, T .J., Johnson, G. O., Miller, J.M., Coburn, J.W., & Beck, T.W. (2004). Acute effects of static static stretching on peak torque in women. *Journal of Strength and Conditioning Research, 18*, 236-241.

Cramer, J. T., Housh, T .J., Weir, J. P., Johnson, G. O., Coburn, J. W., & Beck, T. W. (2005). The acute effects of static stretching on peak torque, mean power output, electromyography, and mechanomyography. *European Journal of Applied Physiology, 93*, 530-539.

Egan, A. P., Cramer, J. T., Massey, L. L., & Marek, S. M. (2006). Acute effects of static stretching on peak torque and mean power output in national collegiate athletic association division I women's basketball players. *Journal of Strength and Conditioning Research, 20*, 778-782.

Fletcher, I. M. & Anness, R. (2007). The acute effects of combined static and dynamic stretch protocols on fifty-meter sprint performance in track-and-field athletes. *Journal of Strength and Conditioning Research, 21*, 784-787.

Fletcher, I. M. & Jones, B. (2004). The effect of different warm-up protocols on 20-meter sprint performance in trained rugby players. *Journal of Strength and Conditioning Research, 18*, 885-888.

Fowles, J. R., Sale, D. G., & MacDougall, J. D. (2000). Reduced strength after passive stretch of the human plantar flexors. *Journal of Applied Physiology, 89*, 1179-1188.

Herbert, R. D., & Gandevia, S. C. (1999). Twitch interpolation in human muscles: mechanisms and implications for measurement of voluntary action. *Journal of Neurophysiology, 82,* 2271-2283.

Holt, B. W., & Lambourne, K. (2008). The impact of different warm-up protocols on vertical jump performance in male collegiate athletes. *Journal of Strength and Conditioning Research / National Strength and Conditioning Association, 22*, 226-229.

Knudson, D. V. (1999). Stretching during warm-up: do we have enough evidence? *The Journal of Physical Education, Recreation, and Dance*, 70, 24-27.

Knudson, D. V., Bennett, K., Corn, R., Leick, D., & Smith, C. (2001). Acute effects of stretching are not evident in the kinematics of the vertical jump. *The Journal of Strength and Conditioning Research*, 15, 98-101.

Knudson, D. V., Magnusson, P., & McHugh, M. (2000). Current issues in flexibility fitness. *President's Council on Physical Fitness and Sports, 3,* 1-9.

Knudson, D.V., Noffal, G.J., Bahamonde, R.E., Bauer, J.A., & Blackwell, J.R. (2004). Stretching has no effect on tennis serve performance. *Journal of Strength and Conditioning Research, 18,* 654-656.

Kovacs, M. S. (2006). The argument against static stretching before sport and physical activity. *Athletic Therapy Today, 11*, 6-8.

Little, T. & Williams, A. G. (2006). Effects of differential stretching protocols during warm-ups on high-speed motor capacities in professional soccer players. *Journal of Strength and Conditioning Research, 20,* 203-207.

Mann, D. & Whedon, C. (2001). Functional stretching: implementing a dynamic stretching program. *Athletic Therapy Today, 6*, 10-13.

Martini, F.H., Ober, W.C., Garrison, C.W., Welch, K., Hutchings, R.T., Kathleen, I. (2004). *Fundamentals of Anatomy and Physiology.* San Francisco, CA: Pearson Benjamin Cummings.

McMillan, D. J., Moore, J. H., Hatler, B. S., & Taylor, D. C. (2006). Dynamic vs. static-stretching warm-up: the effect on power and agility performance. *Journal of Strength and Conditioning Research, 20*, 492-499.

McNair, P. J., Dombroski, E. W., Hewson, D. J., Stanley, & Stephen, N. (2001). Stretching at the ankle joint: viscoelastic responses to holds and continuous passive motion. *Medicine and Science in Sports and Exercise*, 33, 354-358.

National Strength and Conditioning Association. (2008). Retrieved from http://www.nsca-lift.org/

Pearce, A., Kidgell, D., Zois, J., & Carlson, J. (2009). Effects of secondary warm up following stretching. *European Journal of Applied Physiology*, *105*, 175-183.

Perrier, E. T., & Hoffman, M. A. (2009). Effects of static and dynamic stretching on reaction time and performance in a countermovement jump. *Medicine and Science in Sports and Exercise, 41,* 85.

Preedy, V. R. & Peters, T. J. (2002). *Skeletal muscle: pathology, diagnosis, and management of disease.* San Francisco, CA: Greenwich Medical Media.

Shellock, F. G. & Prentice, W. E. (1985). Warming-up and stretching for improved physical performance and prevention of sports-related injuries. *Sports Medicine, 2*, 267-278.

Shrier, I. (2004). Does stretching improve performance? a systematic and critical review of the literature. *Clinical Journal of Sports Medicine, 14*, 267-273.

Siatras, T., Papadoulos, G., Mameletzi, D., Gerodimos, V., & Kellis, S. (2003). Static and dynamic acute stretching effect on gymnasts' speed in vaulting. *Pediatric Exercise Science, 15,* 383-391.

Thacker, S.B., Gilchrist, J., Stroup, D.F., & Kimsey, D.C. (2004). The impact of stretching on sports injury risk: a systematic review. *Medical Science and Sports Exercise, 36,* 371-378.

Unick, J., Kieffer, H. S., Cheesman, W., & Feeney, A. (2005). The acute effects of static and ballistic stretching on veritical jump performance in trained women. *Journal of Strength and Conditioning Research, 19*, 206-212.

Weerapong, P., Hume, P. A., & Kolt, G. S. (2004). Stretching mechanisms and benefits for sport performance and injury prevention. *Physical Therapy Review, 9*, 189-206.

Weldon, S. M. & Hill, R. H. (2003). The efficacy of stretching for prevention of exercise-related injury: a systematic review of the literature. *Manual Therapy, 8*, 141-150.

Witvrouvw, E., Mahieu, N., Daneels, L., & McNair, P. (2004). Stretching and injury prevention: an obscure relationship. *Sports Medicine, 8*, 141-150.

Yamaguchi, T. & lshii, K. (2005). Effects of static stretching for 30 seconds and dynamic stretching on leg extension power. *Journal of Strength and Conditioning Research, 19,* 677-683.

Young, W. B. & Behm, D. G. (2003). Effects of running, static stretching, and practice jumps on explosive force production and jumping performance. *Journal of Sport Medicine and Physical Fitness, 43*, 21-27.

APPENDIX A. DYNAMIC STRETCHES

Dynamic Stretching Exercises

Static stretching is technique that is easy to learn and a form of increasing flexibility. This stretching technique is not pictured or described in further detail because it is the traditional way of stretching. On the other hand, dynamic stretching is a newer form of stretching and warming up prior to a workout, which allows for further detail. The dynamic stretches that are described in this next section are not meant to be considered as the only stretches available. Dynamic stretches may vary from one sport to the next or level of competition. These dynamic stretches are some of the most common stretches used and may be considered as universal stretches among different sports.

Straight-Leg March

This dynamic exercise will focus on the hamstrings and the gluteal muscles. While standing straight, start by kicking one leg out in front of you and extend toes, pointing them to the sky. Using your opposite arm, reach out toward your extending toes, but making sure not to rapidly flex lower back, instead try to keep lower back as straight as you can. Bring leg down and repeat with the opposite arm and leg.

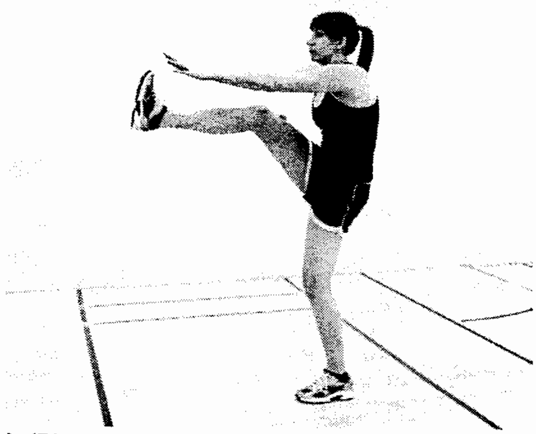

Figure 2. Straight-Leg March (Photograph by D. Dale, 2010).

Carioca

This is a little faster moving exercise focusing on the hips and core. Moving laterally, to the right, cross your left foot in front of right foot and then step with your left foot, while crossing your right foot from behind and repeat. Repeat this until you reach the end distance.

Figure 3. Carioca (Photograph by D. Dale, 2010).

High Knees

This exercise is an adjustment to the basic running form and all body parts will be facing the direction you are running. The adjustment is the addition of bringing your knees up higher than normal and it is important to move as if you were running. Focus on moving feet as quickly as possible and raising knees higher than your waistline.

Figure 4. High knees (Photograph by D. Dale, 2010).

Low Lunge

This is an adjustment to the lunge walk. Stand straight with feet together, step forward with right leg into the lunge position. Then try to place your right elbow on the ground as close to the right heel.

Figure 5. Low lunge (Photograph by D. Dale, 2010).

Scorpion

This exercise will focus on lower back, gluteal muscles, hip flexors, and hamstrings. Start by lying face down on the ground with arms extended out to the side with palms facing down and toes are touching the ground. Squeeze the right glute as the bottom of the right foot is brought to the left hand while trying to keep shoulders on the ground. Repeat this with the other limbs.

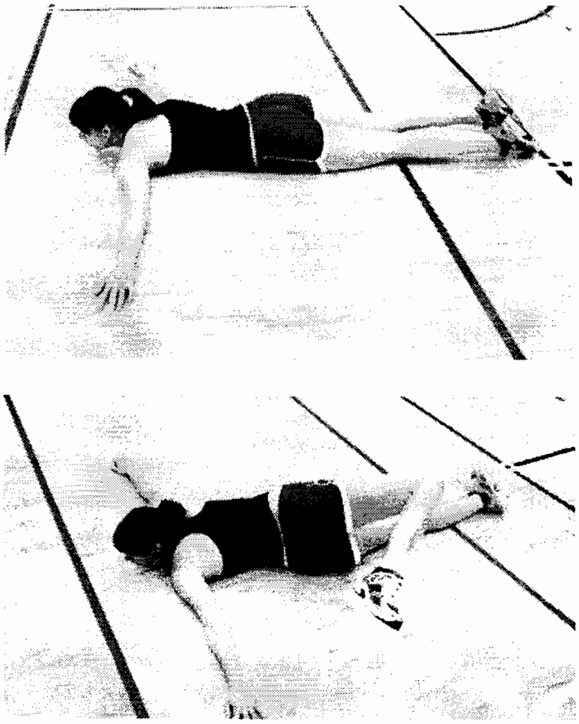

Figure 6. Scorpion (Photograph by D. Dale, 2010).

Hand walks

Stand straight with feet together and begin by bending over until both hands are flat on the ground. "Walk" out with the hands until a "push-up" position is accomplished. Keep your legs straight and take tiny steps inching your feet toward your hands as far as you can go, then stand up. Repeat this until end distance is reached.

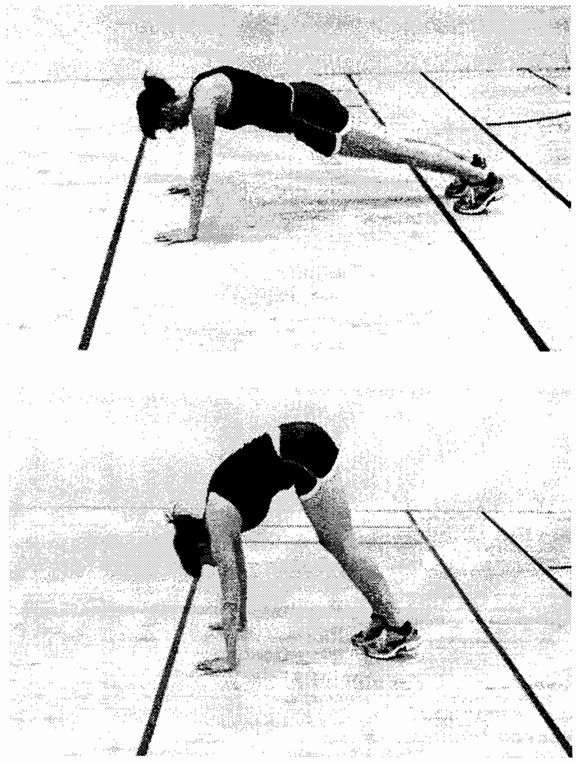

Figure 7. Hand Walks (Photograph by D. Dale, 2010).