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by

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A doctoral document submitted in partial fulfillment
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UNIVERSITY OF NEVADA LAS VEGAS

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ABSTRACT

The Acute Effects of Various Types of Stretching (Static, Dynamic, Ballistic, and No-stretch) of the Iliopsoas on 40-yard Sprint Times in Non-athletes

by

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The purpose of this study was to determine the effect of static, ballistic, dynamic, and no stretching immediately prior to a 40-yard sprint in college students. There were 35 healthy subjects (22 male and 13 female) between the ages of 24 and 37 (Mean = 26.46 yrs, SD = 2.99 yrs) who participated. The experiment consisted of running 4, 40-yard sprint trials immediately following 1 of 4 different stretching protocols. Prior to each 40-yard sprint trial, a 5-minute warm up was performed at 3.5 mph on a treadmill. Each subject received each of the four techniques in a randomized order and ran a baseline sprint prior to each stretching protocol. In each protocol, subjects received one of four stretching techniques: ballistic, dynamic, static, no stretch and immediately ran a timed 40-yard sprint post stretch. The trials were completed within a 2 week time period allowing 48-72 hours between each trial. In the no stretch condition, subjects improved significantly from pre to post sprint times ($p<0.0005$). There were no statistically significant differences in pre and post stretch condition times among the static ($p=0.804$), ballistic ($p=0.217$), and dynamic ($p=0.022$) stretching conditions. These results could be

due to the benefits of a dynamic warm up and also the negative impact of mechanical and neural effects of stretching. Sprint performance may show greatest improvement without stretching and through the use of a dynamic warm up.

INTRODUCTION

Stretching as a means of improving athletic performance is a commonly held belief despite a lack of support in current literature (10). The prevalence of this belief is demonstrated by the number of athletes and non-competitive physically active individuals who regularly engage in stretching immediately prior to activity with the mindset of optimizing their physical capabilities (24). This behavior is most often exemplified by sprinters who stretch various muscles in a variety of fashions immediately preceding a race based on the perception that greater flexibility equates to greater performance in addition to perhaps a general understanding, valid or not, that stretching reduces one's risk of injury (24). The reason behind this common practice is perhaps tied to tradition, as many studies have contradicted the premise that certain forms of stretching, most notably static stretching, immediately prior to activity may actually adversely affect performance (7, 10, 17, 20, 22, 24).

The evidence of the adverse effects of static stretching on athletic performance is well documented and readily available, but does not seem to be succeeding in reaching the athletic community, especially as it relates to sprinting. Nelson et al. examined the effect of partner-assisted static stretching of the calf and thigh musculature on 20-meter sprint performance and observed significantly slower times among post-stretch trials compared to no-stretch trials (17). The prevailing rationale behind this and many other similar findings implicates a decrease in musculotendinous elasticity and subsequent reduction in force production capacity (6, 24). As sprinting performance is intrinsically reliant upon the rate at which one can produce force (i.e., generate power) an examination of the components of power (force, velocity) is warranted. In a study conducted by Kokkonen et al. (10) it was found that maximal muscle strength (one repetition maximum knee flexion and extension) was decreased immediately following static stretching. Additionally, Wilson et al. (23) concluded that a stiffer musculotendinous unit will result in greater force production than one that has decreased stiffness as a result of stretching due to an increased rate of shortening and initial force transmission.

In reviewing the literature on stretching and performance, it seems that the most prominent muscles/muscle groups of the lower limb (quadriceps, hamstrings, gluteus maximus, gastrocnemius) have garnered most of the attention likely because of their visual and literary prominence (15). The examination of these muscles/muscle groups provides an understanding of sprinting in terms of many of its major biomechanical components (hip and knee extension, knee flexion, ankle plantarflexion) but fails to address hip flexion. This neglect is unfortunate as hip flexion may have the greatest influence on sprint speed of any segmental body movement and should therefore be the recipient of greater scrutiny (15). For these reasons, the muscle complex primarily responsible for flexion of the hip, the iliopsoas (IP), should be at the vanguard of future research concerning stretching and sprint performance (9, 15). Yokozowa et al. (25) concluded that IP was more active than gluteus maximus, hamstrings, adductors, rectus femoris, gastrocnemius, soleus, tibialis anterior, and the vasti muscles in running at low, medium, and high speeds. This muscle group has also been shown to have a greater influence on increasing one's running speed than any other muscle/muscle group and is one of three primary muscles/muscle groups (hip extensors, rectus femoris, and iliopsoas) for generation of power in sprinting (15, 19). With this knowledge in mind, it comes as no surprise that Deane et al. (6) found that a hip flexor strengthening protocol decreased

40-yard sprint times by 0.233 seconds, thereby improving performance, in untrained, yet physically active individuals. Further evidence to strengthen the argument for the importance of the IP in sprinting is found in anatomical differences in the muscle among different ethnicities. As it has been shown that physiologic cross-sectional area is an accurate indicator of maximal muscle contraction force, some authors have suggested that blacks may have an advantage over whites in activities such as sprint running (8). Due to the relative dominance of dark skinned ethnicities in sprinting and the anatomical evidence of larger IPs within these ethnicities, logically, one would use this anatomical finding to further support the role of the IP in sprinting.

Regardless of the specific musculature in question, much of the available research has focused on static stretching, whereas other stretching methods may influence performance differently (7). In competitive sprinters, active dynamic stretching of the major muscle groups of the lower limb has been shown to be advantageous in terms of decreasing 50 meter sprint times (7). Additionally, dynamic stretching of the lower limbs in professional soccer players has produced faster 10 meter sprint times and greater maximal speed over 20 meters in comparison to no-stretch measures (13). In contrast, a systematic literature review concerning stretching and performance found conflicting results in examining the effect of dynamic stretching on running speed (21). The authors of this review also made the same conclusion in regard to static stretching and running speed (21).

Given the relative controversy and paucity of literature in this area of study, it was the purpose of this study to examine the effects of no stretching to the acute static, dynamic, and ballistic stretching of the IP on 40-yard sprint times in 18-37 year old non-athletes.

The parameters of our included subjects were influenced by convenience.

METHODS

Experimental Approach to the Problem

The subjects performed a pre, maximal effort, 40-yard dash baseline sprint prior to one of 4 different stretching protocols (static, dynamic, ballistic, and no stretch) targeting the iliopsoas muscles. Immediately following the designated stretching condition, the subjects then performed a post, maximal effort, 40-yard sprint. The pre and post stretching 40-yard sprint times were compared to determine the acute effects of stretching the iliopsoas on 40-yard dash sprint times. Results were also compared between conditions to determine if there was a difference between the types of stretching.

Subjects

Our subjects consisted of 35 students (Non athletes), 10 of which were unable to complete the study due to soreness or injury, from the University of Nevada Las Vegas Doctor of physical therapy program. Among these subjects there were 22 males and 13 females, between the ages of 24 and 37 (Mean = 26.46 yrs, SD = 2.99 yrs). Subjects were not allowed to participate if they were pregnant, currently had a musculoskeletal complication, a health condition that would affect performance or put the subject at risk for injury, or were unable to effectively communicate in English. The subjects were asked to maintain normal activity throughout the duration of the study, but were asked to avoid any strenuous work within 2 hours of any of the 40-yard sprint trials. The study was approved by the university institutional review board, and an approved informed consent form was signed by each of the subjects.

Procedures

The study was performed on an indoor basketball court to standardize environmental conditions. Times were taken using an electronic timing system (Lafayette Instrument Co.,Lafayette, IN) consisting of two sets of tripods (one pair each for start and finish). Each pair of tripods had one laser and one reflector connected to a timer which would start/stop when the subject ran through each respective laser beam. Measurements for the 40-yards were made using a standard field tape measure.

This study consisted of running 4, 40-yard sprint trials immediately following 1 of 4 different stretching protocols. The trials were completed within a 2 week time period allowing 48-72 hours between each trial. The stretching protocols were no stretch (NS), ballistic stretch (BS), static stretch (SS) or dynamic stretch (DS), with the order of the stretching conditions randomized. Prior to each 40-yard sprint trial, a 5-minute warm up was performed at 3.5mph on a treadmill. Following the warm up a baseline 40-yard sprint was performed and timed using the electronic timing system. After the baseline time was collected, the subjects walked at a self-selected comfortable pace for 10 minutes around the perimeter of the basketball courts. During the 10-minute self selected walk, one of the researchers demonstrated to each of the subjects their randomly selected stretching protocol for the day while the subject maintained their walking speed. Upon completion of the 10-minute self-selected walk, the subjects performed the designated stretching protocol and within 60 seconds following the stretch performed another 40-yard sprint. The subjects were blinded to all 40-yard sprint times until the study was completed.

Stretching Techniques

For each of the stretching conditions, excepting the NS condition, the subjects were asked to report their perceived level of stretch on a scale of 0-10, 0 being no stretch and 10 being the most extreme stretch imaginable. The subjects perceived stretch level was not to exceed 7 during each stretching protocol. For the NS condition, instructions emphasized that the subjects were not to perform any type of stretching during this time, and were asked to stand at the starting line for 1 minute before the 40-yard dash trial. In the DS condition (see figures 1 and 2), subjects stood parallel to wall while using the wall to stabilize the body during the stretch. Subjects then flexed the hip and knee as close to the chest as possible. When maximum knee height was reached, subjects forcefully brought the hip into extension. Maintenance of upright trunk posture and avoidance of internal and external rotation of the hip throughout the motion was stressed in order to isolate the iliopsoas muscle. This motion was performed for 15 seconds on one leg and then the subject switched legs and performed the same motion on the other leg, and then repeated it one more time for each leg. In the BS condition (see figures 3 and 4), subjects went into a lunge stance with the leg of the hip being stretched behind the subject and minimal knee flexion. While in the lunge position, the subjects lowered their hips until they felt a moderate stretch in their iliopsoas muscle rated at 7 out of 10. With the subject's iliopsoas muscle in the elongated position, the subject oscillated inferiorly for 15 seconds on each leg twice, alternating between legs being stretched. In the SS condition (see figures 3 and 4), subjects assumed the same position as described in the BS but maintained the stretch without oscillating.

Statistical Analysis

To determine the acute effects of various types of stretching on 40-yard sprint times a 2 (time: pre and post-stretch condition) by 4 (stretch condition: NS, SS, BS, and DS) repeated measures analysis of variance (ANOVA) was performed to determine if there was an interaction in the data. In the event there was an interaction, posthoc testing using 2 repeated measures ANOVAs to compare between stretching conditions, and 4 paired t-tests to compare pre and post 40-yard sprint times, using a Bonferroni corrected alpha (α=.0083), were used to determine where the significant differences were. In addition, a chi-square analysis was done to determine if there was a statistically significant association between soreness/injury and stretching protocol in a total of 10 participants who dropped out due to severe soreness or injury.

RESULTS

There was a significant interaction between stretching conditions and their affects on sprint times, $F(3,72)=9.422$, $p<.0005$ (see table 1 for means and standard deviations). In order to break down this interaction, simple main effects were performed with 2 repeated measures ANOVAs and 4 paired t-tests using a Bonferroni corrected alpha (α=.0083). There was no significant difference between the 4 pre-condition times, p=0.103 (Greenhouse-Geisser) or the post-condition times, p=0.029. There was a statistically significant difference between pre and post-stretch condition times in the no-stretch condition, $p<0.0005$, suggesting that sprint times improved in the NS condition (Figure 5). There were no statistically significant differences in pre- and post-stretch condition times among the static (p=0.804), ballistic (p=0.217), and dynamic (p=0.022) stretching conditions, suggesting that sprint times were unchanged between the 2 trials for each of the three stretching conditions. Chi-square analysis revealed no significant difference, $x^2(3)=.533$, $p=.912$ between injured subjects and stretching condition.

DISCUSSION

The purpose of this study was to examine the acute effects of various types of stretching conditions on the iliopsoas muscle on 40-yard sprint times. We found a significant improvement in times from pre to post in the NS condition, whereas there was no significant change in pre-post sprint times in the SS, BS or DS conditions. These results indicate that the only condition in which the post time improved was the NS condition. These results could be due to both mechanical and neural effects of stretching which we will discuss in further detail.

Because we were intent on investigating the acute effects of stretching, we focused our research on one major muscle group (the iliopsoas muscle). The purpose of focusing on one muscle group is that it allows us to focus on the acute effects (within 60 sec) of stretching on sprinting. If we were to include multiple muscles in our stretching protocol then the muscles stretched at the beginning of the protocol would no longer be in the acute phase (within 60 sec), due to the additional amount of time it would take to stretch other muscles. This protocol differs somewhat when compared to other studies found in the literature, in that, we measured the effects of stretching on a dynamic event almost immediately after stretching (0-60 seconds), whereas other studies investigated the effects of stretching on performance approximately 3-10 minutes following stretching (1, 5, 7, 13, 20, 24).

As has been explained in the introduction, we chose to target the iliopsoas muscle because it has been shown in the literature, to be one of the most important muscles involved in sprinting (9, 11, 15, 19, 25). By stretching this single muscle group, we hoped to see the greatest stretch effect possible on 40-yard sprint performance, while maintaining a short time frame following the stretching conditions.

Contrary to other research, which included multiple muscles in their stretching protocol, we did not find a significant difference between pre and post 40-yard sprint times when subjects were stretched using BS, DS, or SS methods. Although we did not find a significant difference in 40-yard sprint times between pre and post BS, SS, and DS conditions, subjects in our study were significantly faster in post 40-yard sprint times compared to pre 40-yard sprint times in the NS condition.

Decreased sprint times, maximal voluntary contraction, vertical jump height, and various 1 repetition maximum weight lifting tests following stretching, are some of the activities that have been documented in the literature to have an acute negative impact from stretching (1, 3, 5, 7, 10, 17, 20, 22, 24). The three reasons most frequently discussed in the literature to explain these negative effects are; muscle damage, increased musculotendinous length, and decreased compliance.

It has been shown in the literature that stretching a muscle 20% beyond its resting length can cause muscle damage (21). It has also been shown that walking can cause muscle excursion in some sarcomeres beyond 20% their resting length (14)(32); therefore, we feel that our stretching protocol likely caused a stretch beyond 20% and may have induced tissue damage and thereby affected the post stretch sprints. The damage occurred has been thought to occur primarily at the musculotendinous junction because of its unique architecture at this area (1). Moore and Hutton (16) postulated, that pain experienced during a muscle stretch may inhibit muscle activation following a bout of stretching; this pain would likely be felt if a muscle was stretched to the point of damage (beyond 20% resting length), and the stretched muscle would therefore be inhibited. If the muscle was inhibited to a degree by pain, it may decrease the potential force a muscle could produce, thereby decreasing performance.

A more common explanation for decreased performance following stretching is the belief that a recently stretched muscle must shorten a greater distance in order to cause movement due to an acutely longer musculotendinous unit (1, 5, 7, 10, 12, 20, 24). It has been thought that this effect would take place at the level of the sarcomere, causing a decrease in the actin-myosin overlap (5). Therefore each functional unit of the muscle being stretched would have to overcome a greater length change in order for the contracting muscle to produce movement (5). This increase in musculotendinous length and subsequent slack, would logically cause a slower contraction rate, and a decrease in running velocity.

One final mechanical explanation for the negative impact of acute stretching on performance is an increase in compliance of the musculotendinous unit (3, 7, 20, 21, 24). Much like an elastic band, muscles and tendons have the ability to provide recoil energy, which provides force to propel limbs during sprinting and other activities that employ the stretch shortening cycle (18). Research has shown that the stiffness of a muscle can be used as a measure of how much elastic energy is contained in a muscle, following an eccentric phase of the stretch shortening cycle (18, 20, 21). It has even been suggested that there may be an optimal stiffness in which the greatest amount of elastic recoil energy is stored in the muscles and tendons (24). The actual optimal stiffness is not available in the literature; however, many suggest that a stiffer musculotendinous unit would direct the force produced by the muscle more efficiently, directly, and in less time than a more compliant (stretched) unit (5, 10, 24). It should not be assumed, however, that the stiffer the musculotendinous unit the more the elastic recoil. In fact, research by Kubo et al. (12) calculated less hysteresis in the calcaneal tendon following stretching of the gastrocnemius, and suggested that stretching may increase the amount of recoil energy in a musculotendinous unit. With this in mind, logically, it seems that the optimal stiffness of a muscle for elastic recoil is somewhere between a fully stretched muscle and a non-stretched muscle, but more on the stiff side of the spectrum. Therefore, a muscle more fully stretched would contribute less to elastic recoil than a non stretched muscle. Cè et al. (4) found that passive static stretching of biceps brachii caused a significant increase in the amount of time necessary to achieve 50% of peak torque during a maximal voluntary contraction (MVC). They also found that nerve conduction velocity increased during MVC in a control group, whereas no change was observed among those who stretched (4). The authors proposed that these findings could be due to a decrease in myosin phosphorylation and actin-myosin calcium sensitivity caused by stretching (4). Stretch-reflex peak-to-peak amplitude immediately following passive stretching of 1 hour in duration has been shown to be reduced in the soleus and medial gastrocnemius muscles (1). Additionally, a reduction in H-reflex amplitude from 3.6 to 1.9mV has been found during stretching, implicating the presence of neural modification (1). Increased muscle compliance due to stretching may result in a dampened mechanical muscle spindle response, which reduces Ia-afferent activation and causes alpha-motoneurone pool disfacilitation (18).

One limitation to this study was the use of non-athletes instead of athletes. The use of athletes in the study would have been more applicable as the results of this study are more relevant for athletes than non-athletes. Another limitation was injuries to the participants. Many of the participants complained of muscle soreness due to previous trials. This once again could be related to the fact that our subjects were non-athletes. Future research should include the use of athletes to see if these same effects are seen in athletes as well. Research could also be conducted to see if there are any differences between genders, and use of multiple trials in each condition should be considered.

PRACTICAL APPLICATIONS

As shown by our data, the only condition in which sprint times improved was the NS condition. This could be due to the lack of negative effects of stretching and also the benefits of a dynamic warm up. The baseline 40-yard sprint time may have functioned as the dynamic warm up, therefore improving the post NS condition sprint time. As our results have demonstrated, the only condition to show an improvement in sprint times was the NS condition, suggesting that performance may show greatest improvement without stretching and through the use of a dynamic warm up.

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FIGURE LEGENDS

Figure 1 – starting position for dynamic stretch
Figure 2 – end position for dynamic stretch
Figure 3 – starting position for BS, and SS (Lunge Position, prior to lowering hips)
Figure 1 – end position for BS, and SS (for BS oscillation Is performed at this position)
Figure 5 – graph of pre and post condition sprint times

Table 1 - mean sprint times and standard deviations

Figure 2 – starting position for dynamic stretch

Figure 3 – end position for dynamic stretch

Figure 4 – starting position for BS, and SS (Lunge position, prior to lowering hips)

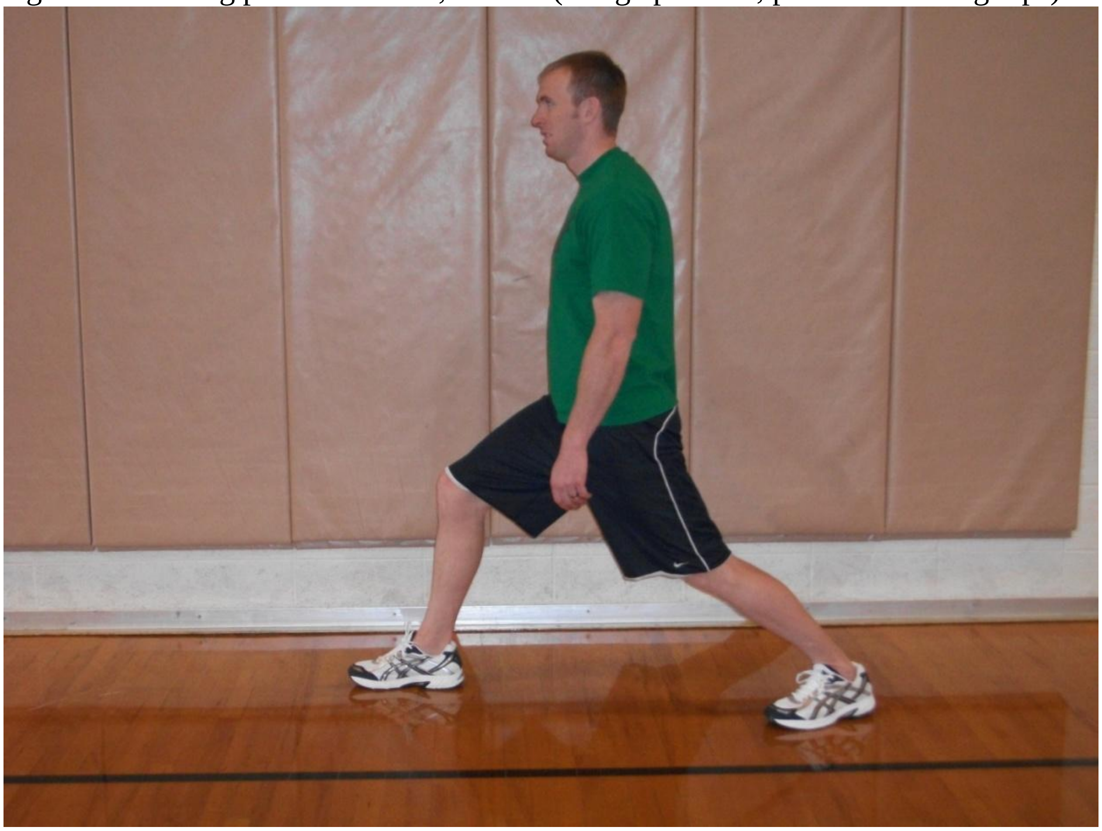


Figure 5 – end position for BS, and SS (for BS oscillation is performed at this position)

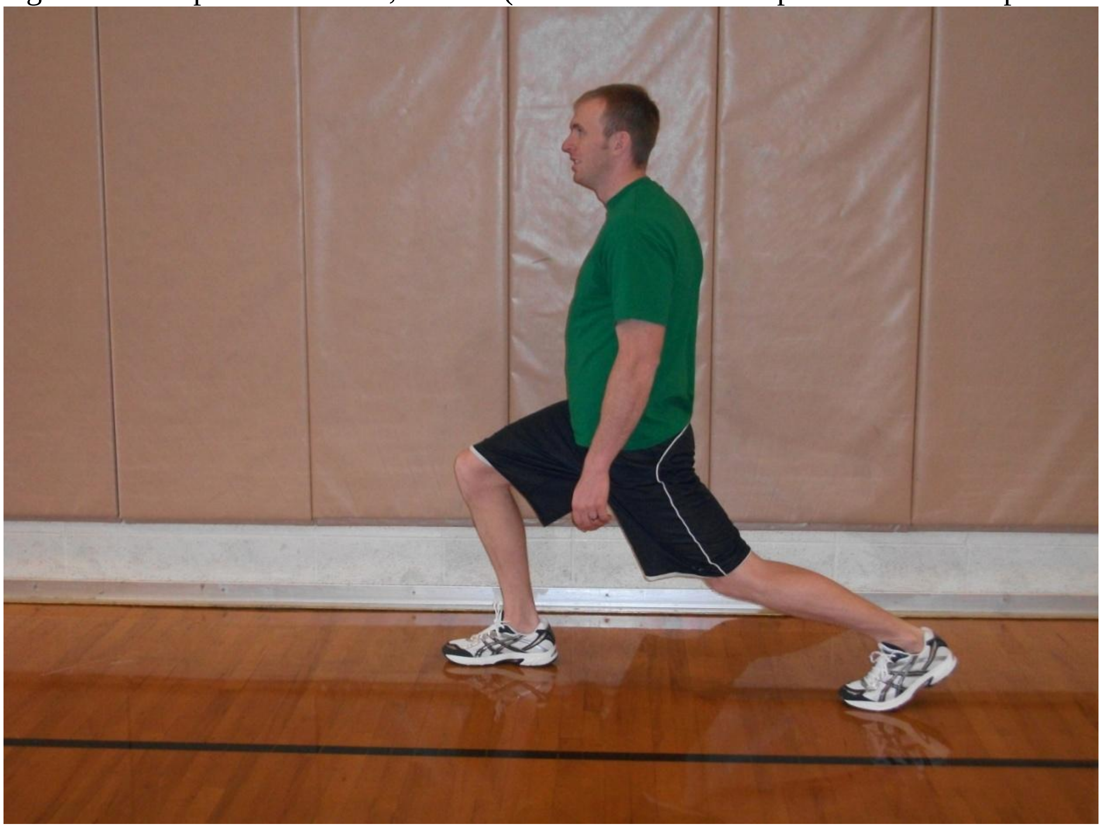
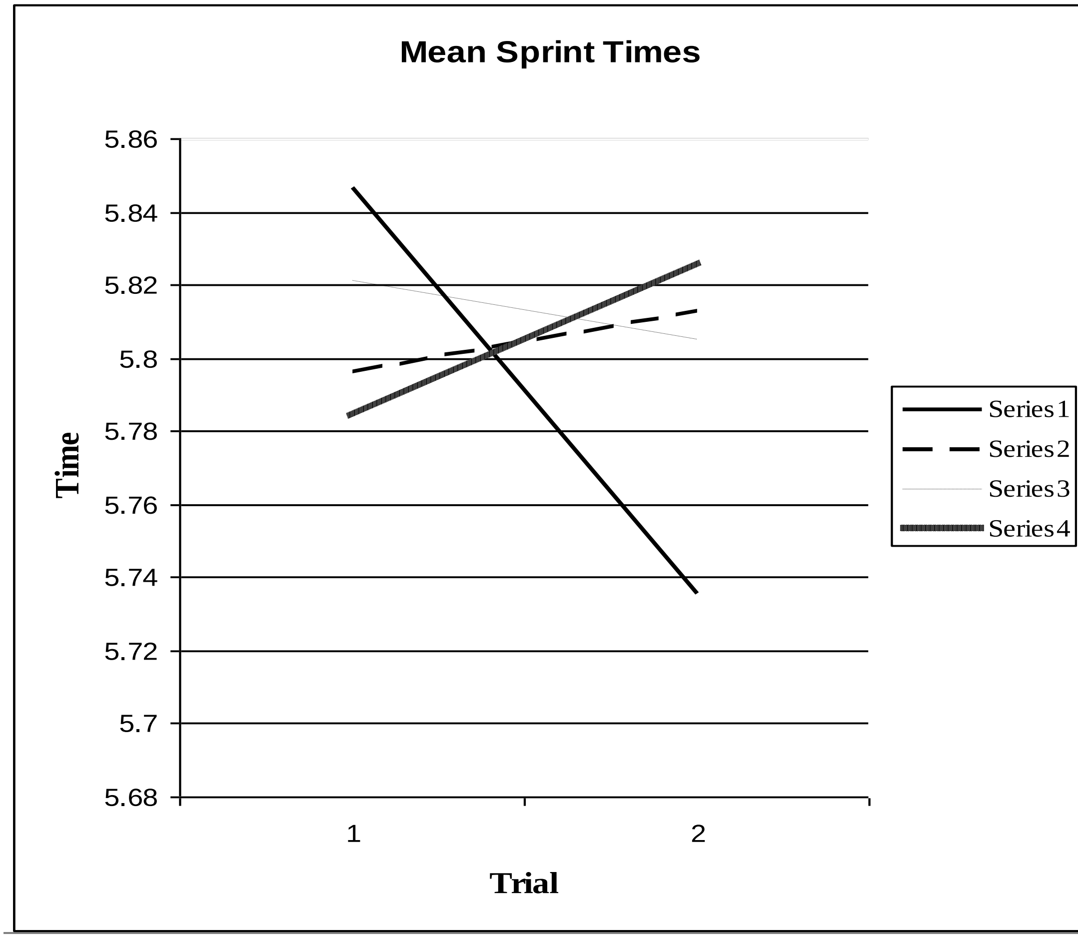


Table 1- mean sprint times and standard deviations

Condition	Mean: Pre-condition	Standard dev: Pre-condition	Mean: Post-condition	Standard dev: Post-condition
No Stretch	5.847	0.525	5.736	0.513
Static	5.796	0.505	5.813	0.511
Ballistic	5.821	0.524	5.801	0.524
Dynamic	5.784	0.499	5.826	0.530

Figure 5- graph of pre and post condition sprint times



Series 1- No Stretch Condition
Series 2- Static Stretch Condition
Series 3-Ballistic Stretch Condition
Series 4-Dynamic Stretch Condition

VITA

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