5-1-2015

Changes in sprint kinetics or kinematics following static or dynamic stretching

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CHANGES IN SPRINT KINETICS AND KINEMATICS FOLLOWING
STATIC OR DYNAMIC STRETCHING

by

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Bachelor of Science in Athletic Training
Slippery Rock University of Pennsylvania
2011

A thesis submitted in partial fulfillment
of the requirements for the

Master of Science—Kinesiology

Department of Kinesiology and Nutrition Sciences
School of Allied Health Sciences
The Graduate College

University of Nevada, Las Vegas
May 2015

We recommend the thesis prepared under our supervision by

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entitled

Changes in Sprint Kinetics and Kinematics Following Static or Dynamic Stretching

is approved in partial fulfillment of the requirements for the degree of

Master of Science - Kinesiology
Department of Kinesiology and Nutrition Sciences

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ABSTRACT

Changes in sprint kinetics and kinematics following static or dynamic stretching

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The purpose of this study was to determine the effects of static or dynamic stretching on hip kinematics and kinetics during intermittent sprinting. To achieve this aim, intermittent sprint athletes were asked to complete either a static or dynamic stretch, followed by a repeated-sprint protocol. Hip joint kinematics and performance measures were evaluated during the sprint, including changes that occurred in these variables over the course of the sprint protocol. In addition, hip flexion torque was measured with an isokinetic dynamometer. Ten male (age = 25±2.3 years, 175±3.2 cm, 76.2±2.7 kg) and female (age = 20±1 years, 166±1.3 cm, 60±1.1 kg) recreational soccer players were recruited from the Las Vegas community. Participants reported to the Sports Injury Research Center for data collection on two days separated by at least 48 hours. Before providing consent (IRB Protocol #724261-2), participants were able to ask any questions and familiarize themselves with the isokinetic dynamometer. Data collection consisted of: 1) 5-minute walking warm up on a treadmill at a preferred speed, 2) baseline hip flexion torque measurements, 3) either a static or dynamic stretch, 4) post-stretch torque measurements, 5) 6 x 20-meter sprints with 2 minutes rest between each trial, and 6) post-sprint torque measurements. On day two, participants completed the alternate stretch condition (step 3). Hip flexion torque output values extracted using Biodex Software were entered into Microsoft Excel and peak torque values were identified for each measurement period (baseline, post stretch, post sprint) for each condition (dynamic stretch or static stretch). These values were analyzed using a 2 (stretch) x 3 (time), repeated measures factorial analysis of variance (ANOVA) with a

Bonferroni adjustment using SPSS for Windows (IBM, v. 22, Armonk, NY). Multiple comparison post-hoc analysis was completed using a one-way repeated measures ANOVA and paired t-tests. Sprint times were recorded during collection and entered into Microsoft Excel, where the average sprint time for each condition was calculated, as well as the time difference between sprints 1 and 6. Two separate paired samples t-tests were completed for average sprint speed and T1-T6 differences for each condition with significance set to $\alpha=0.05$. Hip angular velocity was calculated during the initial swing phase using MaxTRAQ software (Innovision Systems, Inc., Columbiaville, MI). Initial swing was defined as toe-off to maximum knee flexion. These identifying positions were determined using the markers placed prior to data collection. Angular position data for the hip and knee were filtered with a zero lag, low-pass, 4th order Butterworth filter with a cutoff frequency of 12 Hz. From the angular position data, instantaneous angular velocity was calculated for each frame that comprised the initial swing phase of sprints 1 and 6. The length in frames of the phase was normalized by percent, and the phase percent at which peak instantaneous velocity occurred was noted. Paired samples t-tests were completed for both peak instantaneous velocity and percent phase of peak instantaneous velocity for each condition with significance set to $\alpha=0.05$. Results of statistical analysis yielded no significant results. However, angular velocity values and torque measurements were greater following dynamic stretch and sprint times were faster. The lack of statistical significance may be explained by several factors, specifically large variability within a small sample. Future research would benefit by increasing the sample size, matching participant experience and playing level, and potentially increasing the number and length of stretches performed.

ACKNOWLEDGEMENTS

I would like to first thank Dr. Janet Dufek for the role she has played in my education and research endeavors. As a professor, advisor and committee chair, she has challenged me to think critically, imaginatively, and logically. Dr. Dufek has spent more time than I thought was available in a day reading, re-reading, and editing my work, doing the same for others, collaborating with various departments, serving as chair or committee member for multiple students, and basically doing more in the span of a day than most people accomplish in several. Without her guidance, sure, I would have finished; however, the quality of work and breadth of knowledge I would have gained would have been inferior. I am incredibly grateful to have worked with her throughout my master's degree and I look forward to collaborating with her in the future. I would also like to thank the members of my committee: Dr. Julia Freedman Silvernail, Dr. Richard Tandy, Michelle Samuel, and Dr. Venkatesan Muthukumar ("Dr. Venki"). I appreciate the time you have taken from your busy schedules to read documents, attend meetings, put up with Doodle rescheduling and "technical difficulties," and always provide encouragement and feedback. The diverse insight that each of you has provided through my research adventure has been incredibly helpful and appreciated.

Data collection would have been extremely difficult without the help of Sophia Bradley and Sarah Cardona-Paul, who graciously offered to stay outside and ensure that nothing happened to the equipment during the times that I had to go inside to collect Biodex data. They're also great back up timers and even better between-participant companions. Finally, I wouldn't be where I am (or who I am) without the guidance of my family and my husband, Micah. Anyone who has spent more than five minutes with me has been regaled with tales of "Gram and Gramps," and without them, I may have honestly lost a lot of my sanity (as opposed to just a little of it). My husband moved to Las Vegas from Washington in order to be with me, not because of the wonderful lush landscape and mild weather here in Vegas, but because he supports me and my future goals. Words cannot express my gratitude.

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CHAPTER 1: INTRODUCTION

Pre-activity stretching prior to activity is a common practice among athletes, yet there is a lack of consensus as to the type of stretching that should be performed. Various types of stretching have been utilized by athletes, though the criteria for choosing a stretch often amounts to what the athlete or coach is familiar with or has found success with previously. Current research has yet to find a solid answer regarding the best stretch to perform in regards to injury reduction and performance effects. Two commonly-researched types of stretching include static and dynamic, both of which are commonly utilized by athletes prior to practice and competition.[1–4]

Static stretching involves placing a muscle into a stretched position and holding the position for a specified amount of time, typically 10-60 seconds.[5–7] Performing a general warm-up followed by a static stretch of activity-specific muscles is common practice among athletes,[6–8] due to the belief that it may reduce the risk of injury, mentally prepare an athlete for activity, and improve performance.[6–8] Although some research supports a decreased risk of injury following implementation of a stretch regimen,[5–7] other studies have suggested that static stretching prior to performing activities that require maximum force or torque output may have deleterious performance effects.[1,2,9–13]

Alternatively, dynamic stretching involves progressing through a series of controlled movements that involve the muscles and movement patterns to be performed during the upcoming competition or activity.[2] This type of stretching has become increasingly popular, possibly due to the benefits of targeting large activity-specific movements and muscle groups as opposed to single muscles, as well as the continuous movement component involved. Research supports the use of dynamic stretching in place of static stretching,[1–3,14] or a combination of the two[4,15] when considering positive performance effects.

Differences in effects of static and dynamic stretching can be explained physiologically, beginning with the level of stiffness in the musculotendinous contractile unit. Some researchers believe that in order to produce maximal force, the muscle would require a higher level of stiffness, which is a characteristic that is thought to be decreased by static stretching.[2,7,16] By placing and holding the muscle in a stretched position, stiffness is decreased following the activation of proprioceptors and a reflex response. This decreased stiffness is then thought to affect the maximal force output.[2,7,16] Another physiological consideration of static stretching is the viscoelastic property of muscle. A material that is viscoelastic in nature experiences less stress at a given stretched length, which results in stress relaxation.[1,2,17] This viscoelasticity results in increased muscle compliance as the muscle is continually stretched, and this compliance results in decreased stiffness, and thereby decreased force production.[1,2,5,7,17] Due to these considerations, static stretching is typically not considered a favorable choice for activities that require explosive force production.

Conversely, when considering the physiological components responsible for performance changes following dynamic stretching, similarities exist between dynamic stretching and a general warm up, such as increased tissue temperature, increased excitability of contractile tissues, increased kinesthetic awareness, increased oxygen uptake, and improved thermoregulation.[3,14,18–22] Furthermore, a phenomenon known as postactivation potentiation (PAP) may also contribute to enhanced neuromuscular function, which would lead to enhanced performance.[23–25] The premise underlying PAP is that the contractile unit of the muscle has an ability to “remember” types of contractions and thereby produce a stronger contraction when preconditioned by a similar type of movement.[23–25] Therefore, by performing activity-specific movements during a dynamic stretch prior to activity, the involved musculature may be able to produce stronger contractions during activity.

Although these physiological explanations attempt to explain the effects that are sometimes observed among research studies, there still exists a lack of consensus and reproducibility of these effects.[26] This variability can be contributed to several factors, including type of activity performed prior to and following the stretch protocol (i.e. warm up vs. no warm up), length of stretch, and type of athlete utilized (i.e. sprinters vs. long distance runners). Also, few researchers have attempted to determine how long the effects of stretching continue once the stretch is complete. Many studies measured variables immediately after the stretch but did not determine if the measured effects continued for any period of time. Of the studies that investigated this,[12,27–29] only one[12] did so by evaluating performance measures other than flexibility. The current study aims to determine the effects of static and dynamic stretching on intermittent sprint athletes, not only acutely after the stretch, but also after prolonged activity. By more narrowly controlling the type of athlete and activity studied, it may be possible to determine a type of warm up that benefits one type of athlete specifically.

The effect of different types of stretching on sprint performance provides results that are mixed as to whether one type of stretch is superior over another. Some studies suggest that static stretching leads to sprint speed decreases[1,2,13] or no change in sprint time.[30,31] These studies examined static stretching as either the only variable[11,30] or in comparison to dynamic stretching.[1,2,31] However, no studies were found that examined only the effects of dynamic stretching on sprint performance.

Along with the physiological explanations regarding changes in performance, sprint performance effects may also be explained by examining the biomechanical components of sprinting. Speed is defined as the product of stride frequency and stride length. Therefore, increases in both stride frequency and stride length would explain increased sprint speed,[32–34] so as the athlete is able to increase torque production, factors such as angular velocity, stride frequency, and sprint speed would increase as well.[33–37] Stride length may be altered with changes in force production and range of motion.[33] As running speed increases, increases in the range of motion of the lower extremity occur, resulting in increased flexion at lower extremity joints and subsequently lowered center of gravity.[38] These increases in range of motion may occur more readily with the range of motion increases that are demonstrated following both static and dynamic stretching.

Considering the aforementioned discrepancies and gaps in stretching research, as well as the physiological and biomechanical considerations of stretching and sprint performance, there exists a need for research that can consider the various contributions of stretching technique separately. Rather than attempting to measure one type of stretch on one type of athlete and then apply these results to a diverse population, the current study will instead focus on a single type of athlete and activity, and compare dynamic versus static stretching effects on selected kinematic and kinetic variables for a single joint.

Purpose of the Study

The purpose of this study was to determine the effects of static or dynamic stretching on hip kinematics and kinetics during intermittent sprinting. To achieve this aim, soccer players were asked to complete either a static or dynamic stretch, followed by a repeated-sprint protocol. Kinematic measures observed during the sprint protocol included sprint time and angular velocity at the hip joint, including changes that occurred in these variables over the course of the sprint protocol. Furthermore, kinetic data measured included hip flexion torque. This variable was measured with an isokinetic dynamometer.

Research Questions

This study aims to answer three major research questions related to hip kinematics and kinetics in intermittent sprinters following either dynamic or static stretching:

1. What are the immediate and post-exercise effects of static and dynamic stretching on hip flexion torque production?
2. What are the effects of dynamic or static stretching on hip angular velocity during intermittent sprinting?
3. How are sprint times throughout an intermittent sprint protocol affected by the type of stretch performed?

Significance of the Study

As previously mentioned, there is a lack of agreement in whether static or dynamic stretching is more beneficial for performance. This study will attempt to address this conundrum as it applies to a specific population of athletes. Considerations should be made that what benefits one type of athlete (sprinter) may not benefit another (long distance runner). By constraining the study population, conclusions may be drawn that may benefit that specific population. Furthermore, there exists a lack of research regarding the lasting effects of stretching; existing research measures variables immediately after the stretch, but does not consider if those changes would exist following an extended exercise protocol. This study will measure kinetics both following the stretch as well as following a sprint protocol, which may shed light on whether those immediate effects of stretching last through a period of exercise. Additionally, the focus of this research involves kinetic and kinematic measures at the hip, which is currently nonexistent in the stretching literature. Results of this study will begin to fill some of the existing literature gaps, which will increase the overall understanding of the topic and add to the body of knowledge available for athletes, coaches, and sports medicine staff with regard to choosing a pre-activity stretch regimen.

Statistical Hypotheses

The research questions will be addressed with five statistical hypotheses. The null (Ho) and alternative (Ha) hypothesis to be tested are as follows:

Ho_1: There will be no difference in hip flexion torque production between baseline (T1) and post-stretch (T2) following static or dynamic stretching.

Ha_1: Greater increases in hip flexion torque production will occur between baseline and post-dynamic stretch compared to changes between baseline and post-static stretch.

Ho_2: There will be no difference in hip flexion torque production between baseline (T1) and post-sprint (T3) following static or dynamic stretching.

Ha_2: Increases in hip flexion torque production will occur between baseline and post-sprint for both static and dynamic stretching.

Ho_3: There will be no differences in hip flexion angular velocity during the initial swing phase of gait between the first and last sprint following dynamic or static stretching.

Ha_3: Decreases in hip flexion angular velocity during the initial swing phase of gait will occur between the first and last sprint following both dynamic and static stretching.

Ho_4: There will be no differences in sprint times between the first and last sprint following dynamic or static stretching.

Ha_4: Increases in sprint times will occur between first and last sprints for both conditions.

Ho_5: There will be no difference in average sprint times following dynamic or static stretching.

Ha_5: Average sprint times will be faster following dynamic stretching compared to static stretching.

Limitations

Though all efforts were taken to mitigate issues in the experimental design that would skew results, there always exists limitations with any research study.

1) Sprints were performed outdoors, which creates several limitations, including:

-"idle time" existing in order to walk from where torque is measured and sprints are performed (outdoors)

-environmental considerations in regard to performance including wind and temperature

-environmental considerations in regard to visibility of video collection such as brightness, shadows, and time of day.

2) The dominant limb will be the limb measured; however, this will be self-reported and not based on performance test results.

3) Although the subject was asked to sprint at a maximal effort, speed was not controlled by the examiner or revealed to the subject.

Delimitations

Several measures were taken to ensure that data collection was natural for the subject, as well as to ensure that results are easily applicable in the clinical setting.

1) Subjects were instructed to perform stretches for an amount of time that is typically seen in an athletic setting.

2) The amount of time that existed between the stretch and the sprint protocol is similar to what would be seen in a competition setting, in which athletes will warm up, then have several minutes of idle time (pre-game huddles, captain's meetings, athlete introductions, national anthem) before the start of the competition. This time will be quantified during the study.

CHAPTER TWO: REVIEW OF THE LITERATURE

Stretching As a Pre-Performance Activity

Current research suggests that a warm up will prepare the body for physical activity by increasing metabolic rate, heart rate, oxygen delivery, temperature, and flexibility, among various other benefits.[9,20,39] The typical warm up consists of some full-body exercise, such as jogging, followed by a stretch component. It is generally accepted that a warm-up prior to exercise is beneficial; however, controversy exists in the effectiveness of the stretch component of the warm up.[26] Effects on performance based on the type of stretch performed remains relatively inconclusive in the literature and provides debate among researchers, coaches, athletes, and sports medicine personnel as to whether or not athletes should be completing a stretch before activity, and if so, what type of stretch should be utilized.

Over time, different stretch techniques have been developed and utilized. Following early research, many athletes utilized a static stretch regimen based on its perceived ability to help prevent injury[8,40–43] and/or increase performance.[6,44] These studies often ascribe the benefits to an increase in flexibility, which is believed by some to decrease the incidence of injury and improve performance. Later, ballistic stretching was implemented with the idea that the addition of active movement to the stretch would increase the benefits. However, the rapid overstretch utilized in ballistic stretching was believed to increase injury risk.[7] In more recent years, dynamic stretching has been recommended instead.[1,3,9,25] Nevertheless, due to differing and inconclusive protocols and results in the literature, research continues to be conducted to test the validity of claims regarding the effectiveness of various stretching techniques.[26] For the purpose of this study, the literature review will focus only on dynamic and static stretching.

Research results concerning the efficacy of static or dynamic stretching are conflicting; although the most palpable trend exists to suggest that static stretching results in performance decreases[1,2,9,11] and dynamic stretching results in performance increases.[1,3,9,25] However, studies also exist that show no significant effect of either stretch intervention.[15,45–48] A lack of consistency in stretch protocols including specific movements, repetition, and time may explain this lack of consensus, along with the amount of variability that is naturally evident in human movement. With this noted, studies with significant results tend to suggest the aforementioned conclusions of a performance decrease following static stretching and performance increase following dynamic stretching.[1–3]

Static vs. Dynamic Stretching and Performance

Static stretching involves moving a muscle into a stretched position, just prior to feeling pain, and holding the position for 10-60 seconds, with shorter times involving more repetitions of the same stretch.[5–7] Performing static stretching following a warm up activity and prior to performance is common practice among athletes. Early researchers believed that static stretching prior to activity would improve performance, reduce the risk of injury, and mentally prepare an athlete for activity.[6–8] The gentle nature of a static stretch does decrease the risk of injury while performing the stretch;[5–7] however, many recent studies have suggested that static stretching before activity results in a decrease in performance, particularly for activities requiring maximal force or torque production.[1,2,9–12,49] Force measures such as sprint time, vertical jump, and one repetition max (1RM) lifts are commonly studied, as these activities rely on explosive movement and rapid torque production. Studies have shown an acute decrease in vertical jump height,[50–52] sprint speed,[2,11] and 1RM for both hamstrings and quadriceps.[49]

Conversely, dynamic stretching is thought to have either no effect, or a positive effect on performance.[1–4,15] Dynamic stretching has become increasingly popular in all levels of sports and involves progressing through a series of controlled movements that are often sports-specific and occur throughout the active range of motion.[2] Examples include 20-meter skips, high knees, jumping jacks, and similar movements that target activity-specific musculature and include movement of large groups of muscle as opposed to single muscles. It has been suggested by several groups of researchers that performing a dynamic stretch prior to activity will increase acute performance measurements, particularly when compared to static stretching.[1–3,50] Some studies have compared the effects of static stretching versus dynamic stretching on performance measures. Of these comparison studies, several suggest that dynamic stretching increases performance compared to static.[1–3] Other studies recommend a combination of the two.[4,15]

Physiological Effects of Static and Dynamic Stretching

The documented performance decreases following static stretching are often contributed primarily to decreased stiffness in the musculotendinous unit which leads to a decrease in force production and delay in muscle activation.[7,16,17] This change is considered to be due to a combination of neuromuscular and mechanical factors. As a relaxed muscle is placed into a stretched position, muscle spindles located in the muscle belly sense the change in length and, if the rate of change is high, a myotatic reflex will occur and the muscle will contract to protect the muscle. Conversely, if the rate of change is slow, such as the movement in static stretching, muscle spindles will not fire to protect the muscle and instead golgi tendon organs located in the musculotendinous junction will initiate an inverse myotatic reflex, resulting in relaxation.[7,16]

Moreover, skeletal muscle is viscoelastic in nature, thereby producing less stress at a given stretched length, leading to stress relaxation. As the musculotendinous unit becomes more compliant, stiffness is decreased and force development is reduced.[1,2,17] Mechanically, the viscoelasticity of muscle contributes as much, if not more, than stretch reflex reactions, which are commonly cited as the primary cause of muscle relaxation during stretching.[5,7] Although these physiological changes support aforementioned claims that static stretching increases range of motion and may even reduce injury risk, the likelihood of performance deficits often leads to an avoidance of performing a static stretch prior to activity. Overall, static stretching is not considered to be a favorable choice for athletes requiring explosive force production.

Physiologically, the dynamic stretch produces similar effects as the general warm up, such as increased tissue temperature, increased excitability of contractile tissues, increased kinesthetic awareness, increased oxygen uptake, and improved thermoregulation.[3,18–22,50] These desirable performance effects are sought by athletes, coaches and researchers and form the basis of choosing a specific activity to perform prior to competition. During the dynamic stretch movements, contraction of the antagonist muscle group leads to relaxation of the agonist muscle due a neurological response known as reciprocal inhibition.[16,53] Following a dynamic stretch, it is believed that enhanced neuromuscular function may lead to improved power production due to a phenomenon known as postactivation potentiation (PAP).[23–25]

The premise of PAP resides in the fact that successful contraction of skeletal muscle is at least partially dependent on the muscle's contractile history. Limited evidence suggests that if, prior to attempting to produce a forceful contraction of a specific muscle, the muscle is preconditioned by a similar contraction, force output will be increased. This is particularly true of contractions performed against added resistance, but the premise is thought to help explain the increase in force output following a dynamic stretch.[23–25] The caveat to this is that the muscle should not be worked to fatigue during the preparatory contraction.[20,23,24] These findings suggest that a dynamic stretch may enhance muscular contractile ability following muscular contraction, and therefore may increase overall sports performance.

Limitations of Existing Stretch Research

The typical stretch research design consists of subjects performing each activity immediately following a stretch, which only measures acute effects of the stretch. It is common knowledge that athletes engage in activity for extended periods of time, and in the case of intermittent sprint sports, for extended periods of time interspersed with periods of rest. There is a gap in the literature regarding the lasting effects of a stretch such as during half-time or the final period in a competition for an athlete who performs the stretch prior to the start of the competition. Athletes in an intermittent sport who perform a stretch at the beginning of the competition may experience immediate effects, but the question then becomes: Do these effects last the length of a competition and if so, do these effects last throughout an extended activity that involves periods of intense exercise followed by periods of rest?

Several studies exist that analyze the lasting effects of a stretch. Magnusson et al.[29] found that 3 sets of 45-second stretches to the hamstrings resulted in stress relaxation during each stretch but no absolute resistance decrease, meaning that the stretch had no short-term effect on the viscoelastic properties of the muscle.[29] DePino et al.[27] found that increased flexibility following a static stretch of the hamstrings lasted approximately 3 minutes and returned to baseline levels within 6 minutes.[27] Kirsch et al.[28] also found similar results, with flexibility increases lasting less than five minutes. Alternatively, Fowles et al.[12] found that voluntary strength was decreased by up to one hour following a static stretch.[12] Though these studies were able to identify lasting flexibility changes resulting from static stretching, other measures such as strength or performance deficits were only identified in one study.[12] Furthermore, time between stretch and measurement was spent in a resting state, thereby not adequately mimicking the activity of intermittent sprint athletes. The explanation for the differences in results appears to be related to the duration of the stretch; Magnusson et al.[29] utilized 3 sets of 45-second stretches with 30 seconds rest, DePino et al.[27] implemented 4 sets of 30-second stretches with 15 seconds rest, Kirsch[28] et al. utilized 60 second stretches with 5 seconds rest, and Fowles et al.[12] utilized a series of maximal stretches lasting 135 seconds with 15 seconds rest over a period of 33 minutes.

There exists a large literature gap regarding the lasting effects of pre-activity stretching in intermittent sprinters. Young et al.[50] had subjects complete a run, a static stretch, a run + static stretch, or a run + static stretch + practice jumps. Results indicated that the completion of the static stretch, not only alone, but also when combined with the run, led to a decrease in vertical jump performance in comparison to the isolated run or the run + stretch + practice jumps.[50] Similar to previously mentioned research, these results suggest that a static stretch may decrease performance acutely. Yet, when considering the performance increase in the intervention that included practice jumps, these results may suggest that the detrimental effects of static stretching and performance may only occur acutely, and not following additional muscle contraction. This concept would apply to intermittent sprint athletes who may initially experience a detrimental effect of stretching at the beginning of a competition, but not at the end of competition. Further research should be conducted to determine any lasting performance effects of stretching throughout a competition.

Effects of Stretching on Sprint Performance

Several studies have been completed regarding the effects of stretching on sprint performance, the results of which are mixed. Generally, static stretching has been shown to decrease maximal force or torque output and therefore increase sprint time, an effect that has been contributed to the aforementioned physiological effects, particularly decreased stiffness of the musculotendinous unit.[2,11] In 2004, Fletcher et al.[2] found an increase in sprint time following a static stretch when compared to a dynamic stretch. Subjects completed two 20-m sprints with a 2 minute rest between sprints. They concluded that the aforementioned increase in musculotendinous unit compliance occurring with static stretching decreased the muscle's ability to store elastic energy, which decreased the resulting force production, and therefore increased sprint time.[2] A 2007 study completed by Nelson et al.[11] found an increase in sprint times following static stretching compared to a no stretch warm up condition. The study consisted of three 20-m sprints with a minimum of one minute rest between trials. Another Fletcher et al.[1] study examined the effects of static stretching on 50-m sprint times and found an increase in sprint times compared to dynamic stretching, again contributing this effect to decreased stiffness in the musculature. This study involved the completion of two 50-m sprints with a 2-minute recovery between sprints.[1]

Alternatively, Little and Williams[48] suggest that although dynamic stretching is most effective preparation for high-speed activity, static did not prove to be detrimental when added to the pre-activity warm up. They compared the effects of static, dynamic, and a no-stretch condition on four different high-speed sprint drills in soccer players and discovered that dynamic was more effective than no stretch for 3 of the drills, and more effective than static stretching for only 1 drill. Additionally, they found no difference between static and no stretch for 3 of 4, and in 1 drill they found that static was actually more effective than no stretch.[48] Stewart et al.[30] found no difference in sprint time following static stretching compared to a no stretch warm up condition. In this study, subjects completed three 40-m sprints with a three minute rest interval between sprints. The researchers suggested that the effects of static stretching may improve certain aspects of sprinting while hindering others, which may explain the overall null effect. They conclude that the range of motion increases may increase stride length which has a positive impact on sprint speed, while the decreased stiffness may decrease force production and negatively affect sprint speed.[30] Wong et al.[31] combined varying durations of static stretching with dynamic stretching and found no effect on repeated sprints (6 x 25-m, 25 s active rest) between static stretch durations. The researchers cited a counterbalancing effect of static stretch induced decrements with dynamic stretch induced enhancements.[31] No studies were found that examined only the effects of dynamic stretching on sprinting performance.

Biomechanical Considerations of Sprinting

The previously mentioned sprint performance effects of stretching may be further explained by examining the biomechanical components of sprinting. Speed increases are initiated with a lowering of the center of gravity by increasing flexion at the hip, knee, and ankle, and it was demonstrated that a greater range of motion in hip flexion occurred as gait speed increased.[38] Increases in range of motion following both dynamic and static stretching may contribute to this increased range of motion that is necessary for speed increases to occur.

Increases in sprint performance are attributed to increases in speed, which is defined as a product of stride frequency and stride length.[32–34] Both stride frequency and stride length have an effect on sprint speed, and are considered to vary by the individual, depending on factors such as leg length, height, explosiveness, and limb movement speed.[32,34] Research completed by Mero et al.[33] determined that as the sprinter reaches maximum velocity, the two components increase linearly; however, once the sprinter reaches about 7 m/s, increases in stride length occur in smaller increments compared to stride frequency.[33] Alternatively, Salo et al.[34] suggest that reliance on either stride length or stride frequency varies by individual and this individual dependence should be considered when developing training programs. Ultimately, though the individual may rely on one component more than the other, a balance of the two is necessary for optimal sprint performance.[34]

Different factors influence stride frequency and stride length, and have been identified in the literature by Mero et al.[33] and Salo et al.[34] Increases in stride frequency are attributed to the sprinter's ability to increase the velocity at which the limb moves through its range of motion. In order to increase the speed of limb movement, frequency of contraction and limb turnover speed must occur. Changes in these factors are due to neural adaptations that occur with training.[33,34] On the other hand, stride length is considered to be more athlete-controlled, and can be affected with changes related to force production and maintained flexibility.[33] Research performed by Misjuk et al.,[35] Guskiewicz et al.,[54] and Dowson et al.[37] found that when body weight was considered, sprinters who were able to produce higher peak torque in hip flexor and extensor musculature also had faster sprint times.[35,37,54] Furthermore, Mann et al. demonstrated through the use of indwelling electromyography that the most important muscles for increasing sprint speed were the hip flexors.[55] They concluded that contrary to what was popular belief, rapid hip flexion was linked to knee extension, and those two factors coupled with the motion of the arms was what propelled sprinters along the line of progression as opposed to a push off action from hip extensors in the stance limb.[55] Consequently, pre-performance activities that could increase either force production or flexibility may have a positive effect on sprint performance.

Benefits of Current Research

Considering the aforementioned limitations of stretch research, as well as biomechanical considerations of sprinting, the need exists for a study that can begin to evaluate if different stretch conditions affect intermittent sprint performance; and if so, what specific biomechanical measures are affected that combine for the overall effect of sprint performance. If either dynamic or static stretching has an effect on performance, the question then becomes: What specific measurements are affected that contribute to this change in performance?

Measuring sprint times will answer the question of whether either stretch intervention affects overall performance. Furthermore, evaluating individual sprint performances will provide additional insight as to how each of the measured components may contribute to these changes. Measuring angular velocity during the sprints may provide understanding as to how stride frequency is affected by different stretch protocols. Measuring torque before and after stretching, as well as after sprinting may provide information regarding the immediate and post-activity effects of stretching on torque production. This aspect is important when considering an intermittent sprint sport during which athletes typically only stretch before competition. If there are immediate effects of stretching that do not continue once activity has begun, this may affect whether athletes will decide to perform a stretch intervention at all. The results of this research may contribute to the ever-growing body of stretch research and assist athletes, coaches, and sports medicine staff with determining the appropriate pre-performance activity.

CHAPTER 3: METHODS

Purpose

The purpose of this study was to determine the effects of static or dynamic stretching on hip kinematics and kinetics during intermittent sprinting. To achieve this aim, intermittent sprint athletes were asked to complete either a static or dynamic stretch, followed by a repeated-sprint protocol. Kinematic measures observed during the sprint protocol included sprint time and angular velocity at the hip joint, including changes that occurred in these variables over the course of the sprint protocol. Furthermore, kinetic data measured included hip flexion torque, measured with an isokinetic dynamometer at baseline, post-intervention, and post-sprint.

Participants

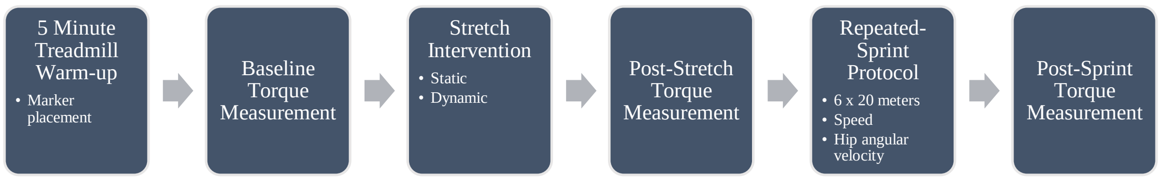
Recreational soccer players were recruited from the Las Vegas community by word-of-mouth and informational flyers. Subjects included 10 male and female recreational soccer players between the ages of 18 and 45 who were free from any lower extremity injury within the past 6 months. Two females (age= 20± 1 years) and 8 males (age= 25±2.3 years) participated. Qualifications for "injury" were defined as musculoskeletal pain that resulted in a cessation of activity for more than one week, with or without a medical diagnosis. Other exclusion criterion included subjects who did not participate in at least the final half of the previous sports season for any reason. Subjects were asked to refrain from "moderate" intensity exercise or greater, as well as lower-body resistance training on the day of and day before testing. According to American College of Sports Medicine guidelines, this would be any intensity greater than 65% maximal heart rate.[56] All procedures were approved through the university's institutional review board.

Procedure

Subjects reported to the Sports Injury Research Center (SIRC) to perform two different stretching interventions over two days with at least 48 hours separating each visit. The subjects were asked to report to the SIRC within the same 2-hour time window each visit. Each visit lasted approximately 35 minutes. Upon the first visit to the SIRC the experiment was explained, questions were answered and each subject signed a consent form approved by the University of Nevada Las Vegas Institutional Review Board (Protocol #724261-2). The subject then filled out a questionnaire regarding dominant leg, stretching habits and current workout schedule (Appendix A). Next, the subject was familiarized with the equipment to be used and then was instrumented with reflective markers placed on the apex of the lateral malleolus, lateral femoral epicondyle, greater trochanter, and apex of the iliac crest of the dominant limb. These locations were shown by Kivi et al.[57] to be satisfactory for determining angular velocity using 2D video analysis. Markers were comprised of a 3.5" x 4" square of reflective tape with a 1x1" square of black contrast tape placed over the anatomical landmark.

Each data collection session included a 5-minute treadmill warm-up at a preferred walking speed, followed by a baseline measurement of hip flexion torque of the dominant limb with the isokinetic dynamometer. Three sets of five repetitions of isokinetic concentric hip flexion contractions were performed at a speed of 180°/second.[58] After baseline measurement, the subject completed the static stretch or dynamic stretch, presenting in counterbalanced order across participants. This was followed immediately by post-stretch measurements of torque using the isokinetic dynamometer at 180°/second for concentric hip flexion. Following the post-stretch measurements, the subject was asked to complete the sprinting protocol, which was followed immediately by the post-sprint torque measurement using the isokinetic dynamometer at 180°/second for concentric hip flexion. A running stopwatch was utilized to quantify the amount of transition time between collection periods. The research procedures are represented graphically in Figure 1.

Figure 1: Data collection procedure



Stretch Protocols

The static stretch condition consisted of 2 hip flexion-specific stretches that are typically performed by athletes. Each stretch was held for 30 seconds and repeated three times bilaterally, alternating limbs between repetitions. Time was kept with a stopwatch controlled by the examiner. The stretches included a standing iliopsoas/quadriceps stretch (Appendix B, Figure 2) and a modified lunge stretch (Appendix B, Figure 3). To perform the iliopsoas/quadriceps stretch, the subject assumed a unilateral stance on the left leg, with the right arm flexed at the shoulder (instructed to "reach toward ceiling."). Simultaneously, the right foot was grasped behind the subject with the left hand and the knee was brought into flexion while keeping the thigh perpendicular to the floor, until a stretch sensation was felt in the right quadriceps and anterior hip. To perform the modified lunge stretch, the participant knelt in a lunge position, with the front hip and knee bent at 90 degrees and the foot flat on the floor. The rear hip was fully extended while the knee was bent at 90 degrees with weight on the knee. A pillow was placed under the rear knee to alleviate discomfort. During the stretch the participant was asked to contract the rear gluteus maximus in order to feel a stretch in the rear hip flexor muscles. Visual representations of all static stretches can be viewed in Appendix B.

The dynamic stretch was comprised of flick backs (Appendix C, Figure 4) and powerful backwards walking (Appendix C, Figure 5). Each movement was performed twice over 15 meters. To perform flick backs, subjects were instructed to begin by jogging, but focus on quickly flexing at the knee to attempt to touch the heel to the ipsilateral gluteus maximus. To perform powerful backwards walking, the participant was instructed to forcefully extend the hip behind them while keeping the knee straight while maintaining backward locomotion. These stretches were chosen due to their specificity of stretching the hip flexors by contracting the hip extensors. These stretches are commonly performed in athletics and should be familiar by name to the subjects, but were demonstrated as requested. Visual representations of all dynamic stretches can be viewed in Appendix C.

Sprint Protocol

Following the post stretch torque measurements, the subject performed an intermittent sprint protocol consisting of six repeats of 20-meter sprints with 60-120 seconds of rest between. The 20-m distance was chosen as it represents the mean sprint distance in intermittent-sprint field sports such as soccer.[59–61] The number of repetitions and rest interval length were chosen based on published repeated-sprint recommendations.[60] Sprints were performed outside of the SIRC and the distance was marked with tape and bordered by timing gates. Subjects were asked to sprint at maximum effort, run through the end of the sprint and come to a gradual stop, rather than decelerating rapidly. After at least 60 seconds and prior to 120 seconds of rest, the subject repeated the sprint until 6 repetitions were completed. Final torque measurements were taken following completion of the final sprint.

Instrumentation

Peak hip flexion torque was measured using an isokinetic dynamometer (100 Hz, Biodex System 3, Biodex Medical Systems, Shirley, NY) with the attachments designated for the hip joint. The subject was placed in a supine position and the dynamometer placed in accordance with manufacturer instructions included in the user manual. Speed was set at 180°/s with concentric action of the hip flexors for one trial with 5 repetitions for each measurement period (baseline, post stretch, post sprint). Misjuik et al. reported that a correlation exists between hip flexion torque production at 180°/s and sprint speed ($r=-0.818$).[35] Hip kinematics were recorded using a high speed video camera (Basler Scout Model scA640-120gm, Exton, PA). Sprint speed was measured using both photoelectric timing gates (Brower TC Timing System, Draper UT) and a manual stop watch.

Data Analysis

Analysis of peak torque, hip angular velocity, and sprint speed were completed. Hip flexion torque output values from Biodex Software were entered into Microsoft Excel and peak torque values were identified for each measurement period (baseline, post stretch, post sprint) for each condition (dynamic stretch or static stretch). These values were analyzed using a 2 (stretch) x 3 (time), repeated measures factorial analysis of variance (ANOVA) with a Bonferroni adjustment with SPSS for Windows (IBM, v. 22, Armonk, NY). Multiple comparison post-hoc analysis was completed using a one-way repeated measures ANOVA and paired t-tests.

Sprint times were recorded during collection and entered into Microsoft Excel, where the average sprint times for each condition were calculated, as well as the time difference between sprints 1 and 6. Two separate paired samples t-tests were completed for average sprint speed and T1-T6 differences for each condition with significance set to $\alpha=0.05$.

Hip angular velocity was calculated during the initial swing phase using MaxTRAQ software (Innovision Systems, Inc., Columbiaville, MI). Initial swing was defined as toe-off to max knee flexion. These identifying positions were determined using the markers placed prior to data collection. Angular position data for the hip and knee were filtered with a zero lag, low-pass,

4^{th} order Butterworth filter with a cutoff frequency of 12 Hz. From the angular position data, instantaneous angular velocity was calculated for each frame that comprised the initial swing phase of sprints 1 and 6. The length in frames of the phase was normalized by percent, and the phase percent at which peak instantaneous velocity occurred was noted. Paired samples t-tests were completed for both peak instantaneous velocity and percent phase of peak instantaneous velocity for each condition with significance set to $\alpha=0.05$.

CHAPTER 4: RESULTS

The purpose of this study was to determine the effects of static or dynamic stretching on hip kinematics and kinetics during intermittent sprinting. To achieve this aim, intermittent sprint athletes were asked to complete either a static or dynamic stretch, followed by a repeated-sprint protocol. Kinematic and performance measures evaluated during the sprint protocol included sprint time and peak instantaneous angular velocity at the hip joint during the initial swing phase of gait, which is defined as toe-off to maximum knee flexion. The changes that occurred in these variables over the course of the sprint protocol were statistically evaluated. Kinetic data measured included hip flexion torque, measured with an isokinetic dynamometer three time periods: 1) baseline, 2) post-intervention, and 3) post-sprint. Results are presented separately by dependent variables.

Angular Velocity

Instantaneous angular velocity values of each frame comprising the initial swing phase were calculated for sprint trials 1 and 6. The peak instantaneous velocity and the phase percent at which it occurred was identified. These data are presented by subject in Table 1. Paired samples t-tests were completed for both peak instantaneous velocity and percent phase of peak instantaneous velocity for each condition with significance set to α=0.05. No statistically significant differences were found among any level or participant.

Table 1: Peak Instantaneous Angular Velocity (degrees/second) and Phase Percent Occurrence

Subject	C1 (Dynamic) T1		C1 T6			C2 (Static) T1		C2 T6	
	Peak (°/s)	% Phase	Peak (°/s)	% Phase		Peak (°/s)	% Phase	Peak (°/s)	% Phase
1	752.6	100	759.1	95		754.2	100	842.5	100
2	554.8	94.7	473.2	90		606.9	94.7	574.4	100
3	365.7	83.3	370.2	87.5		438.2	100	664.8	100
4	929.3	100	674.3	93.3		519.6	70.6	672.9	88.9
5	393.6	85	461.9	85		498.0	100	341.1	90
6	409.7	88.2	615.5	100		416.9	95	457.2	100
7	463.1	88.2	486.4	94.1		324.9	77.8	304.2	78.9
8	501.5	86.7	488.4	85.7		481.4	81	352.5	77.8
9	586.0	88.2	534.0	78.9		297.1	100	357.3	94.1
10	345.6	57.1	449.1	78.9		359.6	88.9	425.7	78.9
Mean	530.2±58.9	87±3.8	531.2±37.1	88±2.2		469.7±43.4	90.8±3.4	499.3±57.1	90.9±3.0

Sprint Times

Sprint times were recorded for all sprint trials for each participant. The mean and standard deviation for subject and condition were calculated, along with the difference between trials 1 and 6. These data are presented by subject in Table 2. Paired t-tests for average sprint time and time difference from first to last sprint revealed no statistically significant results for any trial or condition.

Table 2: Mean Sprint Times (seconds) and Differences from T1-T6

	C1 (Dynamic)			C2 (Static)	
Subject	**Mean and SD**	**T6 - T1**		**Mean and SD**	**T6 - T1**
1	3.572 ± 0.022	-0.10		3.738 ± 0.019	-0.01
2	4.092 ± 0.032	-0.13		4.178 ± 0.053	-0.18
3	3.463 ± 0.016	-0.06		3.383 ± 0.068	0.30
4	3.383 ± 0.023	0.07		3.397 ± 0.048	-0.15
5	3.465 ± 0.009	0.00		3.425 ± 0.034	0.19
6	3.455 ± 0.021	0.03		3.515 ± 0.036	-0.22
7	3.630 ± 0.019	-0.01		3.648 ± 0.029	-0.10
8	3.653 ± 0.011	-0.03		3.403 ± 0.016	-0.09
9	3.637 ± 0.013	-0.02		3.795 ± 0.022	-0.04
10	3.465 ± 0.046	-0.28		3.353 ± 0.021	-0.08
Mean	3.581 ± 0.041	-0.05 ± 0.009		3.628 ± 0.069	-0.04 ± 0.027

(-) Indicates a faster sprint time.

Hip Flexion Peak Torque

Peak torque values were identified in Newton-meters (Nm) for each repetition. These values were averaged for each time condition, creating three values (baseline [T1], post-stretch [T2], post-sprint [T3]) for each participant. The repeated measures factorial ANOVA did not show any significant interactions and was not significant for overall main effects. Differences in values were then calculated for each level; baseline to post-stretch, baseline to post-sprint, and post-stretch to post-sprint. Those data were averaged and compared between conditions, which revealed no statistical significance. These values are shown in Tables 3 and 4.

Table 3: Peak Hip Flexion Torque Values (Newton-meters)

Subject	**C1T1**	**C1T2**	**C1T3**		**C2T1**	**C2T2**	**C2T3**
1	52.61	57.80	61.46		48.18	38.91	51.20
2	172.23	183.44	164.78		151.80	146.02	150.13
3	127.45	131.26	132.10		148.46	160.48	145.88
4	146.34	145.49	150.13		122.29	126.44	139.96
5	130.29	115.56	113.30		132.91	117.82	107.20
6	103.49	98.84	101.41		91.92	94.64	105.89
7	81.85	81.54	83.43		59.75	67.07	78.59
8	73.08	93.51	88.49		146.34	141.73	145.07
9	142.04	155.51	145.88		127.90	127.99	141.00
10	110.41	115.61	124.55		127.99	134.59	133.59
Mean	113.98 ± 11.7	117.85 ± 11.8	116.55 ± 10.4		115.75 ± 11.7	115.57 ± 12.0	119.85 ± 10.6

Table 4: Between-Trial Differences in Peak Hip Flexion Torque (Newton-meters)

C1 (Dynamic)					C2 (Static)		
Subject	**T1 to T3**	**T1 to T2**	**T2 to T3**		**T1 to T3**	**T1 to T2**	**T2 to T3**
1	8.86	5.20	3.66		3.6	-9.27	12.29
2	-7.46	11.21	-18.66		-18.66	-5.79	4.11
3	4.66	3.81	0.84		0.84	12.02	-14.60
4	3.80	-0.84	4.64		4.64	4.14	13.53
5	-16.99	-14.73	-2.26		-2.26	-15.10	-10.62
6	-2.08	-4.66	2.58		2.58	2.71	11.25
7	1.58	-0.31	1.89		1.89	7.32	11.52
8	15.41	20.43	-5.02		-5.02	-4.61	3.34
9	3.84	13.47	-9.63		-9.63	0.09	13.02
10	14.15	5.20	8.95		8.95	6.60	-0.99
Mean	2.58 ± 3.1	3.88 ± 3.1	-1.30 ± 2.5		-1.30 ± 2.5	-0.187 ± 2.7	4.29 ± 3.2

CHAPTER 5: DISCUSSION

The purpose of this study was to determine the effects of static or dynamic stretching on hip kinematics and kinetics with the implementation of a sprint protocol. Equivocal research regarding stretching and athletic performance exists in the literature, which may be due in part to a lack of consistency with research methods utilized. Moreover, few researchers have attempted to measure the effects of stretching with the addition of further muscular activity, such as a sprint protocol. In athletics, particularly intermittent sprint sports such as soccer, basketball or football, an individual will typically warm up and stretch prior to competition, but will not repeat the stretch throughout. The majority of the available research only measures variables immediately after the stretch, and those results have been applied to determine how athletes should be stretching prior to competition. This study utilized the addition of a sprint protocol between variable measurements to determine if the effects of a stretch are continued when a muscle undergoes additional work. Overall, there were no statistically significant results for changes in sprint times, hip angular velocity, or hip flexion torque following either a static or dynamic stretch.

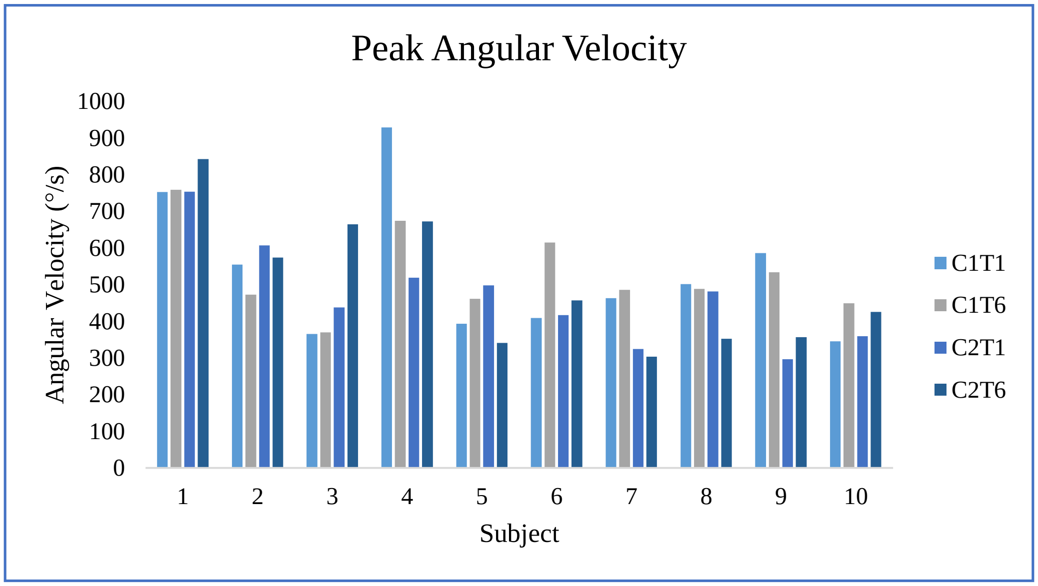
As mentioned previously, there exists evidence in the literature that suggests static stretching may not be beneficial for activities requiring maximal force output.[1,2,9–12,49] However athletes, including participants in this study, continue to utilize static stretching prior to activity with no apparent deleterious effects. This fact, coupled with the lack of statistical significance in the current study and others[15,30,31,46–48,62] suggests that 1) the immediate effects consistently measured in the literature may not extend past the first few minutes after the stretch is completed, or 2) that the implementation of additional activity (such as sprinting during a competition) may null the previously measured immediate effects.

Additionally, though there exists an overarching theme of dynamic stretching being superior to static stretching, there still exists research[30,31,48,62,63] and anecdotal evidence that suggests there are a number of factors that may affect this relationship between stretching and performance. Stewart et al. measured 40-meter sprint times in elite rugby players following either a static stretch or general warm-up and found no significant changes in sprint times following the static stretch.[30] They contributed the lack of significance on what they described as a nulling effect of static stretching; a static stretch may improve certain aspects of a sprint such as range of motion and thereby stride length, but hinder others such as muscle stiffness and thereby leg turnover and stride frequency, causing an overall null effect.[30] Wong and colleagues[31] attempted to determine if changes in repeated sprint ability occurred following varying times of static stretching followed by a short bout (90s) of dynamic stretching and found no significant differences in sprint times.[31] They disclosed that the combination of static and dynamic stretching may have played a role in results, but conceded that current research regarding stretching is equivocal and involves many factors such as stretch duration and measured performance outcomes.[31]

Angular Velocity

A lack of statistical significance may be partially explained by the high variability between trials and participants. This variability (represented in Figure 6) may be due to human, environmental, and equipment errors in the digitizing process. For example, marker visibility was affected by ambient light during different times of day. This effect typically presented for the ankle marker, which may have then affected the knee angular position data. These errors could lead to incorrect identification of initial swing phase. For future studies involving outdoor video collection, this error could be mitigated by collecting all subjects at an optimal time of day, rather than convenience scheduling based on participant availability. Also, there were instances in which the camera and computer failed to connect properly, which caused image error during processing for those frames. Finally, participants were asked to wear tight fitting clothing, but standardized laboratory clothing was not issued. Marker placement and movement may have been affected by the type of clothing being worn. This may be especially true for the iliac crest and greater trochanter markers and therefore hip angular position data, particularly if the shirt or shorts worn were loose-fitting. For future studies, standard tight-fitting laboratory clothing would potentially mitigate this issue.

Figure 6: Peak hip angular velocity (°/s) during the initial swing phase

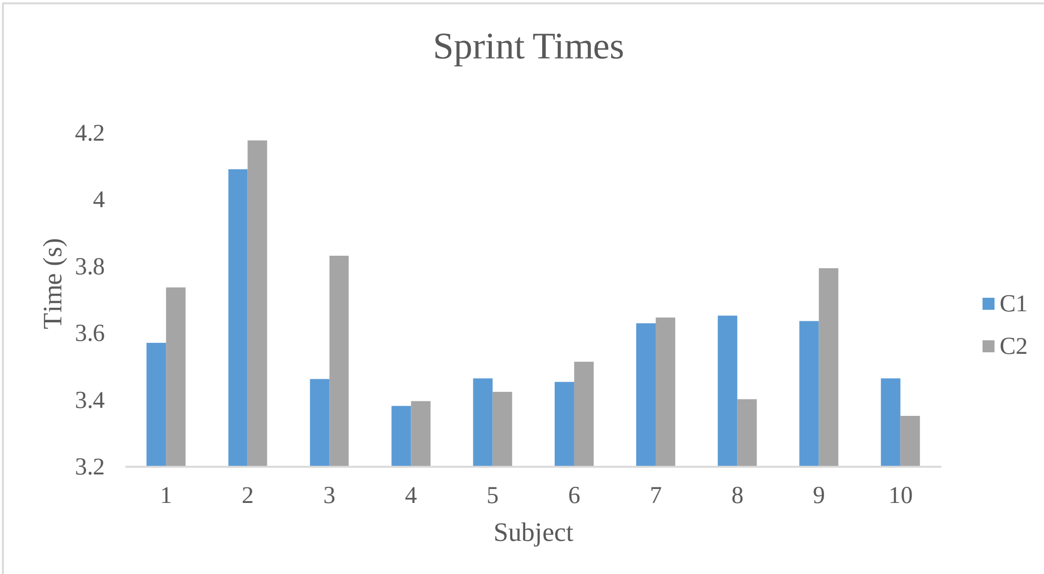


To the knowledge of the author, there exists no research that correlates hip angular velocity during the initial swing phase with sprinting speed. The attempt to determine this was based on the research that suggests sprint speed is increased with increases in stride frequency, defined as the speed at which the leg is moved through its ROM.[33–37] Mann and Hagy[38] suggested that during the initial swing phase, motion at the knee and ankle occurs secondary to rapid acceleration of the thigh into flexion.[38] It was the rapid thigh acceleration by way of hip flexor contraction during the initial swing phase that this study attempted to quantify with limited success. The uniqueness of the current study may be a factor in the lack of significant results due to a shortage of previous literature use as a methodological guide. This fact may be promising for future studies that may attempt to utilize similar techniques. It may also be beneficial to consider measuring the entire swing phase and quantify both hip flexion and hip extension.

Sprint Times

No statistically significant differences were found between first and last sprint time for either condition (see Figure 7). These results align with Little and Williams,[48] who found no significant difference in 20-meter maximal sprint speeds between static or dynamic stretching conditions.[48] That study involved two 20-meter sprints with two minutes rest, as well as other speed and agility tests performed in the same session.[48] Fletcher et al.[2] measured 20-meter sprint speeds in 97 trained rugby players at baseline and following 4 different stretch protocols (passive static, active static, active dynamic, and static dynamic) and found significant increases in time for the passive static and active static groups and a decrease in the active dynamic group, but no statistically significant differences in group data at pre- or post- stretching.[2] It is also worth mentioning that the mean sprint times recorded by Fletcher et al.[2] were similar to the current study, with larger standard deviations. The magnitude of the differences in sprint times were also similar to what was found in the current study.

Figure 7: Average sprint times



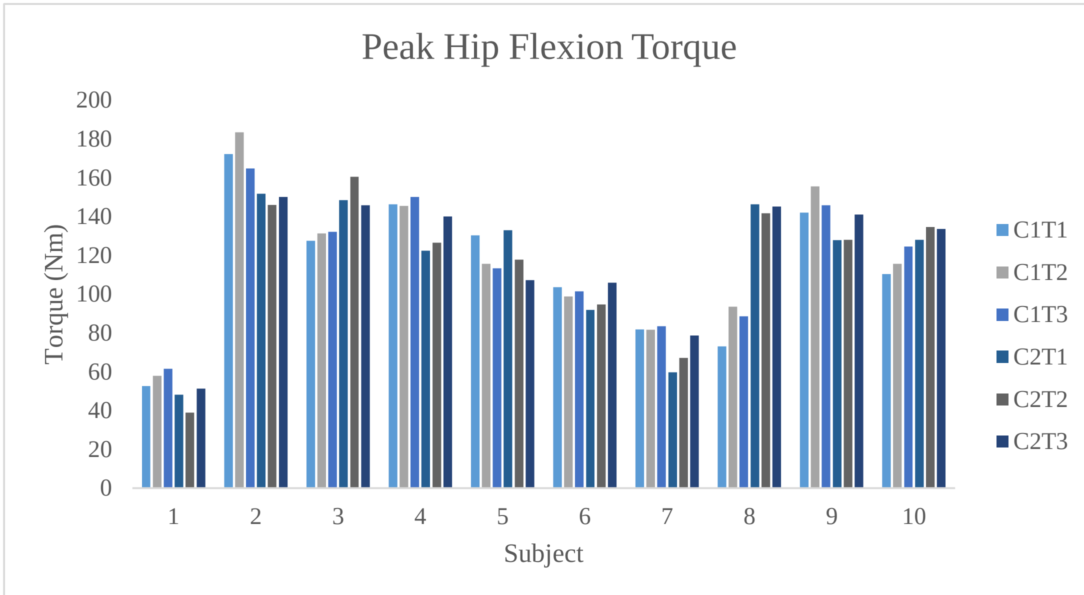
Little et al.[48] compared the effect of static and dynamic stretching on several different tests that were performed consecutively and found that static stretching resulted in significantly faster 20-m times compared to no-stretch, but there was no significant difference in sprint times compared to dynamic.[48] Those authors attributed their results to duration of stretching time and the addition of other measured agility tests. Those conclusions align with the current study; as stated previously, a lack of significance may be due in part to stretch duration or the implementation of additional activity following the stretch.

To elaborate, the sprint protocol in this current study was not utilized specifically to measure changes in sprint times. Instead, the purpose of the sprints was to create a functional sport-specific task that would serve to determine if the effects of a stretch on torque were maintained after activity. As mentioned previously, no studies exist that measure not only the immediate effects of a stretch, but also the effects following functional activity. This research would be more beneficial to the active sports population who tend to stretch only before a competition, and not throughout. Furthermore, in a majority of the stretch-sprint research available in the literature involves stretching more muscle groups for longer periods of time,[1–4,10,15,50] so it is possible that the specificity and length of the stretches in the current study were not enough to elicit a total effect that would affect sprint times significantly.

Hip Flexion Peak Torque

The lack of statistically significant response in hip torque may be due to several factors. First, high variability (shown in Figure 8) existed among a small sample size of participants. The abovementioned changes, though partially in line with the original hypothesis, are in magnitudes that are a fraction of even the lowest torque values. The mean and standard deviation values are evidence of a high amount of variability that may have been reduced had the sample size been larger or comprised of a sample of more homogeneous individuals. Eligibility requirements for this study were very broad and the ensuing participant pool consisted of all soccer players, but from varying ages and levels of experience. Females were underrepresented and consisted of a current Division 1 athlete and a recreational level athlete. Males ranged from the Division 1 athlete to the recreational athlete, including a 41 year old recreational player.

Figure 8: Peak hip flexion torque (Nm)



Furthermore, upon analyzing the torque values for each participant between conditions, several participants had stark differences in baseline trials (T1 in Figure 7) between conditions. This could be due to motivational factors, familiarity with the study, or activities performed outside of the study. During the collection, participants were asked to complete tasks with maximal effort but these maximal efforts were not controlled by the examiner by means of creating a minimum torque value deemed an acceptable trial. It is also considered in retrospect that torque collection may have been more reliable if collected during the sprints with the use of a force platform embedded into the runway. This technique has been utilized to measure muscle torques during both stance and swing phase of running and sprinting.[64] Thus, the "field" component of the intermittent sprint, designed to be more representative of sprint activity, may have negatively influenced the ability to detect significant differences in hip torque.

Nelson and colleagues[63] measured torque production for knee extension at five different velocities (1.05, 1.57, 2.62, 3.67, and 4.71 rad/s) and found that at lower velocities (1.05 and 1.57

rad/s), torque output was decreased following a static stretch, but this effect was not evident for higher-velocity movements (2.62, 3.67, and 4.71 rad/s).[63] The current study measured torque at 180°/s, which is equivalent to 3.14 rad/s and falls within the range of the non-significant findings of Nelson et al.[63] In their study, participants were asked to stretch for 30 seconds, which is the same stretch duration of the current study. However, stretches were only repeated twice rather than three times. A similar study by Egan et al.[65] investigated changes in torque production in knee extensors after a static stretch and found no significant change from baseline at either 60 or 300°/s.[65] Participants in that study were also asked to stretch for 30 seconds, but repeated the stretch 4 times.[65] The participants in the study by Egan et al.[65] were collegiate basketball players, and the authors hypothesized that the effect of stretching is less prominent in trained individuals as opposed to untrained or sedentary individuals.[65] Considering the participant pool in the study by Nelson et al.[63] (recreationally active), as well as the current study (elite or recreationally active soccer players), that hypothesis holds merit.

Alternatively, Papadopoulos et al.[66] also implemented 30-second stretches and found significant decreases in torque production at both 60 and 180°/s (1.04 and 3.14 rad/s) for knee flexors and extensors.[66] The torque decrease found by Papadopoulos and colleagues[66] at 60°/s agrees with the findings by Nelson et al.,[63] but they did have significant results at 180°/s,[66] which was not true for Nelson et al.[63] or Egan et al.[65] Interestingly, the participants in the study by Papadopoulos et al.[66] were non-athletes, which supports the hypothesis by Egan et al.[65] that trained individuals are less likely to have performance deficits following static stretching.

With regard to dynamic stretching and torque production, the aforementioned study by Papadopoulos et al.[66] found no significant difference between no-stretch and dynamic stretch at either 60 or 180°/s.[66] These results align with the current study. All three of the aforementioned studies measured torque production at the knee, while the current study investigated changes at the hip. No research was found that investigated the hip musculature following different stretch interventions.

Ogura et al.[62] attempted to determine if various lengths of static stretching led to force decrements as measured by an isokinetic dynamometer and found that stretches lasting 30 seconds or less resulted in no significant decrease in torque output of the knee flexors, but a duration of 60 seconds resulted in a decrease in torque production.[62] Those findings support the claim that documented deleterious effects of static stretching may be due in part to the length of the stretches performed in said studies.

Overall, the current study intended to focus specifically on hip flexion by choosing stretches that only affected the hip flexors, only measuring hip flexion with the dynamometer, and only focusing on hip flexion angular velocity during the initial swing phase of gait. As mentioned previously, it is possible that the specificity of stretching and measuring only hip flexion may have led to subtle changes that were not properly identified during the use of the isokinetic dynamometer. It would be interesting in future studies to increase either the number of stretches performed or the duration of stretches in order to potentially increase the effect of the stretches on the measured variables. Furthermore, to test the theory regarding trained vs. untrained individuals proposed by Egan et al.,[65] a future study could compare athletes and non-athletes to determine if similar changes occurred in hip flexion torque production following static and dynamic stretching protocols.

Limitations

Several limitations were introduced previously. These limitations were evaluated through the data collection and analysis process. First, limitations involved with the outdoor location included idle time from the Biodex to the sprint location, environmental concerns with outdoor performance, and environmental concerns regarding kinematic analysis. The first limitation regarding idle time proved to be a non-issue, as the longest amount of time between any portions of the collection was less than 90 seconds. However, environmental considerations, both regarding performance as well as kinematic analysis, were present. High winds during collection time caused several collections to be cancelled and rescheduled, due to both performance and equipment concerns that arose. Those participants were rescheduled for 3-7 days later due to scheduling conflicts.

Environmental considerations regarding data analysis also became an issue during the digitizing process. Ambient light from the position of the sun affected the infrared capability of the camera, which caused visibility issues with markers. These issues were primarily limited to the ankle markers, which could have possibly affected the knee angle position data. Furthermore, outdoor collection proved to be problematic in regard to camera and computer connectivity. Unfortunately due to these connection issues, only trials 1 and 6 were recorded. Fortunately, no loss of data occurred for any first or last trials; however, the kinematic data that may have been collected for trials 2-4 may have been useful to provide further insight, especially considering that times were still collected for those trials and a stronger correlation between sprint time and angular velocity may have been created.

Conclusions

The current study aimed to determine if specific kinetic and kinematic measures of hip flexion were affected by different stretching techniques. The implementation of a sprint protocol to determine lasting effects of a stretch provided uniqueness to the study that has yet to be measured in the literature. The current study proved to have no statistically significant results. The lack of significance may be due to a small sample size and high variability within the sample. A factor that should be considered for the variability in all of the measured variables is the experience and current playing level of the participants in the study. Most of the participants indicated that they have played soccer for a majority of their lives, but in some cases there were intermittent breaks in playing level (recreational vs. elite). Of the population sampled, only two participants were actively playing Division 1, while the rest were playing at a recreational or moderate level, which consists of 1-2 games per week. Some of those athletes claimed to supplement their soccer workout days with strength training or cross training, though others reported to only work out on the days of the week that they play in soccer games. These differences in the sampled population may begin to explain the variability in the results of the study.

A common theme addressed in each of the aforementioned research studies is that research regarding the effect of stretching is equivocal and is dependent on several factors, such as stretch duration, activity performed after the stretch, and types of stretches utilized. Further research should be conducted to determine the effects of stretching on immediate and post-activity performance measures. Results of such research would be beneficial for athletes and coaches to determine the type of stretch that should be performed in order to encourage performance increases at the beginning, end, and throughout a competition.

Though the data collected were not statistically significant, they may provide clinical insight as to what the effects of stretching are on hip flexion torque, and if those effects continue once an individual begins activity. The results of this study may provide a framework for future similar studies and serve as inspiration to continue the task of implementing a functional activity into measurements of stretching effectiveness.

APPENDIX A: PRE-RESEARCH QUESTIONNAIRE

Sport (circle one): Men's Soccer Women's Soccer

Age: _____________

Years participating in soccer: _____________

Have you ever had a lower extremity injury? Yes No

If so, when? _____________

Which is your dominant leg? Right Left

Do you usually stretch before a workout or competition? Yes No

If so, do you perform stretches that are dynamic, or static? Dynamic Static Both

(Static stretches are performed by putting the muscle into a stretch position and holding it for a specific amount of time, such as a seated hamstring stretch or standing quadriceps stretch. Dynamic stretching involves putting a muscle or muscle group into a stretched position during active movement, such as walking lunges or high knees.)

Do you usually stretch after a workout or competition? Yes No

If so, do you perform stretches that are dynamic, or static? Dynamic Static Both

Currently, how often are you working out? (Days/week) _____________

How long do you spend working out per session? (Minutes) _____________

What kind of workouts do you typically perform? Cardio Strength Both

APPENDIX B: STATIC STRETCHES

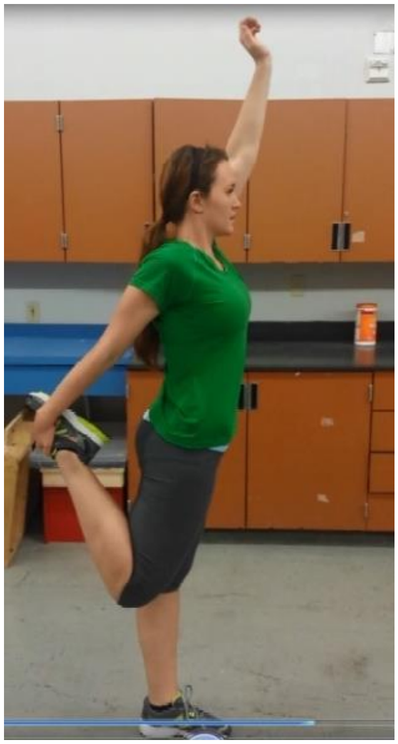


Figure 2*:* Standing Iliopsoas/Quadriceps Stretch

Figure 3: Modified Lunge Stretch

APPENDIX C: DYNAMIC STRETCHES

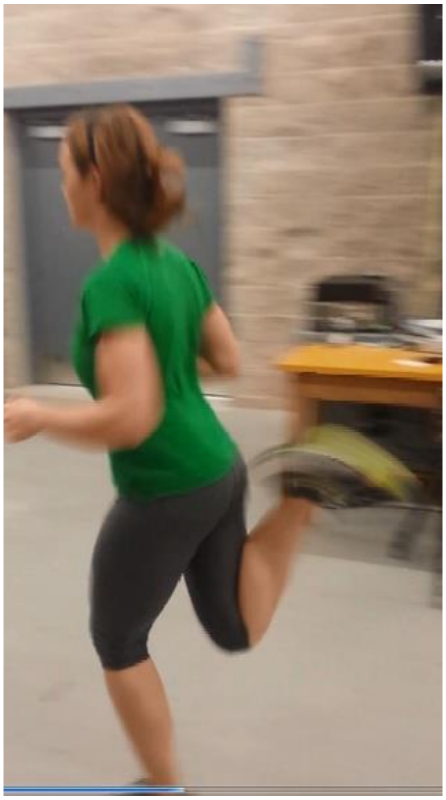


Figure 4: Flick Backs Dynamic Stretch

]

Figure 5: Powerful Backwards Walking Dynamic Stretch

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EDUCATION

University of Nevada, Las Vegas
Master of Science in Kinesiology
Biomechanics Specialization
August 2013—current
Current GPA 3.89
Thesis: Changes in kinematics and kinetics of sprinting following static or dynamic stretches
Advisor: Janet Dufek, PhD

Slippery Rock University of Pennsylvania
Bachelor of Science, Athletic Training Major
August 2008—December 2011
Graduated magna cum laude, GPA 3.77

Youngsville Middle/Senior High School
Graduated summa cum laude, GPA 98.6%

TEACHING & APPOINTMENTS

Graduate Student Instructor
Sports Injury Management 101: Introduction to Athletic Training
Fall 2013, Spring 2014, Fall 2014, Spring 2015
Sports Injury Management 150: Management of Sport Trauma and Illness Lab
Summer 2014

Teaching Assistant/Guest Lecturer
Sports Injury Management 386: Evaluation of Lower Extremity Injuries
Fall 2013, Fall 2014
Sports Injury Management 480: Therapeutic Exercise
Spring 2014, Spring 2015
Sports Injury Management 371: Advanced Clinical Experience in Athletic Training I
Spring 2014, Spring 2015
Sports Injury Management 471: Advanced Clinical Experience in Athletic Training II

Fall 2013, Fall 2014

EMPLOYMENT HISTORY

University of Nevada, Las Vegas
Graduate Assistant
Department of Kinesiology and Nutrition Sciences
August 2013—Present
Responsible for teaching a 100-level lecture course, help with instruction of upper level courses, and assist the Athletic Training Program Clinical Coordinator

Healthtrax International
February 2012—May 2013
Licensed Athletic Trainer
Employed at a major aerospace manufacturing company
Work with employee population to prevent musculoskeletal injuries through the use of Symptom Interventions, Job Site Consultations, Body Mechanics Analyses, and group injury prevention training classes

Stanwood/Camano School District
December 2012—May 2013
Interim Head Athletic Trainer and Sports Medicine Teacher

Mountlake Terrace High School
August 2012—December 2012
Interim Athletic Trainer and Sports Medicine Teacher

Slippery Rock University Office of Residence Life
June 2009—December 2011
Community Assistant

LICENSES & CERTIFICATIONS

Athletic Training Board of Certification
Certified Athletic Trainer, effective January 2012

Nevada State Board of Athletic Training
Licensed Athletic Trainer, effective June 2013

American Heart Association
First Aid and BLS for the Medical Provider, effective August 2013
HeartSaver AED and CPR Instructor, effective August 2013

American Red Cross
CPR/AED for the Professional Rescuer, August 2009—August 2013

PROFESSIONAL MEMBERSHIPS

National Athletic Trainers' Association
August 2010—present

Far West Athletic Trainers' Association
Nevada Athletic Trainers' Association
June 2013—present

American College of Sports Medicine, Southwest Chapter
October 2013—present

UNLV Graduate and Professional Student Association
Council Member, Kinesiology and Nutrition Sciences Representative
September 2014—present

Washington State Athletic Trainers' Association
January 2012—June 2013

PRESENTATIONS & ACCEPTED ABSTRACTS

American College of Sports Medicine, Southwest Chapter
October 2014, Poster Presentation
"Relationship between resistance band tension and muscle activity during use of a hip exercise device"

UNLV Graduate College Rebel Grad Slam: Three Minute Thesis Competition
November 2014, Semi-Finalist
"Relationship between resistance band tension and muscle activity during use of a hip exercise device"

Graduate and Professional Student Association Research Forum
March 2015
"Relationship between resistance band tension and muscle activity during use of a hip exercise device"

American College of Sports Medicine Annual Meeting
Abstract Selected for Poster Presentation, May 2015
"Relationship between resistance band tension and muscle activity during use of a hip exercise device"

AWARDS

Graduate and Professional Student Association Research Forum
March 2015
Honorable Mention

Graduate and Professional Student Association Sponsorship

Conference Travel Award, June 2013
Award Amount $350

iLead Student Leadership Conference
Student Travel Scholarship, March 2011
Award Amount $600

CONFERENCE ATTENDANCE

Athletic Training Educators' Conference
2015

National Athletic Trainers' Association Annual Meeting and Clinical Symposia
2012—2014

American College of Sports Medicine, Southwest Chapter Annual Meeting
2013—2014

Far West Athletic Trainers' Association Annual Meeting
2014—2015

AREAS OF INTEREST

Sports Medicine/Athletic Training
Injury prevention, etiology/pathology of injury, injuries in the 'non-traditional' athlete

Biomechanics
Running/shoe mechanics, acute and overuse injury

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