2017

The Influence of Different Pre-Exercise Routines on Sprint Performance

Rok Mravljak
Eastern Illinois University

The Graduate School

EASTERN ILLINOIS UNIVERSITY

Thesis Maintenance and Reproduction Certificate

FOR: Graduate Candidates Completing Theses in Partial Fulfillment of the Degree
Graduate Faculty Advisors Directing the Theses

RE: Preservation, Reproduction, and Distribution of Thesis Research

---

Preserving, reproducing, and distributing thesis research is an important part of Booth Library's responsibility to provide access to scholarship. In order to further this goal, Booth Library makes all graduate theses completed as part of a degree program at Eastern Illinois University available for personal study, research, and other not-for-profit educational purposes. Under 17 U.S.C. § 108, the library may reproduce and distribute a copy without infringing on copyright; however, professional courtesy dictates that permission be requested from the author before doing so.

Your signatures affirm the following:

- The graduate candidate is the author of this thesis.
- The graduate candidate retains the copyright and intellectual property rights associated with the original research, creative activity, and intellectual or artistic content of the thesis.
- The graduate candidate certifies her/his compliance with federal copyright law (Title 17 of the U. S. Code) and her/his right to authorize reproduction and distribution of all copyrighted materials included in this thesis.
- The graduate candidate in consultation with the faculty advisor grants Booth Library the non-exclusive, perpetual right to make copies of the thesis freely and publicly available without restriction, by means of any current or successive technology, including by not limited to photocopying, microfilm, digitization, or internet.
- The graduate candidate acknowledges that by depositing her/his thesis with Booth Library, her/his work is available for viewing by the public and may be borrowed through the library's circulation and interlibrary loan departments, or accessed electronically.
- The graduate candidate waives the confidentiality provisions of the Family Educational Rights and Privacy Act (FERPA) (20 U. S. C. § 1232g; 34 CFR Part 99) with respect to the contents of the thesis and with respect to information concerning authorship of the thesis, including name and status as a student at Eastern Illinois University.

I have conferred with my graduate faculty advisor. My signature below indicates that I have read and agree with the above statements, and hereby give my permission to allow Booth Library to reproduce and distribute my thesis. My adviser's signature indicates concurrence to reproduce and distribute the thesis.

Graduate Candidate Signature | Faculty Adviser Signature

Printed Name | Printed Name

EXERCISE SCIENCE
Graduate Degree Program

8/17/17
Date

Please submit in duplicate.

The Influence of Different Pre-Exercise Routines on Sprint Performance

(TITLE)

BY

Rok Mravljak

THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF

Master of Science

IN THE GRADUATE SCHOOL, EASTERN ILLINOIS UNIVERSITY
CHARLESTON, ILLINOIS

2017

YEAR

I HEREBY RECOMMEND THAT THIS THESIS BE ACCEPTED AS FULFILLING
THIS PART OF THE GRADUATE DEGREE CITED ABOVE

	8/15/17		8/17/17
THESIS COMMITTEE CHAIR	DATE	DEPARTMENT/SCHOOL CHAIR OR CHAIR'S DESIGNEE	DATE
THESIS COMMITTEE MEMBER	DATE	THESIS COMMITTEE MEMBER	DATE
	8/15/17		
THESIS COMMITTEE MEMBER	DATE	THESIS COMMITTEE MEMBER	DATE

THE INFLUENCE OF DIFFERENT PRE-EXERCISE ROUTINES ON SPRINT PERFORMANCE

Rok Mravljak, B.S.

Faculty of Sports, University of Ljubljana

ABSTRACT

Sprint performance can be enhanced by interventions for short-term (acute) purposes and/or long-term purposes. Acute neuromuscular responses are usually achieved by using different pre-exercise routines at the end of the warm-up period. Recently, there have been several studies examining the effects of various pre-exercise routines on sprint performance, yet there has not been a research study designed that compared the three most commonly used pre-exercise routines in professional and recreational sports (static stretching, dynamic stretching and foam-rolling). Therefore, this study investigated and compared the results of static stretching, dynamic stretching, self-myofascial release and the control group, in order to provide some general findings in this field of sport performance. The purpose of this study was to examine the acute effects of different pre-exercise routines on 60-meter sprint performance. Moreover, the study investigated whether static stretching impairs sprint performance. Ten students from a Midwestern U.S. University were recruited to participate in this study, with 8 participants successfully finished the study. Each participant underwent all four intervention protocols in a randomized order. A repeated measures ANOVA statistical analysis indicated a significant main effect with post-hoc testing comparing 60-meter sprint results for each pre-exercise protocol did not show statistical significance amongst the selected values: SS time – DS time, SS time – CG time, SMR time – DS time, SMR time – CG time, and DS time – CG time ($p=0.061$; $p=0.259$; $p=0.356$; $p=0.111$; $p=0.265$; respectively). However, comparing the results from the SS group and the SMR group showed that the SMR had a significantly greater effect than the SS ($p=0.024$), The findings of this study indicate that using self-myofascial release is a more beneficial pre-exercise protocol for

improving 60-meter sprint performance than either static or dynamic stretching. . Additionally, the results suggest that static stretching does not impair 60-meter sprint performance compared to a control group.

DEDICATION PAGE

I would like to dedicate this project to the most important people supporting me on my academic path. I would like to recognize their unconditional love and support at all times. Thank you to my parents, Magda and Zoran Mravljak, for believing in me and for encouraging me throughout this program. Without you I would never have come this far. Thank you to my grandmother, Bernarda Sušec for your guidance and all the advice you have shared with me. Finally, thank you to my girlfriend Megan R. Cotter for your positive impact and for standing by my side. You have enriched this experience and made every part of the past year special and memorable.

ACKNOWLEDGEMENTS

There are few people I would like to thank for their guidance and support throughout this project. First, a very big thank you to Dr. Brian Pritschet for his mentorship involved in the conducting process accompanied with significant encouragement. Additionally, I would like to thank Dr. Jake Emmett and Ms. Brianne Breidenbach, members of my thesis committee, for their effort and support, and Dr. Hasan Mavi, for his input in conducting this research project.

Moreover, I would like to thank the Department of Kinesiology and Sports Studies at Eastern Illinois University for their help and for making this project possible. Dr. Mark Kattenbraker, Dr. Scott Ronspies and Mrs. Carol Dhom, who welcomed me with open arms and successfully guided me through my Master's program.

TABLE OF CONTENTS

LIST OF FIGURES AND TABLES

CHAPTER I

INTRODUCTION

Race times in sprinting have significantly improved over the past few decades. New strength and conditioning techniques and combinations of specific pre-exercise routines, have brought many advances which have contributed significantly to improvements in sprint performance (Delecluse, 2012; Weiss, M., Newman, Whitmore, & Weiss, S, 2016). Lorenz and Morrison (2015) explored the current knowledge and understanding of periodization in rehabilitation programs and general sport periodization guidelines. They described three different periodization types: linear periodization, non-linear/undulating periodization, and block periodization. Periodization is structured out of numerous micro and meso-cycles forming an annual macro-cycle. Each cycle manipulates the volume and intensity of given exercises to precisely develop an athlete's progression towards reaching peak performance during the determined competition season. Implementing various pre-exercise routines in designed training program have significant acute and long term effects on an athlete's performance (Behm & Chaouachi, 2011; Weerapong, Hume, & Kolt, 2004). A single bout of stretching alters neuromuscular system, and a long-term stretching program results in adaptations in the neuromuscular system influencing range of motion (ROM) and muscle stiffness (Behm & Chaouachi, 2011; Weerapong et al., 2004).

The structure of muscle contains both contractile and elastic components that contribute to force production. Contractile muscle components perform work, transforming the potential energy of ATP into the kinetic energy of fiber shortening, during which the elastic properties of muscle (muscle-tendon unit) stores elastic energy which can also be transformed into kinetic energy (Haff & Triplet, 2016). A muscle-tendon unit in a relaxed state reacts to an external force (i.e. antagonist contraction; exercise therapist) by producing passive torque resulting in passive resistance. This resistance is created by: the cross-connections between the contractile proteins (actin, myosin, etc.), non-contractile proteins (titin, desmin, etc.), and connective tissues of the muscle (endomysium, perimysium, and epimysium). Active stiffness is defined as a resistance produced inside the muscle towards an external force, due to its viscoelastic properties and the level of muscle activation (Weerapong et al., 2004). Different pre-exercise routines alter the properties of the muscle-tendon unit changing its stiffness. Increased temperature inside the muscle affects muscle viscosity. Muscle's viscous elements are described as the muscle's liquid elements. Based on which stretching technique is applied to the muscle, muscle's elasticity may also be altered. Muscle's elastic elements are described as the muscle's solid elements. Warm-up alters the viscoelastic properties of the muscle, resulting in decreased viscosity, which allows higher speed of muscle contraction, and increased elasticity, which reflects a decreased muscle stiffness and enhanced ROM) (Wallmann, Christensen, Perry, & Hoover, 2012).

Training protocols can have a significant influence on sprint performance parameters (Weerapong et al., 2004). The acute effects of pre-exercise routines, such as a warm-up followed by a sport specific static stretching protocol, have shown a positive influence on musculotendinous viscoelastic properties (Behm & Chaouachi, 2011; Weerapong et al., 2004). This may result in an improvement of sport performance if flexibility is a major contributor to that performance. Conversely, this regimen may result in a decrease in force production capacity and may therefore, result in a diminished sport performance (Wallmann et al., 2012). There have been several theories presented which may explain the fundamental reasons behind diminished sport performance after using pre-exercise static stretching routines. Behm and Chaouachi, (2011) and Weerapong et al. (2004) have described the reason as a reduction in the capability for storing elastic energy in non-contractile components of muscles, as static stretching influences passive stiffness and torque inside the muscle which is linked to elastic components of muscles.

Over time there have been numerous routines presented, often called warm-up protocols, that precede the main physical activity, which are performed by athletes with the intention of increasing body temperature and blood flow to the muscles and therefore prepare these muscles for the stress that the individual will be exposed to with exercise. Pre-exercise warm-up protocols have an influence on the cardiopulmonary system, decreasing muscle viscosity and enhancing blood flow and oxygen distribution and therefore prepare an athlete for physical activity with the purpose of preventing injury and/or improving sport performance (American College of Sports Medicine, 2011).

Pre-exercise protocols have been generalized, and are most often used with the intention to accomplish acute effects (improving sport performance), or to target long-term goals (flexibility and general well-being) (Behm & Chaouachi, 2011; Weerapong et al., 2004). These stretching strategies are divided into: static stretching, ballistic stretching, proprioceptive neuromuscular facilitation, dynamic stretching, and myofascial release (massage, foam rolling) (Behm & Chaouachi, 2011; Weerapong et al., 2004; Schroeder & Best, 2015; Ajimsha, Al-Mudahka, & Al-Madzhar, 2015). The general practice is that a well conducted warm-up program consists of exercises that engage body segments and sport specific muscle groups that will experience the highest amount of exercise induced stress and that mimic the subsequent activity as closely as possible (American College of Sports Medicine, 2011).

The most common use of the term "stretching" describes a movement applied by an external and/or internal force in order to increase muscle-tendon length and flexibility/range of motion (Weerapong et al., 2004). The outcome of applying stretching exercises is the elongation of muscles and soft tissues effected by mechanical and neurological mechanisms (Behm & Chaouachi, 2011; Weerapong et al., 2004). The muscle-tendon unit can be stretched and therefore elongated in two different ways. When muscle contracts, the contractile elements (contractile proteins) are shortened, and as a compensatory response, the passive elements of tissues are lengthened (tendon, perimysium, epimysium, and endomysium). When the muscle-tendon unit is lengthening as a whole muscle, contractile elements and connective tissues are elongated because of the application of external force (i.e. antagonist muscle and/or exercise partner). Muscle-tendon unit lengthening results due to changes in the biomechanical properties of the muscle: viscosity and elasticity of the muscle-tendon unit (Weerapong et al., 2004.)

The most basic, common principles of a pre-exercise routine include a minimum of five to ten minutes of low to moderate intensity physical activity (i.e. jogging and running related techniques) preceding a sport specific stretching protocol (American College of Sports Medicine, 2013) which has shown increased nerve conduction velocity, enzymatic cycling and increased muscle compliance (Young & Behm, 2002).

Static stretching is frequently used as a pre-exercise warm-up protocol and as a mode of training for improving flexibility (Young and Behm, 2002). Static stretching involves moving a limb to the end of its range of motion and holding the stretched position for 15-60 seconds (Young & Behm, 2002). Static stretching has been shown as an effective strategy to improve range of motion about a joint or series of joints, which can be described as an enlarged amplitude of movement (Power et al., 2004). Young and Behm (2002) also mentioned that static stretching is usually followed by sport specific movements that should mimic movement patterns most prominently performed in the main part of the workout or sport event.

Dynamic stretching is defined as a controlled movement through the active range of motion for a joint (Fletcher & Jones, 2004). The research literature demonstrates that shorter durations of dynamic stretching either does not adversely affect sport performance or it significantly improves sport performance after longer durations of dynamic stretching (Hough, Ross, & Howatson, 2009). Static stretching is usually followed by sport specific movements, whereas dynamic stretching can be designed to be similar to movements that occur during the main part of the subsequent exercises. Therefore, dynamic stretching is preferable as a part of a warm-up routine designed to prepare an individual for physical activity (Torres et al., 2008). The mechanisms by which dynamic stretching influences and possibly enhances muscular performance are: (a) elevated muscle and body temperature, which results in altered viscoelastic properties of muscle, (b) post-activation potentiation due to enhancements in neuromuscular function resulting in increased cross-bridge attachment, and (c) stimulation of the nervous system, and/or decreased inhibition of antagonist muscles (Fletcher & Jones, 2004; Hough et al. 2009; Torres et al., 2008; Yamaguchi & Ishii, 2005).

Fascia, as referred to by the Fascia Research Congress, (FRC) (Schleip, Jäger, Klingler, 2012) as a "soft tissue" constituent of the body's connective tissue system. The most applicable description for the purposes of this study defines fascia as a fibrous collagenous tissue that take part in force transmission system (Schleip et al., 2012). Myofascial release is an alternative medicine therapy, manipulating "soft" tissues in the body. With self-myofascial release (SMR) an individual uses his or her own body mass, usually on a foam roller, to exert pressure on the affected soft tissues. With the changes of body positions, an individual can target different muscle groups, which usually include, but are not limited to, the quadriceps, hamstrings, triceps surae, gluteus maximus, iliopsoas, hip adductors, trapezius, and rhomboids. There is evidence that SMR is as beneficial in releasing tension in muscle tissues as regular massage, and there are findings suggesting an increase in ROM after applied SMR protocol (Schroeder & Best, 2015; Ajimsha, Al-Mudahka, Al-Madzhar, 2015). Compared to other pre-exercise routines, that influence a muscle's viscoelastic properties by affecting both elastic and viscous properties, myofascial release primarily influences the muscle's viscosity by heating the muscle with various techniques of generating pressure on soft tissues. The result is a reduction in muscle tension and stiffness, reduced muscle pain, swelling, and spasm, greater joint flexibility and enhanced range of motion (Schroeder & Best, 2015). Myofascial release has been shown to be an effective technique to treat soft tissue adhesions, alleviate pain, and reduce tissue tenderness, edema, and inflammation while improving muscle recovery (Paolini, 2009). SMR was found to bring acute and cumulative effects on the viscoelastic properties of the exercised muscle, suggesting that this technique, used as pre-exercise routine, could have beneficial effects on sport performance (Haas, Best, Wang, Butterfield, & Zhao, 2012; MacDonald, Penney, & Mullaley, 2013).

Sprint is an important, and frequently researched sport related movement and is related to the quality of performance in most modern sports. An athlete's ability to sprint and change direction while sprinting is an essential component of physical performance in team and racquet sports. Time-motion analyses, that quantify the physical demands of an individual player during practice or match-play, have supported this statement, for example in soccer (Bloomfield, Polman, & O'Donoghue, 2007) and in handball (Karcher & Buchheit, 2014). Strength and conditioning coaches use this non-instructive method in order to gain valuable data of durations and frequencies of sprinting during the match. Moreover, they can measure energy expenditure through determining exercise-to-rest ratios and the intensity of play (percentage of the maximal running), which evaluates an athlete's current level of season preparation (Bloomfield et al., 2007; Rienzi, Drust, Reilly, Carter, & Martin, 2000).

To summarize, investigating pre-exercise routines has provided valuable and applicable information to the field of exercise science. However, there is no general agreement concerning whether static stretching induced alterations to the neuromuscular system provide more benefits to the individual or whether they should be counterbalanced with dynamic movements. Moreover, there has not been a study conducted that has compared the acute effects of static stretching, dynamic stretching and SMR in order to establish which protocol has a superior effect on sprint performance and how these values will reflect in comparison to the baseline measurements of the control group. Therefore, this study examined four different pre-exercise routines: static stretching (ST), dynamic stretching (DS), Self-myofascial release (SMR), and a control group (CG), and their influence on sprint performance. The purpose of this study was to examine: the acute effects of four different pre-exercise routines on 60 m sprint performance, and additionally to determine whether static stretching is associated with any detrimental effects on 60 m sprint performance.

This study hypothesized that pre-exercise dynamic stretching would elicit superior improvements over foam rolling in 60 m sprint performance, and that static stretching would have detrimental effects on 60 m sprint performance.

DEFINITION OF TERMS

Pre-exercise routine: a low to moderate intensity physical activity, performed with the main goal to optimally prepare an individual's body for the following physical exertions. The mechanisms through, which this can be achieved are elevated body temperature, increased blood flow to the muscle, accompanied with the enhanced cardiovascular and pulmonary system (ACSM, 2011).

Self-myofascial release: Fascia as referred to by the Fascia Research Congress (FRC) (Schleip, Jäger, Kingler, 2012) as a "soft tissue" constituent of the body's connective tissue system. Myofascial release is an alternative medicine therapy manipulating "soft" tissues in the body. With Self-myofascial release (SMR) an individual is using their own body mass, usually on a foam roller, to exert pressure on the affected soft tissues.

Dynamic Stretching: Dynamic stretching is a pre-exercise technique, which consists of performing controlled movements through the range of motion (Fletcher, 2010) where the agonist muscle contracts, the antagonist muscle is being stretched and vice versa (Behm & Chaouachi, 2011).

Static Stretching: static stretching describes a pre-exercise technique, where a muscle is stretched to it's end range of motion and continuously held without any movement for a prolonged period of time (Weerapong et al., 2004).

Sprint performance: maximal "all out" running performance on a designated distance. Sprint is divided into acceleration phase (0 meters to 15 meters) and maximal running phase (20 meters to 100 meters) (Weerapong et al., 2004).

CHAPTER II

LITERATURE REVIEW

This research study was conducted to clarify and determine the effects of different pre-exercise routines on sprint performance. It was aimed to present supportive data on the superior acute effects of dynamic stretching and the detrimental effects of static stretching on sprint performance. The following review of literature reflects current knowledge in the field of pre-exercise routines and sport performance. Defined protocols partake in the warm-up section of the exercise session, and form an acute influence on sprint performance. The subsequent sections describe the neuromuscular changes each pre-exercise protocol causes and how those changes influence sprint performance.

Numerous research studies have examined and compared the effects of different warm-up protocols on sprint, sport, and/or muscular performance (Ayala, De Ste Croix, Sainz De Baranda, & Santonja, 2014; Ajimsha et al., 2015; Beckett, Scheiker, Wallman, Dawson, & Guelfi, 2009; Behm & Chaouachi, 2011; Bishop & Middleton, 2013; Kokkonen, Nelson, & Cornwell, 2017; Taylor, Weston, & Portas, 2013; Weerapong et al., 2004; Wong, Chaouachi, Lau, & Behm, 2011; Young & Behm, 2002). Researchers explained and supported their findings with various theories; however, there are few disagreements amongst the results of these studies when answering the question whether dynamic stretching, static stretching or self-myofascial release present a significant effects on sprint performance, hence providing no general findings in this field of research. Several explanations could address the cause of the differences in the results, which could be due to the modifications in designed research methods, selected measurement techniques, or various subject recruitments and/or characteristics.

Present research study compared different warm-up protocols and their influence on sprint performance. Three intervention pre-exercise routines were selected that have been suggested to have a distinct influence on individual's neuromuscular system (Ajimsha et al., 2015; Behm & Chaouachi, 2011; Schroeder & Best, 2015; Weerapong et al., 2004). Consequently, the review of literature was divided into three subsections as follows: static stretching and sport performance, where viscoelastic properties of muscle-tendon unit, and neurological mechanisms are described; dynamic stretching and sport performance, with the definition of the post-activation potentiation; and myofascial release and sport performance.

Static stretching and sport performance.

Static stretching and the acute effects of pre-exercise routine have been thoroughly examined as it is considered as one of the most widely and commonly used warm-up protocols amongst children in physical education school systems or amongst adults as a part of professional or recreational training program (Young & Behm, 2002; Weerapong et al., 2004). Research investigating the background of most common warm-up patterns, have suggested that athletes or recreational individuals usually start their workout session with a mindset to stretch their muscles immediately before a race or a workout based upon the perception of improved flexibility and decreased risk of injury (Weerapong et al., 2004). To support these suggestions an improvement in flexibility has been suggested to have a significant effect on sport performance, and potentially reduce the risk of injury (Winchester, Nelson, & Kokkonen, 2009).

The reason for practicing such pre-exercise protocol may lay in the tradition of preparing for a sport event; moreover, static stretching has demonstrated the highest level of influence and improvement of range of motion (ROM) in individuals that engage in using static stretching as their preferred stretching technique (Behm & Chaouachi, 2011; Weerapong et al., 2004). There are also research studies that have detected no differences in sport performance as a result of using different pre-exercise routines. However, they have mentioned changes in ROM using different stretching exercises, and have not found any statistically significant results that would suggest superior use of one stretching technique over another (Ayala et al., 2015; Bishop & Middleton, 2013; De Oliveira & Pinto Lopes Rama, 2016; Favero et al., 2009; Serefoglu et al., 2017; Unick et al., 2005; Wallmann et al., 2012; Wong et al, 2011). Yet, only three research studies have examined the influence of a single bout static stretching, without any following sport specific dynamic activity, on sprint performance (De Oliveira & Pinto Lopes Rama, 2016; Favero et al., 2009; Wallmann et al., 2012). Moreover, application of these findings could have some limitations: Wallmann et al. (2012), for example, examined an acute effect of static stretching on sprint performance only for one muscle group (iliopsoas), Favero et al. (2009) found a tendency for stretching to negatively influence sprint performance, and De Oliveira and Pinto Lopes Rama (2016) used a nonrandomized controlled trial, which could influence the validity of the collected data. In contrast, other studies are suggesting that static stretching does not diminish sport performance, using an additional dynamic activity prior to testing trial (Ayala, De Ste Croix, Sainz de Baranda, & Santonja, 2015; Bishop & Middleton, 2013; Serefoglu et al., 2017; Unick et al., 2005; Wallmann et al., 2008; Wong et al., 2011). In some sports, such as gymnastics, hokey (goalkeeper), ballet, wrestling, swimming, and figure skating, enhanced flexibility can improve overall performance (Wong et al., 2011). However, some research indicates that static stretching may cause detrimental effects on sport performance (Behm & Chaouachi, 2011; Weerapong et al., 2004), thus static stretching followed by a dynamic stretching protocol may improve flexibility, and reduce the detrimental effects induced by the static stretching (Chaouachi et al., 2010). Moreover, Wong et al. (2011) investigated different durations of static stretching followed by dynamic stretching, as they wanted to clarify whether shorter bouts of static stretching (30-60 s) would not diminish sprint performance and agility compared to longer duration of static stretching (90 s). Following all three intervention techniques, a dynamic stretching protocol consisted of 90 s in total. Prior to a sprint and agility testing trial, they assessed ROM with the sit-and-reach test. Collected data suggested significant improvements in flexibility scores after 60 and 90 s (36.3%, and 85.6%) compared to 30 s protocol. However, they did not report any significant differences in sprint and agility trials between the intervention groups. Current research indicates possible potentiating factors associated with dynamic stretching that may counterbalance the detrimental factors of static stretching (Behm & Chaouachi, 2011; Sim, Dawson, Guelfi, Wallman, & Young, 2009).

Muscle stiffness (passive and active), ROM, cross-bridge alignment, and neural changes, are all factors that could diminish an individual's ability for maximal force production. Due to the changes in the viscoelastic properties of individual's muscle tendon unit, static stretching has been implemented in basic stretching protocols for decades; however, controversial evidence exists that provides no clear guidelines on the use of static stretching protocols followed by specific sport performances (de Oliveira & Pinto Lopes Rama, 2016).

Some authors have shown diminished results in sport performance after using different stretching techniques, specifically amongst individuals incorporating static stretching in their warm-up protocol, which was and still is most commonly used technique (Behm & Chaouachi, 2011; Weerapong et al., 2004). Research study by Kapo et al. (2016), and a meta-analysis by Simic et al. (2013), investigated effects of static stretching on muscle performance (strength and power parameters), and have discovered negative acute effects on maximal muscle strength and explosive muscular performance (Simic et al., 2013), diminished counter movement jump results, and decreased force manifestations (Kapo et al., 2016). Based on the findings of their study they have reported that diminished muscle performance is a result of acute bout of static stretching, due to stretch-induced transient reduction in stiffness of the muscle-tendon complex. A muscle-tendon complex with reduced stiffness was shown as a less efficient unit transmitting the force to the skeleton (Kapo et al., 2016; Simic et al., 2013). Moreover, numerous studies have supported the statements of detrimental effects of static stretching on maximal isometric force (Power, Behm, Cahill, Carroll, & Young, 2004), and explosive performance as measured by countermovement vertical jump, drop-jump, and sprint performance (Beckett et al., 2009; Fletcher & Jones, 2004; Fortier et al., 2013; Gelen, 2011; Haddad et al., 2013; Meerits et al., 2014; Nelson et al., 2013; Paradisis et al., 2013; Taylor et al., 2013; Winchester et al., 2009; Wong et al., 2011). Findings by Behm, Bambury, Cahill, and Power (2004), indicate possible detrimental effects of static stretching also on balance, reaction time and movement time. Generally, these performance reductions may originate from mechanical (Sim et al., 2009; Weerpong et al., 2004) and neural (Sim et al., 2009; Tylor et al., 2013) factors, which may be present for as long as one-hour post-stretching (Power et al, 2004).

Viscoelastic properties of the muscle-tendon unit.

The viscoelastic properties of muscle alter when an external load is applied. When we stretch, the muscle tissue produces a counter force. Passive force (stiffness) is a result of the resistance created from stable cross-links between actin and myosin, non-contractile proteins of the endosarcomeric and exosarcomeric cytoskeleton (titin and desmin), and connective tissues surrounding muscle, which eventually fuse into muscle's tendon (endomysium, perimysium, and epimysium) (Fortier et al., 2012; Nelson, Driscoll, Landin, Young, & Schexnayder, 2005; Sim et al., 2009; Weerpong et al., 2004). Active force (stiffness) may be produced by the contraction of the muscle (Herbert, 1988; Lederman, 2005; Sim et al., 2009; Weerpong et al., 2004) as the application of the static stretching to the muscle stimulate the reflex arch (muscle spindles, Golgi Tendon Organ). After first 6 sconds of applying the static stretching the stimulus from the Golgi Tendon Organ (GTO) will override the stimulus from the muscles spindles, which will result in the relexation of the agonist muscle. This may eventually result in the impaired muscular force, torque, and power production (Fortier et al, 2012; Sim et al., 2009; Weerpong et al., 2004). Studies suggest that increased muscle compliance (stretch-induced slack in the muscle-tendon unit) is the reason behind detrimental effects of static stretching (Sayers, 2008; Sim et al., 2009; Taylor et al., 2009). Increased muscle compliance results in diminished ability of the muscle-tendon unit to store recoil energy (Sayers, Farley, Fuller, Jubenville, & Caputo, 2008). During eccentric contraction, elastic tendons have the ability to operate the gradual loss of power's intensity. Muscle tendon unit absorbs part of that energy loss, which can be integrated into mechanical energy (Weerapong, et al., 2004). Study by Young and Elliott (2001) have shown a high correlation between the stiffness of the muscle-tendon unit and eccentric muscle performance. Static stretching decreases muscle stiffness or increases muscle compliance, which may result in impairments of muscle-tendon's capacity to absorb and reuse elastic energy during the stretch-shortening cycle (Fortier et al., 2012; Sayers et al., 2008; Sim et al., 2009). This compliance can lead to a greater energy requirement for force production during muscle contraction; therefore, resulting in lower rate for force production, which leads to diminished sprint performance (Sim et al., 2009; Taylor et al., 2008). Additionally, research study by Nakamura, Ikezoe, Takeno, and Ichihashi (2011), has investigated the effect of static stretching on muscle stiffness, tendon stiffness, and muscle-tendon stiffness by using ultrasonography and a dynamometer. The findings of this research have shown decreased muscle and muscle tendon stiffness right after static stretching and 10 minutes after static stretching. This data suggests that muscle's stiffness is mostly affected by application of static stretching. This aspect is described in details in the muscle architecture section.

Neurological mechanisms.

Several research studies have reported detrimental effects after passive stretching on running efficacy due to impairments in coordination (Sim et al., 2009; Tylor et al., 2008; Weerpong et al., 2004). Passive stretching triggers neural changes. Specifically, reduces α-motoneuron excitability which is visible in the depression of the Hoffman-reflex (H-reflex) (Weerapong et al., 2004; Sim et al., 2009). H-reflex reveals electrical stimulation of Ia sensory fibers (afferent neurons) (Weerapong et al, 2004). Muscle spindles innervate muscle fibers and constantly monitor changes in muscle length, and changes in stretching speed. When our muscle is exposed to a rapid stretch, muscle spindles alter the activity of muscle fibers by stimulating the muscle stretch reflex (Haff & Triplet, 2016). The pathway of electrical stimulus starts in Ia sensory fibers, which carry the stimulus to the Central nervous system (CNS). The neuron then forms an excitatory synapse with another neuron whose soma is in the CNS. This neuron will send the stimulus back to the skeletal muscle through lower motor neurons (efferent neurons) and will excite the skeletal muscle causing the muscle to contract (Haff & Triplet, 2016). The same somatosensory neuron (Ia sensory fiber) that excites efferent motor neurons for the agonist muscle, can also alter the excitability of the antagonist muscle. They can stimulate other neurons which are inhibitory neurons, therefore they form a synapse which is inhibitory. They inhibit lower motor neurons that innervate the muscle fibers of the antagonist muscle. This results in relaxed antagonist muscle and this reciprocal reflex enhances the response of the agonist muscle as it does not represent a force fighting against the agonist contraction (Haff & Triplet, 2016). This arch represents a combination of a muscle stretch reflex and a reciprocal inhibition, a response to a rapid change in muscle length. However, if the force increases and creates strenuous tension to our tendon it activates the Golgi Tendon Organ (GTO) which stimulates autogenic inhibition in order to prevent muscle-tendon unit from injury. This results in inhibition of the skeletal muscle of the agonist muscle, and may result in the stimulation of the antagonist muscle. These self-regulatory characteristics of the muscles being stretched may be altered after static stretching, causing reduced efficacy of adaptation to differences in muscle load and length. When neural drive from the CNS is reduced, a stretch reflex initiated from the eccentric phase of the stretch-shortening cycle, which increases muscle activation during the concentric phase, may become insufficient in producing maximal response during concentric phase (Sayers et al., 2008). Therefore, running kinematics alter and ultimately affect optimum power output and sprint performance (Sim et al., 2009; Weerapong et al., 2004; Haff & Triplet, 2016). These findings were supported in the study by Nelson et al. (2005) where they were comparing the acute effects of four different interventions using static stretching either for both legs or for the forward/rear leg in the starting position. Performing static stretching on one leg had the same adverse effects on sprint performance as stretching the muscles in both legs, which suggested an influence of static stretching on CNS.

Time under tension

Researchers have used different modes of static stretching over the years. This was due to different designs of the purpose and the methods of the research studies. However, previous research has some limitations when applying their findings to practical professional or recreational settings as the protocols used to investigate the influence of static stretching were not the best representative of the most commonly used warm-up methods by athletes (Spencer et al., 2005). Sim et al. (2009), report the evidence of detrimental effects of static stretching when the total duration of stretching applied ranged from 90 seconds up to 20-30 minutes per muscle group. Meta-analysis by Behm and Chaouachi (2011), and research study by Unick, Kieffer, Cheesman, and Feeney (2005), have reported that three sets of 15-45 total seconds of stretching do not alter viscoelastic properties of muscle-tendon unit, and that less than 30 seconds of stretching do not adversely influence the performance of trained people. Additionally, Wong et al. (2011), have reported that shorter durations of static stretching (≤ 90 seconds) do not provide significant impairments in sprint and agility performance. On the other hand, Nelson et al. (2005), Taylor et al. (2009), and Winchester, Nelson and Kokonnen (2009), compared the effects of static stretching and the combination of static stretching and sport-specific movements on vertical jump, sprint performance, and maximal voluntary strength, using 30 second stretches for each muscle group. In the contrast with the previous findings they have found detrimental effects of short duration static stretching. Based on the current literature a typical duration of time under tension is in the range between 30-120 seconds (Behm & Chaouachi, 2011; Young, 2007); therefore, this research study used 30 seconds of static stretching for each muscle group in order to clarify and provide some general and applicable findings for shorter durations of static stretching and its acute effects on sprint performance.

Muscle architecture

Lieber and Fridén (2000) define muscle architecture as the number and the orientation of its muscle fibers. Muscle mass and length, fiber length, pennation angle, and sarcomere length, are all architectural characteristics from which a number of parameters can be calculated: the ratio of muscle fiber length to muscle length, and the physiological cross-sectional area (PCSA) (Butler & Dominy, 2016). The distance over which a muscle can be shorten is proportional to the length of its muscle fibers (maximum muscle excursion), whereas maximum muscle force (maximum tetanic tension), which can be generated by a muscle is proportional to its PCSA; therefore, muscle's PCSA is directly associated to muscle force production (Butler & Dominy, 2016; Lieber & Fridén, 2000). Nakamura et al. (2011) have discovered decreased muscle stiffness after static stretching, and they addressed those changes partially to changes in muscle architecture. They have found decrease in pennation angle and an increase in the fascicle length. These changes have shown direct correlation to muscle's force transmission efficacy (Simic et al., 2013).

DYNAMIC STRETCHING AND SPORT PERFORMANCE

Dynamic stretching consists of performing controlled movements through the range of motion (Fletcher, 2010) where the agonist muscle contracts, the antagonist muscle is being stretched and vice versa (Behm & Chaouachi, 2011). Research has shown that dynamic stretching either facilitates speed (Gelen, Dede, Meric, Bingul, Bulgan, & Aydin, 2012), agility, torque (Sekir, Arabaci, Akova, & Kadagan, 2009), strength and power (Manoel, Harris-Love, Danoff, & Miller, 2008), or does not bring any detrimental effects on isokinetic strength and power (Ayala et al., 2014), sprint performance (Torres et al., 2008; Wong et al., 2011), or torque of the muscles on the contralateral side (non-stretched muscle – crossover effects) (Serefoglu et al., 2017). Recently, dynamic stretching has been investigated in various research studies (Behm & Chaouachi, 2011; Bishop & Middleton, 2013; Gelen, 2011; Gelen et al, 2012; Meerits et al., 2014) as researchers were either comparing whether dynamic activities can counterbalance the detrimental effects of static stretching, or they wanted to establish whether dynamic stretching may elicit sport performance. Current knowledge suggests that the mechanism after application of dynamic stretching which may contribute to improvements in strength and power performance (Torres et al., 2008) are; elevated muscle and body temperature (Fletcher & Jones, 2004), post-activation potentiation, a neurological and mechanical stimulus in the stretched muscle caused by voluntary contractions of the antagonist muscle (Gelen, 2011; Torres et al., 2008), stimulation of the nervous system, and/or decreased inhibition of the antagonist muscles (Jaggers, Swank, Frost, Lee, 2008).

Post-activation potentiation

Investigations which emphasized the research on the acute effects of dynamic stretching proposed a significant correlation between post-activation potentiation (PAP) and improved performance (Behm & Chaouachi, 2011; Gelen, 2011; Jaggers et al., 2008; Sale, 2004). Two major components/effects of PAP are revealed; increased neurological excitability and increased rate of mechanical cross-bridge alignments (Behm and Chaouachi, 2011; Gelen, 2011).

PAP can be defined as an acute potentiation of muscle's subsequent contractility caused by voluntary contractions of the antagonist muscle (conditioning contractions) (Gelen, 2011; Torres et al., 2008). Conditioning contractions stimulate phosphorylation of myosin regulatory light chains, increasing Ca^{2+} sensitivity of the myofilaments, which basically supports and improves the interactions between the contractile proteins(actin and myosin) (Gelen, 2011; Sale, 2004). Consequently, greater number of cross-bridge connections will be formed which will increase muscle's force production (Behm & Chaouachi, 2011). Moreover, it has shown greater effects for rapid shortening (concentric) contractions than for isometric contractions (Abbate, Sargeant, Verdiik, & de Haan, 2000), which supports the suggestions of acute improvements in sprint performance after a short bout of dynamic stretching.

PAP may also stimulate an increase in neurological excitability (Sale, 2004). Sport performance (i.e. sprinting) requires a high number of recruited motor units and firing of action potentials (AP) in a maximum rate in order to obtain maximal speed and improved performance. Sale (2004), states that while PAP cannot increase high frequency force it may affect an increased isometric rate of force development which offers benefits when motor units are firing at very high rates. The author states that not enough evidence is offered on this field, therefore further investigations should focus on neurological effects of PAP after dynamic stretching. Sale (2004), finally concludes that conditioning activity resulting in PAP may elicit sport performance, however the recovery period between the pre-exercise and performance may also play a crucial role in the overall outcomes. There is a dilemma about the intensity of dynamic activity and the following recovery period preceding the performance and how these two factors either elicit sport performance (PAP). or diminish sport performance (fatigue and depleted energy sources which are crucial for maximal effort movements. Current research suggests at least 2.5-3 minutes of recovery period after dynamic activity (Sale, 2004) in order to restore energy sources for following performance and to preserve the PAP enhancements for sport performance. Therefore, the recovery period in this research study was 2.5 minutes in duration.

MYOFASCIAL RELEASE AND SPORT PERFORMANCE

Fascia as referred to by the Fascia Research Congress (FRC) (Schleip, Jäger, Kingler, 2012) is a "soft tissue" constituent of the body's connective tissue system. The most applicable description for the purposes of this study defines fascia as a fibrous collagenous tissue that take part in force transmission system (Schleip et al., 2012). Myofascial release is an alternative medicine therapy manipulating "soft" tissues in the body. With Self-myofascial release (SMR) an individual is using their own body mass, usually on a foam roller, to exert pressure on the affected soft tissues. With the changing of body positions, an individual can target different muscle groups, which usually include, but are not limited to, the quadriceps, hamstrings, triceps surae, gluteus maximus, iliopsoas, hip adductors, trapezius, and rhomboids (Schroeder & Best, 2015). There is evidence that SMR is as beneficial in releasing tension in muscle tissues as regular massage, and there are findings suggesting in increasing ROM after applied SMR protocol (Schroeder & Best, 2015; Ajimsha, Al-Mudahka, Al-Madzhar, 2015). Compared to other pre-exercise routines that influence muscle's viscoelastic properties by affecting both elastic and viscous properties, myofascial release influences primarily the muscle's viscosity by heating the muscle with various techniques of generating pressure on soft tissues. The result is a reduction in muscle tension and stiffness, reduced muscle pain, swelling, and spasm, greater joint flexibility and enhanced range of motion (Schroeder & Best, 2015). Myofascial release has been demonstrated to be an effective technique to treat soft tissue adhesions, alleviate pain, and reduce tissue tenderness, edema, and inflammation while improving muscle recovery (Paolini, 2009). SMR was found to bring acute and cumulative effects on the viscoelastic properties of the exercised muscle, suggesting that this technique, used as pre-exercise routine, could have beneficial effects on sport performance (Haas, Best, Wang, Butterfield, & Zhao, 2012; MacDonald, Penney, & Mullaley, 2013).

Self-myofascial release (i.e. foam rolling) has been shown to improve ROM without any associated detrimental effects on performance (Krause, Wilke, Niederer, Vogt, & Banzer, 2017; Rios Monteiro et al., 2017), therefore supporting that myofascial release may contribute to overall performance, and that myofascial release alters neural and mechanical properties of the muscle under different mechanisms. The literature review by Krause et al. (2007) has indicated that possible mechanisms which improve ROM without impairing performance may be; altered passive tissue stiffness, and fascial sliding (decreased viscous properties of muscle-tendon unit). However, these suggestions are still yet to be supported with the results of their study as they are currently undergoing the process of collecting data.

CONCLUSION

To summarize, multiple studies have investigated pre-exercise routines and their effects on sport performance. Researchers desired to determine which protocol brings superior improvements in sport performance (i.e. strength, power, speed, agility), and additionally alter muscle's neuromuscular properties which decrease the risk for injury in elite and recreational populations. Static stretching has been used as a general protocol for improving individual's flexibility for decades, however there is a conflict amongst current research whether static stretching improves performance. Most recent studies suggest that static stretching impairs performance due to decreased neural excitability, and decreased stiffness of muscle-tendon unit. This results in an impairment of the muscle's ability to generate an action potential (AP) at the highest rate, impairs the cross-bridge alignment, and diminishes muscle's ability to absorb and reuse elastic energy during the stretch-shortening cycle (eccentric-concentric contraction). However, these detrimental effects may differ due to different time under tension.

Further studies have incorporated either dynamic stretching or dynamic activities following static stretching and the findings suggest that dynamic stretching counterbalance impairments that are followed by an isolated bout of static stretching. Therefore, most recent research focused primarily on dynamic stretching. Providing some general information about the mechanisms that outweigh the effects of static stretching and whether they could elicit performance when used as a dominant protocol was the main focus amongst researchers. Current knowledge states that dynamic exercises produce an effect called post-activation potentiation. Because of the nature of the execution of dynamic exercises antagonist muscle is stretched due to voluntary contractions of the agonist muscle. The stretch occurs throughout the ROM however without holding at the end of ROM. This results in increased neural excitability, and improved interaction between the contractile proteins within a muscle fiber (actin, myosin). Dynamic stretching additionally showed improvements in ROM.

Self-myofascial release could be defined as a movement during which an individual uses an object (i.e. foam roller) to manipulate the properties of the "soft tissues". Usually self-myofascial release (SMR) was used as a post-exercise routine to increase blood flow in order to enhance body's ability to transport nutrients to damaged tissues, which results in improvement of the recovery period and/or decreased recovery time. However, recently SMR has been used as a pre-exercise routine. As does static stretching, SMR alters muscle's viscoelastic properties due to increased temperature within the muscle. Because this technique offers these changes without stressing muscle's protective organs (muscle spindles and GTO), recent studies have not shown any impairments in performance.

Finally, several investigations have been done in the field of sport and pre-exercise routines, assessing which would improve performance. However, no studies were found in the literature that compared the effects of static stretching, dynamic stretching, and self-myofascial release directly. Therefore, this research study investigated whether an acute bout of static stretching does impair sprint performance, and whether dynamic stretching brings superior improvements in sprint performance compared to self-myofascial release.

CHAPTER III

METHODS

This research study was designed to compare the acute effects of four different pre-exercise routines on 60 m sprint performance. Current research indicates that there is controversy concerning the effects of different pre-exercise routines on sport performance. Therefore, this study focused on clarifying the importance of different pre-exercise routines on sprint performance. Moreover, it investigated which protocols enhances sprint performance, and which possibly causes detrimental effects on sprint performance.

Subjects.

The participants were 10 male students from a Midwestern U.S. University. This study was approved by the Institutional Review Board at Eastern Illinois University and each participant gave their voluntary informed consent (Appendix A) prior to their participation in the study. It was preferred that participants had a recreational background, and scored their body fitness as at least a three (recreationally exercising 2-4 times in one week) on a scale from 1 (being completely inactive) to 5 (recreationally exercising every day). Students that were included in a professional or intercollegiate training regimen were not eligible to participate in this study. Exclusion criteria also included: having incurred a recent injury and/or associated pain that limited exercise, especially leg and lower back muscle injuries or skeletal system (kinematic chain) injuries, and a calculated BMI higher than 29.9 $kg \cdot m^{-2}$.

Potential subjects were introduced to the research study at the Student Recreation Center (SRC) at the Eastern Illinois University. Researchers approached male exercisers as they were coming to the SRC. They were briefly described how they can participate in the study and how the methodology of the study will be conducted. They were asked if they are physically active at least 3 times a week and not more than 5 times a week and whether they are a part of a collegiate athlete sports team. If they met the inclusion criteria and if they agreed to participate in the study they were scheduled for a group meeting in the ATP laboratory in the Lantz building of the Kinesiology and Sports Studies Department, where they were instructed further about the design of the research study. Additionally, they were given an informed consent to sign, and an opportunity to address any concerns or further questions. Next, they underwent the first stage of initial instructions, which included the order of the exercises within each pre-exercise routine and measurements to be made; height and weight, which were used to calculate body mass index (BMI). Subjects were also instructed to avoid any lower body resistance training, vigorous explosive movements or high intensity cardiovascular exercise for at least 48 hours prior to their scheduled testing period, as possible muscle fatigue or tightness could affect their sprint performance.

Data collection was divided into 4 sessions. Each session was performed only once with assistance by a research supervisor, on nonconsecutive days with at least a two-day recovery period between two tests, and no more than four days between the testing trials. Each participant was asked to write a brief feedback on the first and the second day after each session (i.e. testing trial on Monday, written feedback on Tuesday and Wednesday; Appendix 2). If an individual experienced any pain or soreness he was rescheduled for a different testing time. This measurement aimed to avoid the risk of these two factors affecting the validity of collected data, and to prevent any injury.

Protocol.

This study utilized a randomized cross-over design in which each participant performed 4 different testing procedures with a training session performed prior to the 4 pre-exercise routines. Subjects performed a dynamic warm-up protocol before each testing procedure consisting of the following exercises: (a) running for two laps on an indoor track (200 m per lap, 400 m in total), (b) skipping arm run for 30 m, (c) high knee run for 30 m, (d) skipping for the distance of 30 m, (e) sideways run for 30 m, (f) jogging forward/backward for 30 m, (g) walking for 1 lap (200 m in total). The warm-up protocol lasted for approximately 10 minutes, and a 2-minute recovery period was given to each participant before starting with their designated testing intervention. Between the two-minute recovery periods, each participant was instructed how to perform his intervention program before the sprint trial.

Session 1 measurements took place in the Eastern Illinois University Fieldhouse indoor track. On the first day, each participant was given an informed consent form where the research study was explained, and the participant's role was described. They signed the informed consent and were encouraged to ask any questions or address any concerns they may have before starting with the intervention program and testing procedures. Participants performed a 10-minute dynamic warm up protocol consisting of basic athletic movements under supervision. Following the initial warm-up protocol, each participant performed a maximal effort 60m sprint for the purpose of observing their running technique in order to improve it for the actual sprint performance in session 2 which was performed two days after the training trials. This practice was repeated five times in order to optimize their running technique, and a 2.5-minute recovery period was allowed between each trial.

For session 2, participants performed a 10-minute warm up protocol, the same as in Session 1, followed by a 2-minute recovery period, during which they were instructed which intervention pre-exercise routine they would use for that testing trial. After the initial warm-up, subjects were prepared to perform their intervention program preceding their maximal 60-m sprint performance. Two minutes after intervention pre-exercise routine they performed a 60-m sprint. The order of the sprint trials was randomized. Prior to testing trials each intervention program was given an ID code: self-myofascial release (SMF-1), static stretching (SS-2), dynamic stretching (DS-3) and the control group (CG-4). The order of pre-exercise routines was selected randomly using an app for Apple Inc. devices called The Random Number Generator (Nicholas Dean, 2016). Procedures for the sprint condition were as follows: the participants ran individually and were instructed to approach the starting line with the dominant leg (foot) at the line, and the less dominant leg (foot) behind. Their stance required a bend at the knees and a forward lean. The arm position was synchronized with the legs while the back, neck and head were kept straight. Subjects were to remain motionless before the starting signal. The timer was positioned at the 60m distance (finish line), signaling the participant when to start with the movement of his arm, (raised arm returning to normal position). Each subject was instructed to start when the arm completed its full movement. At the same time the timer started measuring the subject's sprint time. The timer used a stopwatch (Accusplit Magnum 725 x) to measure the sprint time to the nearest (0.1 seconds). Only one sprinting trial was assessed. A cool down period was provided, consisting of 2 minutes of walking around the track at a slow pace.

The same protocol from session 2 was repeated four times on nonconsecutive days with randomized order for each of the four intervention programs that are described in details in the paragraph below. The recovery period between each testing trial was at least 2 days, therefore on the third or fourth day the next data collection took place. This prevented performing a testing trial with muscle soreness and fatigue which could result in diminished sprint time, and to prevent better sprint time due to neuromuscular adaptations after more than two weeks of performing pre-exercise routines and sprint performance.

Pre-exercise protocol.

During the entire intervention program, a supervisor was instructed to assure that each pre-exercise routine was performed properly. Each participant performed one set of stretches or foam rolling for each target muscle: iliopsoas, quadriceps, hamstring, and gluteal muscles. These pre-exercise routines preceded one trial of maximal effort 60m sprint performance, in randomized order, to reduce the possibility of bias from an order effect. A recovery period of two minutes was allowed during each task. A recovery period was designed in order to eliminate the possible cumulative effect of fatigue experienced after each trial.

Static stretching protocol (SS):

- Each stretch was held for 30 seconds, the participant was instructed to avoid any bouncing or movement beyond the edge of slight discomfort until they reached the end of the range of motion, followed by immediate stretch on the contralateral side.
- Lunge stretch (iliopsoas): subjects stood approximately two feet away from the wall. They staggered their stance, placing one foot forward with the knee bent, while keeping the back leg straight. They then pressed with one hand against the wall to maintain balance. Slowly they put the knee of the back leg on the floor. They pushed the hips downward and forward. They were instructed to avoid any bouncing and rapid movement. After 30 seconds, they switched sides and repeated the same technique on the contralateral side.
- Quadriceps Stretch (quadriceps): a subject started this movement by lying on the left side of their body, with left arm extended on which they rested the head. They flexed the right knee and raised their heel towards the buttocks. They grasped the right foot with the right hand. Slowly, they pulled the heel towards the bottom, and again refrained from any bouncing. After 30 seconds, they repeated the same movement with the left leg.
- Sitting Toe Touch One Leg (hamstrings): this movement started with the subject sitting with the upper body straight and pushing the knees against the floor. Both legs were extended forward. They leaned forward and

slowly reached toward the toes, and pulled both legs into the chest. They were instructed to maintain contact with the floor with both the buttocks and knees and to relax the neck and shoulders. They were instructed to refrain from any bouncing.

- Chest against the knee (gluteal muscles): subjects started this stretching exercise with a sitting position, and both knees bent to a 90° angle, with one knee bent in front of the body and the other knee bent on the side of the body. They leaned forwards and put their hands on both sides of the flexed leg in front. Slowly they bent forward, and rested the chest on the bent knee. After 30 seconds, they changed sides and repeated the same movement on the contralateral side.

Dynamic stretching protocol (DS):

- Each dynamic stretch was performed for 30 seconds, the participants were instructed to stand parallel to the wall, which they used to stabilize their body while performing the stretch. It was emphasized to avoid any trunk movement and/or trunk flexion or hyperextension. During the exercise performance, they were also instructed to avoid any internal or external hip rotations and/or hip movement left and right.
- Back kicks (iliopsoas): Subjects stood against the wall with the right shoulder facing the wall. They put the right hand on the wall for maintaining balance. They flexed the left hip and knee and brought them as close to the chest as possible. Forcefully yet under control, they pushed

the hip into extension. After performing this movement for 30 seconds, they repeated the same movement with the right leg.

- Bottom kicks (quadriceps): While standing against the wall with the right shoulder facing the wall, they put their right hand on the wall for maintaining balance. Forcefully yet under control, they flexed the right knee and they pushed the heel as close to the buttocks as possible. After performing this movement for 30 seconds, they repeated the same movement with the left leg.
- Forward kicking (hamstrings): While standing against the wall with the right shoulder facing the wall. They put the right hand on the wall for maintaining balance. They extended the left hip slightly with straight leg. Forcefully they flexed the hip, and brought the foot as high as possible, whilst keeping the leg straight. After performing this movement for 30 seconds, they repeated the same movement with the left leg.
- Forward bent knee kicking (gluteal muscles): standing against the wall with the right shoulder facing the wall, they put their right hand on the wall for maintaining balance. They extended the left hip slightly with slightly flexed leg. Forcefully they flexed the hip, and brought the knee as close to the chest as possible. After performing this movement for 30 seconds, they repeated the same movement with the left leg.

Self-myofascial release protocol (SMR):

- Each SMR exercise was performed for 30 seconds. Subjects were instructed to perform dynamic rolling in a supine position, under control, using a foam roller for the following muscle groups: quadriceps, hamstring, gluteal muscles. For the SMR technique engaging the muscle iliopsoas subjects have used a tennis ball
- Trigger point (iliopsoas): each subject maintained balance with both hands and legs, while pressing on a tennis ball. The starting position of the tennis ball was parallel to the belly button, approximately two fingers to the left. They performed the SMR technique to the middle of the pelvic region (from the origin to the insertion of the iliopsoas). They performed this movement for 30 seconds, after which they repeated the same movement on the contralateral side.
- Foam rolling (quadriceps): each subject maintained balance with both hands and the left leg while pressing on a foam roller with the right leg above the tissues of the quadriceps muscle. They performed SMR technique rolling from the origin to the insertion of the quadriceps. They performed this movement for 30 seconds, after which they repeated the same movement on the contralateral side.
- Foam rolling (hamstrings): each subject maintained balance with both hands and the left leg, while pressing on a foam roller with the right leg above the hamstring muscles. They performed the SMR technique rolling from the origin to the insertion of the hamstrings s. They performed this movement for 30 seconds, after which they repeated the same movement on the contralateral side.
- Foam rolling (gluteus maximus): each subject maintained balance with both hands and the left leg while pressing on a foam roller with the right leg above the gluteal

muscles. They performed the SMR technique rolling from the origin to the insertion of the gluteal muscles. They performed this movement for 30 seconds, after which they repeated the same movement on the contralateral side.

Control group protocol:

- After the initial warm-up protocol, subjects performing the control trial, had a 9-minute recovery period in order to start their sprint trial at the same time us their peer participants had. A cool down period was provided, consisting of 2 minutes of walking around the track at a slow pace after the sprint trial for all four intervention groups

STATISTICAL ANALYSIS

The statistical analysis used to describe the subjects and their performance as well as to compare the chosen conditions, static stretching, dynamic stretching, self-myofascial release, and control group, were performed using IBM SPSS statistics (SPSS v20.0.0, Inc., Chicago, IL). Descriptive statistics were calculated for subject characteristics and dependent variables. A four-factor repeated measures analysis of variance (ANOVA) omnibus test was used to determine whether there was a statistically significant difference among the dependent variables. Mauchly's test of sphericity was performed followed by the Huynh-Feldt correction if the sphericity assumption was violated. Some feel that regardless of the Mauchley's test result, a correction should be applied. The argument then becomes one of whether to use the Greenhouse-Geisser or Huynh-Feldt method. For this study, it was determined that the Huynh-Feldt correction would be applied regardless of the Muachly test results. A value of $p \leq 0.05$ was used to determine statistical significance. To evaluate the significance of individual treatment comparison given a significant omnibus test, a paired t-test was applied to each comparison.

CHAPTER IV

RESULTS AND DISCUSSION

The purpose of this study was to investigate and compare the influence of four different pre-exercise routines (static stretching, dynamic stretching, self-myofascial release, and control group) on 60 m sprint performance.

SUBJECTS

Ten college-age students from a Midwestern U.S. University agreed to participate in this study. Two subjects withdrew from the study before completion (one subject injured himself outside the testing procedures, and one subjects was not able to schedule further testing trials due to lack of time to participate). Therefore, a total of 8 participants completed the study in its entirety. Descriptive characteristics for subjects are shown in Table 1.

Table 1 Descriptive characteristics of subjects (n=8)

Descriptive characteristics of subjects (n=8)

Variable	Mean ± S.D.
Age (years)	24.75 ± 3.41
Height (in.)	72.94 ± 3.10
Weight (lbs.)	192.38 ± 27.33
Body Mass Index (BMI) (kg/m^2)	25.46 ± 3.48

Each participant performed individual testing trials on nonconsecutive days. In order to meet the cross-over randomization criteria, each participant randomly chose the intervention protocol prior to each testing trial, by using an app, The Random Number Generator (Nicholas Dean, 2016). Table 2 shows the results of the randomization of intervention order for each subject. This was established with each participant after the warm-up within the 2-minute recovery period when they were instructed which exercises to perform, after they were randomly given an intervention protocol.

Table 2 The order of randomly assigned pre-exercise protocols for each subject

The order of randomly assigned pre-exercise protocols for each subject

Subjects ID	The order of the testing trials
1	SMR, SS, CG, DS
2	DS, CG, SS, SMR
3	DS, SS, MR, CG
4	DS, CG, SMR, SS
5	SS, CG, SMR, DS
6	SMR, SS, CG, DS
7	DS, CG, SS, SMR
8	CG, DS, SMR, SS

*SS – static stretching, SMR – self-myofascial release, DS – dynamic stretching, CG – control group

A repeated measures ANOVA was performed to determine whether any of the pre-exercise warm-up conditions were significantly different from the control and each other. The assumption of sphericity was not violated, as the Mauchly's test showed a probability of p = 0.308. The Huynh-Feldt result has shown statistical significance for the comparison of the SS results and SMR results (p = 0.026, respectively). The Omnibus test showed a statistically significant within-subjects effect and therefore, post-hoc comparisons were made using paired t-test in order to determine which comparisons were statistically significant.

The results for 60 meter sprint times for each intervention are shown in Table 3 (by intervention) and in Figure 1 (by individual). The comparisons of each 60-meter sprint result for each pre-exercise warm-up condition indicated the following: SS time – DS time, SS time – CG time, SMR time – DS time, SMR time – CG time, and DS time – CG time comparisons showed no statistical difference (p=0.061; p=0.259; p=0.356; p=0.111; p=0.265 respectively). However, the 60 m sprint time was significantly lower after performing SMR as compared with SS (p=0.024)

Table 3 Mean values of each intervention group

Mean values of each intervention group

	SS time (s)	SMR time (s)	DS time (s)	CG time (s)
Mean value	8.72	8.51	8.56	8.61
ST. Deviation	0.57	0.49	0.54	0.56

*SS – static stretching, SMR – self-myofascial release, DS – dynamic stretching, CG – control group

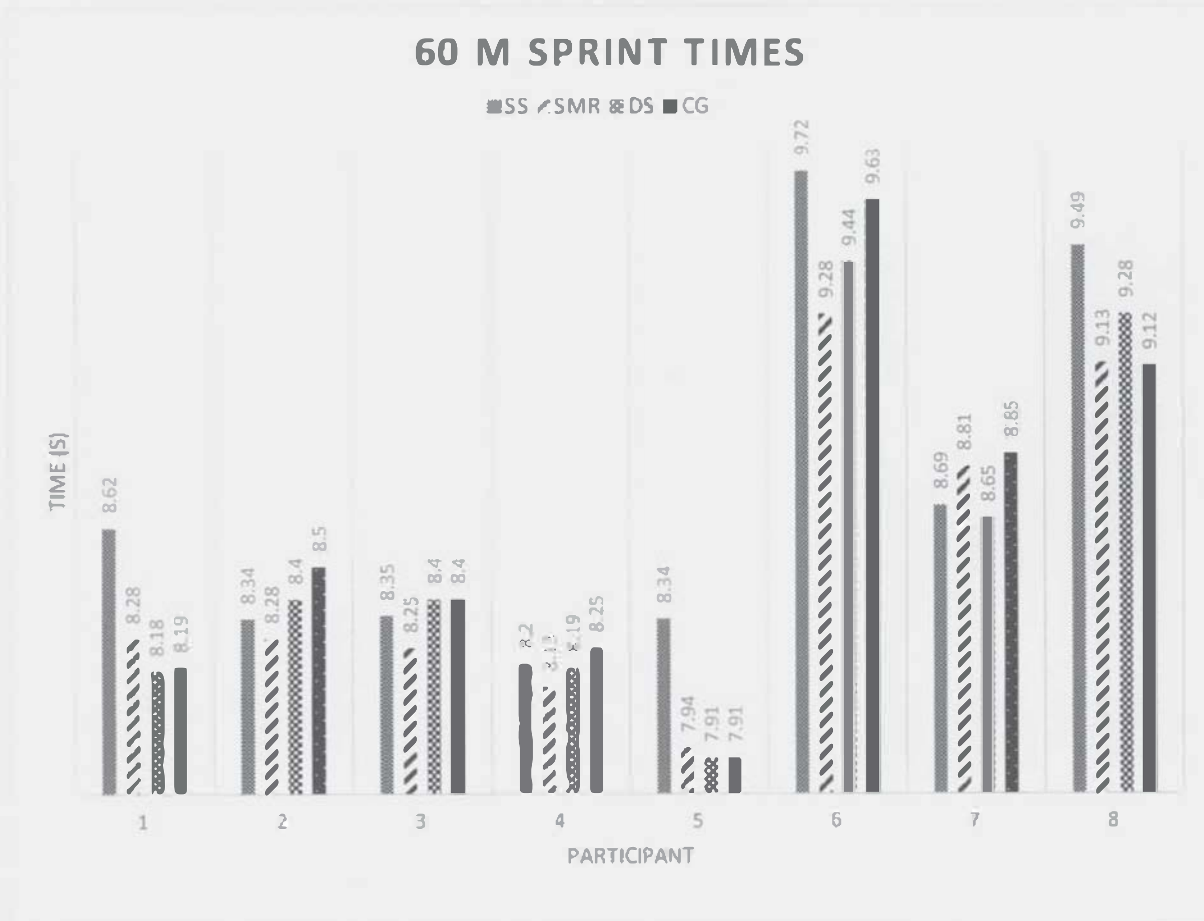

Figure 1. 60 m sprint times.

Participants recorded their somatic feedback post intervention, and no subjects indicated soreness by day two post trial in any condition that delayed the onset of the subsequent trials.

DISCUSSION

This investigation to determine different intervention induced adaptations to the neuromuscular system, which alter sprint performance, did not entirely support the a priori hypothesis. Research on the effects of dynamic and static stretching suggest that dynamic stretching produces statistically greater improvements compared to static stretching (Kapo et al., 2016; Paradisis et al., 2014). Additionally, Behm & Chaouachi (2011), Kapo et al. (2016) and Weerapong et al. (2004) concluded that static stretching impairs sprint performance, and moreover researchers suggested that dynamic stretching may counterbalance the detrimental effects caused by the static stretching exercises (Ayala et al., 2015; Bishop & Middleton, 2013; Serefoglu et al., 2017; Unick et al., 2005; Wallmann et al., 2008; Wong et al., 2011). Alternatively, there are studies that have reported no advantage of dynamic over static stretching. (De Oliveira & Pinto Lopes Rama, 2016; Wallmann et al., 2012). Moreover, protocol methods varied throughout the aforementioned studies, which may cause the discrepancy amongst their findings. A co-founding variables that may play a crucial role is time under tension and the duration of the stretches. Some studies suggest that shorter bouts of static stretching (30-60 s) do not impair sprint performance and agility compared to longer durations of static stretching (90 s) (Wong et al., 2012). The present study used 30 second bouts of selected exercises in all intervention protocols as this duration is commonly used amongst recreational and professional population. The results of the current study found no statistically significant difference when comparing the sprinting times after dynamic and static stretching. In comparing these two pre-exercise protocols, there was a tendency favoring dynamic stretching as the degree of difference ($p=0.061$) approached significance. Furthermore, static stretching did not impair sprinting performance when compared to the control group ($p=0.259$).

Previous studies have shown that dynamic stretching improves speed (Gelen, et al., 2012), agility, torque (Sekir et al., 2009) and strength and power performance (Manoel et al., 2008; Torres et al., 2008). The main mechanism contributing to the enhancement of these characteristics appears to be post-activation potentiation (PAP). PAP is defined as an acute potentiation of muscle's subsequent contractility caused by voluntary contractions of the antagonist muscle (Gelen, 2011; Torres et al., 2008). PAP showed mechanical stimulation, which improves the cross-connections between the actin and the myosin (Gelen, 2011; Sale, 2004). Conditioning contractions stimulate phosphorylation of myosin regulatory light chains, increasing Ca^{2+} sensitivity of the myofilaments, which improves the interactions between the contractile proteins. This results in greater force production (Behm & Chaouachi, 2011). Moreover, PAP enhances neural excitability (Sale, 2004). The current study was unique in the participant recruitment, as it consisted out of college age individuals that were recreationally active, however they were not part of any collegiate athletic and/or professional team.

While static stretching produces significant improvements in ROM (Behm & Chaouachi, 2011; Weerapong et al., 2004), the majority of current research shows detrimental effects of static stretching on the counter movement jump, force manifestation and overall sprint performance (Kapo et al., 2016; Simic et al., 2013). The main mechanism impairing muscle performance is the stretch-induced transient reduction in stiffness of the muscle-tendon complex (Kapo et al., 2016). It results in reduced ability to store the energy in the eccentric phase of contraction and a less efficient transmission of force to the skeleton. However, this study did not supported the detrimental effects of static stretching on the sprint performance. Wong et al. (2012) investigated different durations of stretching bouts and they have found that shorter bouts (30-60 seconds) of static stretching did not impair sprint performance and agility to the same extent as longer duration ($\geq$ 90 seconds) of static stretching. The current study used 30 second bouts of static stretching as an intervention and found that it did not impair sprinting results ($p=0.259$).

Self-myofascial release (SMR) is an alternative therapy that manipulates "soft" tissue in the body (Schleip et al., 2012). The current study used a technique called foam rolling, where an individual uses his or her own body mass against a foam cylinder or ball to exert pressure on the affected soft tissues (tendons, muscles). MacDonald et al. (2013) discovered that SMR increases range of motion (ROM) without a subsequent decrease in muscle activation or muscle force production as it has been shown for other pre-exercise protocols. Moreover, numerous studies have suggested that with benefits to ROM, SMR may additionally have positive effects on sport performance (Haas et al., 2012; MacDonald et al., 2013). It was hypothesized that dynamic stretching would bring superior improvements in sprinting times over SMR. However, this hypothesis was rejected as the results revealed statistically significant improvements only for SMR, indicating that foam rolling had a greater positive impact on sprinting performance than either static or dynamic stretching. PAP has an important dynamic stretching induced mechanism in that is increases mechanical and neural connections, as it improves the alignment and the interaction between the contractile proteins (actin, myosin). It also enhances neural excitability of the motor unit. Compared to SMR, energy expenditure is higher when using dynamic stretching as a pre-exercise protocol as it consists of repeated alternating voluntary contractions between the agonist and the antagonist muscle. Whereas with SMR the energy expenditure is significantly lower as it offers a technique to improve ROM and muscle performance while using the force of gravity and the body weight of the participant, and therefore uses less energy, which may play a decisive role in enhancing overall muscle performance.

Although the present study shown important and valuable findings for the recreational group of college age males, it is important to recognize the potential limitations of the study. First, this was a cross-over randomized research study with a small sample size. Secondly, the age range of the college age students is wide from 22-32 years of age. Additionally, it is difficult to determine an exact cause and effect as the participants were not monitored consistently during the intervention trial period. For example, extended sleep deprivation may strongly impair human functioning (Pilcher & Huffcutt, 1996). The extent of following the predicted time schedules for the absence of resistance training using exercises that engage leg muscle groups was based on the honesty of each individual and the evaluation of the presence of the fatigue on the testing trial days was subjectively and individually assessed.

For the purpose of the future research it would be suggested to include a greater number of participants and to follow up with the subjects more closely by monitoring the volume and intensity of the resistance trainings the subjects have done out of testing trials, and the recovery period between each resistance training session and the following testing trial performance. Since the dependent variable in this study was a short 60-meter sprint, the use of more accurate timing equipment (i.e. photo cells) would allow us to collect data of higher validity with a lower chance of error. Additionally, it would allow for a more precise measurement of the changes in speed after each intervention and how that intervention influenced the overall maximal running performance. Furthermore, being able to assess the force of the "take off" phase of the sprinting start would have allowed the assessment of the effects of the different pre-exercise routines on muscle activation and/or force production.

CONCLUSION

The results of this research study show that using 30 second bouts of self-myofascial release as part of a pre-exercise warm-up, elicits significant improvements in 60 m sprint performance compared to 30 second bouts of dynamic stretching, static stretching and the non-stretching control group. Additionally, it was demonstrated that 30 second bouts of static stretching do not cause detrimental effects on short sprint performance in comparison to the control group.

REFERENCES

Abbate, F., Sargeant, A. J., Verdijk, W. L., & de Haan, A. (2000). Effects of high frequency initial pulses and postetanic potentiation on power output of skeletal muscle. *Journal of Applied Physiology, 88*(1). Retrieved from http://jap.physiology.org/content/88/1/35.long

Ajimsha, M. S., Al-Mudahka, N. R., & Al-Madzhar, J. A. (2015). Effectiveness of myofascial release: systematic review of randomized controlled trials. *Journal of Bodywork and Movement Therapies, 19*(1). Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/25603749

Ayala, F., De Ste Croix, M., Sainz de Baranda, P., & Santonja, F. (2014). Acut effects of static and dynamic stretching on hamstrings response times. *Journal of Sports Sciences, 32*(9). Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/24405028

Beckett, J. R., Scheiker, K.T., Wallman, K. E., Dawson, B. T., & Guelfi, K. J. (2009). Effects of static stretching on repeated sprint and change of direction performance. *Medicine and Science in Sport and Exercise, 41*(2). Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/19127179

Behm, D. G., Bambury, A., Cahill, F., & Power, K. (2004). Effects of acute static stretching on force, balance, reaction time, and movement time. *Medicine and Science of Sports Exercise, 36*(8). Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/15292749

Behm, D. G., & Chaouachi, A. (2011). A Review of the Acute Effects of Static and Dynamic Stretching on Performance. *European Journal of Applied Physiology, 111*, 2633-2651.

Bishop, D., & Middleton, G. (2013). Effects of static stretching following a dynamic warm-up on speed, agility and power. *Journal of Human Sport & Exercise, 8*(2). Retrieved from https://rua.ua.es/dspace/bitstream/10045/29736/1/jhse_Vol_8_N_II_391-400.pdf

Bloomfield, J., Polman, R., & O'Donoghue, P. (2007). Physical Demands of Different Positions in FA Premier League Soccer. *Journal of Sports Science & Medicine, 6*(1). Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3778701/

Bushman, B. (2011). ACSM's Complete Guide to Fitness & Health: Physical Activity and Nutrition Guidelines for Every Age (1st ed.). Champaign, IL: Human Kinetics.

Butler, E. E., & Dominy, N. J. (2016). Architecture and functional ecology of the human gastrocnemius muscle-tendon unit. *Journal of Anatomy, 228*. Retrieved from http://web.a.ebscohost.com.proxy1.library.eiu.edu/ehost/pdfviewer/pdfviewer?vid

=3&sid=e223bd20-d8b6-4582-941b-94b51cc27b05%40sessionmgr4010&hid=4101

Delecluse, C. (2012). Influence of Strength Training on Sprint Running Performance. *Sports Medicine, 24* (3). Retrieved from http://link.springer.com/article/10.2165/00007256-199724030-00001

De Oliveira, F. C. L., & Pinto Lopes Rama, L. M. (2016). Static Stretching Does Not Reduce Variability, Jump and Speed Performance. *The International Journal of Sports Physical Therapy, 11*(2). Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4827370/

Favero, J. P., Midgley, A. W., & Bentley, D. J. (2009). Effects of an acute bout of static stretching on 40 m sprint performance: influence of baseline flexibility. *Research in Sports Medicine, 17*(1). Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/19266393

Fletcher, I. M., & Jones, B. (2004). The effects of different warm-up stretch protocols on 20 meter sprint performance in trained rugby union players. *Journal of Strength and Conditioning Research, 18*(4). Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/15574098

Fortier, J., Lattier, G., & Babault, N. (2013). Effects of short-duration isolated static stretching or combined with dynamic exercises on strength, jump and sprint performance. *Science & Sports, 28*(5). Retrieved from http://www.sciencedirect.com/science/article/pii/S0765159712001864

Gelen, E. (2011). Acute effects of different warm-up methods on jump performance in children. *Biology of Sport, 28*(2), 133-138.

Gelen, E., Dede, M., Meric Bingul, B., Bulgan, C., & Aydin, M. (2012). Acute effects of static stretching, dynamic exercises, and high volume upper extremity plyometrics activity on tennis serve performance. *Journal of Sport Science and Medicine, 11*(4). Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3763304/

Haas, C., Best, T. M., Wang, Q., Butterfield, T. A., & Zhao, Y. (2012). In vivo passive mechanical properties of skeletal muscle improve with massage-like loading following eccentric contraction. *Journal of Biomechanics, 45*. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3732739/

Haddad, M., Dridi, A., Chtara, M., Chaouachi, A., Wong, P., Behm, D., & Chamari, K. (2014). Static stretching can impair explosive performance for at least 24 hours. *Journal of Strength and Conditioning Research, 28*(1). Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/23615481

Haff, G. G., & Triplet, N. T. (Eds.). (2016). *Essentials of Strength Training and Conditioning*, 4th ed. Champaign, IL: Human Kinetics.

Herbert, R. (1988). The passive mechanical properties of muscle and their adaptations to altered patterns of use. *The Australian Journal of Physiotherapy, 34*(3). Retrieved from http://ac.els-cdn.com/S0004951414606061/1-s2.0-S0004951414606061-main.pdf?_tid=f90a835e-2c0f-11e7-896a-00000aab0f02&acdnat=1493383457_cc7e16c8b7a15aa66885142edcb15b0e

Hough, P. A., Ross, E. Z., & Howatson, G. (2009). Effects of Dynamic and Static Stretching on Vertical Jump Performance and Electromyographic Activity. *Journal of Strength & Conditioning Research, 23* (2). Retrieved from http://journals.lww.com/nsca-jscr/Abstract/2009/03000/Effects_of_Dynamic_and_Static_Stretching_on.21.aspx

Jaggers, J. R., Swank, A. M., Frost, K. L., & Lee, C. D. (2008). The acute effects of dynamic and ballistic stretching on vertical jump height, force, and power. *Journal of Strength and Conditioning Research, 22*(6). Retrieved from http://journals.lww.com/nsca-jscr/Abstract/2008/11000/The_Acute_Effects_of_Dynamic_and_Ballistic.18.aspx

Kapo, S., Smajlović, N., Kajmović, H., Čović, N., Čirić, A., Čutuk, M., & Bejdić, A. (2016). Effects of Different Stretching Protocols on Knee Muscles Strength and Power Parameters measured by Biodex Dynamometer. *Tehnicki Vjesnik, 23*(1). Retrieved from https://www.researchgate.net/publication/295254745_Effects_of_different_stretch ing_protocols_on_knee_muscles_strength_and_power_parameters_measured_by_Biodex_dynamometer

Karcher, C., & Buchheit, M. (2014). On-court demands of elite handball, with special reference to playing positions. *Sports medicine, 44*(6). Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/24682948

Kokkonen, J., Nelson, A. G., & Cornwell, A. (1998). Acute Muscle Stretching Inhibits Maximal Strength Performance. *Research Quarterly for Exercise and Sport, 69*(4). Retrieved from https://www.researchgate.net/publication/13422868_Acute_Muscle_Stretching_Inhibits_Maximal_Strength_Performance

Krause, F., Wilke, J., Niederer, D., Vogt, L., & Banzer, W. (2017). Acute effects of foam rolling on passive tissue stiffness and fascial sliding: study protocol for a randomized controlled trial. *Journal of Occupational Medicine and Toxicology, 18*. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5343315/

Lederman, E. (2005). *The science and practice of manual therapy*. London: Elsevier Limited. Lieber, R. L., & Fridén, J. (2000). Functional and clinical significance of skeletal muscle architecture. *Muscle and Nerve, 23*(11). Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/11054744

Lieber, R. L., & Friden, J. (2000). Functional and clinical significance of skeletal muscle architecture. *Muscle & Nerve, 23*(11). Retrieved from http://onlinelibrary.wiley.com/doi/10.1002/1097-4598(200011)23:11%3C1647::AID-MUS1%3E3.0.CO;2-M/full

Lorenz, D., & Morrison, S. (2015). Current Concepts in Periodization of Strength and Conditioning for the Sports Physical Therapist. *International Journal of Sports Physical Therapy, 10*(6). Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4637911/

MacDonald, G. Z., Penney, M. D., Mullaley, M. E., Cuconato, A. L., Drake, C. D., Behm, D. G., & Button, D. C. (2013) An acute bout of self myofascial release increases range of motion without a subsequent decrease in muscle activation of force. *Journal of Strength and Conditioning, 27*. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/22580977

Manoel, M. E., Harris-Love, M. O., Danoff, J. V., & Miller, T. A. (2008). Acute effects of static, dynamic, and proprioceptive neuromuscular facilitation stretching on muscle power in women. *Journal of Strength and Conditioning Research, 22*(5). Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/18714235

Meerits, T., Bacchieri, S., Pääsuke, M., Ereline, J., Cicchella, A. & Gapeyeva, H. (2014). Acute effects of static and dynamic stretching on tone and elasticity of hamstring muscle and on vertical jump performance in track-and-field athletes. *Acta Kinesiologiae Universitatis Tartuensis, 20*. Retrieved from https://www.researchgate.net/publication/270763154_Acute_effect_of_static_and _dynamic_stretching_on_tone_and_elasticity_of_hamstring_muscle_and_on_vertical_jump_performance_in_track-and-field_athletes

Nakamura, M., Ikezoe, T., Yohei, T., & Ichihashi, N. (2011). Acute and prolonged effect of static stretching on the passive stiffness of the human gastrocnemius muscle tendon unit in vivo. *Orthopaedic Research Society, 29*(11). Retrieved from http://onlinelibrary.wiley.com/doi/10.1002/jor.21445/full

Nelson, A. G., Driscoll, N. M., Landin, D. K., Young, M. A., & Schexnayder, I. C. (2005). Acute effects of passive muscle stretching on sprint performance. *Journal of Sport Sciences, 23*(5). Retrieved from http://www.tandfonline.com/doi/full/10.1080/02640410410001730205

Page, P. (2012). Current Concepts in Muscle Stretching for Exercise and Rehabilitation. *International Journal of Sports Physical Therapy, 7*(1). Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3273886/

Paolini, J. (2009). Review of myofascial release as an effective massage therapy technique. *Human Kinetics Journal, 14*(5). Retrieved from https://www.researchgate.net/publication/297566927_Review_of_Myofascial_Release_as_an_Effective_Massage_Therapy_Technique

Paradisis, G. P., Pappas, P. T., Theodorou, A. S., Zacharogiannis, E. G., Skordilis, E. K.,

& Smirniotou, A. S. (2014). Effects of static and dynamic stretching on sprint and jump performance in boys and girls. *Journal of Strength and Conditioning Research, 28*(1). Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/23591944

Pilcher, J. J., & Huffcutt, A. I. (1996). Effects of Sleep Deprivation on Performance: A Meta-Analysis. *American Sleep Disorders Association and Sleep Research Society, 19*(4). Retrieved from https://academic.oup.com/sleep/article/19/4/318/2749842/Effects-of-Sleep-Deprivation-on-Performance-A-Meta

Power, K., Behm, D., Cahill, F., Carroll, M., & Young, W. (2004). An acute bout of static stretching: effects on force and jumping performance. *Medicine and Science in Sport and Exercise, 36*(8). Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/15292748

Rienzi, E., Drust, B., Reilly, T., Carter, J. E., & Martin, A. (2000). Investigation of antropometric and work-rate profiles of elite South American international soccer players. *The Journal of Sports Medicine and Physical Fitness, 40*(2). Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/11034438/

Rios Monteiro, E., Škarabot, J., Vigotsky, A. D., Fernandes Brown, A., Matassoli Gomes, T., & da Silva Novaes, J. (2017). Maximum repetition performance after different antagonist foam rolling volumes in the inter-set rest period. *The International Journal of Sports Physical Therapy, 12*(1). Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5294949/

Sayers, A. L., Farley, R. S., Fuller, D. K., Jubenville, C. B., & Caputo, J. L. (2008). The effects of static stretching on phases of sprint performance in elite soccer players. *Journal of Strength and Conditioning Research, 22*(5). Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/18714249

Sale, D. (2004). Postactivation potentiation: role in performance. *Exercise and Spors Science Reviews, 38*. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1724858/pdf/v038p00386.pdf

Schroeder, A. N., & Best, T. M. (2015). Is self myofascial release an effective preexercise and recovery strategy? A literature review. *Current Sports Medicine Reports, 14*(3). Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/25968853

Schleip, R., Jäger, H., & Klinger, W. (2012). What is "fascia"? A review of different nomenclatures. *Journal of Bodywork and Movement Therapies, 16*(4). Retrieved from http://www.sciencedirect.com/science/article/pii/S1360859212001830

Sekir, U., Arabaci, R., Akova, B., & Kadagan, S. M. (2009). Acute effects of static and dynamic stretching on leg flexor and extensor isokinetic strength in elite women athletes. *Scandinavian Journal of Medicine & Science in Sport, 20*(2). Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4610914/

Serefoglu, A., Sekir, U., Gür, H., & Akova, B. (2017). Effects of Static and Dynamic

Stretching on the Isokinetic Peak Tourques and Electromyographic Activities of the Antagonist Muscles. *Journal of Sports Science & Medicine, 16*(1). Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/28344445

Sim, A. Y., Dawson, B. T., Guelfi, K., J., Walmann, K. E., & Warren, B. (2009). Effects of Static Stretching in Warm-Up on Repeated Sprint Performance. *Journal of Strength and Conditioning Research, 23*(7). Retrieved from http://journals.lww.com/nsca-jscr/Abstract/2009/10000/Effects_of_Static_Stretching_in_Warm_Up_on.36.aspx

Simic, L., Sarabon, N., & Markovic, G. (2013). Does pre-exercise static stretching inhibit maximal muscular performance? A meta-analytical review. *Scandinavian Journal of Medicine and Science in Sport, 23*(2). Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/22316148

Spencer, M., Rechichi, C., Lawrence, S., Dawson, S., Bishop, D., & Goodman, C. (2005). Time-motion analysis of elite field hockey during several games in succession: a tournament scenario. *Journal of Science and Medicine in Sport, 8*(4). Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/16602166

Taylor, J. M., Weston, M., & Portas, M.D. (2013). The effects of a short practical warm up protocol on repeated sprint performance. *Journal of Strength and Conditioning Research, 27*(7). Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/23007489

Torres, E. M., Kraemer, W. J., Vingren, J. L., Volek, J. S., Hatfield, D. L., Spiering, B. A.

Ho, J. Y., Fragala, M. S., Thomas, G. A., Anderson, J. M., Häkkinen, K., & Maresh, C. M. (2008). Effects of stretching on upper-body muscular performance. *Journal of Strength and Conditioning Research, 22*(4). Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/18545177

Unick, J., Kieffer, H. S., Cheesman, W., & Feeney, A. (2005). The acute effects of static and ballistic stretching on vertical jump performance in trained women. *Journal of Strength and Conditioning Research, 19*(1). Retrieved from http://journals.lww.com/nsca-jscr/Abstract/2005/02000/THE_ACUTE_EFFECTS_OF_STATIC_AND_BALLISTIC.35.aspx

Wallmann, H. W., Christensen, S. D., Perry, C., & Hoover, D. L. (2012). The Acute Effects of Various Types of Stretching Static, Dynamic, Ballistic, and no Stretch of the Iliopsoas on 40-Yard Sprint Times in Recreational Runners. *International Journal of Sport Physical Therapy, 7*(5). Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3474300/

Weerapong, P. Hume, P. A., & Kolt, G. S. (2004). Stretching: Mechanisms and Benefits for Sport Performance and Injury Prevention. *Physical Therapy Reviews, 9*. Retrieved from http://www.academia.edu/16839402/Stretching_Mechanisms_and_Benefits_for_Sport_Performance_and_Injury_Prevention

Weiss, M., Newman, A., Whitmore, C., & Weiss, S. (2016). One hundred and fifty years of sprint and distance running- Past trends and future prospects. *European Journal of Sports Science, 16*(4). Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/26088705

Winchester, J. B., Nelson, A. G., & Kokkonen, J. (2009). A single 30-second stretch is sufficient to inhibit maximal voluntary strength. *Research Quarterly for Exercise and Sport, 80*(2). Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/19650391

Wong, D. P., Chaouachi, A., Lau, P. W. C., & Behm, D. G. (2010). Short Durations of Static Stretching when Combined with Dynamic Stretching do not Impair Repeated Sprints and Agility. *Journal of Sports Science & Medicine, 10*. Retrieved from http://www.jssm.org/vol10/n2/23/v10n2-23text.php

Yamaguchi, T., & Ishii, K. (2005). Effects of Static Stretching for 30 Seconds and Dynamic Stretching on Leg Extension Power. *Journal of Strength and Conditioning Research, 19*(3). Retrieved from https://search.proquest.com/openview/4cf1ddfc8737d48ddd2f75dcba0a5d60/1?pq-origsite=gscholar&cbl=30912

Young, B., & Behm, D. (2002). Should Static Stretching Be Used During a Warm-Up for Strength and Power Activities. *National Strength and Conditioning Association, 24*(6). Retrieved from https://www.researchgate.net/publication/229071265_Should_Static_Stretching_Be_Used_During_a_Warm-Up_for_Strength_and_Power_Activities

Young, W. B. (2007). The use of static stretching in warm-up for training and competition. *International Journal of Sports Physiology and Performance, 2*(2). Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/19124908

Young, W., & Elliott, S. (2001). Acute effects of static stretching, proprioceptive neuromuscular facilitation stretching, and maximum voluntary contractions on explosive force production and jumping performance. *Research Quarterly for Exercise and Sport, 72*(3). Retrieved from http://www.tandfonline.com/doi/abs/10.1080/02701367.2001.10608960

APPENDIX 1

CONSENT TO PARTICIPATE IN RESEARCH

Eastern Illinois University

Study Title: Comparison of 4 different pre-exercise routines in sprint performance

Student Researcher: Rok Mravljak, Exercise Science Master's Program

Phone Number: (773)-512-0655

Email: rmravljak@eiu.edu

Research Advisor: Dr. Brian Pritschet

Perspective Participant,

I am a Graduate Student at Eastern Illinois University, Department of Kinesiology. I am planning to conduct a research study, which I invite you to take part in. This form has important information about the purpose of the study, what you will be asked to do if you participate, and the way I will use information about you in case you choose to be a part of the study.

Purpose:

- This study will compare the acute impact of four different pre-exercise protocols, static stretching, dynamic stretching, self-myofascial release (SMR) and a control group on 60 meter sprint performance.

- Participants will be measured on four testing trials on nonconsecutive days with at least 48 hours recovery period in between the testing trials.
- With greater increases in range of motion (ROM) and decreased viscosity of impact, muscles can convey an improved amplitude of movement and technique of running, resulting therefore, in improved sprinting time.

Participants:

- I am looking for 12-20 participants.
- Physically active Males, between 22 yrs. – 32 yrs. of age.
- Must have access to the Student Recreation center at EIU
- Preferred if participant is an enrolled student at EIU but not mandatory.
- Must have been a non-athlete for at least last 2 years (not a participant of a professional training regimen).
- No past or current heart related and/or musculoskeletal issues.

Procedures:

- This study will take approximately 2 weeks in total.
  - Session 1: Filling out an informed consent, measuring height, weight and calculating BMI, testing and developing proper sprinting technique, receiving instruction for all four intervention protocols, and answering any related questions. The assessments will be done in the ATP lab and Field house (Lantz 1011).
- Session 2-5

- Participants will undergo all interventions in a randomized order. The four interventions include: Static stretching group (SS), Dynamic stretching group (DS), self-myofascial release group (SMR), and a control group (CG).
- Prior to performing each intervention on separate days, will undergo a warm-up program in duration of approximately 10 minutes, following which they will be offered a 2-minute recovery period.
- The warm-up protocol will include: (a) mild intensity running for two laps on an indoor track (200 m per lap, 400 m in total), (b) skipping arm run for 60 m, (c) high knee run for 60 m, (d) skipping on the distance of 60 m, (e) sideways run for 60 m, (f) jogging forward/backward for 60 m, (g) walking for 1 lap (200 m in total).
- After a two-minute recovery period followed after the initial warm-up, each participant will perform their designated intervention protocol for that session for approximately 5 minutes followed by an additional 2-minute recovery period. Subjects in the control group will sit on a chair waiting 7 minutes before undergoing their sprint trial.
- Each stretch or SMR will be performed for 30 seconds, the participant will be instructed to avoid any movement beyond the edge of slight discomfort, followed by immediate stretch or SMR on the contralateral side.
- 60m sprint trial: the participants will run individually and will be instructed to approach the starting line with the dominant leg (foot) at the line, and the less dominant leg (foot) behind. Their stance will require a bend at the knees and a forward lean. The arm position will be synchronized with the legs while the

back, neck and head will remain straight. Subjects will remain motionless before the starting signal. The timer will be positioned at the 60m distance (finish line), signaling the participant when to start with the movement of his arm, (raised arm returning to normal position). Each subject will be instructed to start when the arm completes its full movement. At the same time the timer will start measuring the subjects sprint time. The timer will be using a stopwatch (Accusplit Magnum 725 x) to measure the sprint time to the nearest (0.1 seconds).

- After performing the sprint trial each subject will perform a cool down activity which will be consisted out of a 2- minute low intensity walk around the track.
- **All participants must avoid any resistance training** for the period of the research study (14 days.
- I will coordinate with participants to find a time that best works to perform the assessments.
- Some participants may not have performed a sprint on a track for quite some time. After assessing their running technique after the warm up part of testing during the initial session, they will be familiarized with starting technique.
- I will provide a very detailed instruction about the intervention programs for each participant, which will include, warm up exercises, intervention exercises, number of sets, repetitions, recovery period, and cool down portion of their testing trials will be provided.

- Each participant will document whether they experienced any muscle soreness and/or fatigue

Study location:

- Indoor track in the EIU Field House and testing facility in the ATP laboratory located in the Lantz building.

Questions regarding the study:

- If you have any questions regarding this study, feel free to contact me. My information is listed above.

Possible risk or discomforts:

- Your participation in this study does not involve any emotional risk to you beyond that of everyday life.
- As a participant, you are experienced with aerobic training and stretching exercises. Your participation in this study does not involve any physical risk beyond that encountered with typical vigorous exercise . The risk of injury is minimal if exercises are done correctly. Instruction and supervision will be provided in an attempt to ensure that proper form and technique are utilized The only physical pain you may expect to experience is some mild delayed onset muscle soreness. This is a typical response to vigorous exercise and is not considered harmful or unusual.

As mentioned above, information collected will be documented using a numbering system. Participant's personal information will not be made public. We will take steps to minimize this risk, as discussed in more detail below in this form.

Possible benefits to participating in study:

This study can potentially improve your running technique and can lead to a stretching exercise adherence, which can result in improving your sprinting performance. Moreover, you will gain a better understanding of stretching techniques, sprinting technique, and the importance of a warm-up session preceding an exercise program, and the importance of improved flexibility in training. You will learn how to perform a warm-up protocol and a stretching protocol when preparing for vigorous training. You can learn what your sprinting time is and how you can improve your sprinting time, by using four different pre-exercise routines.

This study is designed to increase understanding about the short-term effects of stretching exercises on sprinting performance in physically active college students. The study results may be used to help other people in the future in recreational and professional settings.

Results of this study:

- Results may be used in publications and presentations. Your study data will be handled confidentially. If the results of this study are published or presented, individual names and other personally identifiable information will not be used.
- To minimize risks to confidentiality, your testing results will be maintained in a locked file accessible only by the primary researchers involved in this study.

- Your data may be used in future research studies or with other researchers.
- If we share the data that we collect about you, we will remove any information that could identify you before we share it. Coding will be used to identify you.

Financial Information:

- Participation in this study will involve no cost for you. You will not be paid to participate in this study.

Research Rights as a participant:

- Participation is voluntary.
- You do not need to answer any questions you feel uncomfortable answering.
- You have the right to terminate your participation in this study at any time without penalty or prejudice or loss of benefit that you are otherwise entitled to.

If you have any concerns about your selection or treatment as a research participant, please contact the following:

Institutional Review Board

Eastern Illinois University

600 Lincoln Ave.

Charleston, IL 61920

Telephone: (217) 581-8576

E-mail: eiuirb@www.eiu.edu

You will be given the opportunity to discuss any questions about your rights as a research subject with a member of the IRB. The IRB is an independent committee composed of members of the University community, as well as lay members of the community not connected with EIU. The IRB has reviewed and approved this study.

Chair committee

Dr. Brian Pritschet

blpritschet@eiu.edu

In the event of experiencing pain and/or injury you may contact Student Health Services:

Student health Services

South Quad, 7th Street

Eastern Illinois University

Charleston, IL 61920

www.eiu.du/~health/; 217-581-3013

Consent:

I have read this form and the research study has been explained to me. I have been given the opportunity to ask questions and my questions have been answered. If I have additional questions, I have been told whom to contact. I agree to participate in the research study described above and will receive a copy of this consent form.

Signature of Participant:____________________ Date:_____ Time:______

Printed Name of Participant:____________________ Date:_____ Time:______

Signature of Investigato Date:_____ Time:______

Principal investigator

Rok Mravljak

(773)-512-0655

rmravljak@eiu.edu

APPENDIX 2

Post-intervention feedback	1st day post-intervention	2nd day post-intervention
1. Testing trial		
2. Testing trial		
3. Testing trial		
4. Testing trial		

Name and date: ____________________