Effects of a neuromuscular warm-up program on specific components of athletic performance in youth soccer players

by

Kristyn Victoria Large
BSc, Bethel University, 2013

A Thesis Submitted in Partial Fulfillment
of the Requirements for the Degree of

MASTER OF SCIENCE

in the School of Exercise Science, Physical and Health Education

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Supervisory Committee

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Supervisory Committee

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Abstract

This study aimed to compare the acute effects of two independent warm-up (WU) protocols, neuromuscular warm-up (NMWU) and standardized soccer warm-up (STWU), on three soccer-specific performance tests in adolescent male and female soccer players. Substantial evidence exists of NMWU programs reducing Anterior Cruciate Ligament (ACL) injuries, particularly in soccer. Regardless of this reduced risk of injury, NMWU program adherence is low. Enhanced athletic performance has been reported to encourage consistent WU adherence more effectively than injury risk, especially in youth athletes. Therefore this study compared the effects of a NMWU and a STWU on physical performance in youth soccer players to encourage adherence and implementation.

Following familiarization with a locally developed NMWU, 35 (11 female, 24 male) student-athletes (mean age: 14.7 yrs) from two high school-based soccer academies completed four sessions over a two week period evaluating the effects of WU on three soccer specific performance tests. Performance tests included T-test (agility), vertical jump (Peak Power Output), and 20-m sprint (acceleration and speed). The first week of testing consisted of NMWU familiarization, Yo-Yo Intermittent Recovery Test Level 1, and the collection of physical characteristics. The second week of testing consisted of two testing sessions, WU protocols were randomly assigned to the testing sessions ahead of time (session 1: STWU; session 2: NMWU) and were completed at the beginning of the session prior to testing. A series of five two-tailed repeated measures ANOVA were conducted to
determine significant differences in WU means. The overall group demonstrated a significant increase in Peak Power Output (p=0.001) and agility (p=0.016) following the STWU compared to the NMWU. Neither WU demonstrated a measurable effect on 5m, 10m, and 20m times. The findings of this research may have been influenced by the single use of the NMWU which may have limited the NMWU potential to enhance the three soccer-related performance tests. In order to explore the effectiveness of NMWU on performance enhancement as a means of improving its adherence in youth players, further research implementing NMWU over an extended period of weeks or months should be carried out, consistent with studies demonstrating NMWU impact on ACL injury risk in youth and adults.

Keywords: 1. Neuromuscular Warm-up  2. Athletic Performance  3. Adherence  4. Soccer
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Thank you to my parents, Nigel and Sandra, for supporting and encouraging me throughout this entire process. My grandparents, Gary and Teresa, for always calling to check-in and offer a listening ear. My brother, Patrick, for always encouraging me to continue pushing. Without all of you believing in me I wouldn’t have made it to this point in my life.

Thank you to my research team: Brandon, Cameron, Jed, Kat, Keegan, Marie, Nick, Nikita, and Paige. Without all of you, this project would not have happened. Your constant dedication to assisting on this project blew me away! I can never repay you for how much you helped.

I would like to thank Stefan Fletcher and the team at RebalanceMD for sharing their knowledge and expertise related to NMWU protocols, performance, and injury prevention. The academies who volunteered their time and training facilities, thank you isn’t enough. I appreciate your constant support and patience with me and my team throughout the study.

Thank you Lynneth for helping with data collection, preparation for the CSEP conference, and continuously offering your support. Greg, thank you for always having an open door and supporting me throughout the entire process.

Thank you, doesn’t even begin to explain how grateful I am to have had the honour of working with Kathy Gaul. Kathy, you pushed me outside of my comfort zone to levels I had no idea I could reach. Your constant support and encouragement allowed me to develop as a young professional and has opened new doors for my future I never thought possible. Without you, I would not have completed this process. Your patience and perseverance is truly remarkable.
Dedication

I would like to dedicate this work to my grandmother, Barbara Large.
Chapter 1 Introduction

1.1 Introduction

Warm-up (WU) in sport can be defined as a preparatory period prior to exercise to enhance performance in competition or training (Fradkin, Zazryn, & Smoliga, 2010). Preparing the body for physical activity through appropriate WU protocols is a practice that has been incorporated into training programs based on research suggesting WU prior to activity allows the body to gradually prepare for an increase in physical activity (Bishop, 2003b; Hedrick, 1992). An increase in body temperature, muscle temperature, circulation and heart rate trigger a cascade of physiological reactions increasing blood circulation, and increase the rate at which nerve impulses travel (Bishop, 2003b; Hedrick, 1992; Paradisis et al., 2014; Shellock & Prentice, 1985; Skof & Strojnik, 2007). Effectively WU is a key component in allowing the body’s systems to perform optimally.

Soccer is a sport requiring rapid changes in direction, jumping, kicking, jogging, sprinting, quick accelerations and fast decelerations (Campbell et al., 2014; Mohr, Krstrup, & Bangsbo, 2003; Stolen, Chamari, Castagna, & Wisloff, 2005). These demands of play result in soccer’s classification as a multidirectional sport. The high physiological and biomechanical demands of multidirectional sports places athletes at a higher risk for lower limb musculoskeletal injuries such as anterior cruciate ligament injuries (ACL) (Campbell et al., 2014). Evidence suggests these injuries are the result of insufficient knee and hip flexion (full extension), fatigue leading to poor cognitive decision making (loss of concentration), limited range of motion, lack of coordination, and lack of muscle/core strength (Campbell et al., 2014; Silvers & Mandelbaum, 2007). ACL injuries are most
commonly seen when an athlete is required to decelerate in combination with a change in direction while one foot is planted in a closed chain position (Silvers & Mandelbaum, 2007).

Recently, a WU protocol known as a neuromuscular warm-up (NMWU) was designed to aid in the prevention of lower limb musculoskeletal injuries, specifically ACL injuries in soccer players. NMWU were developed using the foundation of a dynamic WU and typically include agility, plyometrics, proprioceptive and balance training, stretching and strengthening, while simultaneously promoting proper biomechanical patterns (Campbell et al., 2014; Paterno, Myer, Ford, & Hewett, 2004; Renstrom et al., 2008; Vescovi & VanHeest, 2010). Optimizing an individual’s biomechanical movement patterns is an essential component in injury prevention programs (Ardern et al., 2018). NMWU have shown effective in reducing the risk of lower limb injuries through this series of dynamic stretches designed to increase neuromuscular control (Ayala et al., 2017).

Research provides evidence that NMWU are effective in reducing the risk of ACL injuries by 52% in females and 85% in males (Campbell et al., 2014; Sadoghi, Keudell, & Vavken, 2012; Soligard et al., 2008). Despite strong evidence demonstrating a NMWU is capable of reducing the risk of ACL injuries in male and female soccer players of varying ages, there is limited evidence that a NMWU is an effective method of WU to optimize physical performance. An effective WU should be capable of improving performance through an increase in core temperature, resting oxygen consumption, decrease in muscle stiffness, and post-activation potentiation (Bishop, 2003a). The PEP program from the Santa Monica Sports Medicine Foundation, the FIFA 11+ program, and the Harmoknee program are examples of NMWUs developed specifically for high performance soccer injury prevention. These programs aim to increase strength and coordination in the
stabilizing muscles surrounding the knee joint. Encouraging proper biomechanics and technique, along with soft landings and correct posture are the main goals throughout all NMWU (Bizzini, Junge, & Dvorak, 2013b; Herman, Barton, Malliaras, & Morrissey, 2012). Recently, a NMWU was developed by experienced kinesiologists and physiotherapists from a local Victoria, BC clinic using the components of the aforementioned NMWU with the intent of reducing the risk of ACL injuries within the community. The implementation of a NMWU does not in itself directly result in a reduced risk of ACL injuries (Finch, 2006). The goal of a NMWU is to reduce the risk of lower limb musculoskeletal injuries in soccer players and their success relies on program adherence to achieve the programs full potential (Campbell et al., 2014; Griffin et al., 2006; Impellizzeria et al., 2013; Steffen et al., 2013; Yoo et al., 2010). Research demonstrates a reduced injury rate with high NMWU adherence (Hägglund, Atroshi, Wagner, & Waldén, 2013; McKay, Steffen, Romiti, Finch, & Emery, 2014; Sadoghi, et al., 2012; Steffen et al., 2013).

Despite the evidence supporting the effectiveness of NMWU reducing the rate of ACL injuries, adherence and compliance to NMWU has proven challenging (Finch, 2006; McKay et al., 2014). Lack of knowledge about ACL injuries and available injury prevention programs could be a contributing factor to low NMWU adherence (Finch, 2006; McKay et al., 2014; Orr et al., 2013). Research has demonstrated parents, players, and coaches are not receiving information regarding ACL injuries and preventative programs which has created a knowledge gap (Orr et al., 2013). There are several important factors that can impact consistent adherence to NMWU by players; consistent implementation by coaches, and encouragement by parents; in addition to knowledge, enhanced performance
can be used as a motivational factor (Finch, 2006). The components of a NMWU (plyometrics, agility, balance, biomechanics, etc.) are routinely used by sport training professionals to enhance performance (Ebben, Carroll, & Simenz, 2004; Ebben, Hintz, & Simenz, 2005; Simenz, Dugan, & Ebben, 2005; Vescovi & VanHeest, 2010). Exploring whether these components contained within the NMWU are capable of enhancing performance when used as a WU, if successful could be used as a motivational factor.

Demonstrating a program has the ability to enhance performance may be a cornerstone to enhancing NMWU adherence and implementation in youth athletes and coaches as it may be difficult to encourage adherence on injury prevention alone (Kilding, Tunstall, & Kuzmic, 2008; Steffen, Bakka, Myklebust, & Bahr, 2008). Performance is a motivational tool that can be used to encourage implementation and adherence (Bien, 2011; Ebben et al., 2004; Finch, 2006; Vescovi & VanHeest, 2010). Programs that are time efficient, easy to implement, and improve performance, in addition to demonstrating the ability to reduce injury rate, are more likely to have high levels of adherence (Alentorn-Geli et al., 2009; Eime, Owen, & Finch, 2004; Finch, 2006).

1.1.2 Purpose
The purpose of this study was to compare the acute effects of two independent warm-up protocols (a locally developed NMWU and a STWU) on soccer-specific performance tests in adolescent male and female soccer players.

1.1.3 Research Questions
This study was designed to address the following questions:

Does the NMWU program improve post-warm-up athletic performance when compared with a standard dynamic warm up protocol?
Specifically,

a) Does the NMWU have a greater effect on agility compared to a standardized warm-up?

b) Does the NMWU positively impact vertical jump height compared to a standardized warm-up?

c) Is the effect on running acceleration and speed greater with the NMWU compared to a standardized warm-up?

### 1.1.4 Null Hypothesis

Compared with the STWU, the NMWU protocol will have no significantly different effect on any of the measured physical performance tests.
Chapter 2 Literature Review

2.1 Overview

WU allows the body to gradually increase heart rate and circulation, which in turn, increases body temperature and allows the body’s systems to prepare for an increase in physical activity. The cardiovascular exercise component of a WU increases body temperature, circulation, and heart rate (Bishop, 2003a; Christensen & Nordstrom, 2008; Hedrick, 1992). When body temperature increases, so too does the temperature of muscle tissue. Three physiological processes contribute to the increase in tissue temperature: muscular contraction (causing friction between muscle filaments), metabolism of fuels, and dilation of blood vessels in the muscles (Bishop, 2003a; Hedrick, 1992). These processes encourage blood flow to muscles, enhancing oxygen supply during work and increasing the ability for working muscles to extract and use the delivered oxygen due to the dissociation of oxyhemoglobin and myoglobin (Bishop, 2003a; Bishop, 2003b; Hedrick, 1992; Skof & Strojnik, 2007). By increasing the rate at which this process takes place, working muscles are then able to extract and make use of oxygen more efficiently during exercise. Post-activation potentiation as a result of WU results in an increase of neuromuscular activation, increasing the rate of nerve conduction while simultaneously increasing the rate of muscle contractions. In addition, an increase in body temperature is related to an increase in Myosin ATPase activity. Increasing Myosin ATPase activity is associated with an increase in muscle contraction speed (Bishop, 2003a; Christensen & Nordstrom, 2008; Hedrick, 1992). With three different types of WU: passive, general, and specific, all designed to affect and increase body temperature differently in different capacities. Each WU type achieves desired results related to the activity to follow.
2.2 Preparing for Physical Activity

WUs can be categorized into one of three groups: passive, general, and specific (Fradkin et al., 2010; Hedrick, 1992). A passive warm-up involves heating the body using extrinsic means such as hot showers, heating pads, and massages. Passive WUs may divert blood flow to the surface of the skin rather than to the working muscles (Hedrick, 1992). A general WU includes activities using the major muscle groups of the body, such as jogging and cycling. General WUs have been shown to increase body temperature while simultaneously increasing muscle tissue temperature. A specific WU is a general warm-up that incorporates exercises specific to the activities that follow the WU. Incorporating exercises specific to the activities, which follow, has the advantage of improving neural responses by allowing the practice and rehearsal of complex skills. (Hedrick, 1992).

2.2.2 Neuromuscular Warm Up

A NMWU falls under the classification of a specific warm-up integrating soccer specific movement into the WU, and has been developed to reduce the risk and severity of lower limb injuries, specifically ACL injuries in soccer players. Incorporating the basic concept of a specific WU in addition to the integration of agility, plyometrics, stretching and strengthening, while promoting proper biomechanics (Campbell et al., 2014; Vescovi & VanHeest, 2010) NMWU have proven effective in reducing the risk of ACL injuries.

2.3 Mechanism of ACL Injury

Injuries to the ACL occur in two ways, contact and non-contact (Alentorn-Geli et al., 2009; Campbell et al., 2014; Silvers & Mandelbaum, 2007). Contact injuries occur with another player on the field placing an excessive force on the knee joint causing the knee to exceed its natural range of motion (Silvers & Mandelbaum, 2007). Most commonly, non-contact ACL injuries are seen, contributing to two thirds of the total ACL injuries reported
Many factors contribute to non-contact ACL injuries: footwear, environment, weather, playing surface, and research has shown females are predisposed by anatomical and neuromuscular factors (Silvers & Mandelbaum, 2007). When evaluating soccer, non-contact ACL injuries are results of the nature of the sport placing strain on the ACL (Campbell et al., 2014; Ireland, 1999; Silvers & Mandelbaum, 2007). When an athlete is required to make sudden changes in direction, accelerate, decelerate, or lands improperly with insufficient muscle strength or flexion, ACL injuries can occur (Campbell et al., 2014; Silvers & Mandelbaum, 2007).

2.3.1 Neuromuscular Factors Leading to ACL Injury

Neuromuscular differences also play a role in increasing the risk of ACL injury. Females are thought to have less neuromuscular control over their knees than males (Zazulak, Hewett, Reeves, Goldberg, & Cholewicki, 2007a). Compared to males, females contract their quadriceps at a greater rate than their hamstrings causing strain and instability on the ACL (Hewett, 2000). This is thought to be the outcome of female hamstring strength developing at a slower rate than males, resulting in weak hamstring strength comparatively to quadricep strength (Shelbourne, Davis, & Klootwyk, 1998). Research has demonstrated that throughout puberty males display an increase in strength, coordination, and power. The association continues with age, throughout puberty and maturation in males; however this association is not seen amongst females (Myer, Ford, & Hewett, 2004) The lack of increased muscle strength to match continuous muscle growth associated with puberty is believed to cause the development of a neuromuscular imbalance which can lead to less neuromuscular control in lower-extremities, placing females at a higher risk for ACL injuries (Myer et al., 2004; Myer, Ford, Palumbo, & Hewett, 2005). An increase in knee
valgus is noticed amongst females compared to males; this is believed to be due to a lack of muscular strength and neuromuscular control in the hip muscles (Hollman et al., 2009). In a study conducted by Huston and Wojtys (1996), female college athletes demonstrated different neuromuscular recruitment and leg strength imbalances compared to males (Huston & Wojtys, 1996). Females exhibit an increase in quadricep strength and generate power from their quadricep muscles, this imbalance if let to continue past maturation leads to muscle imbalance and places strain on the knee joint (Myer et al., 2004). Due to this muscle imbalance, females tend to contract quadricep muscles when landing and jumping, unlike males, putting stress on the knee and providing the joint with less support (Myer et al., 2004).

2.3.2 Impact of ACL Injuries

Sustaining an ACL injury can remove an athlete from competition for six to nine months particularly if reconstructive surgery is required, followed by necessary post-surgical rehabilitation (Silvers & Mandelbaum, 2007). In addition to removing an athlete from play, psychological disruptions such as anxiety caused by the fear of reinjuring the knee and a loss of confidence on the field are common detriments to the return to full play status (Campbell et al., 2014; Joseph et al., 2013; Myer et al., 2014; Silvers & Mandelbaum, 2007). A few long-term repercussions of an ACL injury include the early onset of osteoporosis, chronic pain, and joint instability (Bien, 2011; Campbell et al., 2014; Joseph et al., 2013; Kostogiannis et al., 2007; Myer et al., 2014; Neuman et al., 2009; Neuman et al., 2008; Silvers & Mandelbaum, 2007). In a follow up study conducted 15 years after sustaining an ACL injury, osteoarthritis was present in 50% of patients (Lohmander, Ostenberg, Englund, & Roos, 2004).
In addition to the impact ACL injuries have on the athlete there is also the financial strain it places on the health care system. It was reported in 2010 that unintentional injuries cost Canadians $22.1 billion and 60% directly cost the healthcare system (Marshall, Lopatina, Lacny, & Emery, 2016). In Canada, 10% of sport injuries reported were sustained in youth soccer athletes, ranging in ages from 11-18 yrs. In a study conducted by Marshall et al. (2016) it was concluded that NMWUs are both cost effective to implement and reduce the risk of ACL injuries, in addition to reducing the cost of ACL injuries on the healthcare system (Marshall et al., 2016). The study evaluated male and female soccer athletes (n=744) ranging in age from 13-18 yrs, participating in indoor soccer. Injuries, time loss and costs on the healthcare system were reported and compared between the control and training (NMWU) group. The study concluded a 38% reduction in injury risk and healthcare costs incurred were 43% less by those participating in the training group completing the NMWU (Marshall et al., 2016).

2.3.3 Neuromuscular Warm-ups and ACL injuries

NMWU are designed to prepare the body for activity while proving to simultaneously reduce the risk of lower limb injuries, specifically in athletes participating in soccer and have proven to reduce the risk of ACL injuries. Soccer is a multidirectional sport—one which requires rapid changes in direction, quick accelerations and fast decelerations (Campbell et al., 2014). Multidirectional sports place high stress on knee joints, specifically on the ACL; 50% of all knee injuries seen in multidirectional sports are to the ACL (Joseph et al., 2013). Soccer athletes are believed to sustain non-contact ACL injuries as a result of insufficient knee and hip flexion, fatigue leading to poor cognitive
decisions, and lack of muscle strength (Campbell et al., 2014; Silvers & Mandelbaum, 2007).

Research has provided evidence that soccer specific NMWU have proven the most effective in reducing the risk of ACL injuries when introduced at a young age, more specifically before the age of 18 yrs (Campbell et al., 2014; Yoo et al., 2010). Further research conducted by Myer et al. (2012) demonstrated that ACL injuries were reduced by 72% in females under the age of 18, and only 16% in females over the age of 18 (Myer, Sugimoto, Thomas, & Hewett, 2012). A meta-analysis and literature review conducted by Sadoghi et al. (2012) provided evidence that the risk of ACL injuries can be reduced using NMWU. NMWU report reduced risk of ACL injuries in athletes by 85% in males and 52% in females (Campbell et al., 2014). Research suggests that NMWUs need to incorporate strength components, plyometrics, and balance exercises to effectively reduce the risk of ACL (Yoo et al., 2010).

Meta-analyses provide substantial evidence that NMWU are effective in reducing the risk of ACL injuries (Campbell et al., 2014). All six meta-analyses have provided evidence that NMWU are effective in reducing the risk of ACL injuries (Gagnier, Morgenstern, & Chess, 2013; Grindstaff, Hammill, Tuzson, & Hertel, 2006; Hewett, Ford, & Myer, 2006; Myer et al., 2012; Sugimoto et al., 2012; Yoo et al., 2010). Grindstaff et al. (2006) reviewed original research and from the five articles that met inclusion criteria they concluded that NMWU reduce the incidence of ACL injuries up to 70% (Grindstaff et al., 2006). Neuromuscular warm up programs are dynamic warm-ups designed to be completed pre-activity to activate the neuromuscular system and focus on key exercises to reduce the risk of ACL injury (Campbell et al., 2014; Paterno et al., 2004; Renstrom et al., 2008;
Vescovi & VanHeest, 2010). Neuromuscular warm-up program protocols typically contain: agility, plyometrics, core, balance, stretching and strengthening, while simultaneously promoting proper biomechanics (Campbell et al., 2014; Paterno et al., 2004; Renstrom et al., 2008; Vescovi & VanHeest, 2010).

2.3.4 Components of Neuromuscular Warm-ups

The FIFA 11+ program consists of three parts totaling 15 different exercises designed to take approximately 20 minutes (Appendix 4A). Part one contains slow speed running exercises combined with controlled one-on-one contact and active stretching. This section contains a total of six exercises and is designed to take eight minutes. Part two consists of strength, plyometrics and balance exercises designed to focus on core and leg strength in addition to agility. Within section two there are a total of six exercises and three different levels of difficulty for players to choose from to best suit their skill level. Section two is designed to take approximately 10 minutes. The last section is composed of three moderate to high speed running exercises combined with cutting and planting movements designed to last a total of two minutes. Correct posture, body control and alignment are key components to focus on throughout the WU.

The PEP program was designed to take approximately 15-20 minutes to complete consisting of five different sections (Appendix 4B). Section one is titled warm-up and is designed to allow the athlete to prepare for activity through running exercises. Section two is titled strengthening and is composed of exercises designed to increase leg strength. The exercises incorporated within this section focus on increasing hamstring and quadricep muscle strength to stabilize the knee joint. Section three consists of plyometric exercises designed to be explosive and assist to build strength, power, and speed. Throughout this
section soft landings and consistent, proper technique are encouraged. Agility exercises
make up section four and are used to increase dynamic stability of the hip, knee, and ankle.
The final section involves lower body static stretching to increase range of motion, improve
mobility, reduce the risk of injury, and reduce soreness.

Both FIFA 11+ and PEP WU programs consist of plyometrics, agility and
strengthening components designed to increase strength of the stabilizing muscles
surrounding the knee joint while increasing range of motion and gradually preparing the
body for an increase in activity. Based on these principles, a local clinic created a similar
NMWU. The RebalanceMD (Appendix 2) contains 18 exercises and takes approximately 20
minutes to complete. Similar to the PEP and FIFA 11+ programs, the RebalanceMD program
is designed to prepare the athlete for exercise while increasing leg strength, range of
motion, and agility through a series of exercises. This NMWU begins with two light
running exercises engaging the musculoskeletal system and increasing blood flow.
Following the running exercises there is a series of 11 dynamic movements containing
plyometrics, agility, and strengthening exercises. Similar to the FIFA 11+ and PEP
program soft landings and appropriate posture are encouraged while the exercises
challenge the athlete to stabilize the knee and hip by engaging leg and core muscles to
avoid improper alignment. This section is followed by two running exercises designed to
increase muscle strength, enhancing power and speed. As in the PEP, the WU concludes
with three dynamic stretching exercises also designed to increase balance.

2.4 Neuromuscular Warm Up Adherence

Although evidence has been provided demonstrating NMWUs are effective in
reducing the risk of ACL and other lower limb injuries, consistent adherence is required to
reach the full potential of such programs (Griffin et al., 2006; Impellizzeria et al., 2013; Yoo et al., 2010). Implementation of a NMWU does not in itself result in reducing the risk of ACL injuries (Finch, 2006), as there are many other factors that contribute to ACL injuries. An intervention evaluated the effects of NMWU adherence on 184 teams (intervention group) and 157 (control group) female soccer teams on the reduction rate of ACL injuries over their season (Hägglund et al., 2013). The study concluded that those in the intervention group demonstrated 64% lower ACL injury rates than the control group; within the intervention group those with high adherence demonstrated an 88% lower ACL injury rate than those with low adherence. This study both provides evidence of the effectiveness of NMWU and the importance of adherence.

Adherence is an important aspect in assuring a program is effective in accomplishing the pre-determined goal of reducing the risk of lower limb injuries, specifically ACL injuries (Campbell et al., 2014; Steffen et al., 2013). Whether it be adherence to medication, exercise programs, or other interventions, understanding what will encourage individuals to comply with injury prevention protocols is essential to reaching the full benefits of such programs.

According to Finch there are several important factors that can lead to coach, player, and parent adherence to injury prevention programs (Finch, 2006). Programs that are time efficient, easy to implement, improve performance, and showcase a proven ability to reduce the risk of ACL injuries are more likely to have high levels of adherence (Finch, 2006; McKay et al., 2014; Soligard et al., 2010). Providing evidence that a specific NMWU can increase athletic performance could encourage both implementation and adherence, in
turn decreasing the risk of ACL injury (Ebben et al., 2004; Finch, 2006; Vescovi & VanHeest, 2010).

2.5 Review of the Physical Demands of Soccer

Athletes are required to run an average of 10-12 km during a 90-minute soccer game (Stolen et al., 2005) with an anaerobic threshold intensity of nearly 80-90% of heart rate maximum, and with high-speed actions such as jumping, kicking, sprinting, change of pace and direction, and tackling (Mohr et al., 2003; Stolen et al., 2005). There is further evidence reporting that an average 96% of all sprint performances during a match are less than 30 m in length, and 49% being less than 10m (Stolen et al., 2005). Research suggests that in soccer there are three independent factors that translate to performance in soccer: acceleration, maximal speed, and agility (Jovanovic, Sporis, Omrcen, & Fiorentini, 2011; Little & Williams, 2005; Vescovi, Rupf, Brown, & Marques, 2011). These three components are considered to be high-speed actions which impact soccer performance and accounts for roughly 11% of the total game (Little & Williams, 2005). High-speed actions are crucial to performance, they can be the difference between winning or losing a match (Jullien et al., 2008; Little & Williams, 2005; Walker & Turner, 2009). One study provided evidence that players with faster 5m, 20m, and agility test times were selected to play in the first game of the season compared to other members of their team with lower reported speeds (Young & Pryor, 2007). Due to the complexity of the sport, it is difficult to evaluate performance in a valid and reliable manner (Currell & Jeukendrup, 2008; Stolen et al., 2005). Having said this, assessing agility, jumping, and linear sprinting are common and related to player performance (Chamari et al., 2004; Hoare & Warr, 2000; Walker & Turner, 2009). Research has demonstrated the importance of muscular strength in relation
to explosive and forceful components of play (Jullien et al., 2008). Strength in lower limb muscle mass is not only related to performance in vertical jump height, but improves performance in acceleration and speed (Jullien et al., 2008; Ronnestad, Kvamme, Sunde, & Raastad, 2008).

**Agility**

Soccer is a multidirectional sport requiring rapid changes in direction without the loss of speed; soccer is a sport requiring high levels of agility and is known to be an important aspect in achieving optimal performance (Jovanovic et al., 2011; Sporis, Jukic, Milanovic, & Vucetic, 2010; Stewart, Turner, & Miller, 2014). Agility related to soccer can be defined as the ability to change direction quickly while maintaining balance using a combination power, strength, and coordination (Jullien et al., 2008; Walker & Turner, 2009). Research suggests that athletes will turn roughly 50 times throughout a soccer match, further demonstrating the importance of agility related to performance (Walker & Turner, 2009).

Evaluating agility in soccer can be done using a T-test. The T-test is a validated and reliable test which is often used to measure an athlete’s lateral, forward and backward running ability while maintaining speed and balance throughout the four-directional test (Pauole, Madole, Garhammer, Lacourse, & Rozenek, 2000). In a study evaluating the reliability and validity of six agility tests on soccer players, it was concluded that three tests were considered to be more reliable and valid tests for evaluating agility in soccer players; the T-test was considered to be one of the three agility tests found to be reliable and valid (Sporis et al., 2010).
Peak Power Output

An athlete’s ability to jump an extra inch may be the difference between winning and losing the ball which could be the determining factor in winning or losing a match (Decker & Vinson, 1996). Research has shown vertical jump scores to be a good predictor of performance in male soccer players (Hoare & Warr, 2000). A vertical jump test allows for the assessment of power, identifying an athlete’s physical ability such as explosive ability (Klavora, 2000).

The vertical jump test was developed from the Sargent jump and can be modified using a Gill Athletics Vertec (Gill Athletics, Champaign, IL) for ensured reliability and validity (Klavora, 2000; Sargent, 1921). In soccer, peak power output is often calculated using vertical jump scores, which has been reported to be closely related to performance (Arnason et al., 2004). Using the highest score for each participant, peak power can be calculated using the following equation: Peak Power (W) = 60.7 × (jump height [cm]) + 45.3 × (body mass [kg]) – 2055 (Sayers, 1999).

Linear Sprinting relative to Speed and Acceleration

Soccer is a sport requiring multiple sprints over varying distances. Sprint tests can be used to evaluate an athlete’s acceleration and speed capacity (Mirkov, Nedeljkovic, Kukoji, Ugarkovic, & Jaric, 2008). Professional players demonstrate a higher performance in various speed tests compared to lower level soccer players, suggesting speed as a factor for elite players and increased performance capabilities (Little & Williams, 2005). Acceleration in soccer can be defined as a player’s ability to reach maximum velocity in a minimal amount of time (Little & Williams, 2005).
The 20-m sprint test measures an athlete’s linear ability to accelerate, maintain speed, and provides their overall sprint time. As previously mentioned, soccer players generally sprint 10-30 meters, for an average of 6 seconds (Little & Williams, 2005; A.Sayers, Sayers & Binkley, 2008). This research suggests evaluating an athlete’s ability to sprint over 20 m to be an appropriate measure of acceleration as it directly relates to the demands of soccer and match play.

2.5.1 Neuromuscular Warm-ups and Performance

Neuromuscular control is the body’s ability to send signals to the brain and react to stimuli unconsciously in an effective manner to protect the body (Shultz, Sander, Kirk, & Perrin, 2005). An athlete’s neuromuscular control provides them with the ability to maintain stability, balance, and to move in response to stimuli (Impellizzeria et al., 2013; Risberg, Mørk, Jenssen, & Holm, 2001; Zazulak et al., 2007a). Training the neuromuscular system to effectively react to stimuli subconsciously improves performance on the field (Bizzini et al., 2013b; Griffin et al., 2006; Herman et al., 2012; Impellizzeria et al., 2013; Risberg et al., 2001; Zazulak et al., 2007a). A neuromuscular training protocol is designed to activate the neuromuscular system, increase joint stability by training the surrounding muscles and create a sense of proper balance, biomechanics and technique (Bizzini, et al., 2013a; Myer et al., 2005; Yoo et al., 2010; Zazulak et al., 2007b). Neuromuscular warm-ups target the neuromuscular system preparing the body for the activity to immediately follow.

There is conflicting evidence that NMWU are capable of enhancing performance. In one study, the effects of the Prevent Injury Enhance Performance (PEP) program on performance was evaluated in a randomized control trial with 58 adolescent female soccer
players (Vescovi & VanHeest, 2010). Four teams were randomly assigned to either the intervention (PEP) or control group and were tested using linear sprinting, countermovement jump, and two agility tests at baseline, 6-weeks, and 12-weeks. The study found that linear sprint times were moderately improved with the PEP program following six weeks, but scores reverted back to baseline when measured again at 12 weeks and the PEP program demonstrated no improvements in countermovement jump or agility scores (Vescovi & VanHeest, 2010). Further studies have been conducted evaluating the effects on NMWU on performance providing conflicting evidence (Ayala et al., 2017; Bizzini et al., 2013a; Daneshjoo, Mokhtar, Rahnama, & Yusof, 2013). These differences could be due to a lack of consistency in methodology and time frame.

### 2.6 Performance Tests

Evaluating performance of athletes using laboratory tests can be time consuming and costly, making them unpractical and inaccessible (Walker & Turner, 2009). Although laboratory based tests are highly reliable and valid measures of an athlete’s performance, their limited accessibility and cost has led to the development of valid and reliable field tests as a practical alternative (Castagna, Impellizzeri, Chamari, Carlomagno, & Rampinini, 2006; Walker & Turner, 2009). Coaches and players rely on field tests to evaluate performance and performance improvements over the season to accurately develop training protocols to address areas of weakness (Sporis et al., 2010). Field tests need to mimic the on field performance the test is attempting to simulate to be valid, highly reproducible to be considered reliable, and sensitive enough to detect small changes in performance (Currell & Jeukendrup, 2008).
Validity

i. Logical or face validity: is the assessment of the accuracy of a test measuring the intended variable, but can be difficult to assess. (Currell & Jeukendrup, 2008)

ii. Criterion validity: allows for the assessment of the objective measure of validity (Currell & Jeukendrup, 2008)
   a. Concurrent: the results of a test resemble that of previously established measurements (Currell & Jeukendrup, 2008)

iii. Construct validity: is the ability to detect an unobservable variable such as performance by comparing the results of related test scores (i.e., professional, recreational) (Currell & Jeukendrup, 2008).

Reliability

There are several factors that contribute to the reliability of a field test: number of trials performed, number of subjects, the skills of the tested population, and homogeneity of the sample (Currell & Jeukendrup, 2008; Mirkov et al., 2008). Field tests need to be highly reproducible, and demonstrate minimal differences in the mean and minimal variation between protocol (Currell & Jeukendrup, 2008; Mirkov et al., 2008). If a field test is unreliable it will not possess the ability to track changes between trials and is considered unsuitable to assess performance (Hopkins, Schabert, & Hawley, 2001).
2.7 Summary

With what we know regarding ACL injuries and their impact on a player’s careers (Campbell et al., 2014; Kostogiannis et al., 2007; Lohmander et al., 2004; Lohmander et al., 2007; Neuman et al., 2009; Neuman et al., 2008; Silvers & Mandelbaum, 2007) and the positive effects NMWU have on reducing the risk of lower limb injuries, specifically ACL injuries (Campbell et al., 2014; Hewett, Ford, Hoogenboom, & Myer, 2010; Renstrom et al., 2008; Sugimoto et al., 2012; Weaver, Marshall, & Miller, 2002) implementation of a NMWU would be beneficial and widely adopted by coaches, players, and parents. However, evidence suggests that adherence and implementation is low, suggesting additional motivational factors need to be explored. Performance as a motivational factor has been suggested to be beneficial in assisting with program adherence and implementation (Finch, 2006). Soccer is a multidirectional sport requiring high performance in areas such as agility, linear speed, and lower limb power and strength (Hoare & Warr, 2000; Jovanovic et al., 2011; Mirkov et al., 2008). Evaluating the effects of NMWU on soccer specific performance variables to increase adherence and NMWU implementation needs to be explored to determine if a NMWU is an appropriate form of WU or should be used as a training tool to reduce the risk of lower limb injuries.
Chapter 3 Methods

In order to evaluate the effects of two different warm-up protocols on athletic performance, an experimental design was employed to conduct a comparison of three post-warm-up soccer-specific performance tests using repeated measures design with participants acting as their own controls. Participants were recruited from two high school soccer academy programs in the lower region of Vancouver Island. Each participant completed 2 sessions per week over 2 consecutive weeks (total 4 sessions). Prior to the second week of testing containing the experimental sessions all participants completed a Yo-Yo Intermittent Recovery Level one (YYIRL1) (Krstrup et al., 2003). During each session of data collection, participants completed the assigned WU prior to completing three dependent performance test variables: agility, acceleration, and vertical jump. The performance variables were measured immediately following each warm up protocol in a standardized order. All testing took place during the regular academy morning training times. Academies completed both testing sessions of the soccer-specific performance tests on their artificial turf, one academy completed the YYIRL1 (Krstrup et al., 2003) on grass and the other academy completed the YYIRL1 on artificial turf. Both facilities were outdoors. The weather was overcast with an average temperature ranging between 8-10 degrees Celsius. This study was conducted under the approval of the University of Victoria Human Research Ethics Board (Appendix 1A).

3.1 Participants

Participants for this research included male and female soccer players, 14-15 years old, who were currently participating in one of the two soccer academies in Victoria, British Columbia. Recruitment was limited to academy student athletes in grade 9, actively
participating in the Reynolds Secondary School or Royal Bay Secondary School soccer academy programs and free of any injury or illness that could limit performance in the testing battery. A combined total of 44 (males n=29; females n=15) student athletes consented to participate in the research study. Athletes provided informed written consent (Appendix 1B) that outlined the voluntary nature of their participation and their right to withdraw at any time without consequence.

3.2 Procedures

There were two study sessions a week for two weeks, totalling four sessions per academy. Table 1 provides a breakdown of the consistent testing schedule used in both academies. The first week of testing consisted of an introduction to the NMWU protocol, collection of participant physical characteristics (height, weight, dominant leg and age), standing reach height, and the completion of YYIRL1. During the first session, participants received an introduction and familiarization to the locally derived NMWU including a detailed description of each of the 18 different exercises within the NMWU (Appendix 2) and a full demonstration. Following the introduction, participants completed the NMWU under the supervision of the research team; proper biomechanics and technique were encouraged throughout the warm-up. Participants resumed regular academy warm-up throughout the rest of the week’s training.

The second session took place 48 hours following the NMWU introduction. During this session, participants were divided into two groups: one group completed the YYIRL1 (Krustrup et al., 2003) while height, weight, and standing reach height were collected with the other group. Upon completion, groups switched. Each academy completed a warm-up of their coach’s choice prior to completing the YYIRL1. This was done to ensure the scores
of the YYIRL were not altered or influenced by implementing a warm-up (WU) protocol that varied from the respective academy’s regular routine.

Participant height and weight were measured using a portable stadiometer (Congenital Scale Corporation, Bridgeview, Illinois) and scale (Health-o-meter, Continental Scale Corporation, USA). Participants removed their runners and wore shorts and t-shirts for the collection of height and weight. Participant standing reach height was measured using the Gill Athletics Vertec (Gill Athletics, Champaign, IL). Following the collection of height, weight, and standing reach height, participants were asked to self-report their dominant leg to a member of the research team. For the purpose of this study the dominant leg was defined as the preferred leg to kick with. Participants were also asked at this time to report their date of birth.

The second week of testing consisted of two data collection sessions separated by 48 hours. Prior to testing, warm-up protocols were randomly assigned to the testing dates. A standardized warm-up (STWU) was implemented to ensure testing consistency amongst both academies as each was using different WU protocols. The STWU was created using common themes identified during a pre-study observational period of both academies current WU protocols. In order to keep consistency amongst the data to combine for analysis as academies were not being compared, both academies completed the STWU the first day of testing in both academies and the NMWU was assigned to the second day of testing. The NMWU (Appendix 2) used for this research is locally derived and was created using the same principles as in the PEP and FIFA 11+. The NMWU consisted of 18 different exercises designed to take approximately 20 minutes to complete. A local NMWU
was selected as the clinic is currently working to implement the program within the community. Appendix 4 provides a comparison of both WU protocols.

*Table 1. Data Collection Timeline (Following Consent For All Participants)*

<table>
<thead>
<tr>
<th>Session #</th>
<th>Data collected</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Week 1:</strong> (test sessions 48 hrs apart)</td>
<td></td>
</tr>
<tr>
<td><strong>Session 1</strong></td>
<td>Introduction to NMWU</td>
</tr>
</tbody>
</table>
| **Session 2** | YYIRL1  
  Anthropometric Assessment:  
  - Height  
  - Weight  
  - Birthdate  
  - Standing reach height |
| **Week 2:** (test sessions 48 hrs apart) |
| **Session 3** | STWU  
  Station 1 - T-test  
  Station 2 - Vertical Jump  
  Station 3 - 20-meter running sprint |
| **Session 4** | NMWU  
  Station 1 - T-test  
  Station 2 - Vertical Jump  
  Station 3 - 20-meter running sprint |
Participants were split into two groups and were staggered. While group 1 completed station 1, group 2 completed the assigned WU. Table 2 demonstrates this rotation.

Table 2. Rotation Through Testing Stations

<table>
<thead>
<tr>
<th>Group 1 Rotation for testing</th>
<th>Group 1 Assigned WU</th>
<th>Station 1</th>
<th>Station 2</th>
<th>Station 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 2 Rotation for testing</td>
<td>Group 2 Assigned WU</td>
<td>Station 1</td>
<td>Station 2</td>
<td>Station 3</td>
</tr>
</tbody>
</table>

3.3 Testing Protocols

Participants were divided into two groups for testing to ensure efficiency and accuracy in testing. At the request of one academy, males and females were tested separately. In the other academy, participants were randomly split into two even groups.

3.3.1 Yo-Yo Intermittent Recovery Level 1 Test (YYIRL1)

The YYIRL1 was used to evaluate each participant’s ability to perform high intensity exercise repeatedly at an increasing pace until they were no longer capable of meeting the test requirement (Bangsbo, Iaia, & Krstrup, 2008). The YYIRL1 is a standardized test conducted over 20 meters with 5 meters of active rest at the end of 40 meters. The test was administered through an electronic recording consisting of a series of beeps and verbal directions and was conducted following standard protocol (Krstrup et al., 2003) (Appendix 3). The last completed YYIRL1 stage for each individual was converted into overall distance (meters) traveled. This test was completed on the second day of Week 1 for participant descriptive purposes.
3.3.2 Agility Test: T-Test

The agility T-Test is a concurrent, criterion related validated test used to measure an athlete’s running agility (Pauole et al., 2000). The T-test was administered following the standard protocol (Semenick, 1990), with the modification of using Brower Timing Lights (Brower Timing System, Salt Lake City, UT) to accurately ensure participants touched the cones and covered the full distance to either end of the “T”. Participants completed two attempts, one attempt shuffling the right first and one attempt shuffling to left first (Appendix 3). The best score for each participant was used in analysis. This test was conducted in Week 2 immediately following the completion of the warm up protocol of the day.

3.3.3 Vertical Jump Height Test

Participants completed two vertical jump (VJ) trials, with all participants in the group completing their first jump before advancing to their second. The VJ was conducted using a Gill Athletics Vertec (Gill Athletics, Champaign, IL) to ensure accuracy and reliability (Klavora, 2000; Sargent, 1921). The best of two trials from each testing session was used to calculate peak power output for each participant. Appendix 3 describes the test details and protocol. Standing reach height was collected for each participant during week 1 of testing and was used to calculate each participant’s jump height. Jump height was used along with other participant’s characteristics to calculate peak power output (W) using the following equation: 

\[
\text{Peak Power (W)} = 60.7 \times (\text{jump height [cm]}) + 45.3 \times (\text{body mass [kg]} - 2055)
\]

(Sayers, 1999). The VJ was conducted immediately following the completion of the Agility T-Test on both test days in Week 2.
3.3.4 20-meter Running Sprint Test

The 20-m sprint test was conducted on the regular playing surface of each academy. Brower Timing lights (Brower Timing System, Salt Lake City, UT) were positioned to accurately and reliably measure and record individual athlete sprint times over a distance of 20 meters, in addition to including times of 5-m and 10-m sprints (Appendix 3). This sprint test was performed immediately following the completion of the VJ Test on both test days in Week 2. Participants completed two trials and the best-recorded trial for each participant was used for data analysis.

3.4 Data Analysis

All data were analyzed using IBM Statistical Package for Social Science (SPSS) version 22.0 software for Windows (SPSS, Inc., Chicago, Ill., USA) with the significance level set at <0.05. The purpose of this study was to identify any differences in performance test results between warm-up protocols and not to compare academies. Participants were recruited from two academies to increase participant numbers, therefore academy data were pooled and analyzed together as a single group. Using G*power (Faul, Erdfelder, Buchner, & Lang, 2009), a power analysis was conducted using an effect size of 0.3, and an alpha level of 0.05 to determine that an optimal subject population of 62 participants is required to reach a power level of 80%. Prior to data analysis, using group data, normality of distribution of data was assessed using a p value of 0.05. There were no violations of assumptions prior to data analysis. Outliers were identified (distribution) and incomplete data sets were removed from the analyses. Missing any session, including the YYIRL1, resulted in an incomplete data set.

A series of five two-tailed repeated measures ANOVA were conducted to identify whether there were main effects for WU (NMWU or STWU), and sex (male or female) on
performance variables (agility, VJ, 20m sprint). The within-subject factor was WU (two levels defined as STWU or NMWU) and between-subject factor was sex (male or female). To account for the assumption of sphericity, the Greenhouse-Geisser condition was used. In addition, the possibility of an inflated Type 1 error due to the series of tests being conducted on the same data set was accounted for by applying Bonferroni’s correction.

This research did not set out to determine if there was a sex main effect but rather to identify the effects of the NMWU on performance in youth soccer athletes therefore, male and female data were pooled and analyzed together. In addition, as there was an imbalance in the number of male and female participants (male n=24; female n=11), a comparison between the sexes was not deemed appropriate. Any sex main effects for the performance variables are reported, however, the focus of the results is of group data (male and female together).
Chapter 4 Results

4.1 Participant Characteristics

Prior to analysis, data were inspected for completeness: of the 44 volunteer participants, a total of 35 completed data sets were available to be used for data analysis (males n=24; females n=11). A total of seven individuals missed a test session resulting in incomplete data sets and were removed from data analysis. Two additional individuals exercised their right to remove themselves from the study therefore the data collected for these individuals were destroyed. Mean physical characteristics for those participants who completed all parts of the study are summarized in Table 3.

Table 3. Mean (SD) Participants Characteristics

<table>
<thead>
<tr>
<th>Variable</th>
<th>Male (n=24)</th>
<th>Female (n=11)</th>
<th>Group (n=35)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
</tr>
<tr>
<td>Age (yrs)</td>
<td>14.67 (0.33)</td>
<td>14.90 (0.37)</td>
<td>14.70 (0.36)</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>58.56 (12.37)</td>
<td>55.02 (6.13)</td>
<td>57.45 (10.84)</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>170.6 (6.55) +</td>
<td>161.90 (5.58)</td>
<td>167.87 (7.41)</td>
</tr>
<tr>
<td>YYIRTL1 (meters)</td>
<td>793.33 (309.31)</td>
<td>596.36 (159.45)</td>
<td>731.43 (284.27)</td>
</tr>
</tbody>
</table>

+ Significantly different from female values, p <0.05.

4.2 Agility T-Test Performance

All participants completed two agility T-Test trials for each WU protocol. Analysis was conducted using each participant’s best score (fastest time) for each WU protocol. Table 3 provides the mean scores (SD) following each WU protocol for sex and group data.

Results indicate, a significant WU main effect, \( F(1, 33) = 6.488, p < 0.05 \), partial \( \eta^2 = 0.164 \), between WU by sex interaction \( F(1, 33) = 6.482, p < 0.05 \), partial \( \eta^2 = 1.64 \), and a main sex effect \( F(1, 33) = 1.312, p < 0.01 \), partial \( \eta^2 = 0.38 \) for agility T-Test performance. The group mean scores demonstrated WU effect that the STWU resulted in a significant improvement in agility time (p=0.016).
4.3 Vertical Jump Performance
Each participant completed two VJ trials for each WU protocol. The best score for each participant was used to calculate Peak Power Output. A WU main effect \( (F(1, 33) = 17.472, p < 0.0005, \text{partial } \eta^2 = 0.346) \), and a main sex effect \( (F(1, 33) = .757, p < 0.01, \text{partial } \eta^2 = .022) \) for VJ Peak Power Output was found. As shown in Table 4, Peak Power Output (Watts) was significantly greater following the STWU compared to the NMWU \( (p= 0.001) \).

4.4 20-meter Running Sprint Test performance
In the running sprint test, 5-meter times were used to assess acceleration, 10-meter times were used to evaluate the ability to maintain speed, and 20-meter times allowed an evaluation of overall speed. No significant differences were found for any sprint variables following either WU protocol (Table 3). However, the results did indicate there was a main effect for sex for all three measurements: 5m \( (F(1, 33) = 1.508, p < 0.0005, \text{partial } \eta^2 = .044) \); 10m \( (F(1, 33) = .495, p < 0.01, \text{partial } \eta^2 = .015) \); and 20m \( (F(1, 33) = .350, p < 0.01, \text{partial } \eta^2 = .010) \).

4.5 Summary
The series of five two-tailed repeated measures ANOVA with a Greenhouse-Geisser correction determined that faster Agility T-test scores and higher peak power output performances were observed following STWU compared to the NMWU. Neither WU protocol resulted in a measurable benefit to acceleration (5m), or speed (10, 20m) performances.
Table 4. Mean (SD) performance scores for STWU and NMWU

<table>
<thead>
<tr>
<th></th>
<th>Male (n=24)</th>
<th>Female (n=11)</th>
<th>Group (n=35)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
</tr>
<tr>
<td><strong>Agility T-Test (sec)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>STWU</td>
<td>12.17 (0.89)**</td>
<td>12.72 (0.28)</td>
<td>12.34 (0.79)*</td>
</tr>
<tr>
<td>NMWU</td>
<td>12.59 (1.05)</td>
<td>12.72 (0.39)</td>
<td>12.63 (0.90)</td>
</tr>
<tr>
<td><strong>Peak Power Output (Watts)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>STWU</td>
<td>3466.23 (842.17)**</td>
<td>3781.35 (2160.31)</td>
<td>3565.27 (1369.10) *</td>
</tr>
<tr>
<td>NMWU</td>
<td>2933.03 (782.37)</td>
<td>3494.01 (2322.66)</td>
<td>3109.34 (1438.95)</td>
</tr>
<tr>
<td><strong>Sprint 5 Meter</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>STWU</td>
<td>1.15 (0.10)</td>
<td>1.18 (0.06)</td>
<td>1.63 (0.09)</td>
</tr>
<tr>
<td>NMWU</td>
<td>1.12 (0.06)</td>
<td>1.15 (0.07)</td>
<td>1.13 (0.06)</td>
</tr>
<tr>
<td><strong>Speed 10 Meter</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>STWU</td>
<td>1.97 (0.14)</td>
<td>2.04 (0.06)</td>
<td>2.00 (0.13)</td>
</tr>
<tr>
<td>NMWU</td>
<td>1.95 (0.10)</td>
<td>1.96 (0.26)</td>
<td>1.96 (0.17)</td>
</tr>
<tr>
<td><strong>Speed 20 Meter</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>STWU</td>
<td>3.47 (0.24)</td>
<td>3.59 (0.09)</td>
<td>3.50 (0.21)</td>
</tr>
<tr>
<td>NMWU</td>
<td>3.49 (0.23)</td>
<td>3.47 (0.44)</td>
<td>3.49 (0.30)</td>
</tr>
</tbody>
</table>

* significant group WU difference, p <0.05
** significantly different from female result post STWU, p<0.05
Chapter 5 Discussion

The purpose of this study was to compare the acute effects of two independent warm-up protocols (NMWU and STWU) on soccer-specific performance tests in adolescent male and female soccer players. The peak power output, measured using a vertical jump test and the agility T-test scores were better following the STWU compared to the NMWU. Sprint running times were not statistically different after either WU protocol. The results of this research contribute to the knowledge and understanding of NMWU’s limited ability to enhance performance in soccer players, suggesting that a single familiarization session, followed by a one-time experience with a NMWU does not contain enough stimuli to increase performance compared to multiple sessions using a NMWU. Despite current research demonstrating a NMWU ability to reduce the risk of ACL injuries, adherence and compliance is low. In addition, there is a lack of research supporting a NMWU ability to enhance performance.

5.1 Methodology and results compared to similar research

In a study evaluating the effects of a one-time use of two NMWU (FIFA 11+ and Harmoknee) and a dynamic warm-up on physical performance tests in 22 amateur soccer players (eight men (age: 19.1 ± 1.3 yrs) and eight females (age: 20.1 ± 1.8 yrs)) Ayala et al. (2017) found that both NMWU resulted in slower 10 and 20 meter sprint times compared to the dynamic warm-up (Ayala et al., 2017). They also reported no statistical differences in any other components of their physical performance test battery. Based on their results, the researchers suggest a NMWU should be implemented as a training component to reduce the risk of injury rate rather than as a WU to improve performance. In contrast to Ayala et al. (2017), two studies have provided different findings, one
evaluated the effects of the Harmoknee program (Daneshjoo et al., 2013) and the other evaluated the effects of the FIFA 11+ program (Bizzini et al., 2013a) on similar performance variables as Ayala et al. (2017).

Bizzini et al. (2013a) evaluated the effects of the FIFA 11+ program by comparing baseline measures with post FIFA 11+ measures to determine if the WU had an effect on performance. Following the completion of the studies data analysis, a separate meta-analysis was conducted evaluating the results of similar studies to determine whether the results found in the Bizzini et al. (2013a) study were consistent with the literature (Bizzini, et al., 2013a). The 20 amateur male soccer players, a little older than the current participants (age: 25.5 ± 5.1 yrs) showed improvements in the performance variables measured (T-test, countermovement jump, sprint times) resulting in the conclusion that a NMWU is an appropriate WU to reduce the risk of ACL injury and should be used to prepare for optimal performance in competition. Although their conclusions were that the NMWU was an appropriate WU benefiting not hindering performance while reducing the risk of ACL injuries, they did not control for the participants’ training programs before testing. Therefore, their results could be a reflection of the training prior to testing in conjunction with the WU. Ayala et al. (2017) tested individuals with a week in between each session and controlled for training, isolating the effects of each WU protocol on performance variables.

Differences in the respective research designs may have led to these conflicting results. Ayala et al. (2017) evaluated the effects of a NMWU on performance by allowing participants one trial session prior to testing to familiarize themselves with the test protocols and the NMWU, a research design similar to the current study. Bizzini et al.
evaluated the effects of a NMWU compared to baseline following a month of NMWU familiarization prior to testing where participants became familiar with the NMWU under the coaching and guidance of FIFA certified instructors. As this research did not compare the NMWU to another form of WU, the interpretation of the findings are limited (Bizzini, et al., 2013a).

Further research evaluating the effects of the Harmoknee and the FIFA 11+ NMWU in 36 male soccer players (age: 18.9 ± 1.4 yrs) demonstrated an improvement in performance variables following both NMWU programs (Daneshjoo et al., 2013). Participants were split evenly into three groups: Harmoknee, FIFA 11+, and control group. The research was conducted over a 2-month period performing the NMWU three times a week, and the control group continued to perform their regular training. Participants in the FIFA 11+ program showed significant performance improvements in VJ (3.7%), Wall-Volley (5.4%), and in the Illinois agility test (1.7%); those in the Harmoknee group demonstrated a significant improvement (5.2%) in the Wall-Volley (Daneshjoo et al., 2013). The results of this research indicate the FIFA 11+ is capable of significantly improving performance of VJ, soccer skill (wall-volley), and agility if used consistently for an extended time, and to a lesser extent the Harmoknee program improves general soccer skill.

Important to consider, when comparing these studies, is the research design applied: Participants completed a total of 24 sessions throughout the evaluation in the Daneshjoo et al. (2013) study, while Bizzini et al. (2013a) had participants complete a month of familiarization with FIFA 11+ certified instructors. Conversely, Ayala et al. (2017), and
the present study, evaluated the impact of the NMWU following one familiarization session prior to testing.

5.1.2 Familiarity of NMWU

In this research study, each academy completed a familiarization of the NMWU, under the supervision of the research team prior to testing, to teach and encourage proper technique and biomechanics. Aside from this occasion, the NMWU was novel to the participants. Lack of knowledge and experience performing the NMWU, and lack of familiarity the NMWU, could have hindered the ability to complete the warm-up successfully and provide full benefit of the exercises. Allowing participants multiple sessions to become familiar with the NMWU could have produced similar results to those from Bizzini et al. (2013a) where the consistent use of NMWU provided improvements in the performance variables measured. Participants in the current research study were familiar with the protocols and exercises performed in the STWU and were able to complete the warm-up without coaching direction. Participants having knowledge of the exercises within the STWU and a lack of knowledge of the exercises contained within the NMWU could have created an unintentional bias towards the STWU, which was made apparent during testing and may have contributed to the results.

5.2 Duration of WU

The length of the NMWU in the present study took an average of 20-25 minutes to complete in order to ensure proper biomechanics during the familiarization session and took an average 18-20 during the testing session. During the testing session the NMWU was roughly 40% longer then the STWU with the STWU taking an average 12 mins to complete. As described in Appendix 4, the NMWU used in the present research contained
12 more exercises than the STWU, contained different exercises, and did not include a static stretching component. The additional exercises in the NMWU were dynamic exercises as well as plyometrics to encourage proper biomechanical movement patterns and increase neuromuscular control associated with preventing lower limb injuries (Vescovi & VanHeest, 2010). These additional exercises are similar to those found in the FIFA 11+, Harmoknee, and the P.E.P ACL injury prevention programs used to reduce the risk of ACL injuries (Emery & Meeuwisse, 2010; Grindstaff et al., 2006; Sadoghi et al., 2012; Soligard et al., 2008). The STWU was created using exercises identified in an observational period by both academies prior to testing. During this observational period, each academy spent an average of 10-12 minutes warming up prior to practice. The STWU was designed to take 12 minutes to complete, reflecting the WU, which was being used by both academies at the time of the study.

Previous evidence suggests acute muscle stretching might hinder the performance of activities requiring torque and maximal force output (Kokkonen, Nelson, & Cornwell, 1998; Nelson, Allen, Cornwell, & Kokkonen, 2001; Paradisis et al., 2014). In addition, neural drive muscle is decreased with acute muscle stretching, which can lead to a decrease in muscle activation resulting in a decrease in performance (Guissard, Duchateau, & Hainaut, 1988; Paradisis et al., 2014). The additional exercises included in the NMWU (Appendix 4), and not in the STWU, such as the single leg jumps and the lunges, could have played a role in limiting the participant’s ability to perform as well in the performance tests compared to the STWU due to an increase in acute muscle stretching.
5.3 Fitness of participants

5.3.1 YYIRL1

For the purpose of this research study, the YYIRL1 was completed as a means of describing the population tested. Although the results were not used in the performance analysis they are important to consider. Research has shown the performance of the YYIRL1 is closely related with physical performance in soccer matches (Bangsbo, Iaia, & Krustrup, 2008; Krustrup et al., 2003). Castagna et al (Castagna, Impellizzeri, Cecchini, Rampinini, & Avarez, 2009) reported mean YYIRL1 scores of 760 ± 283 m in 21 youth male soccer players (age 14.2 ± 0.2 yrs). When compared to the results of the Castagna et al. (2009) study, the current participant YYIRL1 results were slightly below average. Fitness of the participants therefore may have played a role in the findings of this study.

5.4 Determining optimal NMWU frequency to maximize benefits

There is a lack of available details regarding NMWU program prescription dosage; knowledge of how many sessions is required to obtain full injury prevention benefits of such a program could be used to establish a potential increase in performance. If a NMWU needs to be conducted three times a week for 6 weeks, for example, to maximize its benefits on injury prevention, research evaluating the effects of a NMWU should be conducted over a similar time frame to determine the effects on physical performance if there are any. The NMWU might need to be performed regularly over some as of yet determined period of time, perhaps similar to Bizzini et al. (2013a), in order to see an effect on performance.

Some of the components contained within a NMWU have been reported as regularly being used by strength training professionals to increase performance in athletes (Ebben et al., 2004). Further research determining if these exercises contained within a NMWU are sufficient enough to have an effect on performance needs to be conducted,
formulating an accurate time frame to allow for performance improvement. If they are found to be capable of enhancing performance then implementing a NMWU for the appropriate duration of time to see an effect would be an important next step in the development of NMWU. Evaluating the results of a longitudinal study comparing a NMWU and a dynamic WU would be an appropriate way to determine optimal NMWU frequency. The current study and that of Ayala et al. (2017) show no difference in performance following a one-time implementation, however considering the findings of others (Bizzini, et al., 2013a; Impellizzeria et al., 2013) the effects of the NMWU on performance might be obtainable following more regular, repeated implementation. Without a properly established dose response, it is difficult to determine the full benefits and limitations of the NMWU.

5.5 Knowledge Gap

Knowledge is an important factor in enhancing program adherence (Finch, 2006). With conflicting support for NMWU being an effective WU leading to enhanced performance, a different approach to improving NMWU program adherence needs to be explored. Orr et al. (2013) conducted a study evaluating knowledge of lower limb injury (ACL) preventative measures available to coaches, players, and parents to identify knowledge gaps. In this research, adolescent female soccer players, their parents and coaches were found to have a lack of knowledge pertaining to ACL injuries and available prevention programs such as NMWU (Orr et al., 2013).

A descriptive study evaluating player, parent, and coach knowledge of knee injuries and injury prevention was conducted among three age groups (U14, U16, U18) in the Edmonton Minor Soccer Association (Orr et al., 2013). 62% of coaches and 50% of parents
reported an awareness of knee injuries being preventable, but the majority were unable to select appropriate intervention strategies. Less than half of player respondents believed knee injuries to be preventable (Orr et al., 2013). In addition to these findings, 63.8% of all survey participants stated they had not received any information regarding knee injuries (Orr et al., 2013). This study provides evidence that injury prevention information is not reaching the populations such programs have been developed to help. With the individuals responsible for youth soccer athlete development and athletes themselves lacking the appropriate knowledge pertaining to available injury prevention programs, such as NMWU, adherence, compliance, and implementation will remain low.

5.6 Limitations
There are a few limitations that may have impacted the current results. This study did not control for the level of physical training implemented in the respective academy programs, nor did it account for activities participants engaged in outside of academy training. Participants competing in sports outside of their school academy during the period of the study may have been involved in activities leading to muscle fatigue during data collection sessions. Muscle fatigue could have caused the participants to be unable to produce the required force output to achieve optimal performance throughout the testing battery. Controlling for the training would have ensured each academy participated in similar activities, limiting the effects of uncontrolled external training factors.

Participant recruitment was limited to athletes participating in two school-based academies and limited only to grade 9 students. G*power (Faul et al., 2009), analysis would indicate that for an effect size of 0.3, and an alpha level of 0.05, 62 participants would be optimal to reach a power level of 80%, yet there was only 35 participants in this study.
Therefore, the study lacked power which may have affected the ability to detect small changes in performance following either WU protocol and only allowed for large changes to be detected. Expanding recruitment to athletes participating in the recreational and high-performance soccer leagues in Victoria, BC could have increased participant numbers and allowed for a more rich and diverse study population.

Soccer is a sport that requires the use of both anaerobic and aerobic energy systems to meet the physical demands of soccer (Meckel, Machnai, & Eliakim, 2009). Using a testing population with a higher YYIRL1 score might have had an important impact on the performance results following each of the WU protocols and would have allowed for a more in-depth look at the impact of a NMWU on performance.

5.7 Conclusion

In summary, this study explored the acute effects of two different WU protocols on three soccer related performance tests following a one-time use. The principle finding of this research was that no improvements in performance were observed following the implementation of the NMWU compared to the STWU. The STWU produced better Agility T-test performance and VJ peak power output compared to the NMWU. Sprint times were not affected by either WU protocol and research has suggested that acceleration, maximal speed, and agility directly reflect performance in soccer (Jovanovic et al., 2011; Little & Williams, 2005; Vescovi et al., 2011). These high-speed actions account for roughly 11% of total game play (Little & Williams, 2005). The importance of these components not being affected by either WU suggests neither WU is an appropriate means of enhancing soccer performance.
A goal of this research was to provide evidence that would encourage NMWU adherence and implementation. However, this study found that certain performance variables were enhanced following a STWU protocol as compared to the NMWU protocol. The results of this research do not suggest that a NMWU will hinder performance but rather that it may not be as beneficial in enhancing performance compared to other forms of WU. Establishing the required frequency for a NMWU to prove beneficial in reducing the risk of ACL injuries could provide a baseline for consistency in future research evaluating the effects of NMWU on performance. NMWU have proven to be effective in reducing the risk of lower limb injuries such as ACL injuries, yet adherence to such programs continues to prove challenging. Exploration of player, parent, and coach knowledge towards ACL injuries and injury prevention programs should be considered for future research.

Future research exploring WU by sex interaction on performance variables to determine if sex has an effect on a WU ability to enhance performance variables should be conducted. This research suggests a NMWU had no positive effect on physical performance compared to STWU in youth soccer athletes. In order to encourage NMWU adherence and implementation other means of motivational factors need to be explored.


Appendices

Appendix 1A. Human Research Ethics Board

Certificate of Approval

<table>
<thead>
<tr>
<th>PRINCIPAL INVESTIGATOR:</th>
<th>Kristyn Victoria Large</th>
<th>ETHICS PROTOCOL NUMBER</th>
<th>17-039</th>
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<td>Master’s Student</td>
<td>ORIGINAL APPROVAL DATE:</td>
<td>24-Feb-17</td>
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<td>UVic DEPARTMENT:</td>
<td>EPHE</td>
<td>APPROVED ON:</td>
<td>24-Feb-17</td>
</tr>
<tr>
<td>SUPERVISOR:</td>
<td>Dr. Kathy Gaul</td>
<td>APPROVAL EXPIRY DATE:</td>
<td>23-Feb-18</td>
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PROJECT TITLE: An Evaluation of the Effects of a Neuromuscular Warm-up Program on Specific Components of Athletic Performance in Youth Soccer Athletes

RESEARCH TEAM MEMBER
Dr. Kathy Gaul (Supervisor, UVic), Dr. Lynneth Stuart-Hill (Committee Member, UVic), Greg Mulligan (Lab Coordinator, UVic), Marie Schulze (RA, UVic), Nicholas Andres (RA, UVic), Paige Ryan (RA, UVic)

DECLARED PROJECT FUNDING: None

CONDITIONS OF APPROVAL

This Certificate of Approval is valid for the above term provided there is no change in the protocol.

Modifications
To make any changes to the approved research procedures in your study, please submit a "Request for Modification" form. You must receive ethics approval before proceeding with your modified protocol.

Renewals
Your ethics approval must be current for the period during which you are recruiting participants or collecting data. To renew your protocol, please submit a "Request for Renewal" form before the expiry date on your certificate. You will be sent an emailed reminder prompting you to renew your protocol about six weeks before your expiry date.

Project Closures
When you have completed all data collection activities and will have no further contact with participants, please notify the Human Research Ethics Board by submitting a "Notice of Project Completion" form.

Certification

This certifies that the UVic Human Research Ethics Board has examined this research protocol and concluded that, in all respects, the proposed research meets the appropriate standards of ethics as outlined by the University of Victoria Research Regulations Involving Human Participants.

[Signature]
Dr. Rachael Scarth
Associate Vice-President Research Operations

Certificate Issued On: 24-Feb-17
Appendix 1B. Consent Form

An Evaluation of the Effects of a Neuromuscular Warm-up Program on Specific Components of Athletic Performance in Youth Soccer Athletes

You are invited to participate in a study entitled An Evaluation of the Effects of a Neuromuscular Warm-up Program on Specific Components of Athletic Performance in Youth Soccer Athletes that is being conducted by Kristyn V. Large (MSc. Kinesiology Candidate). Kristyn is a graduate student in the department of Exercise Science, Physical and Health Education at the University of Victoria and you may contact her if you have further questions by phone: 250-208-4442, or email: kvlarge@uvic.ca

As a graduate student, I am required to conduct research as part of the requirements for a degree in Master of Science in Kinesiology. It is being conducted under the supervision of Dr. Kathy Gaul. You may contact my supervisor at 250-721-8380 or kgaul@uvic.ca.

Background
Neuromuscular warm-up programs focus on stimulating the nervous system and neuromuscular control allowing the body to better process stimuli. These warm-up programs were created with an emphasis on proper biomechanics while simultaneously preparing the body for activity. Neuromuscular warm-up programs have been demonstrated to reduce the risk of musculoskeletal injuries in males and females; research demonstrates these warm-up programs are effective in reducing the risk of anterior cruciate ligament injuries (ACL) in soccer players. Further research demonstrates such programs are most effective when implemented in youth years. Current research demonstrating the potential to reduce the risk of ACL injury through neuromuscular warm-up programs is strong, however adherence to such warm-up programs is low especially in youth athletes.

Purpose and Objectives
The purpose of this research project is to examine the effects a neuromuscular warm-up program has on different aspects of performance related to youth soccer athletes participating in local High School soccer academies in Victoria, BC. The objective is to provide supporting evidence that a neuromuscular warm-up program can enhance athletic ability to encourage program adherence among coaches, athletes, and parents.

Importance of this Research
Research of this type is important and continues to be a focus as the incidence rate of ACL injuries continues to rise. Injury prevention research suggests that prevention program adherence will increase when the program at question demonstrates a concomitant increase in athletic performance. Currently there is limited evidence
regarding a neuromuscular warm-up programs capability to enhance athletic performance in youth soccer players Contributing evidence that a neuromuscular warm-up program is capable of increasing athletic performance will encourage athletes, coaches, and parents to practice and implement a neuromuscular warm-up program in their training.

Participants Selection
You are being asked to participate in this study due to your current involvement in the soccer academy at Reynolds Secondary School or Royal Bay Secondary School. You are in grade nine, male or female, ranging in age 13-15, and actively participating in regular academy training.

Why have you been selected?
You have been selected to participate due to your current involvement in a youth soccer academy in the Lower Island Region. Your school’s academy is a representation of the male and female soccer population across the Lower Island Region and addresses the general populations level of play.

What is involved?
This study involves the following procedures:
Sessions will take place during regular academy training at the High School’s respective training facility; consisting of four sessions spread out over two weeks.

Week 1:
Introduction to the neuromuscular warm-up program; height and weight will be recorded (first session)
Yo-Yo Intermittent test (second session)

Week 2: Week of data collection

During week two, three athletic performance tests will be completed on two separate occasions (approximately 72 hours apart) following the completion of a prescribed warm-up program.

Three Performance Tests:
- T-test – Measures agility
- Vertical Jump Height – Results will be used to calculate Peak Power output
- 20-m Sprint – Measure Acceleration

Warm-up Protocols:
- Neuromuscular Warm-up Program
- Standardized Dynamic Warm-up Program

Below is an example of what the two-week research period will resemble (Example only, test days will be determined based off of academy schedule)
### Detailed Overview

#### First Session (week one):
Participants will check in at the beginning of each session; any injuries sustained preventing an individual from participation must be reported by the participant to the Principal Investigator (Kristyn V. Large) at this time. Your first session will consist of a detailed introduction to the neuromuscular warm-up program. You will be provided with a handout outlining the warm-up for you to take home. Once a thorough understanding of the warm-up has been reached coaches will resume practice as normal.

#### Second Session (week one):
Participants will check in at the beginning of each session; any injuries sustained preventing an individual from participation must be reported by the participant to the Principal Investigator (Kristyn V. Large) at this time. An overview of the Yo-Yo Intermittent Recovery test will be provided. Following the academy’s warm-up the Yo-Yo Intermittent Recovery test will be completed. A water break will be provided after completion of the warm-up prior to completing the Yo-Yo Intermittent Recovery test.

#### Third/Fourth Session (week two):

<table>
<thead>
<tr>
<th>Week 1</th>
<th>Monday</th>
<th>Tuesday</th>
<th>Wednesday</th>
<th>Thursday</th>
<th>Friday</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Introduction to Neuromuscular Warm-up Program, Height and Weight (Session 1)</td>
<td></td>
<td></td>
<td>Yo-Yo Intermittent test (Session 2)</td>
<td></td>
</tr>
<tr>
<td>Week 2</td>
<td>Warm-up Program (A or B) Followed by Athletic Performance Tests (Session 3)</td>
<td></td>
<td>Warm-up Program (opposing program from session 3) Followed by Athletic Performance Tests (Session 4)</td>
<td></td>
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</table>

Upon arrival to the first training session each participant will be assigned a participant number. This number will be used to record and track data; the participant number will be used throughout the study to ensure confidentiality.

Prior to each session participants will check in and any injuries sustained preventing an individual from participation must be reported by the participant to the Principal Investigator (Kristyn V. Large). An overview of each session will be provided following check-in to prevent confusion throughout the session.
The protocol for both days of testing (third and fourth sessions) will be the same; the warm-up protocol for the day is the only component that will change between sessions. Participants will check in at the beginning of each session; any injuries sustained preventing an individual from participation must be reported by the participant to the Principal Investigator (Kristyn V. Large) at this time. An overview of each test being completed will be provided.

Three soccer specific performance tests will be completed following each warm-up on both days of testing: agility will be measured using a T-test, acceleration will be measured with a 20-m sprint, and a vertical jump height test will be completed to calculate peak power generated from the lower extremities.

_Risks_
There are some potential risks to you by participating in this research. These include fatigue and a low risk of injury. No risk is present that is not present during regular soccer training sessions.

To prevent or to manage these risks the following steps will be taken:

a) Testing will be conducted by the Principle Investigator (Kristyn V. Large) and a team of research assistants

b) You will be familiarized with the equipment and protocols ahead of testing in order to minimize potential discomfort and any risk of injury. All methods will be explained and demonstrated in full prior to each session.

c) The teams trainers and staff will be present at all data collection session, if any injury or discomfort is experienced by a participant the on-site staff is well trained and will take the necessary steps within the school’s protocols in response to the situation. The staff present is the same staff present at all academy training sessions and are well educated on how to handle situation within the school

In the case of a medical emergency the team trainers and staff will handle injuries and discomfort to assure school protocol is followed appropriately. The principal investigator (Kristyn Victoria Large) is certified in standard first aid and cpr/aed level c (expires 01/15/2020) and will assist as needed. The named research assistants in section b project information will be present for all data collection sessions, however they will not take on any responsibilities during medical emergencies other than to offer assistance as directed by those in charge. All research staff has knowledge of human anatomy and will refer a participant to the team’s trainers and staff if they feel a participant is showing signs of an injury or discomfort throughout the testing sessions.

_Participation_
You may be excluded from participation in the study if you have sustained an injury that may prevent safe performance of any research related performance tests. Injuries that have prevented participation in the academy’s training; such injuries include (but are not limited to): sprains, breaks, muscle and/or, ligament tears, and unresolved concussions. If you have been cleared to return to play and are no longer experiencing any repercussions from the injury, you can give consent to participate at your own discretion and parental support/consent.
Benefits
By participating in this research you will gain knowledge of the importance of appropriate warm ups, the athletic performance tests will allow you to gain knowledge regarding your own personal athletic capability, your knowledge of injuries and injury prevention will be increased, and you will have the opportunity to participate in a professional research project being exposed to different research protocols.

Voluntary Participation
The Superintendent of your school board, principal of your school, and the coaching staff of your program have approved this research project and are aware of your right to participate or not. Coaches are aware that not all athletes will want to take part in the research and will coordinate alternate training for those of you who chose not to participate in the research.
Your participation and involvement in this research must be completely voluntary and will in no way have any impact on your involvement in the school’s academy program. You have the right to decline the invitation to participate. Should you choose to participate, and later change your mind, you can withdraw at any time without judgment or personal repercussion and with no risk to your status in the academy. If you chose to withdraw all data collected to date will be destroyed.

Informed consent will be obtained through the collection of consent forms and when you check in at the beginning of each session, you are consenting to participating in the session to follow.

Anonymity
Given the nature of the research testing protocols, your academy teammates who also volunteer to participate in this study will be present during the time of testing, similar to your regular academy fitness testing protocols. Therefore, your participation in the study cannot be fully anonymous.

Confidentiality
Athletes will be given participant ID numbers protecting their identity throughout the testing protocol. Athletes will not be referred to by name by the research staff. Testing protocol will include no verbal announcement of scores, and data collection sheets will be kept in the possession of the research team. Your confidentiality and the confidentiality of the data will be protected by the use of a participant code so that your data will not be identifiable to anyone other than the Principle Investigator and her supervisor. All paper data will be stored in a locked filing cabinet in McKinnon Building, room 171 in the Exercise Science, Physical and Health Education department and will have only participant codes identifying each participant.

Dissemination of Results
It is anticipated that the results of this study will be shared with others in the following ways: a written thesis, oral presentations, and published in a peer-reviewed academic journal. Upon completion the written thesis will be made available publicly online via the university library.
Disposal of Data
Data from this study will be disposed of within five years of study completion. Electronic data will be permanently erased and paper copies will be shredded.

Contacts
Individuals that may be contacted regarding this study include:
Kristyn Large, Principle Investigator
Phone: 250-208-4442
Email: kvlarge@uvic.ca

Dr. Kathy Gaul, Supervisor
Phone: 250-721-8380
Email: kgaul@uvic.ca.

In addition, you may verify the ethical approval of this study, or raise any concerns you might have, by contacting the Human Research Ethics Office at the University of Victoria (250-472-4545 or ethics@uvic.ca).

School Board 61 or 62 and the Human Research Ethics Board have approved this research project.

Your signature below indicates that you understand the above conditions of participation in this study, that you have had the opportunity to have your questions answered by the researchers, and that you consent to participate in this research project.

Pre-Test Session Consent:

<table>
<thead>
<tr>
<th>PARENTS/GUARDIANS</th>
<th>Signature</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name of Participant</td>
<td>Signature</td>
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Post-Test Session Consent:

<table>
<thead>
<tr>
<th>PARENTS/GUARDIANS</th>
<th>Signature</th>
<th>Date</th>
</tr>
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</table>

A copy of this consent will be left with you, and a copy will be taken by the researcher
Appendix 2. Rebalance MD WU
For full WU details visit http://rebalancemd.com/resources/

Soccer Warm-Up Exercises

For all warm-up exercises continue for 20 meters then jog back to the starting line.

1. Jogging & Backward Jogging

Purpose: Prepares the athlete for activity by engaging musculoskeletal system and increasing blood flow. Jogging backwards engaging the athlete’s hamstrings and hip extensors.

Instruction:
- Jog forward at a comfortable pace
- Focus on proper biomechanics of hip/knee/ankle in a straight line, keeping the knees from falling inward toward the opposite knee

2. Side-to-Side

Purpose: This exercise prepares the athlete by engaging inner and outer thigh muscles.

Instruction:
- Start with feet close together, forearms in ‘X’ across front of chest, with knees slightly bent in low ready position (Demonstrate proper position of arms with an X).
- Begin sideways leading with your left foot, pushing off with power to achieve vertical height. As you continue sideways extend arms to shoulder height
- Bring arms back to an X, returning to starting position
- Repeat for opposite direction, initiating stride out with right leg.
Appendix 3. Testing Protocol

_Yo-Yo Intermittent Recovery test Level 1 (YYIRL1)_

Participants were required to get from one end of the 20 meters to the opposing end marked by cones at a set interval indicated by the electronic beep. The test begins at a speed of 10 – 13 km•h⁻¹, following the first four shuttles the speed of the test increases to 13.5 – 14 km•h⁻¹ for a total of seven shuttles, following this the speed continues to increase 0.5 km•h⁻¹ every 8 shuttle runs. Participants have a total of 10 seconds of active recovery in the 5 meters following the 40 meter run (20m times 2).

Each participant was given a warning the first time they were unable to complete the 20m distance before the electronic beep. The second time the participant is no longer able to reach the opposing cones in the appropriate time allotted they will be asked to step off to the side and the last completed level will be recorded. Two research assistants were positioned at either end to assure athletes are meeting the timing appropriately. There is no prescribed end, athletes continued for as long as they could meet the time settings. The YYIRL1 is both a reliable and valid test (Bangsbo et al., 2008; Krustrup et al., 2003; Thomas, Dawson, & Goodman, 2006)

_Agility T-test_

Standard protocol (Semenick, 1990) was followed with the modification of Brower Timing Lights (Brower Timing System, Salt Lake City, UT) being placed at the ends of the T (Figure 1 cones C and D). Brower Timing Lights (Brower Timing System, Salt Lake City, UT) were also used to measure overall time. The additional timing lights accurately determined that participants were properly completing the T-test by touching the cones. Participants completed one trial shuffling out to the left first and one trial shuffling out to the right first. The T-test has been proven to be a valid and reliable test to measure an
athletes agility (Pauole et al., 2000). Athletes received two attempts and the best time was used for analysis. Participants began by passing through the timing light at cone A and ended the test by back peddling through the same timing light. This eliminated the possibility of error if a stopwatch had been used. Cone A will mark the start line. From this cone athletes sprinted forward to Cone B. Once arriving at Cone B, athletes side shuffled to the left to Cone D where they reached down through the timing light and touched the cone with their left hand. From this point athletes side shuffled to the right and touched Cone C with their right hand once again activating the timing light. After having touched Cone C athletes side shuffled to left back to Cone B, then back pedalled to Cone A ending the test (Refer to figure 1). Participants will complete two trials, the best trial will be used for analysis. Every participant completed their first trial before everyone completed their second trial allowing an average 2-3 minutes rest between trials.

Figure 1. T-test, Timing Light Placement (Abián et al., 2016)
Peak Power Output (Vertical Jump)

Using a vertical jump height test lower limb strength was measured by a device called the Vertec. The Gill Athletics Vertec (Gill Athletics, Champaign, IL) has a solid metal base with a vertical pole extended upward. From the pole there are coloured vanes extending horizontally and spaced ½” apart. The vanes rotate easily when tapped by a hand. Participants began in an upright standing position with feet flat on the ground. Bringing their arms back and down while lowering their body into a semi-squat position, participants were instructed to hold this position 1-2 seconds before exploding upwards as high as possible. Participants tapped the highest Vertec “vane” possible with their dominant hand (Figure 2). Protocols followed the Canadian Sport Exercise Physiology guidelines. Prior to testing participants standing reach height was collected to use the best analysis to calculate peak power output. Peak power output was calculated using the following equation: Peak Power (W) = 60.7 × (jump height [cm]) + 45.3 × (body mass [kg]) – 2055 (S. Sayers, 1999).

Figure 2. Gill Athletics Vertec (Wood, 2008)
20-meter Running Sprint test

Participants began standing at the start line in a start position, one foot in front of the other. When instructed by a researcher, the participant accelerated and sprinted as fast as possible over a pre-measured 20-m. Brower Timing Lights were positioned at the start, 5-meter, 10-meter and 20-meter intervals. 5-meter times were used to represent acceleration, 10-meter times were used to assess the participants ability to maintain speed and 20-meter times represented the overall sprint speed. Participants completed 2 trials each, every participant completed their first trial before every participant completed their second, resulting in roughly 1.5 - 2 minutes between trials. The overall best trial for each warm-up protocol was used for data analyses.
Appendix 4. Comparison of NMWU and STWU exercises

<table>
<thead>
<tr>
<th>NMWU</th>
<th>STWU</th>
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<tbody>
<tr>
<td>2. Side-to-Side</td>
<td>2. High knees</td>
</tr>
<tr>
<td>3. Carioca</td>
<td>3. Heel to Butt Kicks</td>
</tr>
<tr>
<td>5. Skipping: Double Arm</td>
<td>5. Passing drill</td>
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<tr>
<td>6. Gate Open &amp; Closed</td>
<td>6. Self-directed static stretching</td>
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<tr>
<td>7. Bunny Hops</td>
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<tr>
<td>8. Zig-Zags</td>
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<tr>
<td>9. Double Leg Jumps Forward</td>
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<tr>
<td>10. Ski Jumps</td>
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<tr>
<td>11. Single Leg Jumps</td>
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<tr>
<td>12. Jumping Header</td>
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<tr>
<td>13. Lunges &amp; Lunge with Twist</td>
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<tr>
<td>14. Long Stride Running</td>
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<tr>
<td>15. Long Leg Running with Straight Leg</td>
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<tr>
<td>16. Supermans</td>
<td></td>
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<tr>
<td>17. Picking up Grass</td>
<td></td>
</tr>
<tr>
<td>18. Brushing Grass</td>
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</tbody>
</table>
Appendix 5A. FIFA 11+

For full WU PDF visit: http://www.yrsa.ca/pdf/Fifa11/11plus_workbook_e.pdf
Appendix 5B. PEP WU

For full WU PDF visit: http://www.aclstudygroup.com/pdf/pep-program.pdf

The Santa Monica Sports Medicine Research Foundation
The PEP Program: Prevent Injury and Enhance Performance

This prevention program consists of a warm-up, stretching, strengthening, plyometrics, and sport specific agility to address potential deficits in the strength and coordination of the stabilizing muscles around the knee joint. It is important to use proper technique during all of the exercises. The coaches and trainers need to emphasize correct posture, straight up and down jumps without excessive side-to-side movement, and reinforce soft landings. This program should be completed 3 times a week. If you are using this program with athletes that are twelve or under, please perform the plyometrics over a visual line on the field or a flat 2" cone and land each jump with two feet. Do not perform single leg plyometrics with young individuals until they demonstrate substantial control. (see addendum)
The field should be set up 10 minutes prior to the warm-up. This will allow for a smooth transition between the activities. A sample field set-up has been included in your packet.

This program should take approximately 15 - 20 minutes to complete. However, when you first begin the program, it may take slightly longer due to the fact that you must first become well acquainted with the program and the transitions. Along side each exercise you will notice a box with the approximate amount of time that should be spent on each activity. This will serve as a guideline to you in order to conduct your warm-up in a time efficient manner.

Section I: Warm-up

Warming up and cooling down are a critical part of a training program. The purpose of the warm-up section is to allow the athlete to prepare for activity. By warming up your muscles first, you greatly reduce the risk of injury.

A. Jog line to line (cone to cone): Elapsed Time: 0 -.5 minute
Purpose: Allows the athletes to slowly prepare themselves for the training session while minimizing the risk for injury. Educate athletes on good running technique; keep the hip/knee/ankle in straight alignment without the knee caving in or the feet whipping out to the side.
Instruction: Complete a slow jog from near to far sideline

B. Shuttle Run (side to side): Elapsed Time: .5 to 1 minute
Purpose: engage hip muscles (inner and outer thigh). This exercise will promote increased speed. Discourage inward caving of the knee joint.
Instruction: Start is an athletic stance with a slight bend at the knee. Leading with the right foot, sidestep pushing off with the left foot (back leg). When you drive off with the back leg, be sure the hip/knee/ankle are in a straight line. Switch sides at half field.