The Effects of a Proper Warm Up in the Prevention of Musculoskeletal Strains in Collegiate Female Field Hockey Athletes

By

Chelsea Klein

Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Education

May 2017

Goucher College

Graduate Programs in Education

Table of Contents

List of Tables

Abstract

The purpose of this study was to determine if a warm up and stretching protocol would have an effect on the injury rate of lower extremity injuries. The goal was to help determine what warm up and stretching technique would help athletic performance and injury prevention. The null hypothesis, that the warm up and stretching protocol will have no effect on the rate of lower extremity injuries on field hockey female athletes, was supported. Research in this area should continue, as there is very little information available.

CHAPTER I

INTRODUCTION

Athletes and coaches often wonder if stretching and warming up before a game has an impact on injury prevention or on performance. For the majority of individuals participating in sports, pre-exercise routines including an aerobic warm-up and stretching are commonly practiced prior to engaging in physical activity. The goal of an active warm up and stretching routine is to optimize performance and reduce the incidence of injury through increased muscle temperature, muscle compliance, and efficiency of physiological responses. Although the need for a pre-exercise routine is somewhat clear, the specific elements that should be incorporated for specific sports are less obvious (Judge, Craig, Baudendistal, & Bodey, 2009).

Stretching is commonly viewed to be beneficial to athletic performance, but recent research shows evidence of “static stretch-induced impairments to subsequent performance” (Samson, Button, Chaouachi, & Behm, 2012, p. 279). Today, many athletic teams are incorporating dynamic stretching into their pre-exercise routine, but still have static stretching for sport specific flexibility. The competitive performance of field hockey players is physically challenging because it is a multi-sprint sport. Field hockey has the same number of players and a similar-sized field in comparison to soccer, making the physical demands just as high. Some of the most important movements required with field hockey are explosive trunk rotation while shooting, sprinting and endurance on offense and defense with good footwork, and keeping a low center of gravity while cutting and stick handling. All of these explosive movements occur constantly in practice and in competition. For this reason, it is essential that the body be ready to withstand these forces and perform these techniques to athletes’ best abilities. While the optimal pre-exercise routine is much debated, coaches, athletes, and athletic trainers want a routine that can help to improve an athlete’s muscle flexibility, prevent muscle injury, and enhance their physical performance for the specific athletic movements for their sport.

Muscle injuries account for one of the most common and re-occurring injuries experienced in sports and cause significant time out of sports. According to the National Collegiate Athletic Association (NCAA, 2009), collegiate field hockey players had the highest incidence rate of muscle injuries of 23.5% of total injuries from the 2004/05-2008/09 seasons. Treatment of these injuries can be problematic and sometimes frustrating for athletic trainers and team physicians. There is pressure from coaches, athletes, and parents for a sports medicine staff to quickly return a player back to sport activity after suffering a muscle injury. Because of this, a member of the sports medicine staff may permit a player to return before the injury has completely healed, predisposing an athlete to have a recurrence and a prolonged absence from competition and training. There are other suggested pre-disposing factors for muscle strains like decreased flexibility, scar tissue formation, body mechanic imbalances, and improper treatment (Melegati et al., 2013). Although there is considerable literature on methods to prevent the occurrence and recurrence of muscle injury, musculoskeletal injury rates still remain high (Melegati et al., 2013).

The services provided by athletic trainers are summarized by the six practice domains, the first domain being injury prevention and wellness protection. Athletic trainers have the responsibility to design and implement conditioning programs (flexibility, strength, cardiovascular fitness) to reduce the risk of injury and illness. There is a high demand in the athletic training profession to find the best strategy to prevent muscle injuries due to the high incidence rate and the decline in an athlete’s performance, playing time, and health.

Statement of Problem

The purpose of this study was to examine the effect of a stretching and warm up protocol on the prevention of musculoskeletal injuries of the lower body of collegiate female hockey players.

Hypothesis

A stretch and warm up protocol will have no effect on the rate of lower extremity musculoskeletal injuries on field hockey female athletes.

Operational Definitions

The independent variable was the *warm up and stretching protocol*. The warm up and stretching protocol was implemented with the women's field hockey team who performed the routine prior to practice and competition.

The dependent variable was *injury rate*. Injury rate of muscle injuries was recorded throughout the in-season through an injury tracking software called SportsWareOnLine.

CHAPTER II

REVIEW OF THE LITERATURE

This literature review examines how a proper warm up and stretching method can have an impact on the prevention of musculoskeletal strains. Typically, athletes warm up and stretch before they participate in any strenuous exercise. The thought behind a warm up and stretching routine is to enhance sport performance and prevent athletic injuries (Baechle & Earle, 2008). The first section of this review provides a background about the physiological properties of skeletal muscle and the processes that it undergoes when stretched and during warm up. The second examines the effects of warm up and stretching on sports performance. The last section reviews the relationship between flexibility and the rate of muscle injuries.

Physical Properties of Muscle

In order to develop a warm up and stretching program, there must be an understanding of the muscular system and the etiology and functional characteristics of skeletal muscle. The U.S. National Institute of Health and National Cancer Institute (NIH) explains that the structure of an individual skeletal muscle consists of many muscle fibers bundled together, wrapped together by connective tissue, and separated into compartments. The fascia helps to protect the muscle by allowing it to withstand forces against muscle contractions and protect the passageways for vessels and nerves. The connective tissues surrounding the muscle on the inside and outside extend out to help form the tendon, which attaches muscle to bone. The four characteristics of muscle are: contractility, excitability, extensibility, and elasticity (McKinley, O'Loughlin, & Bidle, 2016). Contractility refers to the shortening of muscle through muscle contractions. Myofibrils contain sarcomeres that make up each muscle fiber. During contraction, thick and thin filaments pull towards the center of the sarcomere. Before muscle contraction, excitability or "an impulse from a nerve cell" must occur that allows one end of a muscle to move while the other end of the muscle to remain somewhat "fixed" ("SEER Training: Structure of skeletal muscle," n.d.).

Looking at the applied physiology of muscle extensibility and elasticity, there are proprioceptors that have sensitive receptors that sense changes in muscle length and muscle tension. Extensibility refers to the ability for muscle to be stretched, and elasticity refers to the ability of muscle to return to its original state after being stretched (McKinley et al., 2016). In the musculoskeletal system, there are golgi tendon organs and muscle spindles that act as a "built-in protective device" (Smith, 1994, p. 14) to prevent over-stretching. If a change in muscle length goes past the limit of its elasticity, it can cause muscle damage because the muscle will not be able to return to its original resting length. Proprioceptors that detect changes in muscle length are the muscle spindles located in the muscle belly. When active or passive stretch is loaded onto a muscle, the spindles detect these changes and control the lengthening of the muscle through the stretch reflex to control muscle lengthening (Smith, 1994). Golgi tendon organs are proprioceptors that detect changes in muscle tension. They are located in the tendon that attaches muscle to bone. When a muscle contracts or is overstretched, the golgi tendon organ is activated and responds by relaxing the muscle to prevent damage to the muscle. The process is through "sarcomeric lengthening," which helps to "reduce the tension in the muscle and enables the muscle to be stretched further" (Smith, 1994, p. 14).

Mechanisms of Warm Up and Stretching

Before games and practices, athletes usually participate in a low-level exercise program to help them prepare for more strenuous exercise. According to Shellock and Prentice (1985), the two methods generally used are warm ups and stretching prior to athletic participation. The goal of a warm up is to increase body temperature to warm the musculoskeletal structures and stimulate the circulatory system to promote muscle flexibility and coordination (Smith, 1994). It has been indicated in several studies that performance improves at elevated body temperatures (Shellock & Prentice, 1985). The objective of stretching is to decrease muscle stiffness in order to stand “greater energy when forces are applied to it” (Weerapong, Hume, & Kolt, 2004, p. 198).

There are several types of warm ups. They are separated into passive, general, and specific warm-ups. Passive warm up raises the body temperature using diathermy, heating pads, steam baths, and hot showers (Shellock & Prentice, 1985). Although this method raises body temperature through external means, it “is not a practical method for most athletes” (Shellock & Prentice, 1985, p. 268). The theory behind this is that “physical performance will be improved if the body temperature is sufficiently elevated” (Shellock & Prentice, 1985, p. 269). Research has been inconclusive about whether heat and stretching causes increased range of motion in humans (Weerapong et al., 2004). Animal studies have shown how warm muscle “showed less stiffness and more load-to-failure than cold muscle” (Noonan & Best, 1993, p. 518). In most of the studies conducted, Shellock and Prentice (1985) report evidence that warming up muscle tissue reduces “muscle soreness and functional loss” (p. 271). A general type of warm up includes raising the body temperature in the whole body by performing active movements. This includes jogging, biking, jumping, etc. As compared to passive warm up, general warm up raises deep muscle temperature (Shellock & Prentice, 1985, p. 268). Lastly, a specific warm up consists of movements consistent with the type of sport to be played, but performed at a lower intensity. This method of warm up is “useful in physical performance” (Shellock & Prentice, 1985, p. 269) since the muscles most used in the sport will have an increase in muscle temperature while simultaneously training muscles before strenuous activity.

There are four different stretching methods: ballistic stretching, static stretching, proprioceptive neuromuscular facilitation, and dynamic stretching. Static stretching, one of the older stretching techniques that is still popular today, refers to passively stretching the muscle for a period of time ranging from three to sixty seconds (Shellock & Prentice, 1985, p. 273). Studies have shown a decrease in “tendon and aponeurosis stiffness” with static stretching that was held for five to ten minutes (Kubo, Kanehisa, & Fukunaga, 2001, p. 229). Alternately, it has been recommended that when performing static stretching, it should be held for thirty to sixty seconds, but no studies prove this shorter duration has a significant effect (Weerapong et al., 2004). As a muscle stretch is held for extended time, tension builds up, and “the inverse stretch reflex is invoked which induces relaxation in the muscle and enables further stretching” (Smith, 1994, p. 14). Ballistic stretching involves repetitive bounding movements in order to stretch muscles using the momentum of the body to force the muscle to its end range (Smith, 1994). In the past, research showed ballistic stretching to be more harmful than static stretching and increased the likelihood of injury because greater tension is put on the muscle due to the fast rate of stretch and rebound (Smith, 1994). Today, evidence shows that ballistic stretching is not harmful and has been “found to result in less severe muscle soreness than static stretching” (Weerapong et al., 2004, p. 196). Proprioceptive neuromuscular facilitation (PNF) combines the “contraction and relaxation of both antagonist and agonist muscles” in order to promote flexibility (Shellock & Prentice, 1985, p. 273). Some suggest PNF stretching improves range of motion better than static stretching, but there is still debate whether it is a better technique when dynamic flexibility is needed (Weerapong et al., 2004). The main reason why PNF stretching is not generally used before physical activity is because a partner who is experienced in this stretch is needed to help.

In order to understand the benefits of PNF stretching, more studies need to be conducted using the PNF method in order to examine the effects on sports performance and muscle soreness. Dynamic stretching is the last method and is essential in athletic performance, as reported by Shellock and Prentice (1985) in their review of warm up and stretching. They believe in the importance for an "extremity to be capable of moving through a non-restricted range of motion" (p. 274). This involves moving extremities gradually through the range of motion and is typically repeated ten to twelve times (Weerapong et al., 2004).

Devising a warm up and stretch routine before sport participation needs to be specific to the sport and enable the athlete to be mentally prepared for strenuous activity. Proper implementation of the warm up and stretch is just as important, which includes the amount of time for the warm up, the number of repetitions and sets of each exercise and stretch, and the avoidance of over stretching.

Effects of Warm Up on Performance

The intensity and duration of a warm up should be based on an athlete's thermoregulatory system and other external factors, like cold weather. Thermoregulation refers to the ability of the body to maintain its internal temperature. As athletes become more conditioned, they respond "more efficiently to heat produced during exercise" (Shellock & Prentice, 1985, p. 269). There needs to be a balance between the duration and intensity of a warm up in order to elevate body temperature. If the warm up is too challenging for an athlete, it could cause them to be fatigued, which hinders his or her performance. As indicated by deVries (1980), an increase in rectal temperature of at least 1 to 2 degrees Celsius appears to be most sufficient in relation to the temperature benefits of warm up. Since rectal temperature cannot realistically be obtained, the observation of mild perspiration can be another indication of optimal body temperature during warm up. The time it takes to warm up the body depends on the regulation of heat loss through evaporation, which could be forty-five to eighty minutes (Shellock & Prentice, 1985). The physiological processes that occur during a warm up indicate how performance can be improved. The Bohr Effect, described by Bohr in 1904 regarding hemoglobin's oxygen binding affinity, refers to how elevated body temperature helps the release of oxygen from hemoglobin and myoglobin during warm up (Mairbäurl, 2013). The delivery of oxygen to the metabolic system is important in helping to avoid loss of energy and fatigue during athletic performance.

The contractility and excitability of muscle also increases when muscle temperature is elevated above normal body temperature, which is important for speed and coordination (Shellock & Prentice, 1985). An increase in temperature promotes vasodilation of blood vessels in order to "deliver necessary substrates and remove byproducts to and from working muscles," as well as direct blood flow to working muscles in order to increase cardiac output (Shellock & Prentice, 1985, p. 270). Although most of these studies are relatively older, warm up is scientifically proven to have some positive effect on performance. More recent research is needed to outline the most effective and efficient warm up.

Effects of Stretching on Performance

The main goal for stretching is to enhance sports performance through flexibility, strength, power, and endurance. When Fowles, Sale, and MacDougall (2000) looked at the acute effects of static stretch, there was a loss in muscle strength. A similar case study conducted by Laur, Anderson, Geddes, Crandall, and Pincivero (2003) studied the acute effects of prolonged stretch on muscular endurance, which showed a decrease in "the maximal number of repetitions performed with a sub maximal load" and "produced higher perceived exertion scores" (p. 169). In comparison, several studies looked at the long-term effects of static, PNF stretching, or both.

The results of several studies indicated that “flexibility training of about three weeks is beneficial to some performance factors as indicated by the increase range of motion and muscle strength” (Weerapong et al., 2004, p. 202). There has been evidence showing “PNF stretching to be more effective in improving flexibility,” but it has not been consistent (Thacker, Gilchrist, Stroup, & Kimsey, 2004, p. 373). Dynamic stretching has been recently included in studies to see whether it is a useful method due to the controversy of static stretching. Weerapong et al. (2004) believed that dynamic stretching could help “to increase flexibility without decreasing athletic performance” (p. 198). Samson et al. (2012) conducted a study comparing the effects of dynamic and static stretching with the inclusion of a general or an activity specific warm-up. The results supported the use of a sport specific warm up because of the improved sprint time of the participants. Although there was no significance between the dynamic and static stretch groups, the study supports the use of static stretching with the activity specific warm-up. Looking further, Chatzopoulos, Galazoulas, Patikas, and Kotzamanidis (2014) studied the effects of dynamic and static stretching on performance factors, like balance, agility, and power, using the performance tests of a stability platform to assess balance and the 505 agility test, timed sprints to specific cones, to test acceleration. The dynamic stretching method had more benefits on performance than static stretching and no stretching because of the increase in performance of reaction time of the upper extremities. In reference to power, dynamic stretching reports positive effects in sprinting and jump performance (Perrier, Pavol, & Hoffman, 2011).

Effects of Warm Up and Stretching on Injury Prevention

According to Järvinen, Järvinen, and Kalimo (2013), “muscle injuries are one of the most common injuries occurring in sports, their frequency varying from ten to fifty-five percent of all the sustained injuries” (p. 337). Two common injuries to muscle during sport participation are contusions and strains. Contusions are caused from a "sudden, heavy extrinsic compressive force," and strains result from an "excessive intrinsic tensile force" that causes a shearing injury of the muscle (Järvinen et al., 2013, p. 337). Stretching is believed to help prevent muscle strains and muscle soreness, but recent studies report that stretching might not help prevent injuries and could potentially hinder sports performance. Understanding the principles of skeletal muscle regeneration and the healing process muscle undergoes is important in devising a warm up and stretching protocol to help avoid muscle injury and have a quicker return to play after a muscle injury.

Poor flexibility increases the chances of muscle damage when one exceeds the normal range of motion limits of a muscle. Treatment of these injuries requires the athlete to be absent from participation for a period of time, making it frustrating for athletes, coaches, and the team. There have been many studies where results have been inconclusive when comparing the effects of stretching on injury prevention. McHugh, Magnusson, and Gliem (1998) did find that any stretching method helping in the reduction of passive stiffness could be indicated in reducing muscle damage. It has not been determined whether one stretching technique is better than the other in helping prevent injury.

A case study by Malliou, Rokka, Beneka, Mavridis, and Godolias (2007) examined the effects of warm up and cool down on the rate of injury in dance aerobic instructors. The results revealed a significant relation between a fifteen-minute warm up and cool down and a decrease in the amount of injuries of instructors. The dynamic and static stretching exercises performed did not show any significance in the prevention of injuries. Injuries can occur due to other factors besides lack of flexibility or stretching for injury prevention. The combination of both warm up and stretching have yielded results showing the "effectiveness in the prevention of knee and ankle injuries" (Thacker et al., 2004, p. 374). Whether warm up or stretching exercises alone provide the same results has not been proven. Melegati et al. (2013) examined the effects of an injury prevention program of an Italian professional male soccer team on the injury rate of muscle injuries. They devised specific programs based on each athlete's lower extremity flexibility. Researchers did a pre-activity screening using procedures like the Ober test, Thomas test, and a straight-leg-raising test to identify potential problems (Melegati et al., 2013). The study demonstrated the benefits of conducting an injury prevention program specific to an athlete in reducing the amount of muscle injuries and the days absent due to an injury.

Summary

Understanding the musculoskeletal system is crucial to becoming knowledgeable regarding the biology of stretching and warm up. A sport specific warm up has been recommended by many studies before sport activities to enhance body temperature and train the muscles most used in the type of sport. Most studies find static and ballistic stretching to have increased negative effects than dynamic stretching on performance factors. In order to prove dynamic stretching to be the superior method of stretching, more studies need to be conducted. The review of the studies showed no evidence on what stretching technique worked best in helping to prevent muscle injury.

CHAPTER III

METHODS

The purpose of this study was to examine the effect of a stretching and warm up protocol on the prevention of lower extremity injuries.

Design

The study used a quasi-experimental pre/post design. The design consisted of comparing the rate of musculoskeletal injuries to the lower body of each student-athlete from the Fall 2015 season to the Fall 2016 season. The stretching and warm up protocol was implemented over the Fall 2016 semester period (about five months). The dependent variable was injury rate and the independent variable was the warm up and stretching protocol that was implemented for the whole season.

Participants

Participants were from a convenience sample based on being a Division III athlete at the college where the researcher is an assistant athletic trainer. They were team members of the women's field hockey team at a Division III institution in a suburban area in the mid-Atlantic region of the United States. There were twenty-seven student-athletes that were aged 18-21 years who participated in the study. Individuals were excluded if they were still receiving treatments or were not back for full sport activity.

Instrument

The instrument used was the SportsWareOnLine software to assess student-athletes' previous acute or chronic injuries of the Fall 2015 season. SportsWareOnLine was also used to document the injuries that occurred during the Fall 2016 season, specifically the date of injury, type of injury, and location of injury. Only the examiner will have access to this information, keeping the athletes' injuries confidential.

Procedure

Participants were instructed to maintain their normal habits for the duration of the season. The warm up and stretching protocol was developed based on recent research and the past warm up and stretching the field hockey team performed last season. The examiner instructed and demonstrated the new fifteen minute warm up and stretching protocol on the first day of pre-season so that the team could perform it properly before the start of the season. The participants performed this protocol before each practice session and game on one half of the turf field. The examiner supervised the warm up and stretch and helped the participants perfect their movements. The warm up and stretching protocol implemented in walking distance of twenty yards repeating on alternating sides was (Figure 1.):

1. Jog one lap around half field.
2. Standing static quadriceps stretch: Grab the ankle of one leg with the same side hand, keeping chest tall and knee tucked in.
3. Jogging butt kicks (dynamic stretch for quadriceps and hip flexors): Begin jogging by flexing knee and bringing heel back and around to buttocks while maintaining a forward lean.
4. Walking knee hugs (dynamic stretch for gluteals): Bend one knee up into the chest, and then with the same side hand, hug the knee across the opposite shoulder.
5. Dynamic walking with high knees (dynamic stretch for gluteals, quadriceps, lower back, and shoulders): Take an exaggerated high step, driving the knee as high as possible, and simultaneously push up on the toes of opposite foot, using a proper arm swing.
6. Light jog with trunk rotation to both sides (dynamic stretch of abdominal obliques).

7. Lunges forward (dynamic stretch for hip flexor and core): Step forward with one leg, bending the front knee and dropping the back knee straight toward to the ground. Reach both arms overhead and slightly lean back, pushing the back hip forward.
8. Lunges forward (dynamic stretch for groin and hip adductors): Step forward with one leg, bending the front knee and dropping back knee straight toward the ground. Reach arm overhead of the same side of the leg bent behind while keeping lower back and back leg straight, bending the front knee to 90 degrees. Bring feet together and return to standing.
9. Over and under the fence hip stretch (dynamic stretch for hip flexors and groin): Every three steps, march one knee towards your chest, rotate out to the side while keeping it bent, and then return to the ground. Alternate and repeat for half distance, and then switch to circle in across the body and return to the ground.
10. Inverted hamstring stretch with arm reach (dynamic stretch for hamstrings): Stand on one leg with same side arm down, bend over at waist and kick opposite heel to sky to comfortable height, then stand and step back with other foot.
11. Standing figure four stretch (static stretch of the piriformis muscle): Put one leg with the ankle on top of the other knee, lean forward with a straight back at the waist, and on the knee of the weight bearing leg, hold for five seconds.
12. Dynamic figure four stretch (dynamic stretch of the piriformis muscle): Move hip in an upward direction with external rotation while jogging.
13. Ground sweeps (dynamic stretch for hamstring and calves): Step forward with one foot, swing arms backwards, then slowly sweep arms forward, brushing finger tips against the ground then return to standing.

14.Frankenstein stretch (dynamic stretch for hamstrings): Kick one leg up in the air to a comfortable height while trying to touch the toe with the opposite arm.

15.Calf stretch (static stretch of gastrocnemius and soleus): Forced ankle dorsiflexion with knee bent and straight for two sets of twenty second holds.

14. Leg swings (dynamic stretch for quadriceps, hamstrings, and hip adductors and flexors): Swing legs side to side and forward to backward twenty five times each.

15. Shoulder mobility with strap (improve range of motion in shoulders): Move strap with elbows straight overhead and behind, move in clockwise and counterclockwise around center of body, and shoulder internal and external rotation behind the back.

After the participants completed the stretching and warm up protocol, they either began practice or lined up the field to do introductions before the start of a game.

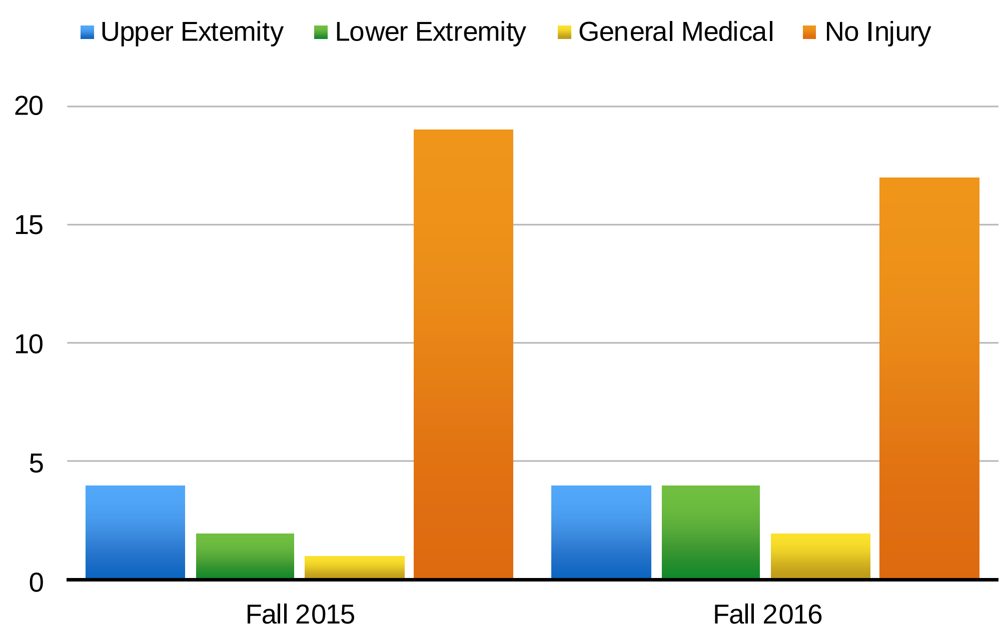
CHAPTER IV

RESULTS

The purpose of this study was to examine the effect of a warm up and stretching protocol on the number of injuries collegiate female field hockey players at a Division III institution. Due to the small number of injuries, no statistical analysis could be performed. The null hypothesis, that the warm up and stretching protocol would have no effect on injury rates, was supported. The Fall 2016 season had more injuries with the implemented warm up and stretching protocol compared to the fall 2015 season. Of the injuries that occurred, most were upper and lower extremity injuries (Figure 1).

Figure 1.

Number of Injuries for Fall 2015 and Fall 2016 Field Hockey Seasons



CHAPTER V

DISCUSSION

The results of this study confirmed the null hypothesis that proposed a stretch and warm up protocol will have no effect on the rate of lower extremity injuries on field hockey female athletes. Although no statistical analysis was conducted, the data indicated an increase in the number of injuries in Fall 2015 compared to the Fall 2016 season.

Implications of the Results

The results demonstrate that the field hockey female athletes were not significantly affected by the stretch and warm up protocol that was implemented prior to the start of the Fall 2016 season. This study utilized a pre- and posttest design in order to see a change in the value of the dependent variable, injury rate, which could be expected to occur with exposure to the warm up and stretching protocol. Compared to the season prior, there was an increase in the injury rate of lower extremity injuries.

Theoretical Consequences

From a theoretical standpoint, this study suggests that warm up and stretching protocols do not necessarily have an effect on injury rates of athletes. It appears that a pre-exercise routine can physically prepare athletes for strenuous activity, but not always prevent injuries.

Threats to Validity

There were several threats to the validity of this study that compromised the results. First, the participants were selected from one liberal arts college located in a suburb of the Atlantic coast of the United States. The study examined only a selection of athletes who came from one school, which had limited diversity. In this case, the diversity of the subjects was so small, female field hockey players, that the results may not be generalized to other athletic populations.

Tailoring the warm up and stretching program to field hockey players also reduces the overall generalizability of this study since sport participation needs are different for specific sports in order to enable an athlete to be physically and mentally prepared for strenuous activity.

Another important concern for the reliability of this study is the efficiency of recording injuries. There was more than one athletic trainer recording initial injuries for both the Fall 2015 and 2016 field hockey seasons using SportsWareOnLine. This could have influenced inter-rater reliability due to inconsistency of multiple observers recording injuries. Each athletic trainer has different educational backgrounds and perceptions on the proper treatment of specific injuries.

Connections to Previous Studies/Existing Literature

There have not been many studies that demonstrate which stretching technique works best in helping to prevent injuries. However, there was a recent study done that examined the effects of an injury prevention program of an Italian professional male soccer team on the injury rate of muscle injuries of the lower extremity (Melegati et al., 2013). Like this study, the researchers focused on injuries of the lower extremity, devised a program based on the specifications of the sport, and performed a comparison of injury rates from the year prior. The differences between the studies were the use of "pre-activity screening procedures" to plan the "injury prevention program," magnetic resonance imaging to have a clear diagnosis of a muscle injury, and recording of days absent due to injury (Melegati et al., 2013). In conclusion, their personalized injury prevention program had a positive effect on the reduction of muscle injuries and days absent due to injury. Having more observers for injury documentation, implementation of screening procedures, and access to diagnostic imaging could have helped this study be more successful in finding a significance in a warm up and stretching protocol on the prevention of lower extremity injuries.

Implications for Future Research

There is a common theme in athletics of incorporating a warm up and stretch in a team's pre-exercise routine, but it is still unclear what elements should be incorporated for specific sports that can help to improve an athlete's flexibility, prevent injuries, and enhance their physical performance. Although there have not been many studies that provides evidence as to which technique works best in helping to prevent injuries, the studies that examine the effects of warm up and stretching on injury prevention and athletic performance are compelling and significant.

Future studies could use a similar intervention that was used in this study; however, larger studies are needed in order for conclusions to be made. Another implication is that kinesiologic testing of flexibility and strength of the lower extremity could be used in the future to create a personalized warm up and stretching program for injury prevention. Lastly, accurate recording of injuries and application of set criteria for lower extremity injuries are needed in order to eliminate confusion about diagnosis of injuries and to spot trends in the evaluation of best practices.

Summary

Athletic performance and injury will always play a major role in collegiate athletics in any division. This study upheld the null hypothesis and indicated that the warm up and stretching protocol did not have an effect on the field hockey players' injury rates, contingent on the fact recording was done properly; instead, the injuries increased. Although this study provided information about the need for a pre-participation routine, more research needs to be conducted to discover which warm up and stretching program is best suited for each sport to decrease the occurrence of lower extremity injuries.

References

Baechle, T. R., & Earle, R. W. (2008). *Essentials of Strength Training and Conditioning* (3rd ed.). Champaign, IL: National Strength & Conditioning Association.

Chatzopoulos, D., Galazoulas, C., Patikas, D., & Kotzamanidis, C. (2014). Acute effects of static and dynamic stretching on balance, agility, reaction time and movement time. *Journal of Sports Science and Medicine, 13*, 403-409.

deVries, H. (1980). *Physiology of exercise: For physical education and athletics* (4th ed). Dubuque: William C. Brown.

Fowles, J., Sale, D., & MacDougall, J. (2000). Reduced strength after passive stretch of the human plantar flexors. *Journal of Applied Physiology*, *89*, 1179-88.

Järvinen, T. A. H., Järvinen, M., & Kalimo, H. (2013). Regeneration of injured skeletal muscle after the injury. *Muscles, Ligaments & Tendons Journal (MLTJ), 3*(4), 337-345.

Judge, L. W., Craig, B., Baudendistal, & Bodey, K. J. (2009). An examination of the stretching practices of Division I and III college football programs in the Midwestern United States. *Journal of Strength & Conditioning Research*, *23*(4): 1091-1096.

Kubo, K., Kanehisa, H., & Fukunaga, T. (2001). Is passive stiffness in human muscles related to the elasticity of tendon structures? *European Jounal of Applied Physiology*, *85*, 226-232.

Laur, D., Anderson, T., Geddes, G., Crandall, A., & Pincivero, D. (2003). The effects of acute stretching on hamstring muscle fatigue and perceived exertion. *Journal of Sports Science*, *26*, 261-72.

McHugh, M., Magnusson, S., & Gliem, G. (1998). The role of mechanical and neural restraints to joint range of motion during passive stretch. *Medicine Science Sports Exercise*, *30,* 928-932.

McKinley, M., O'Loughlin, V., & Bidle, T. (2016). *Anatomy & Physiology: An Integrative Approach* (2nd ed.). London, US: McGraw-Hill Education.

Mairbäurl, H. (2013). Red blood cells in sports: Effects of exercise and training on oxygen supply by red blood cells. *Frontiers in Physiology*, *4*, 332.

Malliou, P., Rokka, S., Beneka, A., Mavridis, G., & Godolias, G. (2007). Reducing risk of injury due to warm up and cool down in dance aerobic instructors. *Journal of Back & Musculoskeletal Rehabilitation*, *20*(1), 29-35.

Melegati, G., Tornese, D., Gevi, M., Trabattoni, A., Pozzi, G., Schonhuber, H., & Volpi, P. (2013). Reducing muscle injuries and reinjuries in one Italian professional male soccer team. *Muscles, Ligaments & Tendons Journal (MLTJ)*, *3*(4), 324-330.

NCAA Sports Medicine Handbook. (2009). Field hockey injuries: Data from the 2004/05 to 2008/09 seasons. *NCAA*.

Noonan, T., & Best, T. (1993). Thermal effects on skeletal muscle tensile behavior. *The American Journal of Sports Medicine*, *21*, 517-25.

Perrier, E., Pavol, M., & Hoffman, M. (2011). The acute effects of a warm-up including static or dynamic stretching on countermovement jump height, reaction time, and flexibility. *The Journal of Strength and Conditioning Research*, *25*, 1925-1931.

Samson, M., Button, D. C., Chaouachi, A., & Behm, D. G. (2012). Effects of dynamic and static stretching within general and activity specific warm-up protocols. *Journal of Sports Science & Medicine*, *11*(2), 279-285.

SEER Training: Structure of skeletal muscle. (n.d.). Retrieved April 14, 2016 from the U.S. National Institutes of Health, National Cancer Institute. Retrieved from http://training.seer.cancer.gov/anatomy/muscular/structure.html

Shellock, F., & Prentice, W. (1985). Warming-up and stretching for improved physical performance and prevention of sports-related injuries. *Sports Medicine*, *2*(4), 267-278.

Smith, C. (1994). The warm-up procedure: To stretch or not to stretch. A brief review. *Journal of Sports Science & Medicine*, *19*(1), 12-17.

Thacker, S., Gilchrist, J., Stroup, D., & Kimsey, C. (2004). The impact of stretching on sports injury risk: A systematic review of the literature. *American College of Sports Medicine, 36*(3), 371-378.

Weerapong, P, Hume, P. A., & Kolt, G. S. (2004). Stretching: Mechanisms and benefits for sport performance and injury prevention. *Physical Therapy Reviews*, *9*(4), 189-206.

Appendix A

Table 1.

Stretching and warm up protocol

1	Jog one lap half field	
2	Standing static quadriceps stretch	Jogging butt kicks
3	Walking knee hugs	A-skips
4	Light jog with trunk rotation	
5	Lunge forward with arms in air	Lunge forward with arm reach to same side
6	Over and under the fence	
7	Inverted hamstring stretch	
8	Standing figure four stretch	Figure four dynamic stretch
9	Ground sweeps	Frankensteins
10	Calf stretch (along fence)	
11	Leg swings (along fence)	
12	Shoulder mobility with strap (group huddle)	

* If there is one technique in the row, the participants did that technique up and down twenty yards. If there is two techniques in the row, the participants did the one technique up and the other technique coming back the twenty yards.