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A Comparison of Hamstring Injury Recovery Rates in Male and Female Athletes

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in Male and Female Athletes

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I. Introduction

Hamstring injuries are among the most common muscular injuries sustained by athletes across multiple levels of various sports (Askling et al). Most hamstring injuries occur during similar movements and under similar conditions, where the muscle is required to be explosive. Thus, athletes that participate in sports where "sprinting, kicking, or high-speed skilled movements" are required, experience an increased likelihood of suffering a hamstring injury (Erickson and Sherry). After injury, athletes are then subjected to different methods of rehabilitation to heal and strengthen the afflicted area. However, some athletes take longer than others to return and impatience may lead to a premature return to sport. Further compounding the importance of adequate rehabilitation, Erickson and Sherry's research has determined that after an athlete is cleared to return, approximately one-third of hamstring injuries will recur with the risk being higher during the first two weeks.

Researchers speculate that outside of intense skilled movements, there are other etiologies that come from the within the athlete. These intrinsic factors include "insufficient flexibility, inadequate strength or an imbalance in strength and/or endurance… insufficient warm-up, premature return to activity following initial injury, and previous injury" (Kroll and Raya). Insufficient flexibility is a popular theory for causing hamstring injuries; however, data is inconclusive about whether increased flexibility prevents the injury, or if it is the increased muscle length that dually decreases the muscle strength. Arguments about inadequate strength cite that overcompensation in the stronger leg or surrounding muscles of the weaker leg can lead to an injury. Insufficient warm-up is also cited as a source of hamstring injuries because as the muscle temperature increases, so does the "load at which muscle tissue would fail when loaded," meaning that the muscle is prepared to sustain more force (Kroll and Raya). A premature return to activity is a common cause of hamstring injuries because the athlete will begin to stress the muscle at pre-injury levels without maintaining the pre-injury strength in those muscles. Similarly, previous hamstring injuries can predispose an athlete to a recurrent injury because of a weakness in the muscle.

Hamstring strains, complete tears, partial tears, spasms, and tendinitis are just some of the possible injuries (Askling et al). Hamstring strains can be organized into three different categories depending upon the severity of the injury. Kroll and Raya identify the different kinds of muscle injuries based on severity. Grade 1 strains are referring to the least severe injury and "represent only minor disruption of the muscle fibers." Grade 2 injuries are more severe as they involve partial tears of the muscle, but function and strength remain intact. Grade 3 injuries are the most severe and refer to a large or complete tear of the muscle fiber.

The location of the injury within the muscle also plays a pivotal role in determining the severity of the injury. As mentioned earlier, hamstring injuries often occur during an explosive movement, where the muscle must contract and lengthen at the same time. Most often, the injury is found in the "region of the biceps femoris… near the proximal muscle-tendon junction… near the common origin of the biceps and semitendinosus" (Kroll and Raya). However, research has shown that some of the worst hamstring injuries, in reference to recovery time, occurred at the "distal tendinous hamstring complex" (Kroll and Raya).

To further understand a hamstring injury, knowledge of the anatomy of the hamstring is crucial. Although the muscle is often called the hamstring, the term actually refers collectively to a group of muscles on the posterior aspect of the thigh. As shown in Figure 1 below, these three muscles are the semimembranosus, semitendinosus, and the biceps femoris. These muscles run the length of the thigh from the hip down to the knee and are considered biarticulate muscles. They can simultaneously function together to perform both flexion and extension movements (Kroll and Raya). An injury to any of these three muscles, whether it is a stretching, tightening, or tearing of the fibers, is referred to as a hamstring injury.

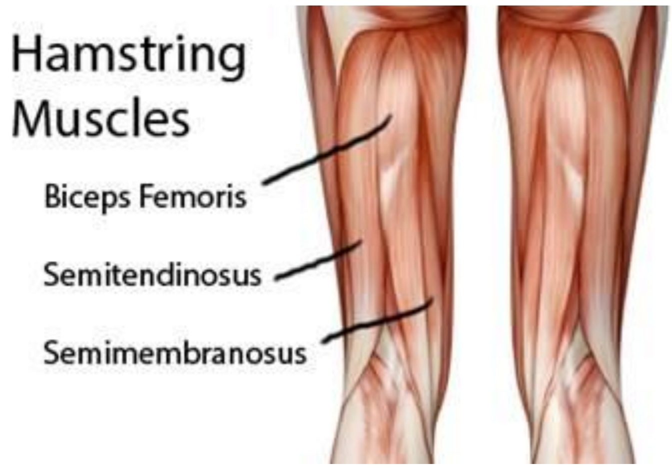

Figure 1: Anatomy of the Hamstring (www.centerworks.com/improving-knee-strength-with-a-2-leg-hamstring-curl-exercise/.)

Another factor that is considered when discussing hamstring injuries in athletes is the prevalence between genders. In general, there is much research about differences between males and females in sports, including injury risks, injury rates, and injury reactions. Research done by Richard Lanese and his colleagues determined that within technically similar sports, the rates of injury, types of injury, and sites of injury were similar. Additionally, research comparing technically different sports with diverse loading patterns reported similar results. Leena Ristolainen and her colleagues studied cross country skiers, swimmers, long-distance runners, and soccer players and found that overall, there were no gender differences in the incidence of acute or overuse injuries. However, there were some differences between genders in the commonality of the anatomical locations of the injuries.

Another study also compared the previously mentioned factors and found that females are injured less often than males when compared across all age groups. Furthermore, males and females are “more similar than different in injury rates across a variety of ages, sports, and levels of play” (Wiese-Bjornstal et al). When comparing behavioral and emotional responses to injuries, it was again found that both genders were relatively similar; however, female athletes reported higher anxiety levels about being perceived as weak while recovering from an injury. Wiest-Bjornstal and colleagues also found that when specifically comparing hamstring injuries, females experiences lower rates of injuries than their male counterparts, and the females’ greater flexibility was cited as a source of protection. Further research, specifically on hamstring injuries in male and female soccer players, determined that men have an “overall higher incidence rate of hamstring strains than women in collegiate soccer” (Cross et al).

The aforementioned difference in hamstring flexibility is one of the most prevalent topics of discussion as an etiology for different rates of hamstring injuries between genders. In a study about running mechanics in flexible and inflexible males and females, it was found that flexible females had greater hip flexion, whereas flexible males had greater peak knee extension than females. Thus, it was determined that different levels of flexibility created compensations in running mechanics that possibly caused the runner to be more susceptible to hamstring injuries (Wiese-Bjornstal).

II. Rehabilitation

Once an athlete sustains a hamstring injury, they often enter a rehabilitation process that aims at healing the muscle. The goal is to return the athlete to sport as soon as possible. Depending on the athletic trainer assigned to the athlete and the severity of the injury, the rehabilitation process varies. Hillary Malmberg has been a certified athletic trainer for eight years, and she has had the opportunity to work with Division One NCAA cross country, track and field, lacrosse, wrestling, soccer, tennis, and basketball athletes. In an interview about her experiences with hamstring injuries, she said they occur no more or less often than other injuries. However, she had noticed differences in the types of athletes with the injuries. Sprinters and soccer players most often presented with hamstring injuries, whereas most other athletes simply presented with hamstring soreness. She noted that deceleration from sprinting was the most common cause of her athletes' injuries, with some occurring during a cutting motion, and few occurring while lifting weights.

When asked about treating males and females, she doesn't approach their hamstring injuries differently in the treatment process, but rather tailors the athletes' rehabilitation to the sport instead of the gender. She determines the severity of the injury through resistive range of motion (ROM) and break testing and then assigns the injury to a number between one and five. A number one is assigned to the most severe of injuries, meaning the athlete exhibits no ROM, and only a muscle twitch is present. As the numbers increase to five, the ROM and muscle strength increases. Once assigned a number, her athletes work through a progression of exercises that focus on the firing of the muscle and increasing ROM. Then, they begin to work on open and close chain exercises which involve non-weight bearing and weight-bearing activities respectfully. Further into treatment, her athletes work on concentric and eccentric exercises. Concentric exercises focus on shortening the muscle while eccentric exercises focus on lengthening the muscle. Finally, her athletes then progress to sport specific work. From there, she monitors their progress until she sees that they are fit to return to sport. Once released, the athlete may still be under some restrictions until further notice from the trainer.

When asked about susceptibility to hamstring injuries, Hillary believes that female athletes are slightly more susceptible because of their hamstring to quadriceps ratio. This is normally a 2:1 ratio; however, it is slightly skewed in females as most females are seen to be quad dominant rather than hamstring dominant. She is unsure whether this increased susceptibility is due to training differences or biomechanical differences. Concerning recovery time, her experience has shown that more females complete a full recovery but then experience a recurrent injury. However, most males will return to sport and continue to play with a lingering pain that never entirely went away from the original injury.

In another interview, John Marshall discussed his experience working with athletes who have hamstring injuries. John has been a certified athletic trainer for four years and has mainly worked with football, men's basketball, and men's track and field. However, he has had experience treating females occasionally as well. In the past four years he has seen hamstring injuries no more or less than any other injuries; however, the incidence rates differ greatly between the sports with which he works. For instance, it wouldn't surprise him for his track and field athletes to present with a hamstring injury, but it is quite rare for a basketball player to sustain one. Currently, about twenty five percent of the roster he is working with is being treated for hamstring injuries.

In his athletes who present with hamstring injuries, the issue is usually noted at either the beginning of a workout, or towards the tail end of practice. He hypothesizes that this has to do with an insufficient warm-up period followed by an explosive movement or from fatigue setting in near the end of a workout and the correct form breaking down. Most often however, his athletes present with a hamstring injury that occurred from a combination of causes rather than a distinct incident. For example, most of his athletes complain of an issue after two to three days of hard practices and lifting, without much recovery time between a heavy weights session and the following practice. Thus, the injury is more from overloading the muscle rather than an acute episode.

When asked about treating males and females, John said he does not approach their rehab any differently. The workouts are instead tailored more to the sport and preference of the athlete. His evaluation of the severity is similar to that of Hillary Malmberg's mentioned above. He uses a manual muscle test with scores ranging from zero to five as the athlete progresses through a series of resisted movements. He also mentioned performing palpation tests on the injured leg with comparison to the uninjured leg to identify a significant tear in the muscle belly. His determination of an athlete's readiness to return to sport was also similar to Hillary's as he uses a rehabilitation continuum that progresses to movements normally associated with the sport. He also mentioned that patient comfort and pain tolerance are large factors in the determination process. For example, some athletes have remained in therapy for months because they feel uncomfortable returning to full usage of the muscle. Yet, some athletes return in one to two weeks because their pain tolerance may be higher.

In his experience, he hasn't noticed any differences in the length of time it takes males and females to recover from hamstring injuries. He noted that this may be due to his lack of experience treating females compared to males. When asked about whether or not females or males are naturally more susceptible to a hamstring injury, he stated that he believes females are at a higher risk. He explained that this belief is based upon research he has read over the last few years. In the research, he has seen that the hormonal fluctuations associated with a woman's menstrual cycle can affect the structural integrity of tendons and ligaments and thus perhaps the muscles. about how a woman's menstrual cycle causes hormonal imbalances. However, he believes that though women may be more susceptible to injuries, they have a naturally higher pain tolerance, which may lead to a female athlete returning to sport faster.

Research conducted by Penny G Kroll and Michelle A Raya has shown that rehabilitation of strength, flexibility, and motor control parameters to preinjury level is critical to prevent reinjury. The purpose of their study was to review the anatomy and biomechanics of the hamstring muscles in relationship to the lower extremities and low back, and to examine possible etiologies, treatments, and preventions of intrinsic hamstring injuries. This research was conducted through a review of pre-existing literature.

Biarticulated type II muscles are particularly susceptible to strains as they often have dual multiple functions. The primary function of the hamstrings is to decelerate the tibia, extend the hip, and stabilize the pelvis while eccentrically counteracting the quadriceps. Injury to the muscle can come from direct or indirect trauma, but oftentimes comes from powerful contractions combined with a forced muscle lengthening. These strains can be categorized into grade 1, 2, or 3 and increase in severity from a minor disruption of muscle fibers to a complete tear (Kroll and Raya).

The researchers determined that there are many possible etiologies leading to a hamstring injury including insufficient flexibility, inadequate strength, inadequate muscle balance, dyssynergic contraction, insufficient warm-up, and premature return to activity following initial injury. There is contradictory data to support these etiologies; however, the researchers concluded that a combination of such factors often plays a role in causing hamstring injuries. The anatomy and dual function of the hamstring at the hip and knee may also play a role in explaining some injuries.

Further research concerning the importance of rehabilitation of a hamstring injury was conducted by Lauren N. Erickson and Marc A. Sherry. They attempted to provide a summary of current evidence for clinicians to improve rehabilitation quality and decision making for athletes returning to sport after a hamstring related injury. The researchers conducted a review of the available literature on epidemiology, risk factors, diagnosis, prognosis, and rehabilitation program interventions for hamstring injuries. They determined that there is an increased risk in sports involving sprinting, kicking, and high-speed skilled movements. They also noted that modifiable risk factors exist such as muscle fatigue, strength imbalance, and reduced flexibility. Furthermore, the injuries most commonly occurred in competitions rather than practice and in the preseason rather than during the regular season. They noted that the most common mechanism leading to a hamstring injury is during the terminal swing phase while running. At this point in time the hamstrings are experiencing conflicting actions as they are at their greatest stretch while also eccentrically contracting.

Erickson and Sherry's statistics showed that the biceps femoris is injured more often than any other portion of the hamstring because of its tendency to increase in activity by 67%

when running speed increases from 80-100%. They also determined that a prior hamstring injury makes the likelihood two times greater for a subsequent hamstring injury, which may be due to the abnormal organization of collagen in the scar tissue. Regarding gender, males were 64% more likely to experience a hamstring strain than females. They concluded that rehabilitation including neuromuscular control, progressive agility, trunk stabilization, and eccentric strength training is most effective at promoting a return to sport. These techniques are also effective for minimizing the risk of re-injury, especially if they are continued even after the return to sport.

Another study that dealt with return to competition after a hamstring injury was conducted to determine if baseline clinical measurements could accurately predict the time of recovery to pre-injury level in athletes. Researchers hypothesized that the clinical findings would reflect the hamstring injury severity at presentation and predict the time to sports resumption. The study was conducted between July 2008 to April 2009 at four centers in France with five medical specialists. Subjects presented within five days of sudden onset pain that occurred during a sporting activity but were excluded if they had a prior injury to the same muscle within the last twelve months. After forty-five days of rehabilitation, they completed a follow-up interview over the phone. The patients were then categorized into two groups based on an early or late recovery, defined as less than forty days and more than forty days respectively (Guillodo et al.).

The results included hamstring injuries for one hundred and twenty patients, specifically one hundred and eight men and twelve women between ages thirteen and sixty-one. Seventy-two injuries were sustained in competition and forty-eight were sustained in training. Sixty-five of the subjects fell into the early recovery category and fifty-five patients fell into the late recovery category. Data analyses determined that the following five specific evaluations were significantly associated with late recovery: visual analog scale (VAS) pain score for pain levels greater than 6, a popping sound during injury, pain every day for more than 3 days, bruising, and more than 15 degrees of motion limitation in the injured side comparatively. The researchers concluded that the baseline clinical evaluation information provided valuable information for predicting the time of recovery to the pre-injury level (Guilodo et al). It is important to note that one limitation to this study was that there were very few females included in the subject pool. Thus, the results may only apply to males.

Research by Carl Askling and his colleagues has been conducted specifically to compare hamstring injury recovery times between sports. The researchers hypothesized that hamstring strains in different sports with similar injury situations would show similarities in symptoms, location, and recovery time. There were thirty subjects from twenty-one sports who had acute sudden posterior thigh pain that occurred from competition, training, or performing. Subjects with earlier injuries or ruptures were excluded. The subjects were given an MRI and interviewed about the movements that lead up to the injury. The results showed that all thirty injuries occurred with extensive hip flexion while the knee was extended. The semimembranosus muscle was the most commonly injured, occurring in 83% of the subjects. The median return time was thirty-one weeks. Fourteen athletes ended their careers because of the injury, while sixteen who continued to play had persistent issues. There was no significant relationship between the location of the pain and the recovery time (Askling et al).

Askling and his colleagues concluded that despite different sports, extensive hip flexion and knee extension led to specific injuries in the proximal posterior thigh. However, it is important to note that two major limitations existed in this study. First, the timing of the

MRIs was not consistent between athletes, so some were further removed from their injury than others, which could account for different results. Second, the rehabilitation programs between the athletes were not controlled, which could account for differences in results.

In addition to comparing recovery time between genders and sports, studies have been conducted to identify future injury risk in athletes who have already sustained a hamstring injury. One such study was conducted using muscle functional magnetic resonance imaging (mfMRI) to examine the risk of sustaining a recurrent injury in male soccer players. The recruitment of soccer players from seven recreational clubs occurred between March and May of 2013. Twenty-seven subjects with a recent history of hamstring injuries and twenty-seven control subjects who were injury free at the time of the mfMRI were selected. In July 2013 the subjects were scanned, then performed a strenuous eccentric hamstring exercise, and were scanned again. The mfMRI was analyzed for a T2 shift in the muscle belly showing the amount of metabolic muscle activity for each component of the hamstring. The athletes then kept a weekly log of their soccer exposure and injury incidence. During the winter of 2014-2015 season, the athletes were contacted for a final injury inquiry and were placed in the following categories: healthy controls, injury history but no recurring injury, index injury, and reinjury (Schuermans et al).

Ten subjects were lost, with twenty-four remaining in the control group and twenty remaining in the injury history group. Four of the forty-four remaining players sustained a first-time injury and six sustained a recurrent injury. The mfMRI results showed that the recurrent injury group had a significantly higher T2 shift in the bicep femoris and semimembranosus. There were no significant differences in comparing the recurrent injury group's data, but those subjects did demonstrate significantly poorer strength endurance. The researchers concluded that the hierarchic shift in the metabolic activity contribution is partly responsible for first-time hamstring injuries. Furthermore, this altered pattern of muscle activation is associated with poorer strength endurance (Schuermans et al). One major limitation to this study worth mentioning is that the cohort only included males.

III. Differences Between Males and Females

There have been multiple studies conducted that aimed at determining whether males or females experience higher rates of injury while participating in sports. One particular study examined male and female injury rates while controlling for length of exposure to injury. Richard R. Lanese and colleagues conducted a study on the following teams at one university: basketball, fencing, gymnastics, swimming, tennis, indoor track, outdoor track, and volleyball. It was not specified whether each team sport had both a male and female team. Injuries were totaled from the first day of practice through the last athletic exposure and were then analyzed for differences between genders.

The results showed that 42% of men and 39% of women sustained injuries. Within each sport, there were only small gender differences that were inconsistent and not statistically significant. Gymnastics was the only sport with differences between genders, where women were injured at a higher rate than men. It was also determined that the sites and types of injuries within the study were similar for males and females. It was concluded that when men and women partake in technically similar sports, they have approximately equal injury rates (Lanese et al).

Another study was similarly conducted to examine injury risk between genders. The researchers distributed twelve-month retrospective injury questionnaires to male and female elite Finnish athletes. The athletes' ages ranged between fifteen and thirty-five years old, and they competed in four different sports that involved different loading modalities. Three hundred and twelve females and two hundred and sixty-two males participated. More male than female athletes reported an acute injury, there were differences in acute injury locations, and males reported higher overuse injuries. However, none of the differences were significant when calculated for 1,000 exposure hours. The only significant result after adjustment for 1,000 exposure hours showed that male soccer players were at an increased risk for posterior thigh injuries. The researchers concluded that the overall gender related risk for acute and overuse injuries between the sexes was small. There were some gender differences in anatomical locations of injuries and sport specific injuries, but this was most probably due to differences in training (Ristolainen et al).

As noted in the previous study, male soccer players were reported to be at a higher risk for posterior thigh injuries than their female counterparts. Another study that was conducted on soccer players to examine hamstring injury rates between the male and female athletes yielded similar results. The researchers analyzed the National Collegiate Athletic Association (NCAA) Injury Surveillance System (ISS) for hamstring injuries between 2004 and 2009. This analysis only included partial or complete hamstring tears in the data. They compared preseason versus in-season injuries and practice versus game injuries. Five hundred and nineteen hamstring injuries were reported in the ISS for 1,083,752 exposures to athletic practices or games. Men were 64% more likely to sustain a hamstring injury than women, and they had significantly higher rates of hamstring injuries in both games and practices when compared to women. Overall, men were 2.42 times more likely to sustain a hamstring injury than women when comparing only games. Thus, it was concluded that male intercollegiate soccer players have a greater incidence rates of hamstring injuries than their female counterparts (Cross et al).

A similar study compared injury rates between males and females who play intercollegiate rugby. It was hypothesized that there would be different injury rates between the male and female athletes. The researchers used a longitudinal cohort with five years of data between the 2006/2007 and 2010/2011 seasons. They analyzed the cadet injury and illness tracking system (CIITS) for any new injuries that occurred during practice or a match that elicited medical attention from an athletic trainer or other medical provider. They calculated the incidence rate for each gender by dividing the total number of injuries by the exposure time for possible injury, and then multiplying it by 10,000 to represent the desired number of athletic exposures (AE). During the five-year period, 129 women and 240 men reported injuries. There were 200 injuries in 71 members of the women's team and 459 injuries in 151 members of the men's team, per 68,633 AE and 121,624 AE respectively (Peck et al).

Overall, there was a 30% higher incidence rate in men compared to women. There were also different injury patterns between men and women, where women were more likely to be injured in their lower extremities, and men sustained more injuries to the shoulders, head, and face. Thus, it was concluded that men sustain more injuries than women in rugby and that the injuries between the sexes have different distributions (Peck et al).

As mentioned earlier, intrinsic factors such as hormonal imbalances, strength imbalances, and inflexibilities can lead to a hamstring injury. Research is still being conducted to determine whether these intrinsic factors are heightened in either males or females and thus lead one gender to be more susceptible to injury than the other. One study was conducted to compare the static hamstring length and sagittal plane mechanics between male and female runners. D. S. Williams and Lee M. Welch hypothesized that hamstring flexibility would result in similar changes in running mechanics when compared between males and females.

The study included 40 total participants that were collected from a convenience sample of runners around a university. The participants had no current lower extremity musculoskeletal injury, and they all ran at least ten miles a week for the previous six months. The subjects were measured for hamstring flexibility with a goniometer and then subsequently assigned to four groups: flexible males, flexible females, inflexible males, and inflexible females. Subjects were then tagged with retroreflective markers and ran ten successful attempts on a 16m runway that was surveyed with a 9-camera motion analysis system. The results showed that males experience greater peak knee extension moments than females, and inflexible runners also demonstrated greater peak knee extension moments than flexible runners. Furthermore, flexible females had more hip flexion than inflexible females and flexible males did (Williams and Welch).

Williams and Welch discussed that inflexible hamstrings could lead to increased knee extension because of the tension in the muscles, and that females are quadriceps dominant and lack the ability to activate their hamstrings as efficiently during running. They concluded that male and female runners respond to landing with different mechanics based on their hamstring flexibility. Thus, a different landing mechanic is an example of just one intrinsic factor that could cause a hamstring injury in an inflexible runner that would not occur in a flexible runner.

Along with physical differences, psychological differences also contribute to variations between male and female athletes. A study was conducted to compare female athletes' injury experiences to that of males. The research was conducted by reviewing the existing literature on the topic. After initially researching injury incidence rates, the results showed that despite the media portraying the opposite, females are injured less frequently than males at all ages. However, this difference between male and female injury surveillance information is probably due to factors such as sport type, level of play, and training load rather than because of the gender difference (Wiese-Bjornstal et al).

In terms of psychological responses, it was determined that females report an overall higher level of sport injury anxiety than males because of a fear of being perceived as weak. Furthermore, females were more communicative during rehabilitation compared to their male counterparts. Interestingly, despite the fear of being perceived as weak, females were more willing to discuss their pain levels with their clinicians than their male counterparts. However, the researchers concluded that males and females are more similar than different in their psychological, psychosocial, and behavioral responses to sports injuries. Thus, gender does matter in the recovery experience, but no more than any other factor (Wiese-Bjornstal et al).

IV. Research

Upon reviewing the literature and speaking to athletic trainers, it was determined that there was much research on the difference in injury incidence rates between the sexes, but very little research on the recovery experience. Thus, this study was conducted to focus specifically on comparing hamstring injury recovery times in male and female athletes. The purpose was to determine if one gender took significantly longer to recover from a hamstring injury than the other gender.

The study took place at Gardner-Webb University between November 1, 2017 and February 2, 2018. It was conducted through the distribution, collection, and statistical analysis of anonymous surveys. The population was chosen to be a convenience sample of athletes on campus at Gardner-Webb. Participants were added to the pool through contacting coaches and gaining permission to survey their athletes. After distributing the informed consent waivers, the surveys were administered by the researcher after practice, by the coach after a meeting, or by a member of the Gardner-Webb strength staff after a weights session.

The survey asked the athlete to identify their gender, sport, age, and history of hamstring injuries. If the athlete had never sustained a hamstring injury, they were prompted to return the survey. However, if they had experienced a hamstring injury, they continued to answer questions five through nine. A survey was considered positive if the athlete indicated they had sustained a hamstring injury, and it was considered negative if no hamstring injury was reported. The remaining questions asked about the mechanism of the injury, the medical intervention required, the severity of the injury, the time away from their sport, and the time spent in physical therapy.

Athletes had the option to choose from a variety of multiple choice answers for the questions about the injury source, medical intervention, severity, and time lost. The question about the time spent in physical therapy was left as a fill in the blank format since answers could vary greatly. The possible mechanisms of injury to choose from included weightlifting, sprinting, cutting, jumping, and "other." The possible medical interventions to choose from included x-ray, MRI, surgery, or no medical intervention. The possible severities to choose from included a muscle strain, a partial muscle tear, and a full muscle tear. The possible intervals to choose from for time lost included no time lost, less than two weeks lost, two to four weeks lost, four to six weeks lost, and more than six weeks lost.

At the conclusion of the data collection period, the teams surveyed included women's lacrosse, women's soccer, women's volleyball, women's swimming, men's swimming, cheerleading, women's track and field, men's track and field, softball, baseball, football, women's tennis, men's tennis, women's cross country, men's cross country, women's basketball, and men's basketball. Even though the cheerleading team is comprised of both males and females, only female members of this team completed the survey. The research was conducted personally by the researcher for all teams except softball, baseball, and men's tennis. The softball coach administered the survey for his athletes, and a member of the strength staff administered the surveys to the baseball and men's tennis players.

Three hundred and nine athletes completed surveys. One hundred and sixty-five females and 144 males participated. Of the surveys returned, 93were positive for sustaining a hamstring injury, with a gender breakdown of 49 females and 44 males. However, two positive female surveys and four positive male surveys were not included in the data analysis because not all questions were answered. After removing the incomplete surveys, the analysis included 303 surveys, with 163 females and 140 males. The characteristics of the data after removal of the incomplete surveys can be found in Table 1 on the following page.

Table 1: Distribution of Females and Males within Each Sport

Sport	Females			Males		
	N	Average age	SD	N	Average age	SD
Volleyball	18	19.5	1.29	0	-	-
Soccer	27	19.2	1.17	0	-	-
Lacrosse	23	19.3	1.4	0	-	-
Cheerleading	21	19.4	0.95	0	-	-
Swimming	10	20	1	9	20.2	0.9
Softball	20	19.3	1.3	0	-	-
Track and Field	14	19.8	1.5	10	19.9	1.4
Basketball	14	19.4	1.4	16	20.1	1.5
Cross Country	9	20.4	1.2	7	20	0.9
Tennis	7	20.3	1.7	11	20.1	1.4
Baseball	0	-	-	35	19.9	1.2
Football	0	-	-	52	19.3	1.2
Cumulative	163	-	-	140	-	-

When separating the data between genders based upon the presence or absence of hamstring injuries, there were 116 females without a hamstring injury and 47 females with a hamstring injury. There were 100 males without a hamstring injury and 40 males with a hamstring injury. Thus, 28.8% of females and 28.6% of males who completed a survey had sustained a hamstring injury. Overall, 28.7% of athletes who completed a survey had sustained a hamstring injury during their athletic career. Furthermore, of the positive surveys turned in, 54% were females and 46% were males. These statistics are shown below in Figure 2 and Figure 3.

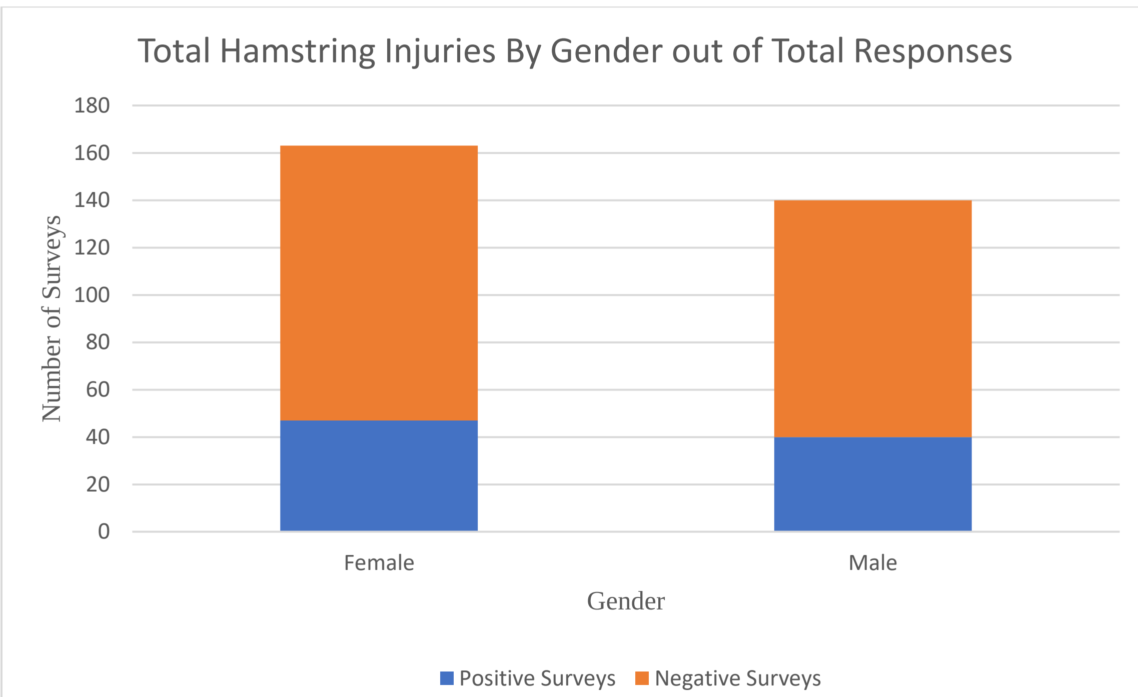

Figure 2: This graph shows the breakdown of responses between genders. Out of one hundred and sixty-three female responses, forty-seven had sustained hamstring injuries. Out of one hundred and forty male responses, forty had sustained hamstring injuries.

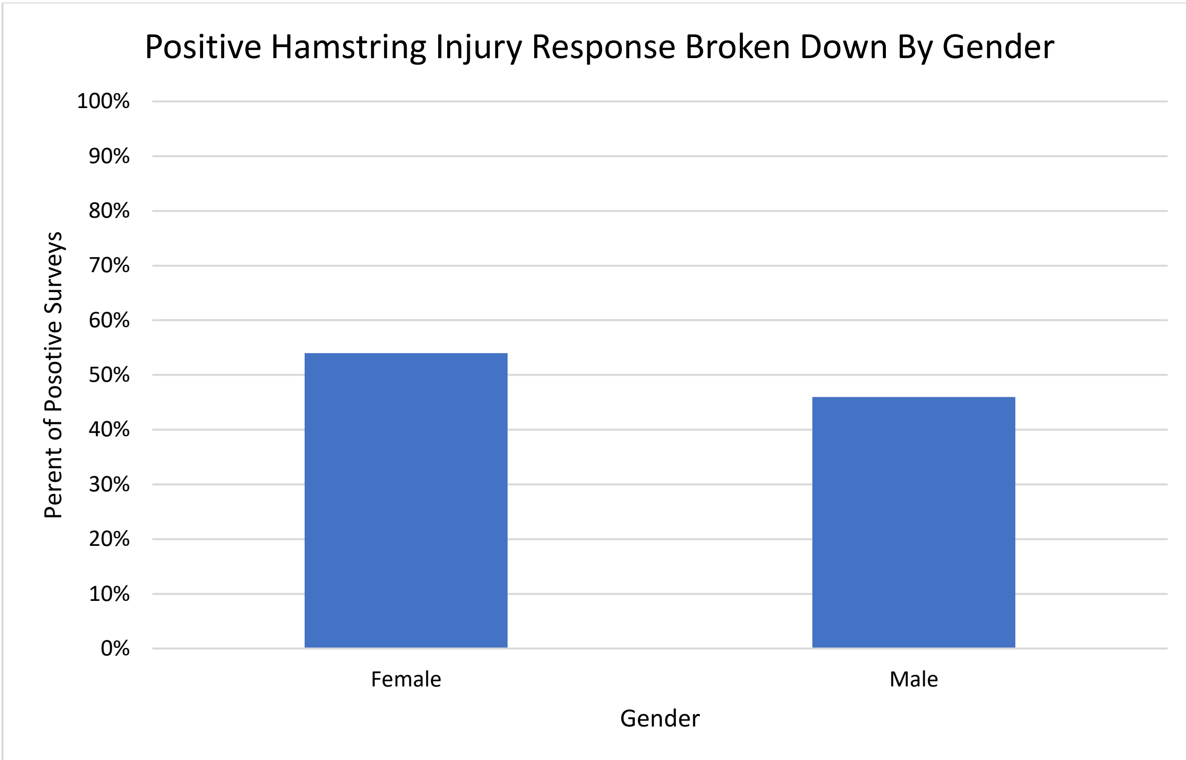

Figure 3: This graph shows the breakdown of the positive responses by gender. Fifty-four percent of the reported hamstring injuries occurred in females, and forty-six percent occurred in males.

Much research has been conducted to determine whether males and females incur hamstring injuries at the same rate. Most researchers have concluded that there is no significant difference in the overall injury rate between genders, but rather that there may exist only small significant differences between genders within a sport. In this study it was observed that similar percentages of males and females reported hamstring injuries as well. Thus, it appeared as though there was no significant difference between the incidence rates. This inference was tested using a chi-square analysis of independence test that analyzed the percentage of males and females that had incurred hamstring injuries. The inference was supported by results that yielded a highly insignificant p-value of 0.9598.

When analyzing the breakdown of hamstring injuries between sports, football, women's soccer, and baseball had the highest reported numbers of hamstring injuries respectively. There were 19 football players, 13 women's soccer players, and 12 baseball players who turned in a positive survey. However, when considering injury prevalence between sports, it is important to look at the number of positive surveys in comparison to the overall number of surveys completed by that sport. This analysis helps to better understand how prevalent hamstring injuries are within the sport as some teams were more than triple the size of others. Two different graphs can be seen below in Figure 4 and Figure 5 that show the comparison between the overall percent of injured athletes by sport, and the prevalence of injury by sport. It should be noted that women's tennis and men's cross country are not included on the next two graphs because neither team had athletes turn in a positive survey.

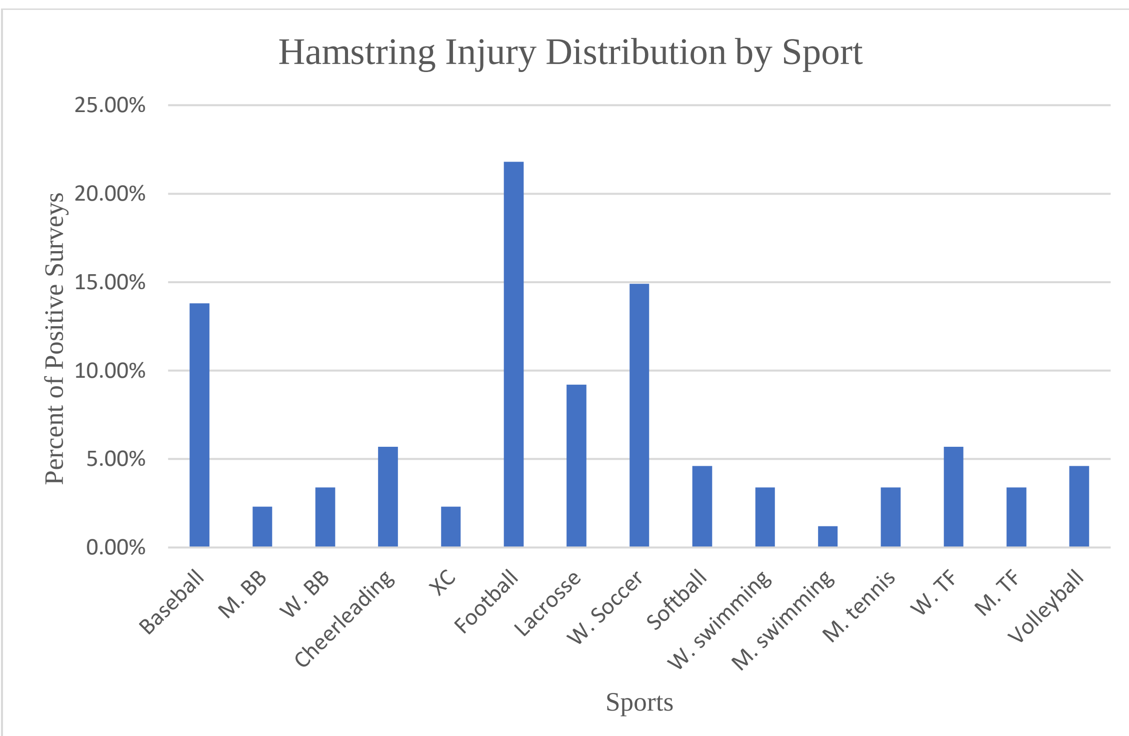

Figure 4: This graph shows the breakdown between sports for the percent of total positive surveys turned in.

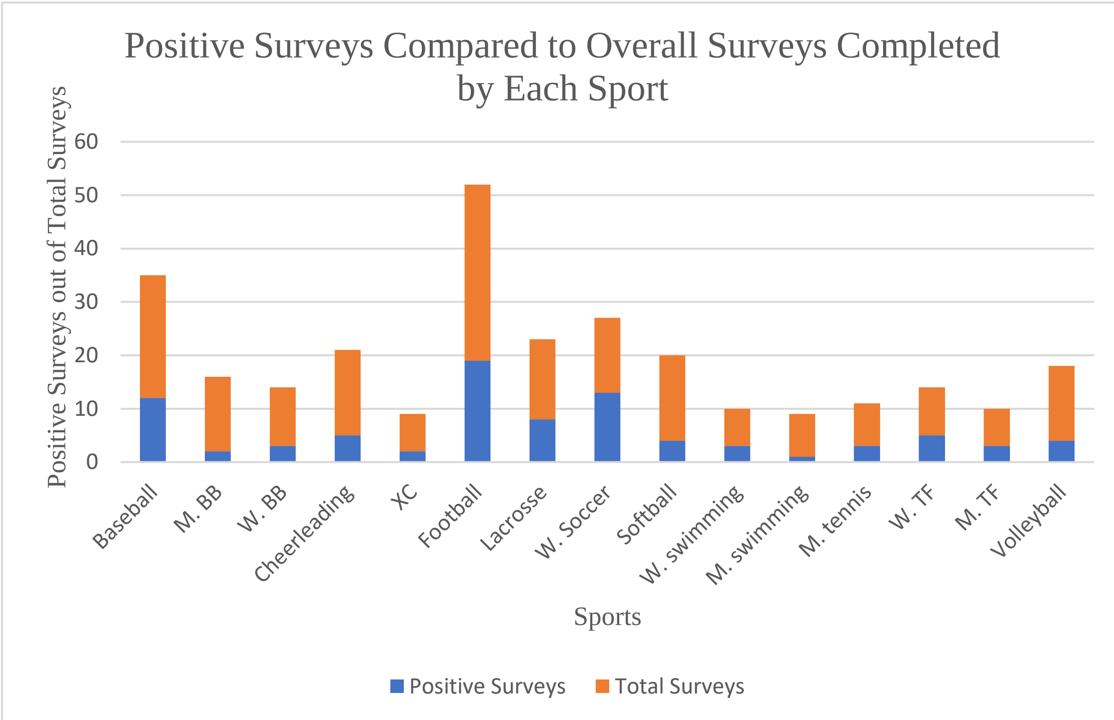

Figure 5: This graph shows the total number of positive surveys between sports compared to the total number of surveys completed by the sport.

In order to analyze length of recovery time between genders, the intervals of time lost were assigned a number between zero and four. A higher number indicated that the interval was longer than an interval that was assigned to a lower number. The intervals were assigned the numbers as follows: no time lost was assigned to number 0, less than two weeks lost was assigned to number 1, between two to four weeks lost was assigned to number 2, between four to six weeks lot was assigned to number 3, and more than six weeks lost was assigned to number 4. The reported time lost intervals for each gender were then entered in the GraphPad Prism 7.4 program for statistical analysis. This program analyzed the data for statistical significance using an unpaired t-test. The descriptive statistics showed that the mean recovery time for females was 1.106 while the mean recovery time for males was determined to be 1.3. Though these means fall between the actual interval values, they show that the average recovery time for both males and females was categorized as number one and thus they took around two weeks to return to their sport after a hamstring injury. The p-value associated with this data was determined to be 0.3865, which showed that there was no statistically significant difference for hamstring injury recovery times between males and females. The results can be seen in Figure 6 below.

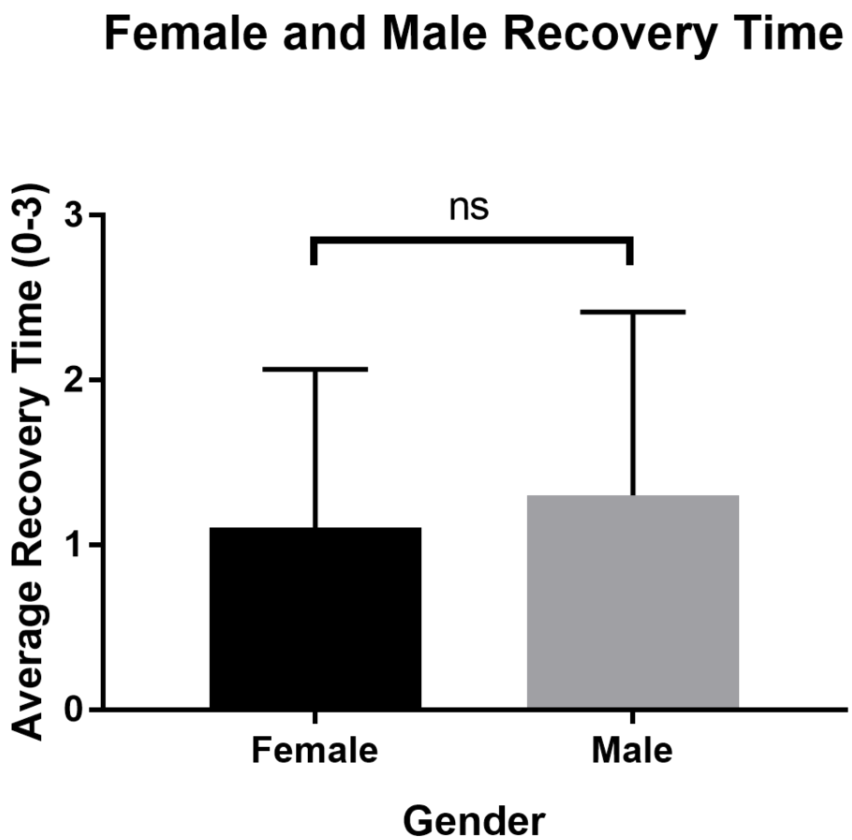

Figure 6: This graph shows the average recovery time organized in intervals for males and females recovering from hamstring injuries. The difference between the two means was not found to be statistically significant.

Though the difference in recovery time between genders was not found to be significant, other variables were available for analysis of significance as well. One such variable was the difference in recovery time between sports. The mean recovery times ranged from a 2 (which was assigned to the interval of two to four weeks) in men's and women's track and field to 0 in men's swimming (which was assigned to no time lost). However, upon the completion of an ANOVA, (analysis of variance) it was determined that there were no statistically significant differences for the recovery times between any of the sports. All p-values for the comparisons were well above the acceptable limit of 0.05. The results can be seen in Figure 7 below, and again women's tennis and men's cross country were excluded as hamstring injuries were not reported in either sport.

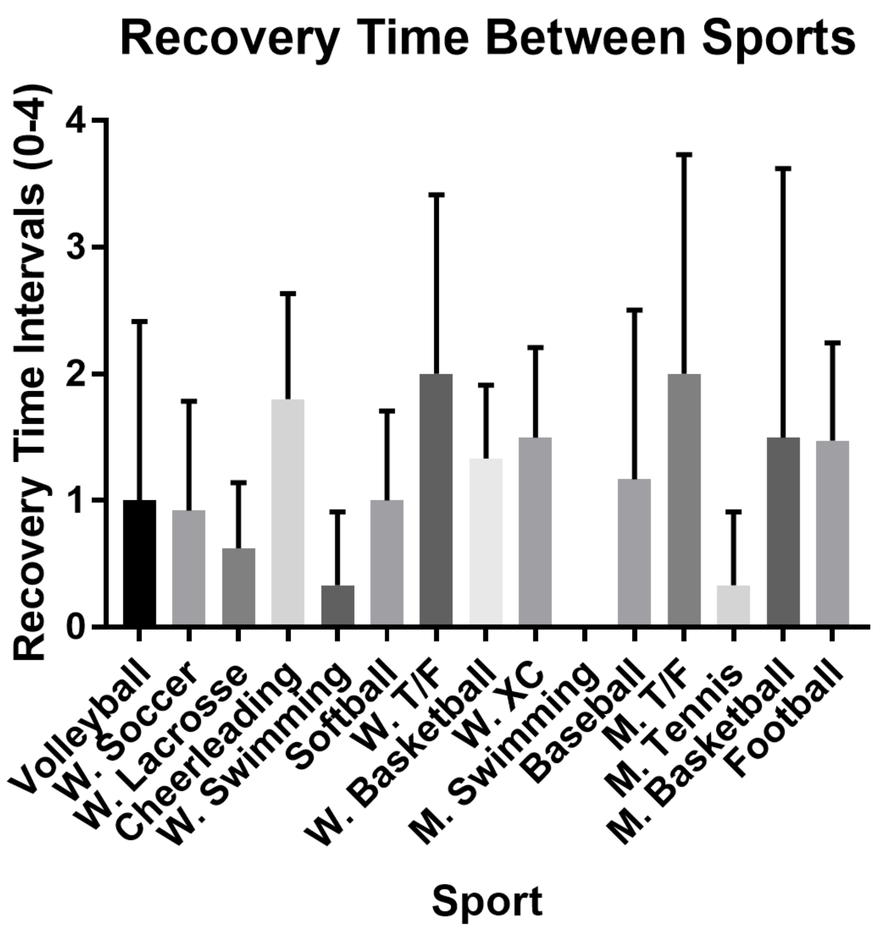

Figure 7: This graph shows the average recovery time in intervals for athletes in each sport.

Another variable analyzed was the mechanism through which each athlete sustained the hamstring injury. As noted earlier, the survey provided five possible options for the mechanism: weightlifting, sprinting, cutting, jumping, and "other." After collecting the surveys, another category was added and labeled "multiple causes" because a handful of athletes circled more than one mechanism for the cause of injury. For example, a hamstring injury can occur while an athlete makes a cutting maneuver whilst sprinting full speed.

The most common mechanism of injury was determined to be sprinting, as it was the cause of more than half of the total injuries. The second most common mechanism was the category labeled "other" where multiple athletes reported hamstring injuries from movements such as over-extension or over-stretching of the muscle. The remaining mechanisms of cutting, jumping, weightlifting, and multiple causes were most prevalent in that respective order. After conducting a t-test, it was determined that with a p-value of 0.6295, there was no statistically significant difference for injury mechanisms between genders. Thus, males and females were not injured more often from one mechanism compared to another. After conducting an ANOVA, almost all of the comparisons were not found to be statistically significant. However, it was seen that there was a statistically significant difference between the number of males injured while sprinting compared to the number of males injured while jumping. This was deemed significant with a p-value of 0.0488. Another significant difference was seen with a p-value of 0.0426 where males were injured more often from sprinting than from a combination of multiple causes. The results can be seen in Figure 8 below.

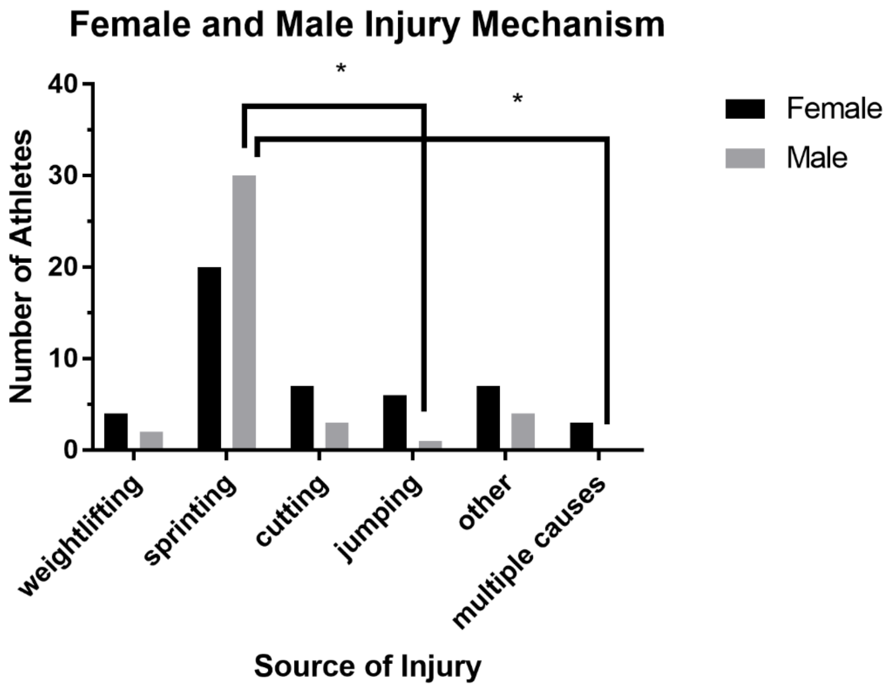

Figure 8: This graph shows the prevalence of injury mechanisms between males and females. The asterisk symbolizes a statistically significant difference between males sprinting and males jumping, and between males sprinting and males multiple causes.

After determining that there was no statistically significant difference for males and females between all possible injury sources, the data were analyzed to determine if there was a significant difference in the average recovery time per each injury source within each gender. The results of an ANOVA determined that there was no statistically significant difference in the recovery time based on the injury mechanism in females. The results can be seen in Figure 9 below.

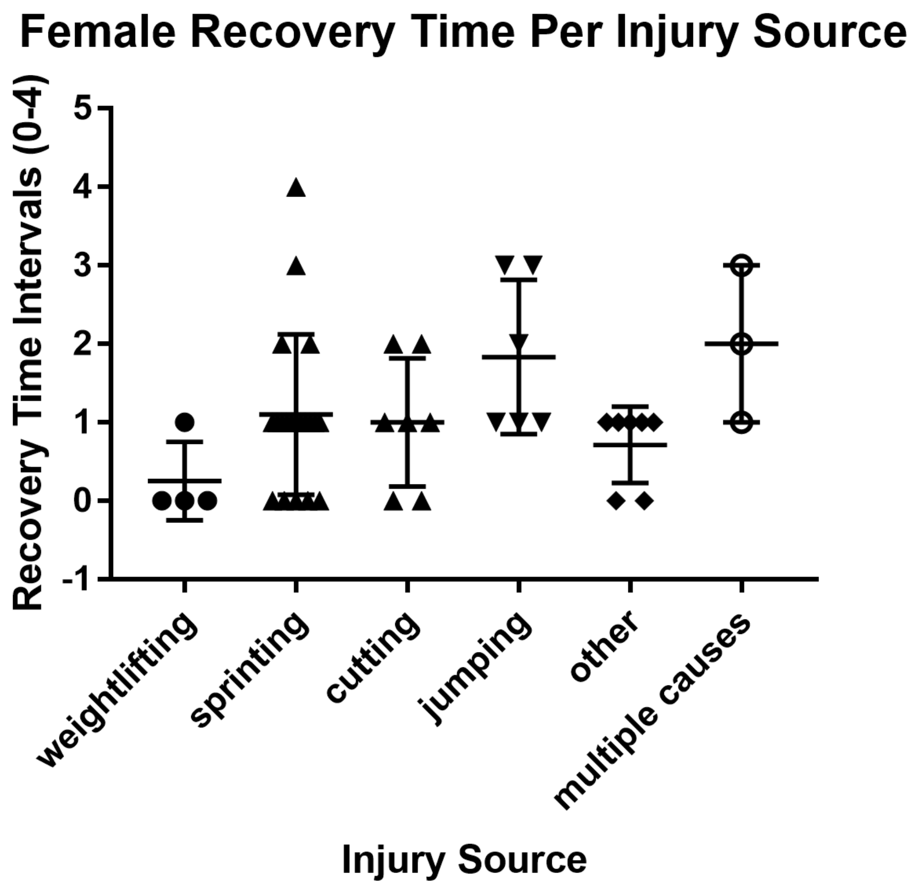

Figure 9: This graph shows the distribution of recovery time intervals reported in females for each injury mechanism.

Another ANOVA was conducted for the same comparisons in males, and it was again determined that there was no significant difference in recovery time based on injury mechanism. The results for the males can be seen in Figure 10 below.

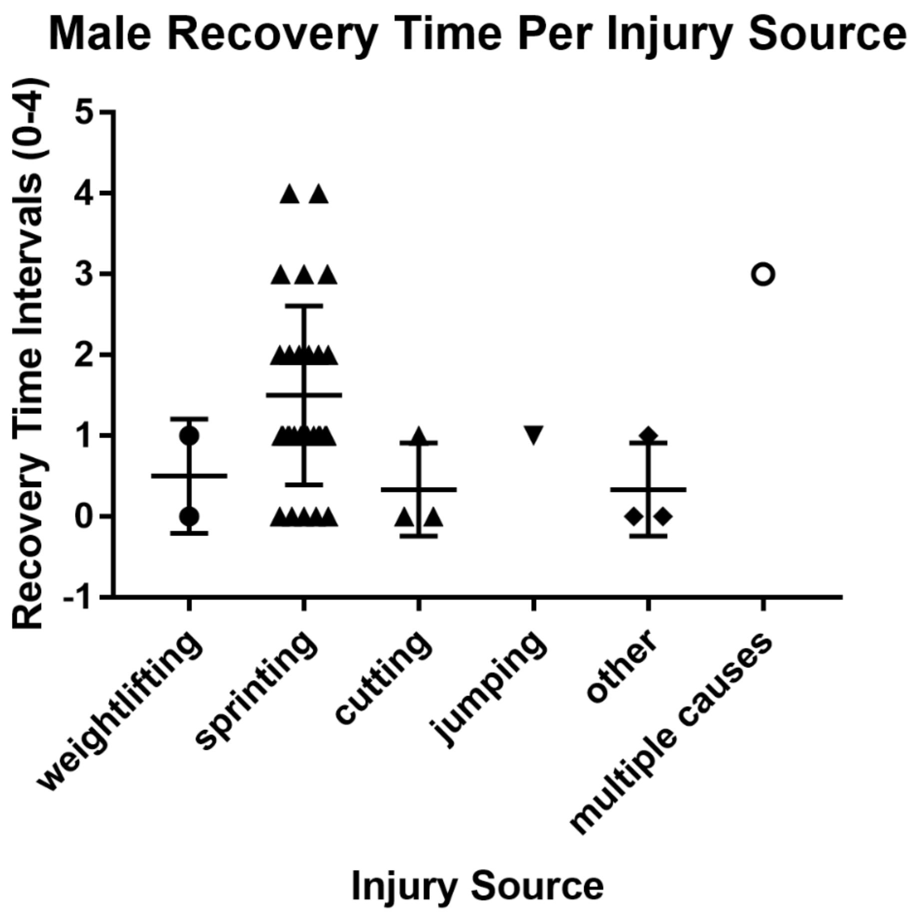

Figure 10: This graph shows the distribution of recovery time intervals reported in males for each injury mechanism.

After determining that there was no significant fluctuation in recovery time when considering injury mechanisms, the data were broken down further by specifically considering the recovery time between genders for one mechanism in particular. Sprinting was the mechanism chosen for further analysis because it was the most common cause of hamstring injuries in both males and females. The data were analyzed using a t-test to determine if there was a statistically significant difference between the recovery times for males and females who sustained their hamstring injury while sprinting. It was determined that there was no statistically significant difference between the genders with a p value of 0.2029. The results can be seen in Figure 11 below.

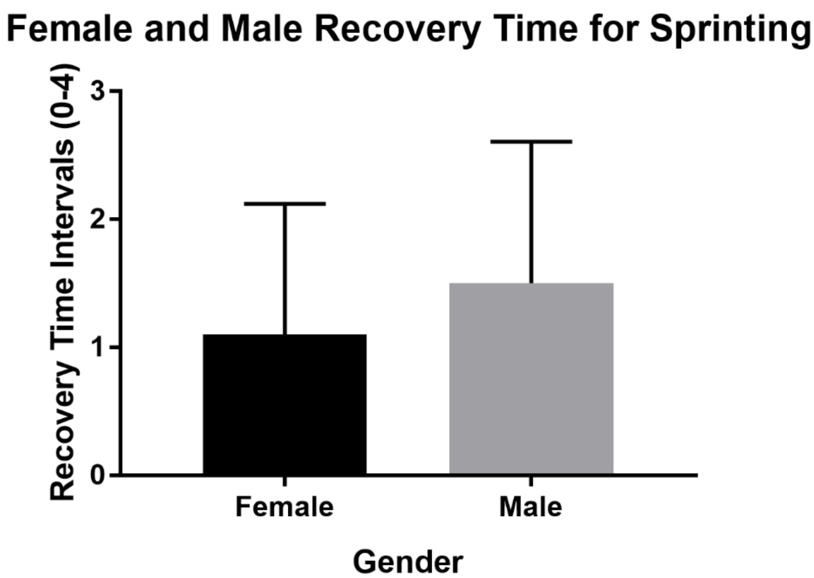

Figure 11: This graph shows the average recovery time intervals for males and females who injured their hamstring while sprinting. This was not deemed statistically significant.

After completing the analyses that determined no significant differences between recovery time intervals between genders, sports, and injury mechanisms, the data were then analyzed for differences that did not take recovery time into account. Specifically, the following analysis was conducted to determine if there was any difference in the prevalence of injury mechanisms associated with each sport. The results of an ANOVA determined that again there was no statistically significant relationship between one specific mechanism for a particular sport compared to another. The results can be seen below in Figure 12.

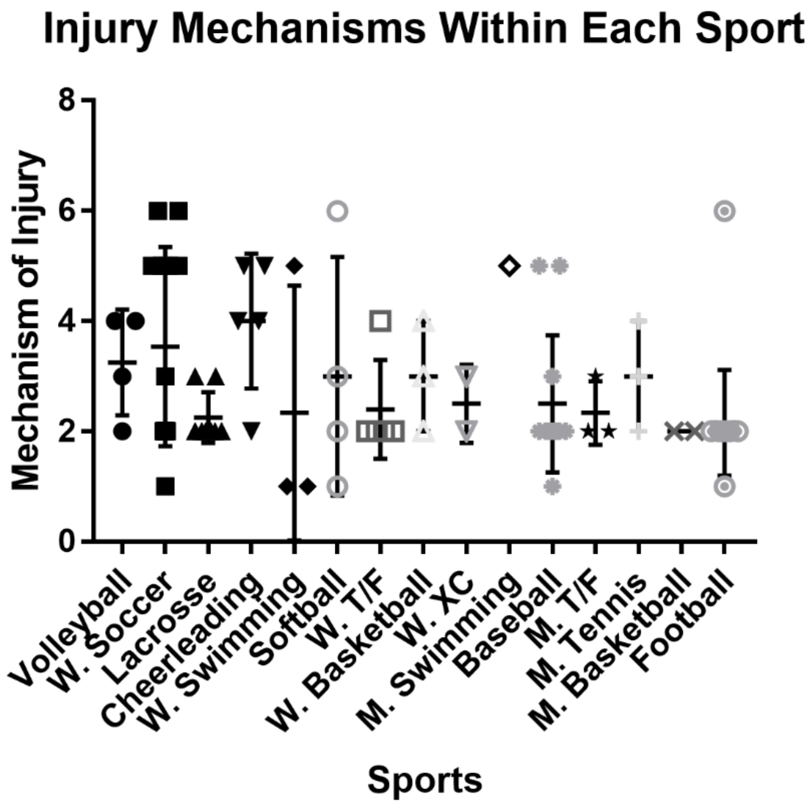

Figure 12: This graph shows the breakdown of the different injury mechanisms reported within each sport.

V. Discussion

In this study, there were eight total analyses conducted in an attempt to determine significant differences between variables. These analyses included the injury incidence rate between males and females and the length of recovery time between males and females. The length of recovery time between sports, the prevalence of injury mechanisms between males and females, and the length of recovery time per mechanism in females were also analyzed. More specific analyses included the length of recovery time per mechanism in males, the length of recovery time from a sprinting injury between males and females, and the prevalence of injury mechanism between sports.

The results of a chi-square analysis of independence for the number of reported injuries in males and females demonstrated that there was no significant difference with a p-value of 0.9598 This result was synonymous with results of the earlier review of previously published work done by other groups, showing that males and females incur hamstring injuries at similar rates regardless of sports. As previously mentioned, any differences in injury rate between the genders as reported in multiple articles included in this study are most likely due to the difference in sport intensity and training patterns rather than gender.

There was no significant difference between the reported recovery times for 47 females and 40 males (t-test, p=0.3865). The mean recovery times for each gender hovered around the “1 interval” which was assigned to less than two weeks away from the sport. With less than 100 data points to compare, one reason for this lack of significance could be because of the relatively small sample size. Another factor that could contribute to the lack of significant difference is the stigma associated with the recovery experience for each athlete. As noted in the literature review, research showed that female athletes often think others perceive them as weak when they are injured. Thus, this may contribute to them returning to their sport early after a short recovery period to avoid others perceiving them negatively. Furthermore, as noted in John Marshall's interview, females have been credited with a higher pain tolerance which may allow them to return to sport at a similar time as a male though they may have had a more severe injury.

There were no significant differences between any of the sports' average recovery intervals (ANOVA, $p>0.05$). One reason for this lack of significance could be that the athletes were all from the same campus, and thus received treatment from the same trainers and progressed through very similar rehabilitation programs. As mentioned in both interviews, the athletic trainers on Gardner-Webb's campus do not modify their treatment based on the sport. If this study were to be conducted across different college campuses where athletic trainers maintained different philosophies on rehabbing their athletes, the results might then show that one sport progresses through a longer program than another, thus resulting in an extended recovery time.

There was no significant difference between the prevalence of injury mechanisms between males and females (t-test, $p=0.6295$). This showed that males are no more susceptible to an injury during certain movements than females and vice-versa. However, after conducting an ANOVA on this data, two significant values were seen. While the ANOVA on the injury mechanisms yielded no differences between males and females, it did show two differences between males. Males sustained hamstring injuries significantly more often when sprinting compared to jumping ($p<0.05$). Furthermore, males sustained hamstring injuries significantly more often when sprinting compared to those sustained from multiple causes ($p<0.05$).

The lack of significance between genders may again be attributed to the small sample size. Perhaps if the study were performed across multiple college campuses or within a larger athletic department, then the results may change. Another reason there may be a lack of significance between the injury mechanisms in males and females is simply the nature of the hamstring injury. Injuries are most likely to happen while the muscle is loaded during an explosive action, and the mechanism of this action is the same in males and females. Despite the significance between the two categories within males, it is important to note that these p-values show significance within this study specifically. It is not meant to provide a sweeping conclusion that all male athletes incur hamstring injuries more commonly when sprinting compared to jumping or when sprinting compared to a combination of causes.

There was no significant difference in how long it took females to return to sport based on how they obtained their hamstring injuries (ANOVA, $p>0.05$). Again, a reason for this lack of significance could be the strict rehabilitation procedures enacted by Gardner-Webb athletic trainers regardless of gender, sport, or injury mechanism. A female who was injured while sprinting would go through the same protocol as a female who was injured while jumping, and thus their recovery times could be anticipated as the same so long as the severities were similar as well.

Similar results were seen for the length of recovery time per mechanism in males, as it was determined there was no significant difference in how long it took males to return to sport based on how they obtained their hamstring injuries (ANOVA, $p>0.05$). Reasons analogous to those mentioned for the lack of significance in females are suspected to be the cause of the lack of significance in males as well.

There was no significant difference in how long it took males and females to recover when their injuries were of the same origin (t-test, $p=0.2029$). This test was conducted to remove the variable of the injury mechanism, but the yield was consistent with that of the earlier t-test that determined there was no difference in recovery times between genders. A reason for the lack of significance can be attributed to the especially small sample size when analyzing injuries from only one mechanism. Furthermore, injuries that occur during the same movements are often similar in presentation and in the way that they disrupt the inner workings of the muscle. Thus, it is understandable that there was no difference in recovery times.

It was determined that there were no significant differences in the causes of hamstring injuries between sports (ANOVA, $p>0.05$). This lack of significance can be attributed to the similar movements required in many of the sports surveyed. With the exception of a few sports, such as swimming and cross country, most sports require explosive sprinting and jumping from their athletes at one point in time or another.

VI. Conclusion

In conclusion, there were no significant differences discovered between the recovery times for male and female athletes rehabbing a hamstring injury. Furthermore, upon analysis of other variables it was determined that there were no significant differences for the incidence rate between males and females, the length of recovery time between sports, the prevalence of injury mechanisms between males and females, the length of recovery time per mechanism in females, the length of recovery time per mechanism in males, the length of recovery time from a sprinting injury between males and females, and the prevalence of injury mechanism between sports.

The two values found to be significant were between males but not between genders. Though these values were found to be significant, they may not be applicable within larger sample sizes. Based on the findings of the literature review and of the survey results analyzed here, it is concluded that males and females are more alike than different in their injury rates and recovery experiences when referring to hamstring injuries.

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