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Examining the Impact of Adding Gluteal Strengthening Exercises to the FIFA 11+ Warm-up Program on High School Girls' Basketball Reported Injuries.

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Introduction: FIFA 11+ is a multi-modal injury prevention program (IPP) that has been shown to decrease injury rates in soccer athletes of both genders and elite male basketball athletes. There is also literature that supports the use of gluteus maximus and gluteus medius strengthening to assist in the prevention of lower extremity (LE) injuries. FIFA 11+ has not been studied specifically examining the prevention of LE injuries in adolescent girl basketball athletes and there are no known LE IPP's that include gluteal strengthening exercises. **Hypothesis:** It was hypothesized that the addition of gluteal strengthening exercises to the FIFA 11+ IPP would result in fewer LE injuries, improved vertical jump performance, and decreased valgus knee movement during drop jump testing between pre-and post-season measurements. **Participants:** Thirteen high school girls (ages 15-18) were selected for this study. **Methods:** A modified FIFA 11+ IPP was used as a warm-up program before each regular-season practice. Data analysis compared the following values from the 2016-17 and 2012-18 seasons using chi-square values: the total number of injuries sustained, the number of chronic and acute LE injuries suffered, and the number of injuries to specific body parts. Pre-and post-season vertical jump averages were compared using a paired t-test. Valgus knee movement during a drop-jump test was recorded and analyzed with a composite scoring system, then compared using a paired t-test. **Results:** In the 2017-18 girls' basketball season, 9 total injuries were reported compared to 12 total reported LE injuries in the 2016-17 season ($p = 0.51$). The most significant change in reduction of injury was in hip/thigh injuries from 4 in 2016-17 to zero in 2017-18 ($p = 0.04$). Vertical jump team averages improved from 16.5 inches to 17.9 inches from pre-to post-season ($p = 0.00$), which is significant. **Conclusion:** The results of this study make it difficult to confidently report the effectiveness of the modified FIFA 11+ warm-up program on reducing LE injury in athletes that participate in sports other than soccer. However, a significant vertical jump improvement in this study does support the literature that the FIFA 11+ program is effective in improving sport-specific skills.

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Introduction

Since the passing of Title IX in 1972, there has been a dramatic increase in female athletes competing in athletics at all levels.[1] The number of female athletes competing at the high school level has increased by almost 80% over the past 2 decades.[2] Participation in athletics has many benefits, such as better academic performance, improved mental health, and better physical activity habits in adulthood.[3,4] While the benefits of being involved in athletics are undeniable, there is always a risk of sports-related injury to the participant.[5]

Many studies have shown higher injury rates in adolescent girl athletes than boy athletes of the same sport.[2] When an athlete suffers from an injury, they often miss practices and competitions, which prevents them from reaping the benefits that athletics have to offer.[6] Not only are these athletes missing out on the benefits of sport, but their future injury risk is increased, which can lead to overall decreased physical activity, discontinued participation in sport, and potential emotional hardships.[3,4] Due to the potential effects of injuries in the adolescent athlete, it is essential to protect this population and prevent these injuries from occurring.

Basketball is a sport that places high demands on the lower extremity (LE), which can lead to an increased risk of injury.[4,7] In 2015-2016, it is estimated that 99, 859 high school girls' basketball athletes sustained injuries while participating in practices or games.[5] The most common injuries reported were ankle sprains and knee sprains, while approximately 92.8% of injuries in this population resulted in more than one day lost from practice or competition.[5]

Many recent studies have found that among adolescent athletes, girls have a higher injury rate than boys.[2,8] There are many factors that put adolescent girls at a higher risk of lower extremity injury than boys their age, but no one anatomical risk factor has been directly

correlated to an increase in lower extremity injury.[1] While the female anatomy cannot necessarily be altered to decrease injury risk, the biomechanics that place the female athlete at risk for injury can be addressed with injury prevention programs (IPP).[1]

Many injury prevention programs have been developed in the past two decades to replace the once standard injury prevention strategy of static stretching. Current research shows that this method has no effect on decreasing the risk of LE injury in adolescent athletes.[9,10] Research has found, however, that combining stretching with strength training, plyometrics, and proprioception training in a multi-modal training program both enhances athletic performance and prevents lower extremity injury.[9,10]

Many different multi-modal injury prevention programs have been developed in recent years that focus on preventing lower extremity injury. The Sportsmetrics and Prevent Injury and Enhance Performance program (PEP) both focus on preventing non-contact injuries to the anterior cruciate ligament (ACL), while the International Federation of Football Associations (FIFA) 11+ program was developed to decrease overall lower extremity injury risk in soccer athletes.[11,12,13] These programs are effective in reducing injury risk in female athletes, with Sportsmetrics and PEP decreasing the ACL injury rate in adolescent female basketball athletes by 74-88%[1,11] and FIFA 11+ decreasing the risk of LE injury by 50% in female soccer athletes.[14,15,16]

The literature also suggests that there may be a link between lower extremity injury risk, especially knee injury, and the strength of hip musculature, primarily the gluteus maximus (Gmax) and gluteus medius (Gmed).[17,18] When the hip abductors and external rotators do not function properly, the result is pelvic drop, hip adduction and internal rotation, as well as an increase in knee valgus angle.[19,20] These biomechanical errors lead to compensatory movement

patterns in the low back, hip, and knee, all leading to increased LE injury risk.[20] Gmax and Gmed work eccentrically to prevent these movements from occurring.[21] While hip abductor strengthening is highlighted in the Sportsmetrics and PEP programs, these muscles are not addressed in the FIFA 11+ protocol specifically.

Purpose

The FIFA 11+ effectively decreases injuries in soccer players and male professional basketball players.[4,14,15,16,22,23] There is also research that supports the use of exercises that strengthen Gmax and Gmed to help in the prevention of LE injuries.[17,18] Currently, there are no known studies on the effectiveness of the FIFA 11+ warm-up in reducing injuries in high school girls' basketball athletes. There are also no known studies on the effects of adding gluteal strengthening exercises to the FIFA 11+ warm-up. The purpose of this professional paper was to: 1) see if the addition of gluteal strengthening exercises in place of certain exercises in the FIFA 11+ injury prevention program resulted in fewer LE injuries in high school girls' basketball players; and 2) determine if the FIFA 11+ warm-up positively influenced performance, specifically vertical jump and drop jump landing technique.

Literature Review

Overview

In the past ten years there has been a 21% increase in high school athletics participation in the United States.[6] In the 2014-2015 school year, an estimated 7.8 million male and female adolescents participated in high school athletics in the United States.[5] The number of female athletes competing at the high school level has dramatically increased by 80% over the past 2 decades.[2]

Basketball is a sport that constantly puts high demands on the lower extremity, which leads to increased risk of injury.[4,7] In the 2015-2016 school year, it is estimated that 99, 598 high school girls' basketball athletes sustained injuries.[5] Almost 60% of these injuries occurred in freshman and sophomore girls and the most common type of injury sustained was a strain or sprain.[5] The ankle, knee, hip and thigh, foot, and lower leg accounted for 57.2% of all injuries to this population of athletes in the 2015-2016 season.[5] The most commonly reported injuries to the lower extremity (LE) were ankle sprains (24.7%) and knee strain/sprains (10.5%).[5] Defending, rebounding, and chasing loose balls accounted for the most common activities leading to injury, behind general play.[5,7] Approximately 92.8% of injuries in this population resulted in more than one day lost from practice or competition.[5] With the significant increase in participation and injury rates in female basketball players, it is critical to examine ways to reduce the number of injuries by understanding at risk athletes and developing injury prevention programs.

Risk Factors for Injury

Many recent studies have found that among adolescent athletes, girls have a higher injury rate than boys.[2,8] More specifically girls basketball athletes are at a higher risk of knee injury than boys of the same age and sport.[2,8,18] There are many factors, modifiable and non-modifiable, that put adolescent girls at a higher risk of knee and lower extremity injury than boys their age, but no one anatomical risk factor has been directly correlated to an increase in lower extremity injury.[1]

Non-modifiable Risk Factors

Anatomically, women tend to have a wider pelvis, greater hip varus angle, increased femoral anteversion, greater knee valgus, and increased external rotation of the tibia when compared to men.[20] These anatomical differences between men and women lead to differences in

biomechanics, mainly a greater Q-angle in women.[20] This angle has been found to be 3-6 degrees greater in women than in men.[20] Increased Q-angle is the speculated cause of many injuries that impact the female athlete.[20] An increase in this angle can cause a more lateral pull of the quadriceps muscles, which increases the valgus stresses on the knee and places the anterior cruciate ligament (ACL) in a vulnerable position for injury.[20]

Modifiable Risk Factors

Strength differences are another biomechanical factor that puts females at an increased injury risk when compared to their male counterparts. Females recruit the quadriceps muscles before the hip extensors to stabilize the knee, leading to hamstring and gluteal weakness.[20] Weakness in these muscles leads to a lack of eccentric control from the proper muscles during deceleration and a high reliance on the quadriceps and passive restraints within the knee, such as ligaments.[20] Females are also often weak in the hip abductors and external rotators which creates increased hip adduction and internal rotation forces on the knee, leading to increased lateral patellofemoral joint stress.[20] This increased stress to the knee joint makes it prone to pain, instability, and injury.[20] While the female anatomy cannot be changed to decrease injury risk, the biomechanics that place the athlete at risk for injury can be addressed with an injury prevention program.[20]

Injury Prevention Strategies

Stretching:

Static stretching of the lower extremity is often standard practice for individuals and teams before participating in physical activity. In one study of Michigan high school coaches, nearly 93% of the coaches believed that static stretching before activity decreased their teams' injury risk.[24] However, current research shows that this method has no effect on decreasing the

risk of LE injury in adolescent athletes.[9,10] Though static stretching improves static flexibility and ROM, it fails to improve dynamic flexibility which is needed during participation in dynamic activities such as sport.[10]

A systematic review by Thacker et al,[10] describes several theories that explain why static stretching is not effective in preventing injury including decreased joint stability and the creation of dangerous body positions that lead to compromising loading effects on ligaments. While static stretching may not be an appropriate injury prevention warm-up, many research studies have found that combining stretching with strength training, plyometrics, and proprioception training can both enhance athletic performance and prevent lower extremity injury.[10]

Gluteal Strengthening:

Current research shows that strengthening of the lower extremity is essential in lower extremity injury prevention.[13] Injury prevention programs often focus on strengthening of the quadriceps and hamstring muscle groups since they provide stability to and act to move the knee joint, a common site of lower extremity injury.[25] Research has also shown that a low hamstring to quadriceps strength ratio is highly associated with knee injury.[25] Danesjhoo et al,[25] found that 8 weeks of the FIFA 11+ program improved the strength ratio of hamstrings to quadriceps, and therefore increased knee joint stability and decreased risk of knee injury. The literature also suggests that there may be a link between lower extremity injury risk and the strength of hip musculature, primarily the gluteus maximus and gluteus medius.[17,18,26] These muscles are not commonly addressed in general injury prevention programs and are not addressed in the FIFA 11+ protocol specifically.

The gluteus maximus (Gmax) is the largest muscle of the hip and has two primary functions: hip extension and hip external rotation, while the superior portion of Gmax also

contributes to hip abduction.[19,27] Gmax functions to propel the body upward and forward from hip flexion, stabilizes the pelvis during quick changes in direction, and is used to accelerate the body during sprinting, squatting, planting and cutting to the opposite side.[27] Proper activation and strength of the gluteus maximus is imperative to performing the movements necessary to compete in the sport of basketball.

Though smaller in size than the gluteus maximus, the gluteus medius (Gmed) generates an impressive amount of force on the hip joint.[27] It is anatomically broken down in to three sections: anterior, middle, and posterior.[27] Gmed functions to stabilize the pelvis and femur throughout the weight-bearing stance phase of gait.[27,28] The Gmed also functions as a powerful hip abductor.[26] The anterior portion alone assists in hip internal rotation and hip flexion, while the anterior and middle fibers function to help initiate hip abduction.[19,27] The posterior fibers help the gluteus maximus with hip extension, abduction, and external rotation.[19,27] All of these functions allow the gluteus medius to help stabilize the pelvis, especially when the body's base of support is limited, for example, when an athlete is on one leg during activity.[27]

Weakness or deficiency in the Gmax and Gmed musculature has substantial effects on lower extremity biomechanics that are linked to pathology.[19,29] When the hip abductors and external rotators do not function properly, the result is pelvic drop, hip adduction and internal rotation, as well as an increase in knee valgus angle.[19,20] These biomechanical errors lead to compensatory movement patterns in the low back, hip, and knee, all leading to increased injury risk.[19] Gmax and Gmed work eccentrically to prevent these movements, so weakness in these muscles is often countered by increased activation of quadratus lumborum in the lower back.[19,21] Weakness in Gmax and Gmed is linked directly to anterior cruciate ligament injury, iliotibial

band syndrome, ankle instability, and patellofemoral pain syndrome (PFPS), all of which are common injuries in adolescent female athletes.[17,18,19,20,26,28]

Due to research supporting the roles of gluteus maximus and gluteus medius in correcting biomechanical errors and helping to prevent or rehabilitate athletes from injury, there has been a focus on researching which exercises best target these muscles. Many studies use electromyography (EMG) to look at how much muscle activity is needed to train the gluteal muscles properly for rehabilitation and injury prevention. EMG is used to measure the activation of a specific muscle, as measured by electrical activity levels within the muscle.[19] A stimulus of 40-60% of maximum voluntary isometric contraction (MVIC) is needed to promote strengthening of the specific muscle, therefore, that is the level of activation that is appropriate for Gmax and Gmed strengthening.[19,21] In most studies, researchers first record the research participants EMG activity during a maximum isometric contraction and this number serves as a baseline that the researchers can then compare EMG levels to while the participant is performing the exercises.[21]

In one literature review, researchers pooled together multiple studies on Gmax and Gmed strengthening to find which rehabilitative exercises promote the activation levels required for strength building.[27] They grouped the exercises into four levels of EMG MVIC percentage: low-level activation, moderate-level activation, high-level activation, and very high-level activation.[27] The high-level activation group EMG values fell between 41-60% MVIC, which is the value range required for strengthening and the very high-level activation values were anything above 60%.[19,21,27] The forward step-up was the exercise with the highest gluteus maximus activation, followed by single-leg deadlift and single-leg squat.[27] The exercises with the highest MVIC percentage for gluteus medius activation were a side bridge and single-leg squat.[27]

In another study, researchers compared gluteus maximus and gluteus medius activation levels across commonly used strengthening exercises.[29] This study is unique in that the researchers included exercises with and without external resistance such as bands or weights. The lateral band walk, with the band placed around the ankle, was effective in achieving Gmed activation at a level appropriate for strengthening.[29] They also found that a single-leg plyometric lateral hop activated the gluteus medius at an appropriate threshold for strengthening.[29]

MacAskill et al.[21] looked at many of the same exercises as the previous research articles and found many of the same results for which exercises most effectively activate Gmax and Gmed. The researchers found that non-weight bearing exercises with external resistance resulted in greater muscle activity than functional weight-bearing exercises without an external load.[21] EMG values were above 100% during both prone hip extension with a cuff weight placed proximal to the knee and side-lying hip abduction with a cuff weight placed around the ankle.[21] These values are well above the required MVIC for muscle strengthening.[21]

Multi-modal Programs:

Recent research has found that a multi-modal approach incorporating proprioceptive training along with LE strengthening and plyometric training can result in a significant decreased risk of injury.[3,7,10,30] Soomoro et al.,[29] found that adolescent athletes may see the most potential benefit from this type of injury prevention program (IPP) more than any other group of athletes. Many different multi-modal IPP's have been developed in recent years that focus on preventing lower extremity injury. The Sportsmetrics and Prevent Injury and Enhance Performance program (PEP) both focus on preventing non-contact injuries to the anterior cruciate ligament, while the International Federation of Football Associations (FIFA) 11+ program was developed to decrease overall lower extremity injury risk in soccer athletes.[11,12,13]

Sportsmetrics was developed in 1996 as a 6-week ACL injury prevention program.[12] This program is best suited for off-season or pre-season training, as it is broken down into three sessions per week, with each session lasting 90-120 minutes.[31,32] It consists of a dynamic warm-up, jumping exercises, flexibility exercises, strengthening exercises, plyometric drills, and endurance drills.[32] In the past few years, Sportsmetrics has modified their original ACL injury prevention program to better suit multiple women's sports, including basketball, volleyball, tennis, and soccer. These programs include the basic Sportsmetrics exercises, but also add in sports-specific drills. The goal of producing a more sports-specific program was to improve compliance to such a rigorous and time-consuming program.[31]

This program has been shown to significantly reduce the risk of non-contact ACL injuries in young female soccer and basketball athletes.[12] Many factors related to athletic performance are also positively impacted by Sportsmetrics, such as increased VO_2max and lower limb landing alignment from a drop jump.[31,32] Both PEP and Sportsmetrics have been found to improve the isokinetic strength of the hamstrings and improve the hamstrings to quadriceps ratio, both of which are possible risk factors for female athlete injury.[32]

The Prevent Injury and Enhance Performance program was developed in 1999 by the Santa Monica Orthopaedic and Sports Medicine Research Foundation as a non-contact ACL injury prevention program.[11,33] PEP is a concise 20-minute program that consists of a dynamic warm-up, static stretches to the LE, strengthening exercises, plyometrics, and agility exercises.[1,11] This program addresses the proprioceptive feed-forward mechanism, or the ability to stabilize the knee joint by anticipating external forces, therefore protecting the internal structures.[11] One point of focus throughout the program is verbal feedback regarding LE movements during all activities, emphasizing reduced knee valgus.[11]

PEP has been shown to reduce the risk of non-contact ACL injury by 74-88% by strengthening the hip musculature and reestablishing proper movement patterns in the lower extremity.[1,11] In a slightly modified version of PEP, Lim et al,[33] found PEP to improve LE strength, flexibility, and LE biomechanics in female high school basketball players. Another study by Pollard et al.[11] found that PEP is effective in modifying the biomechanical and neuromuscular risk factors that predispose female athletes to ACL injury. The main findings in the study were decreased quadricep activity with increased hip extensor activity to control the deceleration phase upon drop landing when compared to pre-PEP intervention.[11] While both Sportsmetrics and PEP are effective at decreasing non-contact ACL injuries in female athletes, there are other injuries that occur in the lower extremity that can also be prevented.

One multi-modal IPP that includes aerobic conditioning, strengthening, and neuromuscular training for the lower extremity is the International Federation of Football Associations (FIFA) 11+.[13] The FIFA 11+ was developed to decrease injury risk in soccer athletes.[13] It is composed of 10 exercises that focus on core strengthening, eccentric training of the quadriceps and hamstrings, proprioceptive training, dynamic balance, and plyometric drills.[13]

FIFA 11+ has rapidly gained popularity with soccer coaches and athletes due to the simplicity of administration and impressive injury reduction rates.[13] The program is recommended to be used as a warm-up prior to practices and only takes 20 minutes to complete.[13] Though there is discrepancy on how many weeks of participation are necessary to see positive results, participants that perform the FIFA 11+ exercises 1-2 times per week have seen the greatest strength gains.[13] A systematic review of research on the effectiveness of FIFA 11+ of reducing injury risk in soccer players found that teams that implement the FIFA 11+ warm-up program have seen between 30-70% fewer injuries.[13]

After the development of FIFA 11+ in 2006, the first randomized control trial (RCT) of the effectiveness of the program was published in 2008 and reported that it significantly prevents non-contact injuries in young female soccer players.[16] Both Soligard et al.[14] and Steffen et al.[15] reported that FIFA 11+ reduced the number of injuries in adolescent female soccer athletes by up to 50% in RCT's. FIFA 11+ has been researched with adolescent and college aged male soccer athletes and shown to have a similar effect on injury reduction of about 40%.[16,22,23] The FIFA 11+ program reduces injury risk by improving neuromuscular control of the LE and core, promoting functional balance, increasing core and hip muscle activation and strength, and improving the hamstring to quadriceps strength ratio.[16] Other positive outcomes of FIFA 11+ such as improved jump height and sprint speed are directly applicable to sport performance.[13]

Since FIFA 11+ was designed by and for soccer athletes, most of the research on the program has been done with soccer athletes. There is one RCT that researched the effectiveness of the FIFA 11+ warm-up on injury prevention in male basketball players.[4] Longo et al.[4] found the FIFA 11+ warm-up program effective in reducing the injury rate in male basketball players. There was a significant decrease in serious injuries to the ankle and knee as well as a decline in time missed due to injury in the group that participated in the FIFA 11+ program when compared to the control group.[4] Though this warm-up program was designed to prevent injury in soccer athletes, it has been shown to be effective in non-soccer athletes as well since the program focuses on attributes of injury prevention that apply to many sports, like LE strengthening, proprioception, functional balance, and proper cutting and landing mechanics.[4]

The FIFA 11+ prevention program is broken down into three different parts: running exercises, strength exercises, and advanced running exercises. The strength section focuses on exercises that promote lower extremity and core strengthening, balance, and proprioception.[34]

These exercises are designed to all have three levels of increasing difficulty that make the program adaptable to challenge each participant individually.[33] The strength section of the FIFA 11+ program also includes plyometric drills.[34]

The strength portion of the FIFA 11+ includes exercises that target the lower body and have a positive effect on LE injury prevention, such as the Nordic hamstring exercise and a squat progression.[13] While these exercises are beneficial, based on the literature previously discussed, these exercises may not be the best for targeting the gluteus maximus and gluteus medius, both of which have been found to be imperative to adding to LE injury prevention programs, especially in girls.[17,18,19,20,29]

The Nordic hamstring raise, which is included in the FIFA 11+ injury prevention program, is effective in eccentrically training the hamstring muscles and has been shown to decrease the risk of hamstring strains in randomized controlled trials.[34-38] In multiple EMG studies, hamstring activation levels during the Nordic hamstring exercise are above 60% of maximal isometric contraction during the eccentric portion of the movement, which is sufficient for strengthening.[37,38] In a systematic review and meta-analysis of studies looking at the Nordic hamstring exercise in an injury prevention program found that including this exercise decreased the number of hamstring injuries in soccer players.[36] A common trend amongst the research on injury prevention and the Nordic hamstring exercise is that eccentric training of the hamstrings is essential in preventing hamstring injuries.[36-38] None of the current studies on the Nordic hamstring exercise compare its effectiveness to any other exercises that are commonly used to eccentrically train the hamstrings.

While the Nordic hamstring exercise is great at eccentrically training the hamstrings, it is a bilateral exercise, meaning that if an athlete has one limb that is stronger than the other, they

could compensate for the weakness in their other leg by using the stronger limb.[35,39] One study proposed that the hamstrings should be trained unilaterally to more effectively mimic how the limbs function during sport, when they are challenged to function somewhat independently.[39] Another negative aspect of the Nordic hamstring exercise is that it may be difficult for weaker athletes to perform correctly.[39]

Based on the research, it can possibly be concluded that eccentrically training the hamstrings is essential to preventing hamstring and ACL injuries.[35-39] The Nordic hamstring exercise is effective at strengthening the hamstring muscles, but has multiple downfalls as an exercise. Tsaklis et al.[39] studied the EMG level of the single leg deadlift exercise and found that it activates the hamstrings at a MVIC level that is appropriate for strengthening the hamstrings. Other research shows that this exercise effectively activates the gluteus maximus and eccentrically trains the hamstrings.[27,35,39] Additionally, the single leg deadlift trains the limbs unilaterally, promoting both balance and proprioception training for the athlete, possibly strengthening its need to be added to an injury prevention program, such as the FIFA 11+.

The balance and proprioception portions of this program are essential in training the body to maintain core stability and proper mechanics throughout movement.[35] This type of training is often labeled neuromuscular training and is focused on improving functional joint stability.[40] Such training is linked to increased joint stability and decreased injury risk.[35] Balance is defined as the ability to stabilize and minimize movement of the body on a decreased base of support, such as standing on one leg.[40] Activities in basketball such as pivoting, rebounding, running, and shooting a lay-up all involve controlling and stabilizing the body over one leg through movement.

A crucial component of balance is proprioception.[35] Proprioception is defined as the body's ability to sense joint movement (kinesthesia) and to sense the joint's position in space.[35] One study on girls' high school basketball players found that a 6-week balance and proprioception training program improved both static and dynamic balance in these athletes.[40] The FIFA 11+ includes balance exercises as part of its program including exercises such as single leg balance and plyometric exercises that target proprioception, such as jumping and landing.[35]

Overall, there are several factors that contribute to lower extremity injury prevention and multiple programs that have been studied in the literature. The FIFA 11+ has been shown to decrease injuries in both soccer players of both genders and male professional basketball players.[4,27] Additionally, there is plenty of literature that supports the use of gluteus maximus and gluteus medius strengthening exercises to assist in the prevention of LE injuries.[19,27,28] Currently, FIFA 11+ has not been studied specifically examining prevention of LE injury in adolescent girl basketball athletes and there are no known LE injury prevention programs that include proven gluteal strengthening exercises.

Methods

Participants:

The subjects included in this professional paper project consisted of thirteen high school girls (age: 16.46 ± 0.97, height: 67.46 ± 3.07 inches, weight: 140.54 ± 18.51 lbs.) selected to participate on the varsity and junior varsity basketball teams at Hellgate High School (Missoula, MT). Prior to beginning the project, subjects participated in open try-outs for all girls enrolled as students at Hellgate High School. Based on this try-out, the coaching staff determined which

student-athletes were best qualified to participate on which team. Throughout the duration of the season, the varsity and junior varsity teams practiced with each other in the same gym at the same time. These two teams also played the same number of games against the same opposing schools throughout the season.

The try-out to determine these teams began November 16th, 2017. Following the final day of try-outs, the student athletes that participated in the try-out were informed on whether they made the team and which team they would be playing on throughout the season. Some athletes participated on both the JV and varsity games, and some participated solely on the varsity or JV teams. Regardless of what team they played games with, all athletes completed the injury prevention program during the designated the JV/varsity practice time. In the instance where an athlete played with both the JV and varsity teams, they were subject to a limit on the number of quarters they could play each day per Montana High School Association (MHSA) rules. Those selected to play for JV/Varsity were asked to participate in this study, which was reviewed and approved by the University of Montana Institutional Review Board (IRB). The athletes were sent home with an informed consent, parental consent, and assent form. The forms were returned the first day of practice which was when pre-season vertical jump and drop-jump testing was measured, and implementation of the injury prevention program began.

The student-athletes on the JV and varsity teams began the injury prevention program on November 20th, 2017. The injury prevention program was only used prior to practices and not before games. For the first two weeks of the season, no games were scheduled. During those weeks, the JV and varsity teams practiced 5-6 times per week, with Sunday being a mandatory rest day. All practices were between 1.5-2 hours in duration. Once games began, the JV and varsity teams played a maximum of 2 games per week and practiced 3-4 days per week.

Every time the injury prevention program was implemented, the program was under the guidance of myself (athletic training student), the head athletic trainer at Hellgate High School, the Hellgate High School head girls' basketball coach, and the Hellgate High School JV girls' basketball coach. Prior to the implementation of the warm-up, the coaches received a handout explaining the modified FIFA 11+ program to refer to throughout the season (Figure 1).

Injury Prevention Program Implementation:

The injury prevention program followed a similar structure to the FIFA 11+ injury prevention protocol. Many studies have found the FIFA 11+ injury prevention protocol to be effective in preventing lower extremity injuries.[4,13,14,16] For this program, some modifications were made to increase participant compliance, as a major factor that is believed to contribute to the success of injury prevention programs is adherence to the program.[16,41] Start to finish, the FIFA 11+ program takes about 20 minutes to be completed in its entirety.[13,41] Allowing 20 minutes for a warm-up each day before practices may not be realistic for the majority of athletic teams at the high school level.[41] To make the program more realistic for a high school warm-up before practice and to promote greater compliance, certain exercises were removed from the protocol, while ensuring that all muscle groups and important movements are still targeted in the program.[41] To further increase compliance, only half of the strengthening exercises were performed per session in an attempt to make the warm-up more time efficient.[41] The student-athletes performed each strengthening exercise 2 times per week. Research has shown that performing the FIFA 11+ exercises as few as 1.5 days per week can positively impact LE strength and neuromuscular control.[13]

The injury prevention program began with a series of running drills, following the basic FIFA 11+ protocol (Figure 1, Part 1). The beginning running drills are used to prepare the body

for further activity by increasing core body temperature and moving the athletes through active lower body range of motion (ROM).[14] All exercises in this section of the prevention program were performed identically to how this section was designed in the original FIFA 11+ protocol.[41] Each running drill began with the athletes starting on the baseline on the basketball court. From there the athletes performed each exercise to the half court line (13 meters). Once they reach the half court line, they performed the same exercise back to the baseline. All beginning running drills were completed at a moderate pace and performed each day before practice.[14]

Following completion of the running drills, the athletes immediately began the strengthening portion of the injury prevention program, which included plyometric drills (Figure 1, Part 2). Some exercises were changed to address strengthening the gluteus medius and gluteus maximus, which have been shown to play a major role in the prevention and rehabilitation of injuries to the lower extremity.[18,21,27,29] To target these muscles, the single leg deadlift and side-lying hip abduction were added (Figure 1, Part 2). Studies have shown that these exercises effectively recruit the gluteus maximus and gluteus medius muscles at an appropriate level for strengthening to occur.[19,21,27]

The single leg deadlift was chosen to replace the Nordic Hamstring raise for exercise 9. (Figure 2) Eccentric training of the hamstrings is a known effective hamstring injury prevention strategy and thus needs to be included in every lower extremity injury prevention program.[35-39] The single leg deadlift is incorporated in this program because it challenges the athletes balance, eccentrically trains the hamstrings, and activates the gluteus maximus muscle at a level that should promote strengthening.[27,36,40] The side-lying bridge with hip abduction has been shown to be very effective at activating and strengthening the gluteus medius, however, it was not included in this injury prevention protocol because it is possibly too difficult for some athletes to

perform correctly.[19] To replace the side-lying bridge with hip abduction, the side-lying hip abduction exercise has been included in this program. This exercise is utilized because it has been shown to effectively activate the gluteus medius, which helps to prevent injury in the lower extremity by assisting with proper lower extremity alignment and mechanics during activity.[19,21,29] All athletes began performing this exercise without the use of a band for external resistance. They progressed to using an elastic band for external resistance when they could properly execute the exercise using only their own bodyweight.

Strengthening exercises that were still included from the original FIFA 11+ injury prevention program were the single leg balance exercise, walking lunges, and standing vertical jump. These exercises were kept in the program due to research supporting the inclusion of balance and plyometric exercises in successful injury prevention programs, as well as showing the FIFA 11+ program can improve balance and jump height.[6,13,30] Additionally, research shows that the lunge exercise activates the gluteus maximus to the appropriate levels for strengthening when the torso remains erect.[26]

As previously mentioned, the FIFA 11+ program has been shown to produce adequate gains in strength and neuromuscular control to be effective in preventing injury when the exercises are performed only 1-2 times per week.[13] Due to this knowledge, only half of the strengthening exercises were performed daily in an attempt to improve compliance.[41] On the first day of the week, the athletes performed side-lying hip abduction, sideways static bench, and single leg deadlift, and standing vertical jumps. The next day static bench, walking lunges, and single-leg balance with partner hand touches were performed. This format of dividing the strengthening exercises was used throughout the basketball season. Using this method insured

that each exercise was performed 1-2 times per week, which was reported to be effective in preventing lower extremity injury.[13]

After the strength exercises, the athletes finished the warm-up program by completing another series of running exercises (Figure 1, Part 3). These exercises are intended to help further prepare the athlete for practice by executing movements that they would perform in sport. Performing these movements in a more controlled environment allows the athletes to focus on proper LE biomechanics in each drill, with the intention of the strength, proprioception, and skills generated in this section of the injury prevention program translating to better and safer athletic performance. To increase compliance and shorten the length of time the program, the plant and cut exercise was eliminated. The bounding and accelerations across the court were left unchanged and completed from baseline to the other baseline, 3 times each.

Data Collection:

As previously mentioned, the project began November 20th, 2017 following the conclusion of the girls' basketball open try out. Out of a total of twenty-two girls on the varsity and JV girls' basketball roster, seventeen completed the pre-season testing, fourteen completed the post-season testing, and a total of thirteen consent forms were returned (n=13). Prior to the first day of practice, the athletes' vertical jump and drop jump measurements were recorded. These tests were performed to see if the results of this project would support the current literature surrounding the effects of FIFA 11+ and other LE injury prevention programs on LE biomechanics and sports-specific performance measures. The literature states that the FIFA 11+ program is effective in improving vertical jump [6,13,30], but is lacking on research to support any improvements in LE biomechanics. The drop jump test was measured to observe if the FIFA 11+ program was effective in improving LE proprioception and biomechanics. The literature states

that a multi-modal LE injury prevention program, Sportsmetrics, improved lower limb alignment during drop-jump testing.[32] Participation in PEP, another IPP, has been found to change the landing mechanics of female athletes during the drop-jump test.[11] These same tests were performed during the last week of the regular season to compare changes and the FIFA 11+ warm-up's effect on performance measures and proprioception/kinesthesia.

Vertical Jump:

Vertical jump was measured using Just Jump! Just Run! mat (Probotics, Inc). Each athlete performed three maximal vertical jumps and the results were recorded. The athletes were instructed to step onto the Just Jump! mat and perform a maximum-effort, double leg vertical jump. They could squat and use their arms to swing for momentum, but were instructed not to tuck their legs at their peak vertical height, to avoid altering actual vertical jump height measurements. A pre-and post-season team average for this performance measure were calculated for use in further data analysis.

Drop Jump:

The drop jump test was performed by having each athlete perform three trials of landing in a squat position off of a 12-inch plyometric box. Athletes' were observed during landing for valgus knee movement. During the drop jump movement, the researchers focused on observing knee valgus movement while the athlete was moving into the squat position or while sitting in the squat position. Knee valgus was determined to be positive (knee valgus present) when both knees did not maintain neutral alignment either during the squat movement or while holding the squat position. Positive knee valgus was awarded zero points and no knee valgus movement was awarded one point. After completing three drop-jump trials, each athlete was awarded a composite score. This composite score was calculated by adding the values of each drop jump

trial to achieve a sum total with a maximum score of three and a minimum score of zero. A team average score, calculated using each athlete's composite score, was recorded pre-and post-season to be used in data analysis.

Injury Prevention Protocol:

The warm-up protocol (Figure 1) was completed 3-6 times per week until the Montana high school basketball regular season ended on February 24, 2018. At the conclusion of the project, the head girls' basketball coach had the opportunity to continue using the injury prevention program through the remainder of the post-season, but injuries from this portion of the season were not included in the results of this project.

Data Collection:

Data collected for the season included injuries reported by the Hellgate High School head athletic trainer. For this project, an injury was defined as any musculoskeletal injury that was sustained from a basketball related activity and required evaluation and treatment by the athletic training staff.[38] All of the injuries were recorded in Hellgate's SportsWare Online subscription. From this project, lower extremity injury numbers were analyzed from the 2016-2017 JV and varsity girls' basketball season and compared to the lower extremity numbers for the 2017-2018 JV and varsity basketball season. This information was then broken down into the number of ankle/foot, lower leg, knee, thigh, and hip injuries sustained during each season for comparison. During the 2016-2017 season, the basketball team completed a standard active/dynamic warm-up that included no strengthening or plyometric exercises. The data analysis portion of this project began once the regular season ended.

Data Analysis:

To determine the statistical significance of the injury prevention program being an effective method of preventing lower extremity injuries, a chi square test was calculated using Microsoft Excel ($p < 0.05$). This test compared the total number of injuries reported in the 2016-17 and 2017-18 seasons. Chi square tests were also calculated comparing the acute and chronic reported injuries between seasons and the reported injuries to specific body parts between the 2016-17 and 2017-18 seasons. Further statistical analysis was completed by calculating paired t-tests to compare vertical jump values as well as drop jump composite scores pre-and post-season to evaluate the effectiveness of the FIFA 11+ program on sports specific skills and LE biomechanics.

Results

Lower extremity injuries did not differ between the 2017-2018 and 2016-2017 seasons ($p = 0.51$) (Table 1). The number of acute and chronic injuries for each season were also not statistically different between seasons ($p = 0.42$ and $p = 0.65$). LE injuries were also compared by injured body part and chi-square values were calculated (Table 2). A significant difference was noted in hip/thigh injuries between seasons ($p = 0.04$).

Vertical jump and drop jump testing values were also compared through paired t-tests as a part of the data analysis of this project (Table 3). The pre-season vertical jump team average was 16.5 inches and improved to a post-season average of 17.9 inches ($p = 0.00$) (Figure 2). The pre-season team average drop jump test composite score was 1.38 and improved to 2 in post-season measurements ($p = 0.58$) (Figure 3). Additional results that are not statistically relevant to this study are discussed in Appendices 1.

Discussion

The efficacy of the FIFA 11+ program has been studied previously in both male and female soccer athletes of a variety of ages, as well as elite male basketball athletes in randomized controlled trials, showing decreased risk of lower extremity injury.[4,14,15,16,22,23] Though we found a trend for decreased lower extremity injuries in the 2017-18 season when compared to the 2016-17 season, the results of this study were not statistically significant. Therefore, it is difficult to confidently state the effectiveness of the FIFA 11+ warm-up program in reducing LE injury risk in high school athletes of sports other than soccer.

Though the results of this project were statistically insignificant, there was a decrease in LE injuries in the 2017-18 season when compared to the 2016-17 season, which shows that LE injuries can be decreased with the implementation of a multi-modal injury prevention program, such as the FIFA 11+. We saw an increase in performance measures as well, which supports the literature stating that FIFA 11+ and other multi-modal injury prevention programs can improve LE biomechanics and performance in sports-specific skills.[6,11,13,30,32] These are clinically relevant results for health care professionals working with high school basketball athletes.

The literature suggests that strengthening the hip musculature, especially the gluteus maximus and gluteus medius may reduce lower extremity injury risk.[17,18,26] Weakness in both gluteus maximus and gluteus medius is directly related to ACL injury, iliotibial band syndrome, ankle instability, and PFPS.[17,18,26,27] It appears that the introduction of gluteus maximus and gluteus medius strengthening exercises to the FIFA 11+ program may have had a positive effect in reducing the number of low back, hip, and thigh injuries during the 2017-18 season, but did not positively impact the number of knee, ankle, or lower leg injuries.

Vertical jump performance changes were significant, which is supported by the literature.[13] There was a slight improvement in valgus knee movement during drop jumping as well, which is clinically relevant and supports the use of an injury prevention program to improve LE biomechanics, but the changes were insignificant. While these results are encouraging and support the use of an injury prevention program like FIFA 11+, the improved performance cannot be linked directly to participation in the injury prevention program alone. These athletes were participating in basketball practices and games 5-6 days per week, strength training, and for some athletes, other sports, such as club volleyball, which all could have an impact on the results of vertical jump testing and valgus knee movement on drop jump.

The literature shows that higher adherence to an injury prevention program corresponds positively to higher injury preventative effects of the program.[16,42] It is also reported in the literature that adherence is one of the most challenging aspects of implementing an injury prevention program.[42] For this program, some modifications were made to increase participant adherence, as a major factor that is believed to contribute to the success of injury prevention programs is participant adherence to the program.[16,39] The FIFA 11+ program takes about 20 minutes to be completed in its entirety.[13,39] Allowing 20 minutes for a warm-up each day before practice is not realistic for the majority of athletic teams at the high school level.[38] To increase adherence, only half of the strengthening exercises were performed per practice, which shortened the total time of the program to around 10 minutes. Research has shown that performing the FIFA 11+ exercises as few as 1.5 days per week can still positively impact LE strength and neuromuscular control.[13]

As stated above, adherence to an injury prevention is the greatest factor contributing to its success.[42] Both the coaches and athletes of the Varsity and JV girls' basketball teams were

enthusiastic and bought in to the warm-up program at the beginning of the season. Since the same warm-up protocol had been used the year prior with the boys' basketball team, both the coaches and athletes had an idea of what to expect. Through communication with the girls participating in the warm-up program, they seemed more motivated by the physical effects of the strengthening exercises (such as leg and core appearance) than any injury preventative effects.

Limitations

While precautions were taken to improve adherence and promote success of the injury prevention program, there were limitations to this project. Potentially the greatest factor that limited this project was adherence to the program. A previously stated, research that shows that higher coach and player adherence leads to greater injury preventative effects.[42] The same research also states that FIFA 11+ should be tailored specifically to the athletes participating in it to further promote adherence.[42] For this project, there could have been better communication between the researchers, coaches, and athletes prior to the initiation of the program. Prior to initiating the program, there could have been more conversations on how the program should reduce injury rates and potentially improve sports-specific skills. These conversations may have improved adherence and promoted more buy-in from both the coaching staff and the athletes.

The girls that participated in this study began the program with energy and excitement towards the injury prevention program but became bored of doing the same exercises each week, which led to decreased effort and buy-in to the program. The addition of the elastic band to add resistance to the side-lying abductions as well as progressing to a more challenging side plank created new challenges for the athletes, but many of the other exercises remained the same throughout the duration of the project. While the original FIFA 11+ program provides three levels of each strength exercise to allow for progression, a protocol was never established to

determine if athletes would progress independently or as a whole team. This may be the greatest challenge in implementing an injury prevention program in a team atmosphere.

Another limitation of this project is lack of a randomized control group. Having a control group either within the team or with a team with similar training and game schedules, but a different warm-up program, would have been useful to compare the effectiveness of the warm-up program on lower extremity injury prevention. If the study would have had a control group to compare injury statistics to, there would still be limitations because it is hard to determine the effects of factors such as weight training or physical condition before the season began. A final limitation of this project was a small sample size (n = 13). A larger sample size would allow for more athlete exposures and would increase the power of the statistical analysis of this project.

Future Recommendations

This project has established that the FIFA 11+ program, with added gluteal strengthening exercises, may reduce the number of injuries sustained by high school girls' basketball athletes, but more research needs to be completed to confirm the effectiveness of this program on athletes outside of soccer. Future research with larger sample sizes and randomized controlled trials would help to solidify the effectiveness of the FIFA 11+ program in reducing injury in athletes outside of soccer. This research should focus on clear communication with both coaches and athletes prior to implementation of the program to create buy-in and promote adherence. Research on PEP, an injury prevention program discussed earlier, shows that verbal cueing during LE movements led to improved technique and decreased knee valgus.[11] A randomized control trial that compared the results of drop jump knee valgus pre-and post-season with the implementation of verbal cueing throughout the FIFA 11+ warm up would supplement the existing research in the literature.

Conclusion

Currently, there are no known studies on the effectiveness of the FIFA 11+ warm-up in reducing injuries in high school girls' basketball athletes. There are also no known studies on the effects of adding gluteal strengthening exercises to the FIFA 11+ warm-up. The purpose of this project was to see if the addition of gluteal strengthening exercises in place of certain exercises in the FIFA 11+ injury prevention program will result in fewer LE injuries in high school girls' basketball players. Based on the findings of this project, the FIFA 11+ injury prevention program, along with gluteal strengthening exercises, appears to be effective in reducing lower extremity injuries in high school girls' basketball athletes, but more research needs to be completed to support this claim.

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Figures

Figure 1. Modified FIFA 11+ Warm-Up Protocol

PART 1: Running Exercises (to half court and back)

1. Jog to half court
2. Hip out every 5 steps
3. Hip in every 5 steps
4. Circling partner (2-3 times)
5. Running and jumping (contact)
6. Quick run forwards and backwards (run to first cone, back pedal to baseline, run to second cone, back pedal to first cone, etc)

DAY 1: Strengthening Exercises

Side-lying Hip Abduction

Athlete will lay on their side with the hip in a neutral position. They will start this exercise with the elastic band placed at the knee joint line. Athlete will be instructed to brace their core and abduct their leg while maintaining a neutral hip position.

2 sets of 10 reps (each side)

Verbal Cues: "Keep your hips stacked", "Brace your core"

Sideways Static Bench

Athlete will lay on their side with the knee and lower leg bent to 90 degrees. They will be instructed to support their body by resting on their forearm. The exercise will begin when the athlete lifts the uppermost leg until knee, hip and shoulder are in a straight line. Hold this position for 20-30 seconds.

2 sets of 20-30 seconds (each side)

Verbal Cues: "Keep arm directly under shoulder", "hips forward"

Single Leg Deadlift

Athlete will be instructed to maintain a slight bend in their planted leg. The movement begins with the athlete contracting the glute muscles and hinging at the hip. The athlete will be instructed to brace their core and maintain a flat back throughout the exercise.

2 sets of 10 reps (each side)

Verbal Cues: “Chest forward”, “Shoulder blades back”, “Tight core”

Jumping Vertical Jumps

Athlete will begin standing with feet hip-width apart. Hands are placed on hips. Athlete is instructed to squat slowly until knees are bent to approximately 90 degrees. They will hold this position for 2 seconds. From the squat position, they will jump as high as they can and land softly on the balls of their feet, with knees slightly bent.

2 sets of 30 seconds

Verbal Cues: “Don’t let your knees knock in” “Knees out”, “Land soft”

DAY 2: Strengthening Exercises

Static Bench

Athlete will begin lying stomach down, supporting their body weight on their forearms and toes. Elbows should be directly under shoulders. To begin the exercise, the athlete will lift their body up and support their weight on their forearms. Body should remain in a straight line.

2 sets of 20-30 seconds

Single-Leg Balance: Partner Hand Touches

Athlete will begin standing on one leg. They will balance on one leg while attempting to challenge the balance of their partner with their hands. Hold for 30 seconds. Change legs and repeat.

2 sets of 30 seconds (each leg)

Verbal Cues: “Engage your core”, Tighten your core”

Walking Lunges

Athlete will begin with feet hip-width apart, hands placed on hips. Athlete is instructed to lunge forward at a steady pace. Hip and knee on forward leg should be bent to 90 degrees. Upper body and hips should remain steady, torso should remain erect.

2 sets of lunging to half court and back

Verbal Cues: "Knee out", "Chest up", "Stay tall"

PART 3: Finishing running exercises (full court reps)

1. Bounding: jog a few steps then bound 8 steps, jog rest of court (3 x)
2. Running 75, 80, 100% max (3 x)

Program should be completed within 8-10 minutes.

Figure 2. Vertical Jump Pre-and Post-season Comparison

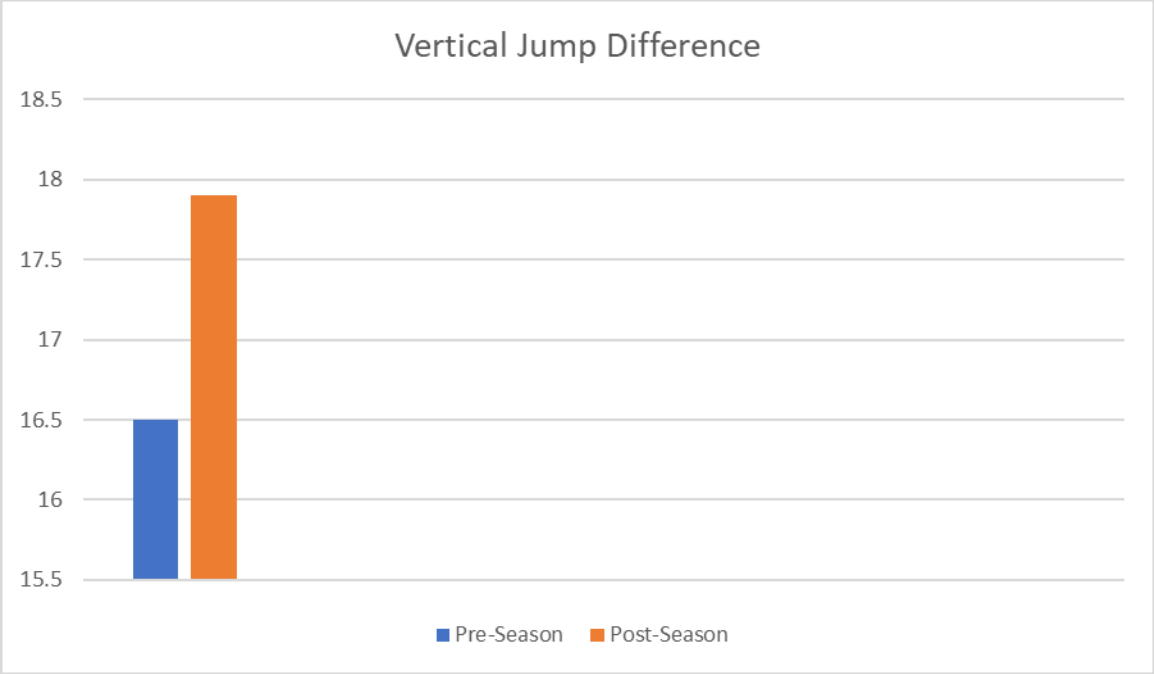
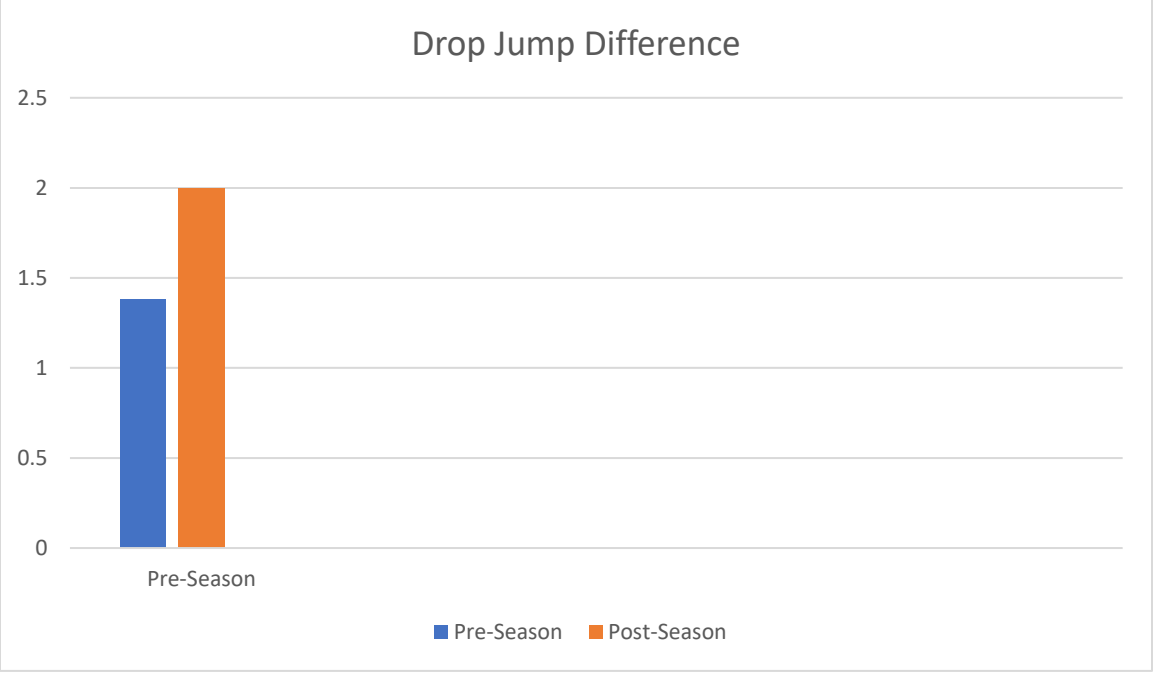


Figure 3. Drop Jump Composite Score Pre-and Post-season Comparison



Tables

Table 1. Comparison of Injury Statistics Between 2016-17 and 2017-18 seasons.

Year	# of Injuries	Acute	Chronic
2016-17	12	9	3
2017-18	9	6	3
P-value	0.51	0.43	0.66

Table 2. Comparison of LE Injury by Body Part.

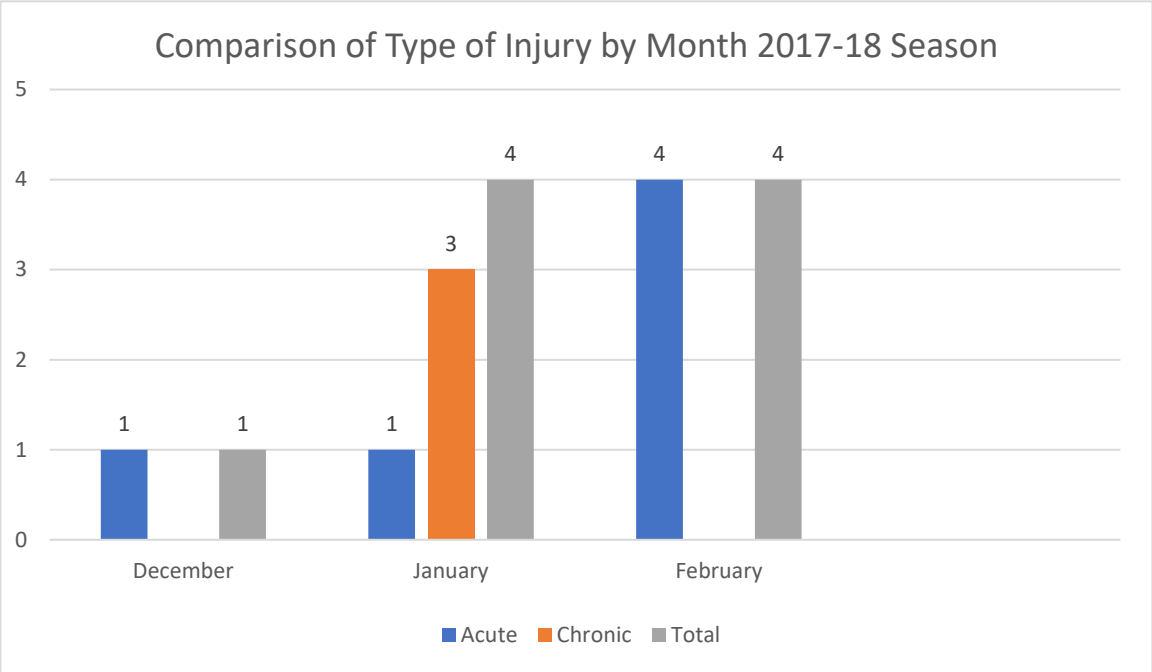
Year	# of Injuries	Back	Hip/Thigh	Knee	Low Leg	Ankle
2016-17	12	2	4	0	2	4
2017-18	9	0	0	3	3	3
P-value	0.51	0.16	0.04	0.08	0.66	0.71

Table 3. Vertical Jump and Drop Jump Testing Values.

	Pre-Season	Post-Season	Significance
Vertical Jump (inches)	16.5	17.9	.000
Drop Jump Composite Score	1.38	2	.58

Appendix

Appendices 1: Timing of Injuries by Month



The above graph displays the injuries reported throughout the 2017-18 season by the month they were recorded. This graph also breaks down the injury classification into either chronic or acute. In December and January, the girls' Varsity and JV basketball teams mostly played one game per week, with the rest of the week's basketball activity being practices. All of the chronic injuries (3 total) occurred in this time frame and only 1/3 of the acute injuries (2 total) occurred in these months. The incidence of mostly chronic injuries in December and January may be related to the structure of the practices and the focus on aerobic conditioning during this part of the season, but more research needs to be done to confirm this relationship.

In February, the girls' varsity and JV teams played two games per week on Thursday's and Saturday's. The majority of the acute injuries reported in this study occurred during this month (4 total), but no chronic injuries were reported during this time. These results may be related to a variety of variables, such as game frequency, rest between games, or physical and

emotional fatigue late in the basketball season. More research should be done to support these claims.