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Analysis of the Difference in Landing Between Male and Female High School Soccer Athletes.

Jessica Vogt
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Abstract

Introduction: Females are consistently found to be at a higher risk of tearing their ACL. Extensive research has been completed previously to determine what causes an ACL tear and why this separation exists but a confirmed conclusion has not been found. Potential extrinsic factors such as decreased knee flexion and increased valgus have commonly been suggested as increased stressors on the ACL. The focus of this study is to determine if there is a significant difference in these two factors between males and females.

Methods: Seven healthy and highly trained subjects between the ages of 17 and 18 who do not have a history of anterior cruciate ligament injury. Three trials of the subject stepping off a 63.5 centimeter bleacher and landing naturally. Frontal and sagittal plane filmed. One trial chosen to be digitized and analyzed with MaxTRAQ software. Specifically, knee flexion and valgus angles were measured with the software at initial contact of the landing and for maximum angle.

Results: Females landed with more knee flexion at initial contact and more valgus at initial contact. Maximum knee flexion angles were only slightly different. When comparing maximum valgus, females exhibited more than males. Significant difference was not found among males and females for knee flexion. Female valgus angles were found to be significantly different than male valgus angles.

Discussion: Results comparable with current research pertaining to valgus data. Knee flexion results differ. Important for understanding ACL risk of future athletes and the potential for training interventions.

Conclusion: Original hypothesis found to be incorrect. Only a significant difference in valgus angle was found. Additional research with more subjects is needed to determine accuracy of results.
Introduction

Anterior cruciate ligament tears is not an unfamiliar injury to athletes. According to a 13 year descriptive epidemiological study by the National Collegiate Athletic Association looking at soccer players, female athletes sustained 394 anterior cruciate ligament injuries while 192 male athletes injured their ACL\(^1\). It can easily be seen from the NCAA’s data that anterior cruciate ligament injuries do not treat all genders equally. The NCAA concluded that, “the rates for all ACL injuries for women were statistically significantly higher (p< .01) than the rates for all ACL injuries for men, regardless of the sport.” This one example is representative of the trend that continues to be seen.

The same results are also found when looking at high school varsity athletes. The American Orthopedic Society for Sports Medicine released a study conducted by John Powell that found of all injuries recorded in the sport of soccer, 15.1% and 19.4% occurred in the knee for male and females, respectively. Further, when looking specifically at ACL surgical repairs, the female’s rate was about four times higher than the rate for the males\(^6\).

The distribution of anterior cruciate ligament injury by gender is not the only component that is unbalanced. The large majority of ACL injuries are not caused by contact although exact mechanisms are unclear. Potential intrinsic and extrinsic factors have been identified but thorough research has yet to come to a confirmed conclusion. This study is relevant due to the longstanding uncertainty in what is causing the incidence of female anterior cruciate injuries to be higher among all types of athletes, especially in soccer. Additional data will be helpful in confirming or denying the current research and its findings.

The extrinsic factors, since they have the potential to be altered, are of particular interest in this study. Malinzak et al has found that females have smaller knee flexion angle, greater
knee valgus angle, increased quadriceps muscle activation, and decreased hamstring muscle activation. Chappell et al studied these four factors and concluded that they increase the load on the anterior cruciate ligament.

Specifically, this study will focus on knee flexion angle and knee valgus angle from a vertical drop landing. The purpose of this study is to measure and analyze both angles at initial contact from the drop and maximal angles throughout landing and to see if there is a significant difference between genders. Therefore, the independent variable is gender and position (initial contact and maximum) while the dependent variables are knee flexion angle and valgus angle. It is hypothesized that when male and female subjects land form a 60 centimeter drop jump, there will be a significant difference in knee flexion and valgus angles in regard to gender.

**Methods**

**A. Subjects**

The subjects used in this study were seven volunteers from U-19 elite club soccer teams from Northern Kentucky. These athletes participate in year-round soccer competition for their high school and club teams. All are members of the top select teams of their club determined through tryouts. It is estimated that they practice five days a week in-season for high school with one game per week. When high school season is finished, club takes over with two to three trainings per week and one game on the weekend. Each athlete is highly fit and familiar with the movement required of this study.

Four of the subjects are female and three male. Four subjects are seventeen and three are eighteen. The average height among all subjects is 69.4 inches or about 5’9”, 143.9 pounds is the average weight, and the average body mass index is 20.9. Broken down by gender, the mean
for the male subjects was 72.3 inches or about 6'0" for height, 157.7 pounds for weight, and 21.2 for BMI. For the females, 67.25 inches or 5’7” was the mean height, 133.5 pounds the mean weight, and 20.7 as the mean BMI. Each subject had a healthy body mass index. There was no history of ACL injury among the subjects. They would have been excluded if it was present. A breakdown of age, height, weight and BMI for each subject is included in Table 1.

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**Table 1.** The demographics of each subject used in this study are included. Subject number 2, 3 and 7 are male. The remaining subjects are female.

**B. Data Collection Procedures**

Two cameras were utilized for this experiment. A Go Pro Hero 4 Black Edition camera was used to film the frontal view. A Go Pro Hero 3 Silver Edition camera was used to film the sagittal view of the subject’s left leg. The frontal view of the subject’s left leg was filmed ten feet away or 3.05 meters from the edge of the bleacher that the subject was jumping from. The sagittal view was filmed thirteen feet or 3.96 meters away from the edge of the bleacher. The cameras were held at a comfortable position near the chest by the experimenters seated on the blacktop throughout the whole data collection period. The same two experimenters filmed all trials. Each camera had the capacity to film at “Ultra High Speed 1080p120 Frames per Second” but previous settings failed to be adjusted before filming. The Go Pro Hero 4 Black Edition
filmed the frontal movement at 240 frames per second while the Go Pro Hero 3 Silver Edition filmed the sagittal movement at 30 frames per second.

To calibrate the cameras to record at the same time, the recorder at the frontal view would say “1, 2, 3 GO” to initiate both recorders to turn their cameras on. Then after hearing “GO,” the subject counted to three in their head and stepped off the bleacher at their discretion. This method was chosen to make certain that adequate time was provided before the subject stepped off so that the full movement was recorded by both Go Pros. The Go Pros were not able to be synced perfectly, but additional video cutting tools will be used during data collection to record data at the same points.

All subjects and trials were recorded at a local high school on a Sunday, aside from one subject who was recorded on the previous Saturday. All other conditions were the same. Subjects were not given specific instructions on what to wear except that they should wear comfortable shoes that would help them complete the activity naturally. Once they arrived at the testing site, the subjects were all marked by the same experimenter. Orange athletic tape with a black circle marked in the middle by permanent marker was used. The tape was placed on the left leg specifically at the lateral aspect of the knee and ankle, the greater trochanter, the anterior superior iliac spine, and the middle of the patella. Subjects were asked to feel around and find the different anatomical markings based on instruction and the experimenter then confirmed they were correct and placed the tape. This method was used to make the subjects feel comfortable.

Aluminum bleachers sitting on top of concrete near a soccer field were used as a platform for the subject to step from. The subjects were instructed to step off the bleacher that is 25 inches or 63.5 centimeters from the ground, land naturally, and then jump vertically. The vertical jump was used to ensure that they athletes naturally absorbed the landing in a way that they would
normally when playing soccer. No example was shown by the instructor to avoid coaching bias. The athletes were able to practice the movement if they requested before filming started.

Three trials, at a minimum, were filmed for each athlete. A successful trial was considered one where the Go Pros were turned on correctly, the athlete gave adequate time before stepping off to allow the Go Pros time to record the full movement, and the athlete followed the instructions properly. Additional trials may have been recorded for some athletes if they did not follow correct directions in the first trial or there was an issue with the recording devices or other equipment.

One video was chosen for each athlete depending on the following criteria: all data points throughout the whole drop, landing, and jump were recorded in the Go-Pro’s field of vision; the athlete appeared to give effort in completing the task as naturally as possible; and the performance did not appear to be an outlier performance. All three trials were watched together and if one appeared to be significantly different from the other two, it was not used. It was really important the video chosen reflected a natural landing performance for each subject. The videos were then converted into AVI files so that they can be digitized by the MaxTRAQ software that will be used for data collection.

C. Dependent biomechanical variables analyzed

The dependent variables of this project were analyzed by the MaxTRAQ software. Specifically, the videos were digitized and then the angle tool was used to measure knee flexion and valgus. The points of reference for the angles were the anterior superior iliac spine, patella, greater trochanter, lateral aspect of the knee, and lateral aspect of the ankle that were marked with orange tape and a black dot on the subjects. The black dot was what was clicked in the
MaxTRAQ software. The tape and black dot were used in order to quickly and accurately choose the anatomical landmarks of interest for each subject.

The knee flexion angle was measured relatively because all points were on the body. Specifically, the greater trochanter, lateral aspect of the knee, and lateral aspect of ankle was marked to record knee flexion. This is seen in Figure 1. To determine valgus, an absolute angle was measured with the anterior superior iliac spine and patella as seen in Figure 2.

**Figure 1.** This screenshot depicts subject 3’s maximum knee flexion during their landing from the bleacher.
After digitizing each video and using the angle tool to measure each angle of interest for each frame, the videos were saved as an ASCII file within MaxTRAQ to be converted in Excel. In Excel the frame numbers were listed along with respective XY coordinates of each point and the angle—either knee flexion or knee valgus—at each frame. Excel was then used for further data analysis. All angles from all trials were able to be used exactly as transferred in Excel aside from the angles for one subject. One trial measured knee flexion opposite than expected by measuring the angle on anterior side of the knee as opposed to the posterior side as seen in figure 2 above. These angle values then needed to be converted by subtracting what was reported in Excel by MaxTRAQ from 360 degrees. Valgus was also measured incorrectly for the one subject. The data had to be subtracted from 180 degrees so that it was reported consistently with

**Figure 2.** In this screenshot, subject 2 has just made initial contact with the concrete from their drop. The frame has been digitized and the subject’s valgus angle is measured.
the other trials. After making these simple calculations, the data was ready to be compared among the subjects.

Results

Knee flexion angles and valgus angles were measured and recorded for all seven subjects while dropping from the bleacher. The angle seen at landing and the maximum angle were both recorded and used for analysis. Reminder, due to the method in which MaxTRAQ measured the angles, the smaller the angle value is, the greater the knee flexion. Similarly for valgus, the smaller the angle, the more valgus there is.

In order from largest to smallest, indicating least flexion to most flexion, the females had values of 142.79 degrees, 138.42 degrees, 132.49 degrees, and 124.60 degrees at landing. In comparison, the males produced knee flexion values of 146.37 degrees, 137.33 degrees, and 134.85 degrees at landing. The mean female knee flexion was 134.58 degrees with a standard deviation of 7.88 and 139.52 degrees with a standard deviation of 6.06 for males. At maximum, the female’s angles were 95.72 degrees, 93.88 degrees, 89.24 degrees and 80.55 degrees with a mean value of 89.85 (standard deviation 6.77). The male’s produced maximum angles of 96.80 degrees, 90.58 degrees, and 80.36 degrees with a mean of 89.25 and a standard deviation of 8.30.

For valgus, the females were measured to have angles of 94.89 degrees, 90.22 degrees, 89.56 degrees, and 88.22 degrees at landing. The mean valgus angle for females is 90.72 degrees with standard deviation of 2.90. The maximum valgus angles for the females are as follows: 94.89 degrees, 88.29 degrees, 76.66 degrees and 75.21 degrees. The mean is 83.76 with a standard deviation of 9.45. The males exhibited 97.86 degrees, 96.78 degrees, and 96.64 degrees of valgus at landing with the mean being 97.09 with a standard deviation of 0.47. Their maximum valgus values came out to be 97.38 degrees, 96.86 degrees, and 96.47 degrees with a
mean of 96.90 with a standard deviation of 0.46. All eight mean and range values (knee flexion at landing, maximum knee flexion, valgus at landing, maximum valgus for males and females) are presented in Table 2.

<table>
<thead>
<tr>
<th>Female</th>
<th>Male</th>
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Table 2. This table lists the means and range in one column and the standard deviation for each dependent variable in another column. MaxTRAQ was used to measure the appropriate angles for every frame of the video. The angle at landing from the drop off the bleacher and the relatively maximum angle for each variable was recorded and used to calculate mean and standard deviation.

When looking strictly at the means for knee flexion and valgus at landing and maximum knee flexion and valgus, the females exhibited more knee flexion when landing, lesser maximum knee flexion, more valgus at landing, and more maximum valgus than compared to males. In other words, the males landed with less knee flexion initially but proceeded to have more maximum flexion than the females. The males also had less valgus throughout the motion of landing and absorbing the drop from the bleacher. A bar graph of the results are clearly shown on Figure 3. It is important to note that these conclusions are only based on the numerical values of the means for each dependent variable.
Figure 1. This bar graph displays the male (black bars) and female (light gray bars) means for each dependent variable side by side for comparison. The male subjects had the higher means for each variable, aside from maximum knee flexion. A higher knee flexion angle indicates that the subject’s knee was more extended whereas a lower knee flexion angle would represent that the subject’s knee was more flexed. When an athlete’s valgus angle measurements began decreasing through the movement, this meant that they were presenting with valgus. The smaller the angle, the more extreme the valgus.

Two sample t-tests with assumptions of unequal variance were ran for each of the four dependent variables: knee flexion at landing, maximum knee flexion, valgus at landing, and maximum valgus. The p value for each variable was as follows: 0.19 (knee flexion at landing), 0.46 (maximum knee flexion), 0.01 (valgus at landing), and 0.03 (maximum valgus). An alpha level of 0.05 was assumed therefore a value of less than that indicates significance. Therefore, the difference between knee flexion at landing and maximum knee flexion between males and females were not found to be significant. However, the differences in mean valgus angle at
landing and mean maximum valgus angle between males and females was found to be statistically significant.

**Discussion**

The results indicated that there was not a significant difference in knee flexion between males and females. This was true when comparing knee flexion angles at landing and maximum knee flexion of each subject. However, there was a significant difference found in valgus angle between males and females. The females had significant smaller angles which indicates more valgus according to how they were measured.

There has been much debate on what exactly causes a valgus knee position. According to Hewett in his summary of his two decade long research, when an athlete lands in knee valgus it is a result of something that he has termed “ligament dominance.” This dominance is a neuromuscular imbalance that results in the athlete absorbing most of the ground reaction force with their ligaments instead of their muscles when landing from a jump or drop. This causes an issue because when the ligaments sustain such a high force it puts extra impulse force on them past what they are designed for and thus causes the ligament to tear.

Hewett goes further to explain that females experience ligament dominance more than males because they allow more lateral trunk movement when landing and/or less neuromuscular control in their frontal plane. This extra trunk movement causes their center of mass to move laterally as well. When they land with a lateral center of mass, the ground reaction forces will move laterally as well. This lateral shift of the center or mass and ground reaction forces pushes the knee joint into a valgus position.

Hewett also reported that females are more dominant with their quadriceps muscles and they recruit their hamstrings and gluteus muscles less than their male counterparts. This is
important because the neuromuscular imbalance of “ligament dominance” can be avoided with more recruitment of the posterior kinetic chain. It appears that the significant knee valgus in the female subjects of this study can be explained by Hewett’s research although it cannot be confirmed because tests were not done to measure muscular strength and activation during the landing tasks.

The results of my study have split reviews according to previous published research. When comparing this study to results from three different published research studies, similar valgus data was found but the knee flexion outcomes differ slightly. All three research studies involve the subjects dropping from a 60 centimeter platform while this current study had the subjects drop from a 63.5 centimeter bleacher. Therefore, the results are able to be compared.

To begin with knee flexion angles, Vibert et al found a significant difference between male and female knee flexion from a 60 centimeter height at initial contact with the ground. However, they did not find a significant difference in maximum knee flexion angles. The females of their study landed with their knees more extended initially than the males. Decker et al came to a similar conclusion. Their female subjects also landed with more extension at initial ground contact from a 60 centimeter drop. This was decided by looking at individual knee flexion angles. The difference in means was not found to be significant.

The current study differed by not finding a significance difference in knee flexion for males and females. Additionally, the males of this study actually landed in a more extended position than the females according to the mean. When looking at individual data, all three male subjects landed with less knee flexion than the female’s mean angle. The maximum knee flexion mean angles were very similar. The means were off by only 0.6 degrees. The major difference between these two published research studies and this study is that the mean subject age for the
other studies was between 26 and 28 while the mean age of this study is 17.4. An age gap of between nine and eleven years could explain the difference in results. Additionally, the subjects used in the two cited studies were recreational athletes whereas the current subjects are highly trained soccer athletes.

The research done by Russell et al mimics what was found in this study. At initial contact from a 60 centimeter drop, the female subjects exhibited greater valgus than the male subjects. A multitude of additional research articles were also cited to support Russell et al’s findings. The results of this study also found that the females landed with more valgus than the males. Both the current and previous studies found the angle differences between males and females in regard to valgus to be significant.

The results of this study are important and practical for athletes, practitioners, coaches and readers alike when interested in becoming more educated on potential gender differences in lower body biomechanics. These differences could lead to understanding why such a large gap exists between male and female risk for anterior cruciate ligament injuries. Hewett et al has found that “ACL injuries occur with a four to six fold greater incidence in female compared to male athletes playing the same high risk sports.” The one thing that can be taken away from this study is that a significant difference is present in regards to knee valgus angles in males and females when landing from a drop jump. This is a potential risk factor for increased load on the anterior cruciate ligament and further research could help determine if it is the cause of the incidence gap in anterior cruciate ligament injury among genders.

A five degree increase in valgus angle from neutral will increase the load on the anterior cruciate ligament by at least six times. This is critical in the search to determine why females
have a higher risk of ACL injury. Retraining female athletes to land with less valgus could help to prevent future injury.

Aside from anterior cruciate ligament injuries, athletes are at risk for additional injuries as well with a valgus force. These injuries include medial collateral ligament sprains and medial meniscus tears. Athletes and/or coaches should be aware of this danger. It is important to pay close attention to an athlete to observe if they display valgus when jumping, landing from drops, cutting, squatting, etc. because this could indicate that they are at risk for noncontact injury.

This study could have been improved by using higher frame rate Go Pro cameras, requiring the athletes to wear tight-fitting clothing, and recruiting more subjects. To begin, Go Pro cameras that measured a larger frame rate and using the same frame rate for each view would have enhanced the results. The frontal plane videos, where knee flexion angles were measured from, were recorded at 240 frames per second. On the other hand, the sagittal plane videos where valgus was measured, was recorded at only 30 frames per second. Although it was not a huge inconvenience, the decreased frame rate for the sagittal view produced less data. There were less angles that could be measured by MaxTRAQ throughout the drop. As a result, there were less recorded valgus angles for each subject in comparison with the knee flexion angles. More accurate valgus means would have been produced if more were able to be measured throughout landing and absorption.

Secondly, the study could have been improved if the subjects were asked to wear tight-fitting clothes, especially bottoms, such as leggings or spandex. This would have led to more accurate anatomical markings with the tape. The subjects in this study wore whatever was comfortable which meant that most were wearing loose shorts. During the drop movement, the shorts moved around freely thus the orange tape moved around freely. This orange tape was
what was used in MaxTRAQ to mark points and measure angles. If the tape moved after being placed, chances are the anatomical markings were not correct for some of the frames. More accurate data would have been calculated if the orange tape stayed consistent with the anatomical landmark.

The final limitation of this study was the number of subjects. With only four females and three males, the sample size was only seven. A small sample size runs the risk of inaccurately representing the general population. For more legitimate results, a larger sample size is recommended.

It would have been interesting to measure additional angles than knee flexion and knee valgus. One more anatomical marking could have allowed for hip flexion to serve as a dependent variable as well. Hip flexion influences how erect the person is when landing from a drop or jump. An erect posture has been suggested as a position that puts more stress on the anterior cruciate ligament. In combination with knee flexion, hip flexion would have quantified this posture for each subject.

**Conclusion**

The takeaway from this study of landing mechanisms between male and female high school soccer athletes is that a significant difference was found in valgus angle among genders. Specifically, females showed more valgus when compared to males. This data can be used to alter training for females differently from their male peers to attempt to train them to land with proper mechanics in order to reduce strain. Additional research is needed to determine if the results of this study are reliable and valid. The original hypothesis stated that a significant difference would be found in maximum knee flexion and valgus angles and angles at landing.
from a 60 centimeter drop between genders. However, the hypothesis was proved incorrect since a significant difference was only found between genders in knee valgus at landing and at maximum.
References


