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Submitted by

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Elizabeth Fortener

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INTRODUCTION

Knee injuries are the second most common type of injury that occurs in basketball and volleyball.\textsuperscript{1,2,3,4,5} In addition, they are the most common form of severe injury and the most common form of injury that requires surgery in athletes who play basketball and volleyball.\textsuperscript{4,5,6}

The two most common complaints of the knee are anterior cruciate ligament tears (ACL) and patellofemoral pain.\textsuperscript{7} Past studies have examined whether different foot types contribute to these complaints, (Hopper) but the classification of foot type was problematic because many subject’s feet were placed into the category of “other”. Because of this concern, recent research has begun to examine the medial longitudinal arch as a means to classify arch height, although these studies still use various methods to determine arch height. In addition, many of these studies have conflicting results.\textsuperscript{10,11,12}

The purpose of this study was to examine the relationship between navicular height and the incidence of knee injuries in high school athletes participating in volleyball or basketball. This observational, longitudinal study measured the navicular height of 23 male and female high school volleyball and basketball players and compared the navicular height to the incidence of knee injuries. The researchers used a plastic ruler to measure the height of the navicular, similar to the method used by Holmes et al.\textsuperscript{13} Four measurements were taken of each subject’s foot, one at each of the following positions: subtalar joint neutral (STJN), relaxed stance, maximum pronation, and maximum supination. These measurements were recorded by a separate researcher to ensure that the researcher performing the measurements was blinded to the results.

A log was provided for subjects to record all knee injuries that occurred during the basketball or volleyball seasons. Subjects were asked to record when the injury occurred, where the pain was felt on the knee, what knee was injured, if the subject was seen by a doctor for the injury, and if the injured knee was braced or taped at the time of the injury. The researchers
collected the logs at the end of the basketball season to examine the data.

This study used a 2-factor ANOVA to analyze the data obtained. It was hypothesized that volleyball and basketball players with a lower navicular height will sustain more knee injuries than volleyball and basketball players with a higher navicular height.

**LITERATURE REVIEW**

More than 30,000 serious knee injuries are projected to occur in females each year.\(^{14}\) This number increases when males are included. Toth et al\(^{14}\) studied ACL injuries occurring in females. In the colleges that were used in this study, the knee injury rate was 1 out of 10 for females. In the high schools that were used in this study, the injury rate was one-tenth the rate of college female athletes, but when taken into consideration the greater amount of participants at the high school level than the collegiate level, high school athletes accounted for twice the number of knee injury occurrences.\(^{14}\)

Hickey et al.\(^{2}\) studied a group of elite female basketball players over a six-year period in Australia. They found that the most injured area of the body for this group of athletes was the knee at 18.8% of the injuries sustained. During this time period 16 surgeries occurred as result of injuries during the basketball season. Thirteen of these injuries involved the knee.

Gomez et al.\(^{4}\) examined 100 Texas high schools girls’ varsity basketball teams for a season. They found the knee to be the second most common site of injury accounting for 19% of all injuries occurring. This study also found that knee injuries sustained throughout the season were more severe than other injuries and made up 64% of all the surgeries that occurred as a result of these injuries.

When examining one season of basketball, Colliander et al.\(^{3}\) found 19% of males and 17% of females that participated in Swedish elite basketball sustained knee injuries. Of these numbers, 56% of the male’s and 38% of the female’s knee injuries were classified as severe.
These numbers show that not only are females suffering from knee injuries, but so are males.

Most of the studies done to date are on college/elite athletes or adults. The studies that have been done on high school aged athletes have just been injury reports. Little research has been done to examine the relationship of navicular height and lower extremity injuries on other athletes, in particularly high school basketball and volleyball players.

One theory behind knee injuries is limb alignment. Arch height has been suspected to be related to the incidence of these injuries. A naturally everted foot has a lower navicular height than a foot that is in subtalar joint neutral. This alignment may cause compensatory effects within the lower extremity such as when the subtalar joint is everted, the talus adducts, and the tibia follows the talus, therefore internally rotating. Nigg et al. found that the eversion of the foot to the internal rotation of the tibia had a very high correlation ($r^2 = .991$). James stated, “…when internal tibial rotation is increased or prolonged with excessive pronation, more transverse rotation much be absorbed in the knee joint with subsequent disturbance of the normal tibio-femoral rotational relationship and an alteration in normal patellofemoral mechanics.” Buchbinder et al. stated, “with prolonged pronation both the origin and the insertion of the quadriceps are located lateral to the patella, and internal rotation of the limb creates an abnormal lateral pull on the patella.” This is called the Q-angle. An increased Q-angle has also been said to predispose an athlete to knee injuries.

In order to examine the effect of arch height on knee injuries, a consistent method is needed to measure and determine the position of the weight bearing foot. Multiple methods have been described in the literature. Some of these measurements include footprint measurement, visual assessment, and palpating the height of the navicular tuberosity of the foot.

Footprint measurement is one method that has been modified throughout the years. The footprint angle from Schwartz draws a line down the medial border tangent to the calcaneus
and head of the first metatarsal. Another intersecting line is drawn from the most medial point on the metatarsal head to the most lateral portion of the medial border. The footprint index from Irwin\textsuperscript{24} is a ratio of the non contact surface of the foot to the contact surface of the foot (minus the toes). Both of these methods had high reliability coefficients (.971 and .982 respectively) but problems occurred when the arch was so high that there was no contact of the midfoot or the arch was so low there was no non-contact of the foot.

Another method used is visual assessment. Four orthopedic surgeons and two podiatrists reviewed 40 slides of people’s feet that were not participating in the study to discuss the criteria they would use to assess the feet. They used a 5-point scale with 1 being clearly flat-footed to 5 being clearly high arched. A ranking of 3 was the mid point, being a normal arch. Then the pictures of all 246 subjects’ right feet were examined independently and without discussion. The results showed very little agreement among the clinicians. If the subject was rated having a high arch by one clinician, there was a probability of 0.00 to 1.00 with the mean being .17 that another clinician would also rank that subject as having a high arch. This probability for ranking a subject as having a flat foot was .32-.79 with a mean of .57.\textsuperscript{22} Both of these methods show a need for a more reliable and simpler way to classify a person’s arch type.

Holmes et al. developed a tool to measure arch height.\textsuperscript{13} They palpated the navicular tuberosity and marked it with a pen. Arch height was measured from the mark on the navicular tuberosity to the ground using a ruler imbedded into a foam block. This ensured the ruler was flat against the ground and straight up for each measurement. They demonstrated that the data obtained from this device had intra-rater reliability with an ICC value ranging between 0.94-0.96.\textsuperscript{13}

With this simple and reliable method, more studies need to focus on high school athletes who participate in volleyball and basketball. A number of studies have observed college or elite
athletes and found that knee injuries are a very common and severe form of injury that occurs during play. With the trend the way it is in these athletes, it is also possible for this same trend to be occurring in high school athletes as well. With more data on injury trends in high school basketball and volleyball, it may be possible to identify a factor associated with those injuries to put in place some intervention to help reduce the incidence of these injuries.

**Problem**

In all sports, knee injuries are common, making up 15-50% of all injuries that occur.\(^1\) According to other research the percentage of knee injuries in basketball and volleyball remain around 20%.\(^1,2,3,4\) It has also shown that an even higher percentage of these knee injuries are severe, requiring more surgery than any other kinds of injury, and that knee injuries are the most common cause of permanent disability.\(^3,4,5,6,8\) The medial longitudinal arch height has been shown to be related to knee injuries and could be a possible link to these injuries.\(^10,11,12\) Despite this link, few studies have examined the relationship between the incidence of knee injuries and the arch height of the foot of high school athletes.\(^10\)

**Purpose**

The purpose of this study was to determine if a relationship exists between knee injuries and navicular height in High School volleyball and basketball players.

**Hypothesis**

It was hypothesized that volleyball and basketball players with a lower navicular height will sustain more knee injuries than volleyball and basketball players with a higher navicular height.

**Significance**

If the hypothesis is supported by the study it will be possible to determine which
volleyball and basketball players have a higher risk for knee injuries to put in place some kind of inhibitor, such as an orthotics or a brace, to help prevent or lower the incidence of knee injuries in order to maintain the quality of the performance.\textsuperscript{10}

**METHODS**

**Design**

This was an observational, longitudinal study measuring High School volleyball and basketball players’ arch height and observing them throughout the season to see who does and does not experience a knee injury.

**Subjects**

Subjects were High School male and female basketball and volleyball players on the Varsity and reserve teams from three northwest Ohio rural high schools. Subjects ranged in age from 13-19 years old. They were excluded from the study if they had a recent or current lower extremity injury. They were included if they were active participants on the volleyball or basketball teams from these 3 high schools.

The investigators visited the three high schools to recruit participants by asking for volunteers. If the athletes chose to participate they were required to provide parental consent or personal assent. The study was approved by the Institutional Review Board for the Protection of Rights of Human Subjects at the Medical College of Ohio at Toledo (IRB #104830).

**Measurement**

The measurements were taken by using a plastic ruler to measure the palpated navicular height, which simulated the measuring technique used by Holmes\textsuperscript{13}. The navicular was palpated while the subjects were in a non-weight bearing position. The navicular height was measured in centimeters, from the pen mark on the navicular bone of the foot to the floor, in a weight bearing position in four different conditions: STJN, relaxed stance, maximal supination, and maximal
pronation.

The researcher measured 10 subjects for a total of 20 feet to test intra-rater reliability. Adequate reliability was not obtained as can be seen in Table 1.

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<td>0.75</td>
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<tr>
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</table>

Table 1. Intraclass Correlation Coefficient values for the four variables, with the 95% confidence intervals.

**Procedure**

The researchers visited the male and female basketball and volleyball teams from 3 Northwest Ohio area high schools to explain the purpose of the study. All athletes between the ages of 13-19 were asked to participate. At that time the subjects had ample opportunity to ask any questions. After the presentation, subjects received parental consent forms (if under the age of 18) or personal assent forms to allow participation in the study.

The participating athletes turned in their consent/assent forms to the coach or athletic trainer. The forms were then collected by the researchers one week after the distribution of the forms. During the time of the second visit, the injury logs were distributed to participating athletes. The mechanics of all possible injuries were demonstrated to the subjects. Pictures of all injuries were illustrated on the form and were explained during the demonstration (Appendix A).

Also at this time the navicular tuberosity of each subject participating in the study was measured. These measurements were taken only one time. The measurement was from the navicular tuberosity on the inside of the person’s foot to the floor while the person was standing with full weight bearing. The subjects were then asked to keep the provided log and record all
knee injuries. If they sustained a knee injury, they were to record where the knee pain/injury occurred and how the injury occurred if they could remember. Other information recorded on the log sheet was the date the injury occurred, which knee was involved, if they saw a doctor for the injury, and if the knee was braced or taped at the time of the injury.

The injury logs were collected at the end of the basketball season. This data was then analyzed to see who sustained a knee injury, who did not, and compared those to the navicular heights of each group.

**Data Analysis**

This study used a two-factor ANOVA with repeated measures to compare the independent variable, those who sustained a knee injury to those who did not sustain a knee injury, with navicular height as the dependent variable. There were four different levels of the dependent variable: STJN position, relaxed stance, maximal supination, and maximal pronation. This statistical test was used to test the following hypothesis: that volleyball and basketball players with a lower navicular height will sustain more knee injuries than volleyball and basketball players with a higher navicular height.

The p-value was set at <.05 to reduce the chance that results will occur by chance. This study may help physical therapists, athletic trainers, and coaches take an active role in helping to prevent or lower the risk of knee injuries in their patients or athletes. This could be done by using some intervention to prevent the navicular from dropping as much as it normally would in an athlete with a naturally low navicular height.

**RESULTS**

It was hypothesized that volleyball and basketball players with a lower navicular height will sustain more knee injuries than volleyball and basketball players with a higher navicular height. Results of this study show no statistical significance between higher and lower navicular
heights and knee injuries.

Twenty-three subjects participated in this study. Males accounted for 60.9% (n=14) while females accounted for 39.1% (n=9) of the subjects. Of the 46 feet, three out of the nine females sustained a knee injury (33.3%), while only 1 out of 14 males sustained a knee injury (7.1%). A two-factor multivariate analysis of variance (2-way ANOVA) was performed to compare the injured and non-injured group’s navicular height values. Table 2 shows the ANOVA table, which shows the statistical values found for this test. Figure 1 demonstrates mean values for the injured and non-injured group’s navicular heights at all four positions. These values were not found to be significant with a p-value of >.05, although there seemed to be a possible trend with the injured group having lower navicular heights than the non-injured group in all four positions.

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</table>

Table 2. ANOVA table for comparison of injured to non-injured group’s navicular height.

Figure 1. Significant values were not found for these four groups when comparing the injured group to the non-injured group over each measure. (p-value >.05)
Another 2-factor ANOVA was used to determine if there was a difference in total STJ ROM between the injured and non-injured groups. These results were statistically significant (p-value <.05) with the injured group having less total STJ ROM than the non-injured group. Table 3 shows the ANOVA table. These results are depicted in a bar graph in Figure 2.

![Table 3. ANOVA table comparing injured and non-injured group’s total STJ ROM.](image)

**DISCUSSION**

Our hypothesis was: that volleyball and basketball players with a lower navicular height will sustain more knee injuries than volleyball and basketball players with a higher navicular height. The results found in this study were not statistically significant to support this hypothesis. However, there was a definite trend noticed in support of the hypothesis.

Knee injuries have been found to be the second most common injury athletes sustain while participating in basketball and volleyball, with an overall percentage of about 20% reported by most studies.¹²³⁴⁵ This study found that overall 8.7% of the participating subjects sustained a knee injury. When separating males and females, it was found that males sustained 7.1% and females sustained 33.3% of the knee injuries. The overall percentage of 8.7% does not
show similar results as other studies.\textsuperscript{5,16,25} The limiting factor in this case was most likely that the number of subjects participating in the study was not sufficient enough to obtain similar data as other studies. On the other hand the ratio of female to male injury rate seems to correlate well with other studies.\textsuperscript{5,16,25} This study found that females were 4.69 times more likely to sustain a knee injury than their male counterparts. Other studies to date have found similar results with actual likelihood females would sustain a knee injury ranging from 2-6 times more likely than males.\textsuperscript{5,16,25}

This study attempted to examine the relationship between the navicular height of athlete’s feet to the incidence of knee injuries. No significant difference was noted when comparing the navicular height at all four stance positions between the injured and the non-injured groups (p-value >.05). However, there seems to be a trend showing that the athletes who sustained a knee injury had a lower navicular height at all four stance positions. This, again, is demonstrated in Figure 1 in the results section of this paper. An explanation of why this trend seems to exist is because three of the four knee injuries were to females. Female’s feet are shorter than male’s feet and therefore will have a lower navicular height than males will have. This cannot be determined from our data though because this information was not collected from the subjects.

A possible reason for why these results were not significant if foot size is not a factor, is that there were only 46 feet examined. A greater number of subjects would possibly have yielded significant results.

Also examined in this study was whether or not there was a difference between the injured group and non-injured group in available total amount of STJ range of motion (ROM). This was not a part of the hypothesis, but an additional factor examined. Surprisingly, even with only four knee injuries reported, significant results were obtained (p-value <.05). With only four knee injuries, there would have to be a greater difference in total STJ ROM for the results to be
significant than would be needed if there were a greater number of subjects sustaining a knee injury.

Hopper 2 et al.\textsuperscript{9} studied a group of female netball players ranging in ages of 16-21 years old. They found that “movements at the STJ were significantly different between those players who sustained a knee injury and the uninjured players”. Their thought about these findings was that “an increased STJ range of movement may be more accommodating to force distribution during the foot-ground contact”. The results from this study support the results found in Hopper 2 et al by having statistically significant data of greater STJ ROM in the non-injured group than the injured group. These results are demonstrated in Figure 2 located in the results section of this paper. These results contradict the suggestion that high-arched feet are inflexible, while flat feet are hypermobile.\textsuperscript{26,27}

The method to measure navicular height in this study was similar to the method used by Holmes et al.\textsuperscript{13} The difference from this study compared to Holmes’ was that the researchers in this study used a plastic ruler that was not imbedded in a foam block. Holmes et al.\textsuperscript{13} used this foam block to eliminate any discrepancy in placement of the ruler on the surface to measure the navicular height. The method used by the researchers for this study proved to not be reliable with ICC statistics ranging from .62 to .89.

This could have happened for many reasons, one being that the method used by Holmes et al\textsuperscript{13} was not replicated exactly. There could have been error in the measurement technique if the researcher did not position the ruler at the same angle for each measurement. This is what the foam block Holmes et al\textsuperscript{13} used eliminated. Another factor that could have caused the researcher to not be reliable is the fact that the subjects are moving their ankle at their own will. They could have moved it further one time compared to the other without realizing that they could go further.
CONCLUSION

A significant difference was found in total STJ ROM when comparing the injured group to the non-injured group of high school basketball and volleyball players. This was not one of the researchers’ hypotheses, but should be examined more fully in a larger population to determine if this holds true for other populations, especially because of the contradicting results of whether higher arched feet are more flexible or less flexible than lower arched feet.

No significant difference was found for the hypothesis, that volleyball and basketball players with a lower navicular height have a greater risk of suffering from a knee injury than volleyball and basketball players with a higher navicular height. Results concluded from this study show that there appears to be a trend that supports this hypothesis, but no significant data was obtained. Since there appears to be a trend in this direction, the main limiting factor seems to be limited number of subjects that participated in this study. If more subjects participated in a similar study, better results could be found to determine if the results obtained in this study happened by chance, or showed a true trend among high school athletes.

If these results can be found, it might be possible to reduce the number and or severity of knee injuries that occur every year to high school athletes that are participating in basketball and volleyball. Going further beyond that would be to use some type of intervention for prophylactic prevention of knee injuries to even younger athletes before they reach high school aged.
REFERENCES


