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The Relationship Between Navicular Height and the Incidence of Ankle Injuries in High School Athletes

Submitted by
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The Relationship Between Navicular Height and the Incidence of Ankle Injuries in High School Athletes

Cari Dannemiller

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INTRODUCTION

Ankle injuries are the most common type of sport related injury. Ankle ligament injuries account for 75% of all sport related ankle injuries, making it the most common type of ankle injury. Inversion ankle injuries are the most common type of ankle ligament injuries, accounting for 85% of all ankle ligament injuries. The lateral ligaments are smaller and weaker than the medial ligaments in the ankle. When an athlete lands on an uneven surface, a supination torque is placed on the lateral ligaments causing these ligaments to be overloaded with force and cause damage to occur\(^2,14\). Recent research has begun to consider that the aforementioned injuries may be caused by navicular height, although many of these studies have conflicting results\(^4,11,14\).

LITERATURE REVIEW

Most of the studies done to date are on college athletes or adults\(^2,14,19\). Little research has been done to examine the relationship between navicular height and lower extremity injuries on other athletes, in particular high school basketball and volleyball players.

One theory behind ankle injuries is limb alignment\(^3,12,19\). Arch height is thought to be related to the incidence of these injuries\(^7,15,19\). An arch greater than the subject’s subtalar joint neutral is in a position of less eversion and has a greater tendency to fall into inversion. Donatelli reported those individuals with restricted motion in the foot, such as those with a high navicular, have a reduced ability for the foot to act as a shock absorber. Having a foot with a high navicular, also known as a foot with abnormal supination, reduces the foot’s ability to pronate. At heel strike the foot should be in a neutral position and begin to pronate immediately, which produces a rigid level to push off from. However, with abnormal supination the foot pronates later in the stance phase. This causes the foot to be less stable during the push-off phase of the gait cycle possibly causing trauma to the foot\(^4\).
Williams et al performed a study with 40 runners in order to see if foot types could be associated with injury patterns. The runners were divided into two groups; 20 runners were in the high arch group and 20 were in the low arch/lower navicular height group. The runners were between the ages of 18 and 50 with a mean age of 27.8. The results of the study showed that those in the high arch group suffered more ankle sprains compared to those in the low arch group. These results were statistically significant. The most common injury sustained in the high arch group was lateral/inversion ankle sprains. The researchers suggested that a possible cause of the increase in lateral ankle sprains in the high arch group may be due to the increase in lateral loading on the foot \(^{(13)}\).

Wright et al used a forward dynamic simulation model during a side-shuffle movement in order to determine if foot position at touchdown influenced ankle sprain susceptibility. It was hypothesized that increased inversion at touchdown would cause an increase in inversion sprain susceptibility. The first half of stance phase of a side-shuffle movement was performed. Since the researchers hypothesized that ankle sprains are more likely to occur when landing on an uneven surface, the simulated side-shuffle movement was performed on 50 irregular floor conditions. However, the results of this study did not support the hypothesis that increased inversion at touchdown would cause an increase in inversion sprain susceptibility \(^{(14)}\).

In another study Bahr et al. studied 233 volleyball players to determine the incidence of acute volleyball injuries. The results showed ankle injuries, observed in 54% of the players, to be the most common injury. Out of the 54% of ankle injuries sustained, 65% of those injuries were ankle sprains making it the most common type of ankle injury. The results from this study are supported from previous studies that have shown ankle sprains to occur 25-50% of the time \(^{(1)}\).
In order to examine the effect of arch height on ankle 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. In addition, the footprint angle from Schwartz (17) 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 (10) 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 that the entire foot was in contact with the surface.

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 subject’s 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. (5)

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 \(^7\). They palpated the navicular tuberosity and marked it with a pen. They measured arch height 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 could be reliable.

**Problem**

Of all the injuries that occur during basketball and volleyball, ankle injuries account for one quarter to one half of those injuries \(^1\). Because of this high rate of injury, about 53% of the total time missed in a basketball season was secondary to an ankle injury \(^10\). The height of the navicular is considered an intrinsic factor that may increase the risk of an ankle injury occurring \(^2,13\). Few studies have examined the relationship between the incidence of ankle injuries and the arch height of the foot of high school athletes. \(^1,9\)

**Purpose**

The purpose of this study is to determine the relationship between ankle injuries in high school volleyball and basketball players and navicular height, and to determine if the navicular height can predict ankle injuries.

**Hypothesis**

It is hypothesized that volleyball and basketball players with a higher navicular height will sustain more ankle injuries as compared to those with a lower navicular height. It is also hypothesized that those with a higher navicular height will be more likely to sustain an inversion injury compared to an eversion injury.

**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 ankle injuries to occur. One can then use
some kind of inhibitor, such as an orthotic, to help prevent or lower the incidence of ankle injuries in order to maintain the quality of performance.

METHODS

Design

This will be an observational, longitudinal study measuring high school volleyball and basketball players’ navicular height and observing them throughout the season to see who does and does not experience an ankle injury.

Subjects

Twenty-three subjects from the male and female basketball and volleyball varsity and reserve teams participated in this study. This resulted in 46 ankles for observation. The researcher recruited subjects by visiting 3 northwest Ohio rural schools and asking for volunteers. All subjects were required to provide parental consent and personal assent to participate in this study. 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 device used by Holmes (7). The subjects’ navicular height was measured in a standing position, with the height of the navicular measured relative to its vertical distance from the floor. Navicular height was measured in four positions; subtalar joint neutral, neutral, maximum pronation, and maximum supination. When measuring maximal pronation and supination the subjects were instructed to keep the 5th and 1st metatarsal in contact with the ground.
Procedure

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

The athletes turned in their consent forms to the coach. The researcher then collected the forms one week after the distribution of the forms. At this time, the injury logs were distributed to participating athletes. The mechanics of all possible injuries were demonstrated to the subjects. Pictures of all demonstrated injuries appeared on the form and were explained during the demonstration. Also at this time, the navicular tuberosity was measured on each subject. This measurement was only taken once. The measurements were 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 subject’s were then asked to keep a journal and record all ankle injuries and the type, either pronation or supination, of injury. In addition subjects recorded the day the injury was sustained, and which ankle was injured.

The injury logs were collected at the end of each sport’s season. This data was then analyzed to see who had sustained an ankle injury, who had not, and compare those to the navicular heights of each group.

Data Analysis

This study used two-factor ANOVA with repeated measures. The first factor divided the subjects into two groups, those who sustained an injury and those who did not sustain an injury. The second factor compared the different measuring positions of navicular height and compared
these results to both the injured and non-injured groups. The hypotheses for this study are as followed:

1. those with a higher navicular height will sustain more ankle injuries than those with a lower navicular height
2. those with a higher navicular height will sustain more inversion ankle injuries than eversion ankle injuries.

The p-value was set at < .05. If the results are observed as expected, this study may help prevent the occurrence of future ankle injuries. Those athletes with a high navicular can use protective mechanisms, such as taping, bracing, or orthotics, to help prevent these injuries from occurring and/or to reduce the occurrence of these injuries.

RESULTS

The researcher measured the navicular height of ten subjects, for a total of 20 feet, in all four positions in order to test the intra-rater reliability. Reliability was not obtained as demonstrated in Table 1.

Table 1.

<table>
<thead>
<tr>
<th>Measure</th>
<th>ICC</th>
<th>Lower</th>
<th>Upper</th>
</tr>
</thead>
<tbody>
<tr>
<td>STJ Neutral</td>
<td>0.71</td>
<td>0.38</td>
<td>0.88</td>
</tr>
<tr>
<td>Relaxed Stance</td>
<td>0.62</td>
<td>0.25</td>
<td>0.88</td>
</tr>
<tr>
<td>Max Pronation</td>
<td>0.89</td>
<td>0.75</td>
<td>0.96</td>
</tr>
<tr>
<td>Max Supination</td>
<td>0.66</td>
<td>0.3</td>
<td>0.85</td>
</tr>
</tbody>
</table>

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. The subjects were high school aged (13-19) male and female basketball and volleyball players on the varsity and reserve teams from 3 northwest Ohio rural schools. The researcher excluded any subject if they currently had a
lower extremity injury. The study included subjects that were of high school age and actively participating in basketball or volleyball.

Of the 46 ankles observed, 19.6% (n=9) sustained an ankle injury. Of those injured, 17.4% (n=8) were inversion sprains and 2.2% (n=1) were eversion sprains. A two-factor multivariate analysis of variance (2-way ANOVA) was performed to compare the injured and non-injured groups at the four different measurement positions of navicular height. A potential trend was noted between those with a higher navicular height sustaining more inversion injuries, although this value was not statistically significant (p>.05). This is shown in Table 2.

<table>
<thead>
<tr>
<th>Position</th>
<th>Estimated Marginal Means</th>
</tr>
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<tbody>
<tr>
<td>STJNR</td>
<td>no</td>
</tr>
<tr>
<td>RELAXR</td>
<td>yes</td>
</tr>
<tr>
<td>PRONR</td>
<td></td>
</tr>
<tr>
<td>SUPR</td>
<td></td>
</tr>
</tbody>
</table>

There was also a difference noted between males and females in relation to ankle injuries. An odds ratio was performed to compare if there was a difference in the occurrence of injury between males and females. Males were reported 5.14 times more likely to sustain an ankle injury as compared to females. This is shown in Table 3.

<table>
<thead>
<tr>
<th>Table 3</th>
<th>Ankle Injury</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No</td>
</tr>
<tr>
<td>Male</td>
<td>6</td>
</tr>
<tr>
<td>Female</td>
<td>8</td>
</tr>
</tbody>
</table>
DISCUSSION

The most frequent type of injury to occur in recreational sports is said to be ankle injuries. The recreational sports that ankle injuries commonly occur in are those consisting of lateral cutting movements and jumping because of the possibility of landing on uneven surfaces, such as basketball and volleyball \(1, 2, 9, 10, 14\). Previous studies have shown that ankle injuries occur about 25% of the time \(^1, 2\). The results of this study found similar results in that 19.6% of the subjects sustained an ankle injury. Other studies have found that about 73-85% of those ankle injuries are caused by trauma to the lateral ligaments secondary to an excessively inverted ankle \(^1\). This study found that only 17.4% of the injuries were inversion injuries. This may be lower than previous studies due to the small sample size used.

The purpose of this study was to determine if the relationship between navicular height and ankle injuries. It was hypothesized that a higher navicular height would contribute to more ankle injuries. The results demonstrated a potential trend for those with a higher navicular height to sustain more ankle injuries as compared to those with a lower navicular height; however the results were not statistically significant \((p>.05)\). It was also hypothesized that those with a higher navicular height would be more likely to sustain an inversion injury as compared to an eversion injury. The results did not support this hypothesis since the data was not statistically significant \((p>.05)\), but a potential trend was noted for those with a higher navicular height to sustain in inversion injury rather than an eversion injury.

Additionally, this study found that males were shown to be 5 times more likely to sustain an ankle injury as compared to females. Previous research from Bahr et al supports these findings, while the results of Hickey et al contradict the current findings. More research is needed in this area to see if there is a difference between the injury rate in females and males.
It has been reported in previous studies that those with a higher navicular height tend to sustain more inversion ankle injuries due to the anatomical make up of the foot. In persons with a greater navicular height, the foot is placed in an inverted position. When an ankle is more inverted than normal during heel contact of the gait cycle, the force being placed on the subtalar joint may be greater, causing excessive inversion. The same mechanism occurs with running, causing an even greater amount of force to be placed on the subtalar joint (14).

At heel strike the foot is in a neutral position and begins to pronate immediately as the body advances into the stance phase creating a rigid level for the foot to push off of during the push-off phase of the gait cycle. However, this does not occur in a foot with a higher navicular. These individuals either pronate late in the stance phase, or do not pronate at all creating an unstable foot to push off of. A more unstable foot during push-off places a large amount of force on the ligaments of the ankle, especially the lateral ligaments, in order to stabilize the ankle. Since the lateral ligaments are smaller and weaker than the medial ligaments, damage is more likely to occur to the lateral ligaments resulting in an inversion ankle sprain.

CONCLUSION

It is currently unknown why some athletes sustain more ankle injuries than others. The height of the navicular is thought to be related to the amount of ankle injuries sustained, but little research has looked for a relationship. In those studies that have looked for a relationship between ankle injuries and navicular height, variable results have been noted when comparing data. Although the results from this study did not show a statistically significant relationship between navicular height and ankle injuries, a trend was possibly noted. More research is needed which compares navicular height and ankle injuries in order to see if a true relationship exists. This study can help physical therapists determine which athletes will sustain more ankle injuries based on navicular height.
REFERENCES


