

The Relationship Between the Use of Foot Orthoses and Knee Ligament Injury in Female Collegiate Basketball Players

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Background: Anterior cruciate ligament injuries are more prevalent in female athletes than in male athletes. Basketball is a high-risk sport for anterior cruciate ligament injury in female athletes. This study was conducted to observe the effect of a foot orthosis on the knee ligament injury rate in female basketball players at one US university.

Methods: One hundred fifty-five players on the women's basketball team were observed for knee ligament injury from 1992 to 2005. Athletes in the 1992–1993 to 1995–1996 school years (July–June) did not receive a foot orthosis and served as the control group; the treatment group comprised the athletes during the 1996–1997 to 2004–2005 school years (July–June). Athletes in the treatment group received a foot orthosis before participating in basketball. Data analysis included knee ligament injury rates and a comparison of injury rates with an incidence density ratio.

Results: Athletes in the control group had three collateral ligament injuries and three anterior cruciate ligament injuries, for an injury rate of 0.50 for both the anterior cruciate ligament and collateral ligaments. Athletes in the treatment group had four collateral ligament injuries and one anterior cruciate ligament injury, for an injury rate of 0.29 for the collateral ligaments and 0.07 for the anterior cruciate ligament. Athletes in the control group were 1.72 times more likely to sustain a collateral ligament injury and 7.14 times more likely to sustain an anterior cruciate ligament injury than the treatment group.

Conclusions: Foot orthoses may contribute to a decreased knee ligament injury rate in female collegiate basketball players. (*J Am Podiatr Med Assoc* 98(3): 207-211, 2008)

Injuries to knee ligaments are more prevalent in female basketball players than in their male counterparts. More specifically, female basketball players are between 2.44 and 8 times more likely to sustain an anterior cruciate ligament (ACL) injury than male basketball players.¹⁻³ Although the etiology of these injuries in female basketball players is unknown, characteristics such as kinetic differences, neuromuscular differences, differences in the width of the

femoral notch, hormonal differences, and differences in lower-extremity structure are possible etiologies for the increased prevalence of knee ligament injuries in this population.^{4,8}

Several authors have studied differences in lower-extremity structure between women and men as a possible etiology for knee ligament injury, reporting differences in foot structure when comparing ACL-injured participants with normal participants.^{4, 8, 9} A relationship between ACL injury and foot alignment leading to overpronation has been identified. The theoretical foundation for increased ACL injury incidence is related to the mechanics of pronation.¹⁰ During pronation the tibia internally rotates and the knee moves into a valgus position, increasing tension on the ACL.¹¹ There is also increased tension placed on the medial collateral ligament when the knee is positioned in valgus.¹¹

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Foot orthoses have been used to successfully treat lower-extremity structural malalignments accompanying lower-extremity pathology. Although the relationship between tibiofemoral joint injury and foot orthoses has not been studied, the patellofemoral joint has been shown to react favorably to treatment with foot orthoses.¹²⁻¹⁴ There is evidence that foot orthoses can decrease the amount of rearfoot pronation, decrease the amount of tibial internal rotation that accompanies rearfoot pronation, and improve the timing of rearfoot pronation and tibial rotation.¹⁵⁻¹⁷ In reviewing the current literature on knee ligament injury patterns, the mechanics of pronation, and the theoretical foundation behind the use of foot orthoses, it could be concluded that the use of foot orthoses may improve the rate of knee ligament injuries.

The purpose of this study was to determine if the use of an accommodative foot orthosis has an effect on the incidence of knee ligament injury. Specifically, we compared the rate of knee ligament injuries in a group of female collegiate basketball players who wore foot orthoses with a group of female collegiate basketball players who did not wear foot orthoses.

Materials and Methods

Subjects

All members of the women's basketball team at one university from 1992 to 2005 participated in this study. Athletes in the 1992-1993 to 1995-1996 school years (July-June) did not receive a foot orthosis, whereas those in the 1996-1997 to 2004-2005 school years (July-June) wore foot orthoses for all basketball-related activities and agreed to wear them during basketball participation throughout the study period. A University Health Science Center Institutional Review Board approved this research. Average subject characteristics are shown in Table 1.

We used the term *knee ligament injury rate* to refer to the number of knee ligament injuries divided by the number of games and practices within a given basketball season (hereafter referred to as exposures). Any injury outside of the regular practices and games was not included. Knee ligament injuries included any

knee ligament injury that precluded an athlete from participating in an exposure for the team during any year of the study. We expected the rate of knee ligament injury to be significantly lower in those basketball players who wore the accommodative foot orthoses.

The number of subjects for each year of the study was calculated by counting the number of basketball players on the team roster at the end of the season. The season-ending roster included all injured and uninjured players each year. Any player with a knee ligament injury during the preseason, regular season, or postseason was included in this study. All players were observed retrospectively by reviewing injury records to determine if they had a knee ligament injury during their collegiate career. All knee ligament injuries were diagnosed by the team orthopedist. Knee ligament injury rates for the control group were compared with rates in the treatment group.

Foot Orthoses

The athletic department purchased the foot orthoses and provided them to the athletes. The foot orthoses consisted of a medium-density (35-durometer) ethyl vinyl acetate, over-the-counter shoe insert with a standard 3° rearfoot post and a standard arch fill (Blue EVA; Foot Management, Pittsville, Maryland). Each player was asked to wear her foot device during all basketball activities. In an effort to improve compliance, the athletic trainer primarily assigned to women's basketball questioned players on their foot orthosis usage throughout each season. Players were advised to observe their foot orthosis frequently for wear such as holes in the medial forefoot. Most athletes used two to three pairs of foot orthoses per season. Returning athletes received a new pair at the beginning of each season. No athletes were known to be noncompliant.

Data Analysis

The Student *t* test was used to determine if there were differences in age, mass, height, and body mass index (the weight in kilograms divided by the square of the

Table 1. Characteristics of 132 Female Basketball Players

Group	Mass (kg)	Height (cm)	BMI	Age (years)
Control	65.7 (2.6)	175 (22.4)	22.00 (1.3)	19.71
Treatment	71.3 (3.2)	177 (22.0)	23.27 (1.5)	19.87

Abbreviation: BMI, body mass index (the weight in kilograms divided by the square of the height in meters).

Note: Data are given as means (SD).

height in meters) between the two groups of athletes. If there were differences in any of the anthropometric measures, a post hoc test was performed to determine if these values had an effect on injury rates. The Wilcoxon and log-rank tests for event data and the Cox proportional hazards regression model were used.¹⁸ SAS version 9.0 procedures LIFETEST and PHREG were used for the analysis.¹⁹ The use of PHREG allowed analysis of covariance with like adjustments for the anthropometric measures when comparing the rates of injury between groups.

Standard definitions for epidemiology research were used in this study. The benchmark study on ACL injury in female athletes by Arendt et al¹ used the same methodology. Included in these definitions are exposures, subjects (athletes), players × exposures (the number of players on the end-season roster multiplied by the number of exposures), and the knee ligament injury rate. These figures were used as criteria for comparing athletes. An exposure was defined as any exposure to an injury during the study period. At the end of each season the athletic department's compliance officer calculated the number of practices and games to arrive at the number of exposures. The compliance officer also calculated the number of subjects. To normalize the injury data, the numbers of knee ligament injuries were expressed per 1,000 exposures (Table 2).²⁰

To further compare those athletes who wore a foot orthosis with those who did not, an incidence density

ratio was computed.²¹ This comparison is computed by dividing the injury rate for athletes in the control group by that for athletes in the treatment group. The incidence density ratio allows for a more direct comparison of injury between the two groups when the number of exposures between groups is unequal.²¹ The level of significance was set at $P \leq .05$.

Results

Anthropometric Measures

There was no difference in the age of the athletes in the two groups. However, athletes in the control and treatment groups had different values for their mass ($P = .0016$), height ($P = .015$), and body mass index ($P = .001$). Mass, weight, and body mass index had no effect on the knee ligament injury rate based on the Cox regression model (mass, $P = .50$; height, $P = .50$; body mass index, $P = .61$).

Knee Ligament Injury Rates

Table 2 outlines the injury rates for all athletes. All injury rates are presented as the number of injuries per 1,000 exposures. In the control group, both the ACL injury rate and the collateral ligament injury rate were 0.50. In the treatment group the ACL injury rate was 0.07, and the collateral injury rate was 0.29. There were no combined ACL and medial collateral

Table 2. Knee Ligament Injury Data

Group	No. Players	No. Exposures	Players × Exposures	ACL Rate	Collateral Rate	Overall Rate
Control						
1992–1993	12	125	1,500	1.33	0.00	1.33
1993–1994	12	124	1,488	0.00	0.67	0.67
1994–1995	11	122	1,342	0.74	0.74	1.49
1995–1996	13	126	1,638	0.00	0.61	0.61
Subtotal	48	497	5,968	0.50	0.50	1.00
Treatment						
1996–1997	10	122	1,220	0.00	0.00	0.00
1997–1998	14	117	1,638	0.00	0.00	0.00
1998–1999	12	124	1,488	0.67	0.67	1.34
1999–2000	14	132	1,848	0.00	0.00	0.00
2000–2001	12	121	1,452	0.00	0.68	0.68
2001–2002	12	122	1,464	0.00	0.68	0.68
2002–2003	10	134	1,340	0.00	0.74	0.74
2003–2004	12	124	1,488	0.00	0.00	0.00
2004–2005	11	140	1,540	0.00	0.00	0.00
Subtotal	107	1,136	13,478	0.07	0.29	0.37

Abbreviation: ACL, anterior cruciate ligament.

Note: Rates are per 1,000 exposures.

ligament injuries sustained by subjects in this study. There were no knee ligament injuries that occurred outside of the exposures (practices and games).

Differences Between Groups

There were three ACL and three collateral ligament injuries in the control group; the treatment group had one ACL injury and four collateral ligament injuries. The ACL was 7.14 times more likely to be injured in the control group, and the collateral ligaments were 1.72 times more likely to be injured. The incidence density ratio for ACL injury was $P = .05$, and the incidence density ratio for the collateral injury was $P = .49$.

Discussion

This study provides evidence that athletes who wore foot orthoses had fewer ACL injuries than those who did not wear any. Although there were no differences in the collateral ligament injury rates between the groups, the ACL injury rate was significantly ($P = .05$) decreased in a group of female basketball players wearing foot orthoses.

When comparing the results of our treatment group to other epidemiological studies of knee ligament injuries and female athletes in collegiate basketball, some differences further outline the treatment effect of the foot orthoses in this population. Arendt and Dick² reported an ACL injury rate of 0.28 per 1,000 exposures and a collateral injury rate of 0.29 per 1,000 exposures. However, the ACL injury rate (0.07 per 1,000 exposures) observed in our treatment group was less than those observed by Arendt and Dick. More specifically, athletes in our treatment group were four times less likely to sustain an ACL injury than athletes in the study by Arendt and Dick.

There are several possible explanations for the overall decrease in ACL injuries in our treatment group. Numerous authors have outlined a coupling between the subtalar joint and rotation of the tibia.²²⁻²⁷ An increase in subtalar joint pronation leads to an increase in the amount of tibial internal rotation and knee joint valgus.¹⁰ Increased tibial internal rotation and knee joint valgus increase the tension on the ACL. Foot orthoses have been shown to decrease the amount of tibial internal rotation and improve the timing of subtalar joint pronation and internal rotation of the tibia.^{15, 17, 25} If foot orthoses decrease the amount of tibial internal rotation and improve the timing of pronation, the potential for ACL injuries may decrease.

Other programs have decreased the amount of tibial internal rotation and knee joint valgus. Jump-training programs, such as those discussed by Hewett et

al,²⁸ alter the alignment of the lower extremity during landing. Jump-training programs require the subject to keep the knee aligned over the foot. By aligning the knee over the foot during landing, the athlete decreases the amount of tibial internal rotation and knee joint valgus. Therefore, the method to prevent ACL injury with a jump-training program is similar to the effect provided by the foot orthoses.

Although Hewett et al²⁸ reported a positive treatment effect with a jump-training program, the overall numbers of knee ligament injuries were quite small. Basketball players sustained five serious knee injuries and three ACL injuries in the control group and two serious knee injuries (one ACL and one ACL/MCL) in the treatment group. Despite a larger number of participants in the control and treatment groups, their number of injuries and the injury rates per 1,000 exposures were very similar to our results.

There were coaching changes during the 13 years of our study. The change in coaching style and training intensity could have affected our results. However, at no time during this study was there any attempt to train the female basketball players in a jumping-and-landing or run-and-cut training program designed to decrease the frequency of knee ligament injuries.¹⁸ Also, the time spent in practice and games throughout the study was limited by National Collegiate Athletic Association regulations. The average number of exposures per year was 1,497 for the athletes who wore foot orthoses and 1,492 in the control group.

The compliance of the athletes wearing the foot orthoses must be questioned. The athletic trainer in charge of women's basketball was able to observe and question athletes on their usage of the device, but there was no way to have complete assurance that athletes wore their foot orthoses 100% of the time they were participating in basketball activities.

Although our methods were standardized and similar to those of previous work in ACL epidemiology research, the chance of statistical error is present.^{1, 3} By virtue of using the number of players on the roster at the end of the season, there is a chance that some subjects participating in a given practice or game were not included. Secondary to the manner in which subjects were counted, a statistical error is possible. This possibility is a limitation of this study.

The relatively small sample size must also be considered a limitation. Despite the fact that this study encompasses 13 years, there is a relatively small sample size. The control period was 4 years and involved 48 players, whereas the treatment group covered 9 years and 107 players. An increase in the number of control and treatment subjects would allow for firmer conclusions.

Conclusion

Female basketball players wearing foot orthoses were compared with those who did not wear orthoses to determine if there was a difference in their knee ligament injury rates. There were six knee ligament injuries (three ACL and three collateral) in the 4 years foot orthoses were not used, whereas there were only five injuries (one ACL and four collateral) in the 9 years when foot orthoses were used. The use of foot orthoses appears to contribute to a decrease in the knee ligament injury rate for female collegiate basketball players.

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Conflict of Interest: None reported.

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