Lower extremity injury in female basketball players is related to a large difference in peak eversion torque between barefoot and shod conditions

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**Recommended Citation**
Yentes, Jenna M.; Kurz, Max J.; and Stergiou, Nicholas, "Lower extremity injury in female basketball players is related to a large difference in peak eversion torque between barefoot and shod conditions" (2014). *Journal Articles*. 120.
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Lower extremity injury in female basketball players is related to a large difference in peak eversion torque between barefoot and shod conditions

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Received 13 July 2012; revised 30 August 2012; accepted 12 November 2012

Abstract

\textbf{Background:} The majority of injuries reported in female basketball players are ankle sprains and mechanisms leading to injury have been debated. Investigations into muscular imbalances in barefoot versus shod conditions and their relationship with injury severity have not been performed. The purpose of this study was to investigate the effects of wearing athletic shoes on muscular strength and its relationship to lower extremity injuries, specifically female basketball players due to the high incidence of ankle injuries in this population.

\textbf{Methods:} During pre-season, 11 female collegiate basketball players underwent inversion and eversion muscle strength testing using an isokinetic dynamometer in both a barefoot and shod conditions. The difference between conditions was calculated for inversion and eversion peak torque, time to peak torque as well as eversion-to-inversion peak torque percent strength ratio for both conditions. Lower extremity injuries were documented and ranked in severity. The ranked difference between barefoot and shod conditions for peak torque and time to peak torque as well as percent strength ratio was correlated with injury ranking using a Spearman rho correlation ($\rho$) with an $\alpha$ level of 0.05.

\textbf{Results:} The ranked differences in barefoot and shod for peak eversion and inversion torque at 120°/s were correlated with their injury ranking. Ranking of the athletes based on the severity of injuries that were sustained during the season was found to have a strong, positive relationship with the difference in peak eversion torque between barefoot and shod ($\rho = 0.78$; $p = 0.02$).

\textbf{Conclusion:} It is possible that a large discrepancy between strength in barefoot and shod conditions can predispose an athlete to injury. Narrowing the difference in peak eversion torque between barefoot and shod could decrease propensity to injury. Future work should investigate the effect of restoration of muscular strength during barefoot and shod exercise on injury rates.

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Keywords: Ankle sprain; Isokinetic dynamometer; Muscular imbalance; Strength

1. Introduction

More than 60% of all college women’s basketball injuries occur in the lower extremities.\textsuperscript{1} Over a 16-year period, 24.6% of these injuries were due to ankle ligament sprains during games and practices. Ankle ligament sprains were the second ranked injury leading to 10 or more days of activity loss, with knee internal derangement being the first leading cause.\textsuperscript{1} Furthermore, a history of ankle sprains would leave a player five times more likely to sustain another ankle injury.\textsuperscript{1} The incidence of injury in female high school basketball players

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http://dx.doi.org/10.1016/j.jshs.2012.11.004
demonstrates a similar pattern, with ankle sprains as the leading injury sustained.2

Several investigations into the primary etiology of ankle sprains have been conducted to probe the biomechanical mechanisms that may be responsible for the high incidence of ankle ligament sprains in female basketball players. Baumhauer et al.3 concluded that eversion-to-inversion strength ratio was a predictive measure of ankle injury. This finding has not been consistently supported, as these results have not been clearly replicated.4,5 Hence, several other measures have been evaluated including ankle strength,4,7 postural sway,6,7 proprioception,5 shoe height,8,9 and peroneal reaction time.10,11 Fong et al.12 recently listed the two main causes to ankle sprains as improper foot positioning during heel strike and delayed reaction time of the peroneal musculature. Even still, the etiology of ankle sprains has yet to be clearly defined.

There is strong evidence that shoes can control the motion and position of the foot and provide cushion.13–16 However, despite the advances in shoe construction, lower extremity injuries are still being reported in large numbers.1 Prevention of injury may be dependent on intrinsic muscular strength of the ankle complex. In terms of foot and ankle musculature, the tibialis anterior (inverter) and triceps surae could be considered as larger muscles, that are most responsive to movement in the sagittal plane and not as responsive to movement in the frontal plane.17 Smaller musculature about the ankle and foot provide stability quickly and easily to the ankle joint complex by reacting faster to joint movement changes.17 Nigg18 has demonstrated that increased strength in these smaller, intrinsic muscles may lead to improved performance and protection, while the opposite can also be true. Therefore the strength of these smaller, intrinsic muscles may have an important relationship with susceptibility to lower extremity injury.

Avoidance of excessive movement about the ankle is provided by the ankle musculature, but only if the musculature is properly activated. This is especially true for smaller intrinsic muscles which provide stability to the ankle joint complex by reacting faster to joint movement changes.17,18 Essentially, deconditioned musculature may not only cause a decrease in the force production to control excessive subtalar motion, but also may delay neuromuscular responses.11 Support for this notion has been demonstrated when soccer and cross-country runners with and without ankle instability were tested for central and peripheral reaction times. It was found that players with severe ankle instability demonstrated peripheral latency of peroneal muscles.11 When activated, the ankle and foot musculature take considerable milliseconds (i.e., 92–133 ms) after the latency period before maximal muscular strength can be developed.8 It is possible that deconditioning or atrophy of the muscular structure of the foot and ankle would cause a delay in peripheral reaction, leading to increased latency response of muscle activation and eventually a decrease in the ability to quickly generate force.19,20 It has also been suggested that decreased sensations provided by wearing shoes may promote the skeletal musculature of the foot and ankle to become deconditioned.21 This is not to say that if a shoe provides artificial strength, that barefoot play is recommended, rather the goal is to identify a testing method that will allow for identification of athletes predisposed for injury.

Therefore, the purpose of this study was to investigate the effects of wearing athletic shoes on muscular strength and its relationship to lower extremity injuries, specifically female basketball players due to the high incidence of ankle injuries in this population. It was hypothesized that individuals that demonstrated similar ankle eversion strength between barefoot and shod conditions would be less susceptible to injury. Ankle eversion muscle strength provides support and functions as a dynamic stabilizer of the ankle against inversion; thus playing an important role in preventing inversion ankle sprains and/or lower extremity injury. In order to test this hypothesis, ankle inversion and eversion peak torque in both barefoot and shod conditions was measured prior to a college basketball season. Injuries were then measured prospectively and were recorded throughout the season. At the end of the season, athletic trainers ranked the athletes in terms of injury severity. Ranked differences in peak torque of the athletes were then correlated with ranked injury severity. Thus, a unique feature of this study is its prospective nature and such studies are scarce in the literature.

2. Methods

Eleven female basketball players (age: 20.4 ± 3.2 years; height: 172.0 ± 7.6 cm; mass: 73.5 ± 15.9 kg) from the University of Nebraska at Omaha were consented and participated in the study. The participants were healthy and free from any present musculoskeletal injury. All testing was conducted during the basketball pre-season. All procedures were approved by the University’s Institutional Review Board.

Prior to testing, subjects warmed up on a Monarch stationary bicycle at a self-selected pace and resistance for a minimum of 10 min. Eversion and inversion muscular strength when barefoot (barefoot condition) and while wearing their own high-top, basketball shoes (shod condition) were recorded using an isokinetic dynamometer (Biodex System 2.0; Biodex Medical Systems, Shirley, New York, USA). The subjects wore their own shoes to minimize any shoe-type effect by introducing discomfort or lack of adaptability due to the usage of a new shoe. Each subject was seated, with the trunk, thigh, and shank secured. Standard positioning for the ankle inversion and eversion testing was used according to the manufacturer’s guidelines. Subjects were seated and their right leg was raised so that the shank was perpendicular to the footplate attachment. With the shank supported, the right foot was secured into the footplate in neutral position and zero degrees plantarflexion. Isokinetic testing of the right ankle was administered at 120°/s within a comfortable range of motion (mean ± SD) for barefoot condition (76.8° ± 12.1°) and shod condition (71.1° ± 16.7°). Three maximal repetitions were performed. A minimum of 24 h of rest was required before the subject returned to undergo testing under the second condition. Presentation of barefoot and shod conditions was randomized between subjects. Prior to each recorded performance, the
Relationship between lower extremity injury severity and torque in barefoot and shod conditions

A subject was allowed to perform submaximal and maximal repetitions to prepare for each tested velocity. Verbal encouragement and visual feedback of the results were given in order to obtain maximal effort. After all testing was completed three subjects (subjects 2, 6, and 10) were eliminated from the analysis due to errors in data collection.

Inversion and eversion peak torque and time to peak torque was recorded for barefoot and shod conditions and the difference between conditions was calculated. A positive (+) difference indicated that the barefoot condition demonstrated greater torque and a negative (−) difference indicated that the shod condition demonstrated greater torque. A difference near zero would indicate similar torque values in both the barefoot and shod conditions. For purposes of this study, either a large (+) or large − difference in peak torque between conditions was considered detrimental. This is because, whether or not + or −, the shoes had an affect on performance. In one case, a large + difference, in the shoe condition the athlete was weaker and for a large − difference the shoe has made the athlete artificially stronger. Therefore, the absolute values of the differences were then ranked. The largest absolute difference between barefoot and shod conditions was ranked as a 1 and the smallest absolute difference was ranked as an 8. For time to peak torque + difference indicated that the barefoot condition demonstrated a greater amount of time to reach peak and a − difference indicated that the shod condition demonstrated a greater amount of time to reach peak torque.

In addition, eversion-to-inversion peak torque percent strength ratios were also calculated for both barefoot and shod conditions. The eversion peak torque is divided by the inversion peak torque and multiplied by 100. These were calculated in order to compare our results to previous studies that have investigated the relationship between percent strength ratios and injury occurrences. Percent strength ratios were ranked for both the barefoot and shod conditions from largest percentage to smallest. The largest percentage was ranked as a 1 with the smallest percentage ranked as an 8.

During the basketball season, injuries were recorded (Table 1). An injury was defined as a lower extremity impairment that caused a functional limitation of play or caused the athlete to miss practice(s) or game(s). The University athletic trainers provided diagnosis and reporting of injuries. The university athletic trainers completed ranking of the athletes based on the severity of injuries that were sustained during the season. To maximize objectivity, injuries were first divided into ankle/foot complex injuries and all other lower extremity injuries. Ankle/foot complex injuries were ranked first and severity was based on the number of practices and games missed. After the ranking of all ankle/foot complex injuries all other lower extremity injuries were ranked. Severity of lower extremity injuries was based on the total number of practices and games missed, as with the ankle/foot complex. An injury ranking of 1 would indicate the most severe injury and a ranking of 8 would indicate no injuries.

Peak torque, time to peak torque, and percent strength ratio were checked for normality using Shapiro–Wilk’s W test. Thus, mean difference between conditions was investigated by employing dependent t tests. The ranked difference between barefoot and shod conditions for inversion and eversion, time to peak torque as well as the ranked percent strength ratio for both conditions was correlated with injury ranking using a Spearman rho correlation (r). Based on the hypothesis, a positive relationship would be present. An individual with an injury ranking of 1 would have a large difference in torque or large percent strength ratio; whereas, an individual with an injury ranking of 8 would have a difference in torque near zero or a small percent strength ratio. Strengths of correlations were defined as follows: ±1.00 to 0.80 = very strong; ±0.79 to 0.60 = strong; ±0.59 to 0.40 = moderate; ±0.39 to 0.20 = weak; ±0.19 to 0 = no relationship. All statistical analysis was done using SPSS 16.0 (IBM Corporation, Armonk, NY, USA). The α level was set at 0.05.

3. Results

There were no significant differences in peak torque between barefoot and shod conditions for either inversion or eversion (Table 2). There was no significant difference in time to peak torque or eversion-to-inversion percent strength ratio between barefoot and shod conditions. Ranking of the athletes based on the severity of injuries that were sustained during the season was found to have a moderate to strong positive relationship with the difference in peak inversion torque between barefoot and shod conditions (r = 0.49, p = 0.02). There was

<table>
<thead>
<tr>
<th>Variable</th>
<th>Barefoot</th>
<th>Shod</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak inversion (N × m)</td>
<td>10.1 ± 4.9</td>
<td>11.1 ± 4.1</td>
<td>0.698</td>
</tr>
<tr>
<td>Time to peak inversion (ms)</td>
<td>280.8 ± 64.1</td>
<td>257.0 ± 68.0</td>
<td>0.290</td>
</tr>
<tr>
<td>Eversion-to-inversion percent</td>
<td>154.3 ± 54.8</td>
<td>119.7 ± 16.6</td>
<td>0.248</td>
</tr>
<tr>
<td>strength ratio (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1

Athletes’ injuries documented and ranking based upon severity.

<table>
<thead>
<tr>
<th>Subject number</th>
<th>Injury(ies)</th>
<th>Practices/games missed</th>
<th>Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>L-knee, 3° ACL</td>
<td>10/20</td>
<td>6</td>
</tr>
<tr>
<td>3</td>
<td>No injuries</td>
<td>0/0</td>
<td>8</td>
</tr>
<tr>
<td>4</td>
<td>L-hip, trochanteric bursitis</td>
<td>0/0</td>
<td>7</td>
</tr>
<tr>
<td>5</td>
<td>L-ankle, ATF sprain</td>
<td>1/0</td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td>R-knee, plica irritation</td>
<td>0/0</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>L-ankle, patellar tendinitis</td>
<td>0/0</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>L-foot, accessory navicular</td>
<td>4/10</td>
<td>1</td>
</tr>
<tr>
<td>9</td>
<td>w/avulsion fracture</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>R-hip, trochanteric bursitis</td>
<td>0/0</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>R-low leg, tib-fib strain</td>
<td>0/0</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>R-knee, contusion</td>
<td>0/0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>R-hip, IT strain</td>
<td>0/0</td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: ACL = anterior cruciate ligament; ATF = anterior talofibular ligament; IT = iliotibial tract.
no significant correlation with the difference in inversion peak torque in barefoot and shod conditions (Table 3). Ranking of the athletes based on the severity of their injuries sustained during the basketball season did not demonstrate significant correlations with time to peak torque or eversion-to-inversion percent strength ratio while barefoot or shod (Table 3).

4. Discussion

The current study investigated the relationship of the rank of lower extremity injuries sustained during a collegiate basketball season and the ranked difference in peak eversion and inversion torque between barefoot and shod conditions in female basketball players. In agreement with the proposed hypothesis, the ranked difference between barefoot and shod conditions for peak eversion torque at 120°/s demonstrated strong correlations with ranked lower extremity injuries. Collegiate female basketball players that demonstrated a large difference in peak eversion torque between barefoot and shod conditions demonstrated a greater tendency for lower extremity injuries during a collegiate basketball season. These findings indicate that the difference in evotor musculature performance between barefoot and shod conditions may play an important role in preventing lower extremity injuries.

In addition to acting as a dynamic stabilizer of the ankle, the peroneal musculature provides support to the lateral ligaments of the ankle and functions as a static stabilizer of the ankle against inversion. To prevent ankle inversion injury, it has been hypothesized that preactivated evotor musculature can be employed as a strategy to stiffen the structures about the subtalar joint.23 Ashton-Miller et al.23 provided evidence that if the evotor musculature was fully activated, without the use of high-top shoes, an orthosis or athletic tape, that this muscle group could enhance passive resistance at an inversion angle of 15°. In some cases, the evotor musculature alone was able to generate three times the amount of torque without the use of high-top shoes, orthoses and/or athletic tape.23 Ottaviani et al.9 have further extended this notion by hypothesizing that for any given body size, increased muscular strength of the evotor muscle group would allow for greater resistance to inversion about the subtalar joint. On the other hand, extreme peak eversion torque has been related with complications in the Achilles tendon, by forcing the Achilles tendon laterally and distributing stress unevenly across the tendon.24 It is apparent that the evotor musculature play an important role in preventing ankle injury; however, there is also evidence that too much of a contribution from the evotors may also lead to injury.

Previous studies have found no significant differences in peak eversion torque between subjects with and without ankle instability3,4,6 and between dominant and non-dominant limbs.7 However, we were unable to find a study that investigated the difference in peak eversion torque between barefoot and shod conditions correlated with ranked injuries sustained within a competitive season. It is possible that a large difference between barefoot and shod conditions would predispose an athlete to lower extremity injury. When an athlete is stronger in the barefoot condition than the shod condition, the shoe is making them weaker. Wearing shoes can lead to deconditioning in intrinsic ankle musculature through underutilization.17,25 Habitually barefoot runners demonstrate altered mechanics26,27 and possibly lower injury rates21 yet, there is no clear evidence.17 Based on previous findings, it is believed that persons that wear shoes more often lose sensory feedback that is needed to produce protective adaptations to movement, such as diminishing impact through the medial arch or alteration of mechanics.21 Further, decreased proprioception due to previous ankle injury in addition to weakness exhibited in the peroneal longus and brevis muscles (ankle evotors) is also related with a history of ankle injury.5 Prolonged peroneal reaction times have been targeted as a main cause of ankle instability,10,11 leading to delayed generation of peak torque.8 Neuromuscular deficits would then lead to a compromise in the protective effect of the evotor musculature on ankle joint stability.4 Although, barefoot play is not feasible, it is possible that training of intrinsic musculature under barefoot conditions would be advantageous to the athlete during shod play.

Conversely, when the athlete is stronger in the shod condition than in the barefoot condition, the shoe provides artificial strength. Rehabilitation of foot musculature is possible,21 allowing for the skeletal muscle to adapt to barefoot conditions. Indirect evidence is supportive by suggesting that using a wobble board-based balance training program in healthy adolescents led to a reduction in sports-related injuries through increased strength of muscles crossing the ankle joint complex.28 A similar study investigating the effect of proprioceptive balance board training in adult athletes on ankle sprain re-injury is currently being conducted.29 Future work should investigate the ability of rehabilitation of intrinsic foot musculature and its association with lower extremity injury in female basketball players. It is possible that by increasing the strength of intrinsic musculature while barefoot, the ankle would better react to movement.

Table 3

<table>
<thead>
<tr>
<th>Variable</th>
<th>$\rho$</th>
<th>$\rho^2$</th>
<th>$p$ value</th>
<th>Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>Difference in eversion peak</td>
<td>0.78</td>
<td>0.60</td>
<td>0.02</td>
<td>Strong</td>
</tr>
<tr>
<td>Difference in inversion peak</td>
<td>0.06</td>
<td>0.89</td>
<td></td>
<td>No relationship</td>
</tr>
<tr>
<td>Difference in time to peak eversion</td>
<td>0.30</td>
<td>0.09</td>
<td>0.48</td>
<td>Weak</td>
</tr>
<tr>
<td>Difference in time to peak inversion</td>
<td>0.22</td>
<td>0.05</td>
<td>0.61</td>
<td>Weak</td>
</tr>
<tr>
<td>ETI percent strength ratio while barefoot</td>
<td>0.32</td>
<td>0.10</td>
<td>0.44</td>
<td>Weak</td>
</tr>
<tr>
<td>ETI percent strength ratio with shoes</td>
<td>0.10</td>
<td>0.01</td>
<td>0.82</td>
<td>No relationship</td>
</tr>
</tbody>
</table>

Note: Ranking of the athletes based on the severity of injuries that were sustained during the season was correlated ($\rho$) with the ranked difference in peak torque between barefoot and shod conditions. A positive correlation would indicate that athletes with the most severe injuries to the ankle/foot complex were related to large differences in peak torque between conditions or a large percent strength ratio. Abbreviation: ETI = eversion-to-inversion.
Relationship between lower extremity injury severity and torque in barefoot and shod conditions

Previous studies have attempted to relate occurrences of injury to muscular imbalances, specifically eversion-inversion strength ratio. Many of these studies have demonstrated that no differences in eversion-inversion strength ratios exist between persons with and without ankle instability. To our knowledge, our study is the first study that related muscular imbalances between barefoot and shod conditions to lower extremity injuries. In agreement with these previous studies, we did not find a significant association between injury and the difference between barefoot and shod conditions for eversion-inversion strength ratio (Table 3).

Limitations of this study include the investigation of concentric torques only. Future work should investigate the difference in eccentric peak torque during barefoot and shod conditions as well. Previous work has demonstrated that subjects with and without a history of injury demonstrate a lack of difference in eccentric peak in-eversion torque. It is possible that a difference would exist in these individuals if tested with and without shoes. In addition, the injuries reported in this current study were constrained to the lower extremity. The correlation between the difference in peak eversion torque in barefoot and shod conditions may have been stronger if injury reporting was limited to only the ankle joint. In an attempt to overcome this limitation, we ranked ankle/foot complex injuries first, followed by all other lower extremity injuries. This would indicate that an injury ranking of 1 would be the most severe ankle/foot complex injury. Nevertheless, the strong correlation exists even with reporting all lower extremity injuries. Further, previous injury was not recorded. It is feasible that previous injury to the lower extremity predisposed individuals to current injury.

5. Conclusion

This study was the first to investigate the ranked differences in ankle strength between barefoot and shod conditions and their relationship to ranking of the athletes based on the severity of lower extremity injuries that were sustained during a collegiate basketball season. A unique feature of this study is its prospective nature and such studies are scarce in the literature. We found that the difference between barefoot and shod peak eversion torque at 120°/s was significantly and strongly related with lower extremity injury severity. It is possible that a large discrepancy between strength in barefoot and shod conditions can predispose an athlete to injury. Future work should investigate the effect of restoration of muscular strength during barefoot and shod exercise on injury rates. Based on the findings of this current work, by narrowing the difference in peak eversion torque between barefoot and shod conditions would decrease injury severity in female basketball players.

References


