Role of Hyperpronation as a Possible Risk Factor for Anterior Cruciate Ligament Injuries

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Abstract:

Objective: The purpose of this study was to examine the relationship between hyperpronation and the occurrence of noncontact injury to the anterior cruciate ligament (ACL).

Design and Setting: Subjects were categorized as either ACL injured (ACLI) or ACL uninjured (ACLU). All ACLI subjects received their injuries from a noncontact mechanism. To justify using the ACLI subjects' uninjured legs as representative of their preinjury state, a ***t*** test was used to compare the differences between the left and right foot for the ACLU group on both measurements. Based on the results of the ***t*** test, a regression analysis was performed to determine whether group membership could be predicted from navicular drop. All measures were performed in a university athletic training room.

Subjects*:* Fourteen ACLI subjects (age = 21.07 ± 0.83 yr, ht = 174.81 ± 8.29 cm, wt = 72.32 ± 13.47 kg) and 14 ACLU subjects (age = 21.14 ± 2.03 yr, ht = 177.35 ± 11.31 cm, wt = 72.99 ± 14.81 kg) participated.

Measurements: Hyperpronation was assessed via the navicular drop test and the calcaneal stance test.

Results: No significant difference ($p > .05$) between feet for the navicular drop test was found. However, there was a significant difference ($p < .05$) between feet for the calcaneal stance test, and, thus, this measure was not used in the regression analysis. Using the navicular drop score, the regression analysis was unable to predict group membership.

Conclusions: Hyperpronation as measured by the navicular drop test was not a predictor of ACL injury, and, thus, may not be a predisposing factor to noncontact ACL injuries.

Article:

Anterior cruciate ligament (ACL) injuries are often debilitating and a major setback in an athlete's career. Of particular interest is the anterior cruciate rupture that occurs without contact (for example, during a cutting action, where the athlete flexes and rotates the knee).1 The frequent incidence of noncontact ACL injuries has led researchers to study whether some athletes are more prone than others to this type of injury.[2,3]

Some studies have suggested a relationship between certain anatomical features and a possible predisposition to injury of the ACL.[2-9] In particular, intercondylar notch size, high navicular drop scores, and large amounts of anterior tibial translation have been linked to ACL injuries.[2-9] Beckett et a1[2] studied navicular drop in a group of ACL-injured and ACLuninjured subjects. The ACL-injured group had significantly higher navicular drop test scores compared to the ACLuninjured group. It was concluded that hyperpronation and the occurrence of ACL injuries may be related.

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Woodford-Rogers et al[3] measured navicular drop, calcaneal alignment, and anterior tibial translation in both high school and college football players, female basketball players, and female gymnasts with ACL injuries. For comparison, a group of 22 uninjured ACL athletes were matched to the first group by sport, amount of playing time, and level of competition. The results indicated that navicular drop and anterior tibial translation were more prevalent in the ACL-injured group than in the ACL-uninjured group.[3]

The previous studies[2,3] suggest a relationship between hyperpronation and a predisposition to ACL injuries. However, it is uncertain whether hyperpronation as measured by navicular drop alone is an adequate predictor of noncontact ACL injuries. Thus, the purpose of this study was to examine the relationship between ACL injuries and hyperpronation using a combination of navicular drop and calcaneal stance measures.

MATERIALS AND METHODS Subjects

Prior to participating in the study, all subjects were required to read and sign a human subjects informed consent form. All subjects were chosen by their willingness to participate and the ACL-injured subjects by their history of a noncontact ACL injury. The subjects were divided into two groups, an ACLinjured group (ACLI) and an ACL-uninjured group (ACLU). The ACLI group (age = 21.07 ± 0.83 yr, ht = 174.81 ± 8.29 cm, wt = 72.32 ± 13.47 kg) consisted of 14 subjects, 7 males and 7 females. The ACLU group consisted of 14 subjects, 7 males and 7 females (age = 21.14 ± 2.03 yr, ht = 177.35 ± 11.31 cm, wt = 72.99 ± 14.81 kg), who had never had a previous ACL injury. All subjects in the ACLI group had an MRI or arthroscopically documented partial or complete ACL tear that resulted from a noncontact injury. Two of the ACLI subjects had bilateral ACL ruptures. Of the injured group, two of the ACL-injured knees had been conservatively managed and 14 had been surgically reconstructed.

Navicular Drop Test

The navicular drop test was performed as described by Brody.[10] Subjects were seated in a chair with both feet resting on the floor, and the navicular was marked with an ink marker. The subtalar neutral position was determined by having the tester palpate the talus and navicular with the thumb and index finger, respectively. The foot was then passively everted and inverted until the tester determined the medial and lateral aspects of the talus to be equally prominent on both sides. The subjects were then required to hold this position while an index card was held in contact with the floor and their foot. A point was then drawn on the index card corresponding to the previously identified spot on the navicular. With the index card held in this position, the subjects then stood with their weight equally distributed on both feet. A second point was then made on the card corresponding to the new position of the navicular in the weight-bearing position. The distance between the two points, termed the navicular drop, was measured in millimeters using a ruler.

Calcaneal Stance Position Test

The calcaneal stance position testa was taken using a carpenter's combination square to mark the midpoint of the calcaneus and gastrocnemius/soleus muscle group. Each midpoint was marked with an "X" using nonpermanent ink. Tibial length was measured from the medial malleolus to the tibial tubercle. The "X" for the gastrocnemius/soleus muscle group was positioned at 60% of the tibial length measurement from the medial malleolus. After the midpoint was established, a plumb line was dropped from the superior angle of the left scapula to the floor to establish stance width (Fig 1). Both feet stayed in this position, and the calcaneal stance board was moved behind the foot being measured. The subjects stood with their feet placed in the heel holder at the front of the calcaneal stance board to insure that the distance between the foot and the camera was constant (Fig 2). A second plumb line was attached in the rear to provide a fixed perpendicular line for consistent measurements. This plumb line bisected the "X" made on the calcaneus. A photograph of each foot was taken using a 35-millimeter camera that was fixed to the calcaneal stance board. The calcaneal stance angle was identified as the angle between the plumb line bisecting the calcaneus and the line from the midpoint of the gastrocnemius/soleus to the midpoint of the calcaneus. This angle was then measured from the photograph with a protractor.

Reliability

Intratester reliability was assessed on the navicular drop test and the calcaneal stance test by requiring the ACLU subjects to perform each of the two tests twice on each foot. For the navicular drop test a different index card was used to record each measurement. On the back of each card there was a number corresponding to each subject and an "L" or an "R", for the left or right foot. Following the data collection, the cards were randomly shuffled and the navicular drop was

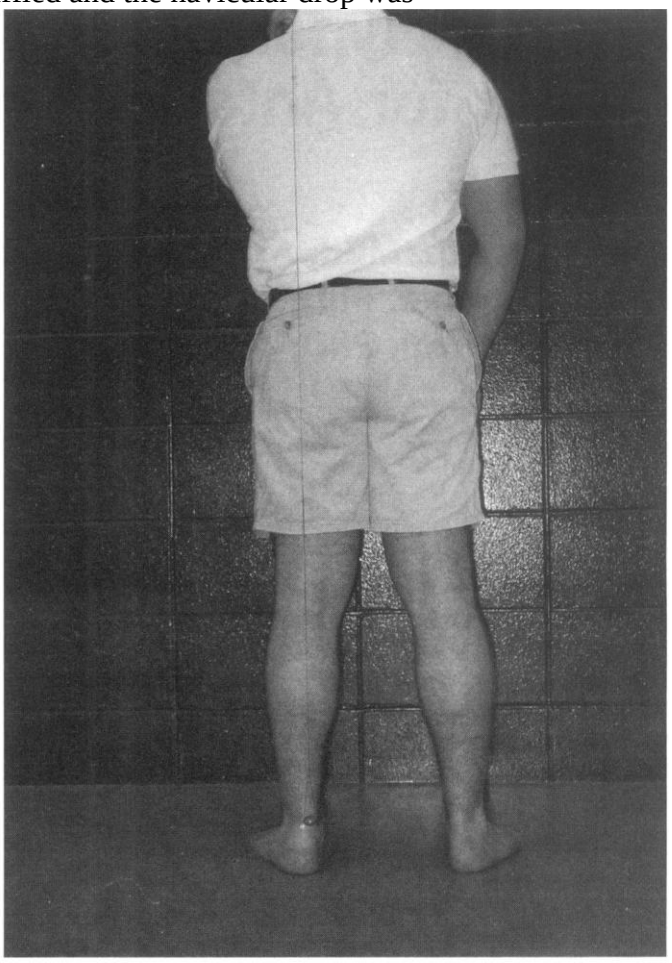

Fig 1. Plumb line dropped through the inferior angle of scapula.

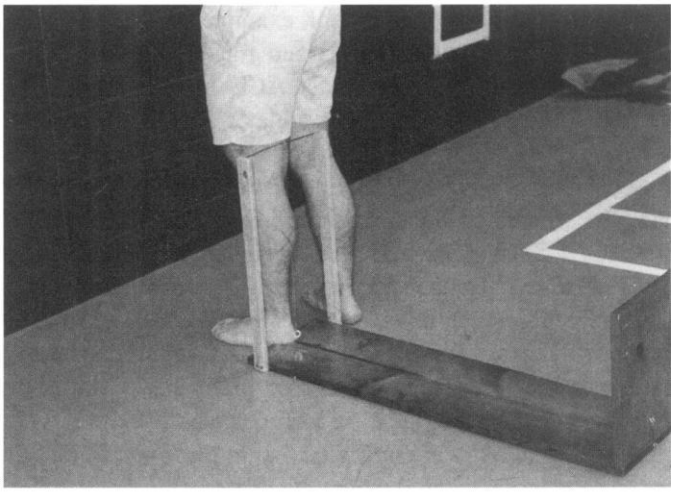

Fig 2. Calcaneal stance board positioned behind subject.

measured with the ruler. After all of the cards were measured, the data were then categorized by each number and by left or right foot. The values for the two different sets of cards were used to determine the intraclass correlation coefficient (ICC) using formula (2,1).[11]

The reliability for the calcaneal stance position test was assessed by taking two pictures of the left and right foot of the ACLU group. The entire methodology of the calcaneal stance position test was repeated each

time. A numbered card was placed next to the leg and in the view of the camera. Also, an "L" or an "R" was placed on the card to indicate the left or right foot. To blind the tester, the numbers in the photograph were covered with tape prior to measurement. The tester then used a protractor to measure the angle of calcaneal eversion from the pictures. Afterwards, the numbers were uncovered, and the photographs were matched by number and side. The values for the two different sets of photographs were used to determine the intraclass correlation coefficient using formula (2,1).[11]

Data Extraction and Analysis

The ACLI group completed each test once for each foot. For the ACLU group, each test was done twice for each foot in order to assess reliability. The mean of the two scores for each leg for the ACLU group was used for the data analysis. Initially, a ***t*** test was used to determine differences between the left and right feet of the ACLU group for both measurements. Following the ***t*** tests, the uninjured limb of the 12 unilaterally injured ACLI group members was matched by side to a limb of 12 randomly selected members of the ACLU group. The navicular drop measures of these matched limbs were used in a regression analysis to predict group membership. The alpha level of all statistical tests was set at $p = .05$.

RESULTS

For the navicular drop test, the ***t*** test indicated that there was no significant difference between the left and right feet of the ACLU group. Table 1 shows the means for both the ACLI and ACLU groups. For the calcaneal stance test, the ***t*** test found a significant difference between the left and right feet of the ACLU group. Table 2 shows the means for both the ACLI and ACLU groups. Originally, both the calcaneal stance and navicular drop scores were to be used in the regression analysis. However, because the right and left feet measurements were different for the calcaneal stance test, it was not included in the regression analysis. The regression analysis between group membership and navicular drop.

For the reliability assessment, the ICC for the navicular drop test equaled 0.72 (SEM = 1.79 mm) and 0.82 (SEM = 1.15 mm) for the left and right feet, respectively. Similarly, for the calcaneal stance test, the ICC was equal to 0.74 (SEM = 1.21 degrees) and 0.91 (SEM = 0.84 degrees) for the left and right feet, respectively.

Table 1. Means and Standard Deviations of the Navicular Drop Test

	Right/Injured*	Left/Uninjured
ACLU	6.21 ± 2.64 mm	6.79 ± 3.19 mm
ACLI†	6.33 ± 3.11 mm	7.17 ± 4.17 mm

* Right leg for uninjured group. Injured leg for injured group.
† ACLI scores are for n = 12. Scores for the 2 subjects with both legs injured are not included.

Table 2. Means and Standard Deviations of the Calcaneal Stance Test

	Right/Injured*	Left/Uninjured
ACLU	2.54 ± 2.8°†	1.11 ± 2.23°
ACLI‡	−0.38 ± 2.17°§	2.13 ± 2.36°

* Right leg for uninjured group. Injured leg for injured group.
† Right > left ($p < .05$).
‡ ACLI scores are for n = 12. Scores for the 2 subjects with both legs injured are not included.
§ Negative scores on the calcaneal stance test indicate greater pronation.

DISCUSSION

Our findings were that the navicular drop test did not distinguish the ACLI group from the ACLU group and that the calcaneal stance measure differs between left and right feet. These findings differ from the results of Beckett et al[2] and Woodford-Rogers et al.[3] Beckett et al[2] found a significantly greater amount of navicular drop in ACL-injured subjects as compared to ACL-uninjured subjects. Although our measurement procedure for navicular drop was identical to that of Beckett et a1,[2] our study differed in the number of testers and in the subject population. For example, our total subject population was 28 subjects in comparison to the 100 subjects used by Beckett et al.[2] Of the 50 ACL-injured subjects (39 male, 11 female) in the study by Beckett et al,[2 23] had been injured in a contact situation and 27 had been injured in a noncontact situation. All of our ACLI subjects had a noncontact mechanism as their history of injury.

The noncontact-injured subjects in the study by Beckett et al[2] had average navicular drop scores of 13.2 ± 4.1 mm and 12.7 ± 3.7 mm for the right and left feet, respectively. These scores were much greater than our ACLI group, which had means of 6.33 ± 3.11 mm and 7.17 ± 4.17 mm for the injured and uninjured feet, respectively. One possible explanation for this difference is that a majority of the ACL-injured subjects in the study by Beckett et al[2] were male (39 male, 11 female). It is possible that, because males on average tend to be taller than females, they may have higher arches, resulting in more distance for the navicular to drop.[3]

Woodford-Rogers et a1[3] also found ACL-injured subjects had a significantly greater navicular drop than ACL-uninjured subjects. Once again the methodology for the navicular drop test was identical to ours. However, they matched the ACLU and ACLI groups by team, position, and extent of participation. Thus, it is possible that by matching, they were able to eliminate extraneous factors that prevented us from having significant findings.

With regard to the calcaneal stance test, it is difficult to make comparisons with Woodford-Rogers et a1[3] because of differences in measurement procedures. Nevertheless, it is interesting to note that they were not able to successfully predict ACLI and ACLU group membership and that we found the calcaneal stance test scores of the ACLU group's left and right feet to be significantly different. This difference may explain why Woodford-Rogers et a1[3] were unable to predict group membership. Because of this difference, we were unable to justify using the ACLI subjects' uninjured legs as their preinjury state for this test, and, thus, did not include it in the regression analysis to predict group membership.

One possible explanation for the left and right feet being significantly different in the ACLU group is the difference in girth measurements of the calves. If the two calves of one person have unequal girth measurements, then the midpoint of each calf may be different. This difference of the midpoints would affect the size of the calcaneal stance measure. Therefore, girth measurements of the calves, rather than just the midpoint, should become part of the testing protocol for the calcaneal stance test.

In addition to the regression analysis, the reliability of both measures was also evaluated. One study has examined the reliability of the navicular drop test. However, previous studies examining the reliability of the calcaneal stance test

could not be found. For the navicular drop test, Picciano et al [12] had two inexperienced testers measure thirty feet on two separate days using the Brody method.[10] This allowed for assessment of inter- and intratester reliability. They reported the intertester ICC, using formula (1,1), to be 0.57 with an SEM of 2.72 mm. For the intratester reliability, they reported ICCs for the two testers of 0.61 and 0.79 with SEMs of 2.57 and 1.92 mm, respectively. Their results for intratester reliability are lower than ours. One reason for these differences may be due to the different ICC formulas used in the studies. ICC (1,1) is more conservative than formula (2,1) and produces smaller values. Based on the recommendations of Shrout and Fleiss,[11] formula (2,1) is the most appropriate formula for intratester reliability assessment. Thus, we believe our ICCs more accurately estimate the reliability of these measures.

Based on the regression analysis, it was not possible to predict group membership from navicular drop scores. As such, our findings do not support static hyperpronation as a possible risk factor for ACL injuries. However, it should be cautioned that this and previous studies2,3 are based on the assumption that the uninjured leg is representative of the preinjury state. Unfortunately, there is no way to validate this assumption without conducting a prospective study. In other words, it is possible that navicular drop, as measured in our and other studies, may or may not predict ACL injury because of biomechanical changes in the uninjured leg resulting from changes in the injured leg. Thus, we strongly recommend further study. Our suggestions are to perform a prospective study and to standardize the techniques of both the navicular drop test and the calcaneal stance test so that reliability is more consistent. We also suggest further research using dynamic measurements of pronation. McPoil and Cornwall[13] and Hamill et al[11] have found that static measurements of pronation do not indicate that excessive pronation will occur during dynamic activity. Finally, more research should be conductedon other possible anatomic risk factors.

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