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Metrecom Measurement of Navicular Drop in Subjects with Anterior Cruciate Ligament Injury

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Objective: Research suggests that excessive pronation of the foot contributes to the incidence of anterior cruciate ligament (ACL) tears by increasing internal tibial rotation. Studies have documented greater navicular drop values in individuals with a history of an ACL tear using methods that may not accurately follow the motion of underlying bone. The purpose of our investigation was to compare the navicular drop of subjects with a history of ACL tears with healthy controls when measured by a Metrecom.

Subjects: Eighteen subjects previously diagnosed with a torn ACL were matched by age, sex, and limb to noninjured control subjects.

Design and Setting: Static group comparisons of navicular drop in subjects with an injured ACL and subjects having no history of ACL injury.

Measurements: A single investigator performed the measure of navicular drop. The position of the navicular tuberosity was digitized while the subject stood barefoot on a flat surface in subtalar joint neutral and in relaxed stance. Intrarater reliability was assessed using intraclass correlation coefficient and standard error of the measurement. An independent t test assessed the difference between the amount of navicular drop in the ACL group and the controls.

Results: Analysis of repeated measures, intraclass correlation coefficient (2,1), demonstrated intrarater reliability for the measure of navicular drop to be 0.90; the standard error of measurement was 1.19 mm. The independent t test showed a statistically greater amount of navicular drop in the ACL group.

Conclusions: Excellent intrarater reliability was demonstrated when using the Metrecom to measure navicular drop. Excessive subtalar joint pronation, measured as navicular drop, was identified as 1 factor that may contribute to ACL injury.

Key Words: pronation, internal tibial rotation, navicular bone

The contribution of abnormal biomechanics in the foot to the development of knee pathology is clinically important in the prevention and treatment of injury.[1–5] During weightbearing, the foot and knee act as interactive segments, with pronation of the foot and internal rotation of the tibia occurring simultaneously.[6] One mechanical function of the anterior cruciate ligament (ACL) in the knee is to limit the internal rotation of the tibia.[7] Studies suggest a contributing mechanism to ACL injury is excessive tibial rotation due to hyperpronation of the subtalar joint, with the resulting strain on the ACL increasing the risk of a tear.[8–10]

Navicular drop is a clinical measure of foot pronation,[11] defined as the change in height of the navicular bone when the foot moves from subtalar neutral to a relaxed weightbearing stance.[12] We identified 4 studies that investigated the measure of navicular drop in subjects with a history of an ACL tear.[8–10,13] Three studies documented significantly greater navicular drop in patients with ACL injuries when compared with matched controls.[8–10] Smith et al,[13] however, reported no difference between groups. Three of the studies[8,9,13] measured navicular drop by recording the vertical change in the position of a pen mark on the skin overlying the navicular tuberosity, a method previously described by Brody.[12] The height of the navicular tuberosity was first marked on a file card or measured by ruler with the subject in subtalar neutral. The subject was then allowed to resume normal weightbearing stance, and the height of the pen mark was again recorded. Loudon et al[10] measured the change in the most distal point of the navicular tuberosity, which although not specified, would indicate direct palpation was used to identify the measurement site.

Testing for reliability was reported in only 2 of these 4 studies. Smith et al[13] repeated measures on the noninjured control group (intraclass correlation coefficients [ICC] values were 0.72 for the left foot and 0.82 for the right). Loudon et al[10] reported excellent intratester reliability for their method (κ value of 0.87).

Three aspects of these previous studies are problematic. First, the reported intratester reliability of the navicular drop measure[10,13–15] varies greatly, depending on the skill of the tester and the level of control exerted over repeated foot placement. Not testing or reporting reliability severely limits the usefulness of the data. Second, measurement of a pen mark is subject to skin movement.[16] Third, tracking the change in height of a pen mark or bony landmark attempts to measure the vertical component of displacement; however, navicular drop includes movement components in the medial and anterior directions as well.[17]

The purpose of our investigation was 2-fold. First, we wanted to assess the reliability of the measure of navicular drop when using a Metrecom (FARO Medical Technologies Inc, Lake Mary, FL). The second purpose was to compare the Metrecom-measured navicular drop of subjects with a history of ACL tears with that of noninjured matched controls. The

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null hypothesis was that navicular drop would not differ between groups.

METHODS

This study received approval from the Institutional Review Board of Physiotherapy Associates, which also approved the informed consent form signed by each subject. Thirty-six subjects volunteered for the study. Eighteen subjects (12 men, 6 women) had a history of an ACL tear diagnosed by a physician. Sixteen subjects had tears confirmed by magnetic resonance imaging or arthroscopy; 2 tears were diagnosed clinically, with the diagnosis supported by a KT-1000 test. ACL-injured subjects were matched with control subjects by age, sex, and limb. Sixteen subjects in the ACL group had undergone reconstructive surgery, and 2 had been treated conservatively. The mean age of the ACL group was 29.9 ± 9.5 years; range, 18 to 49 years. The control group (mean age = 29.9 ± 8.6 years) had no reported history of ACL injury. No subjects had a history of foot or ankle trauma during the 6 months before testing.

A single examiner measured navicular drop using the Metrecom. The Metrecom is an electromechanical, 3-dimensional digitizer (Figure 1).[17] The Metrecom measures the 2 positional points in 3-dimensional space and calculates the change in distance for the investigator, who is blinded from the results during the test. Linear accuracy, repeatability, and linearity of the system have been demonstrated.[18] A mean accuracy of 0.9 mm was reported when the Metrecom was used to digitize a calibration device.[18]

Subjects stood on an elevated platform with their feet a comfortable distance apart. The probe of the Metrecom was placed directly under the tuberosity of the navicular (Figure 2). The subject inverted the foot while the examiner palpated the congruency of the talar head in the mortise joint for subtalar neutral position. Once positioned, the location of the tuberosity was digitized. The probe of the Metrecom remained positioned

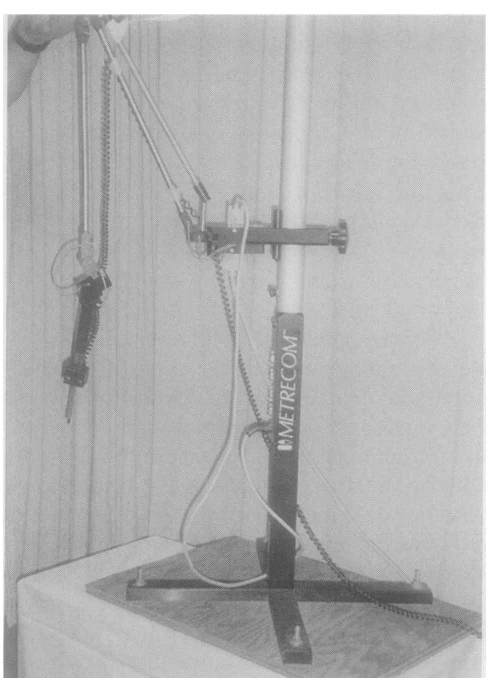

Figure 1. The Metrecom digitizing unit.

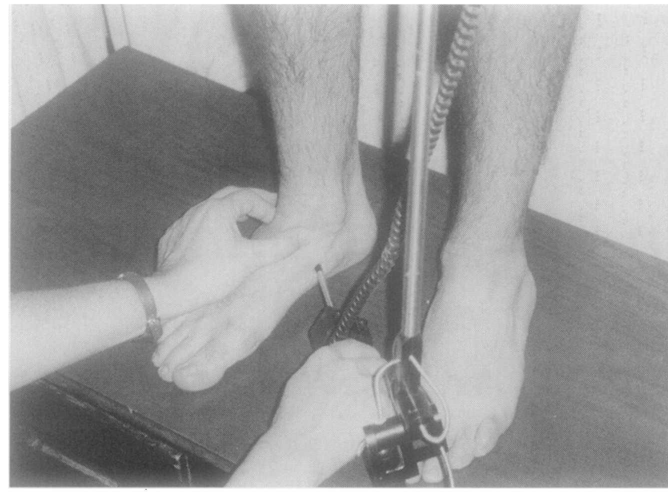

Figure 2. Metrecom measurement of navicular drop.

under the tuberosity as the subject then resumed a normal, relaxed stance, and the second point was digitized. To test for reliability, the measure was repeated on all subjects. The average of the 2 trials was computed as the measure of navicular drop. Both feet were tested in all subjects. The limb with the ACL injury was considered the test limb (10 right and 8 left limbs) and matched with the same limb from the control group.

Intratester reliability of the navicular drop measure was determined using ICC (2,1),[19] and the standard error of measurement was calculated. We used an independent t test to assess the difference in navicular drop between groups.

RESULTS

Mean, standard deviations, and range of values for navicular drop are summarized in Table 1. ICC intrarater reliability was 0.90, with a standard error of measurement of 1.19 mm. The independent t test showed a statistically ($P < .05$) larger navicular drop in the ACL group. The noninjured limb of the ACL group also had a statistically ($P < .05$) larger navicular drop than the ipsilateral limb in the control group (Table 2). Values for navicular drop measured in ACL-injured subjects by sex are provided in Table 3. There was no significant difference between male and female values in the ACL-injured group.

DISCUSSION

Measurement Reliability

Navicular drop has been reported to be between 6 and 9 mm of movement in healthy, normal subjects.[8,17,20] The control group in our study consisted of a varied population of healthy, active individuals, and their mean navicular drop value (8.1 mm) fell within this range. In studies comparing ACL-

Table 1. Navicular Drop Values (mm)

Group	Mean	SD	Range
Control	8.1	2.8	3.5–13.5
ACL injured	10.5*	4.0	6.0–20.0

*Statistically significant difference from controls ($P < .05$).

Table 2. Navicular Drop Values of Noninjured Limbs (mm)

Group	Mean	SD	Range
Control	8.1	3.0	3.5–14
ACL injured	10.1*	3.6	5.5–16

*Statistically significant difference from controls ($P < .05$).

Table 3. Navicular Drop Values of ACL-Injured Group by Sex (mm)

Sex	n	Mean	SD	Range
Females	6	10.2	3.5	5.5–15.5
Males	12	10.7	4.3	6.5–20

injured with normal subjects, the mean navicular drop measurements have varied, depending on the subject population (Table 4).[8–10,13] One study's authors did not report mean values of the drop measure but grouped subjects according to low (< 6 mm), normal (6 to 9 mm), or high (> 9 mm) amounts of movement.[10] The ACL-injured groups in 3 studies[8,9,13] had significantly greater navicular drop values than healthy, normal subjects. The results of our study support these findings.

Smith et al[13] reported finding no significant difference in navicular drop between noncontact ACL-injured subjects and controls. It is not clear why their results contrast with other published data. They cite sex differences as a possible explanation, suggesting that women have smaller drop values. Thus, with an equal number of ACL-injured women[7] and men included in their study, the mean value for the injured group was diminished. We found, however, that the ACL-injured women in our study had a mean navicular drop value comparable with that of the men (Table 3). Both men and women in the ACL-injured group demonstrated greater navicular drop values than the control subjects. Other possible explanations offered by Smith et al[13] for the lack of difference between groups included sample size and the use of noncontact ACL-injured subjects. The other reported studies (Table 4) that did show significantly larger navicular drop values in ACL-injured subjects also included small sample sizes, similar subject populations, noncontact ACL-injured subjects, or a combination of these factors.[8–10]

Positioning of the subjects in our study followed the procedure described by Brody.[12] Previous studies[8–10,13] examining the relationship between ACL injuries and navicular drop followed Brody's method of manual measurement, but unlike Brody, varied the weightbearing position of the subjects between conditions. The subjects were seated (rather than standing) during measurement of the navicular position with the foot in subtalar neutral. The subjects then stood during the second measure. A study by Joyce et al[21] demonstrated that the variation in loading does have an effect on the overall movement of the navicular, with seated subtalar neutral to standing subtalar relaxed positioning resulting in larger navicular drop values.

Measuring the change of position of a pen mark on the skin is inexpensive and easy to perform in a clinical setting; however, navicular drop is a relatively small measure of displacement. Due to skin movement, the mark may not reflect the same relative position on the tuberosity as the navicular drops from subtalar neutral into pronation.[16] When measuring millimeters of bony displacement, movement of the skin can have a large impact on the measurement total. Added to the potential error of determining the subtalar neutral position,[15] the value of the measurement can be significantly affected; thus, issues of reliability and accuracy become critical when reporting navicular drop data.

We demonstrated excellent intratester reliability for the measurement of navicular drop. The probe of the Metrecom was positioned under the navicular tuberosity, and contact was maintained throughout the procedure. The probe's position was unaffected by skin movement. The examiner's hand never left the palpation points on the head of the talus; thus, a shift from subtalar neutral by the subject was easily detected and corrected. Controlling these factors of error in the measure of navicular drop provides data that are closer to reflecting the true motion that occurred.

Relationship of Navicular Drop to ACL Injury

McClay and Manal,[5] using 3-dimensional kinematic gait analysis, demonstrated greater internal rotation of the tibia during running in subjects with excessive foot pronation ($11.1 \pm 3.5°$ versus $8.9 \pm 2.5°$ for the controls). Statistically significant higher peak velocities of foot eversion and knee flexion, as well as greater knee-flexion angles, were also seen in the pronation group when compared with normal subjects.[22] Excessive rearfoot pronation has been linked to overuse injuries of the knee.[23–24] Navicular drop studies suggest a link between excessive subtalar pronation and ACL injuries.[8–10] In our study, the similarity in navicular drop values between the injured (10.5 mm) and noninjured limb (10.1 mm) of the ACL group support the suggestion that the higher values were not due to the injury or surgical repair but inherent in the individuals with ACL injury. A bilateral comparison of the control group's navicular drop

Table 4. Reported Navicular Drop Values in ACL-Injured versus Healthy Subjects

Investigator	Group	Age (years)	n	Mean (mm)	Injury Mechanism
Woodford-Rogers et al[9]	ACL	19.1 ± 6.0	14 m*	8.4 ± 4.2	Mixed
	Control	18.1 ± 1.6	14 m	5.9 ± 2.4	
	ACL	19.5 ± 1.7	8 f*	5.0 ± 2.5	Noncontact
	Control	19.0 ± 1.2	8 f	3.0 ± 1.1	
Beckett et al[8]	ACL	22.9 ± 7.6	11 f, 39 m	13.0 ± 4.4	Mixed
	Control	21.8 ± 9.4	11 f, 39 m	6.9 ± 3.2	
Loudon et al[10]	ACL	26.5 ± 7.6	20 f	†	Noncontact
	Control	26.2 ± 7.8	20 f	†	
Smith et al[13]	ACL	21.1 ± 0.8	7 f, 7 m	6.3 ± 3.1	Noncontact
	Control	21.1 ± 2.0	7 f, 7 m	6.2 ± 2.6	

*m, males; f, females.
†Mean values not reported. Fifteen ACL subjects had > 9 mm of drop, 14 control subjects had < 9 mm of drop.

values also demonstrated similarity (8.1 mm for both limbs). These values were significantly lower than those of the ACL group, supporting the concept that excessive pronation may be a factor in ACL injury.

Further study is needed to determine if this is a causal relationship or related to generalized tissue laxity. The complexity of the anatomical relationships in the lower extremity,[25-27] coupled with the variance in subject population and data collection procedures, only allow us to suggest an association. ACL tears are a common injury. If excess pronation and tibial rotation contribute to the incidence of injury, screening and possible prevention with orthotic management of the foot could benefit many.

CONCLUSIONS

Our study is the first to report values for ACL-injured subjects using the Metrecom as the measurement tool. Excellent intrarater reliability for this method was demonstrated. The results of this study support previous work, which indicates that excessive pronation of the foot is a factor that may be associated with ACL injury.

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