Concurrent Validity of the Anterior Drawer Test and an Arthrometer in Evaluating Ankle Laxity

Thomas J. Disanto, MEd, ATC, CSCS; C. Buz Swanik, PhD, ATC; Kathleen A. Swanik, PhD, ATC; Stephen J. Straub, PhD, ATC; and Alan R. Needle, MS, ATC, CSCS

ABSTRACT
This study focused on the concurrent validity and reliability of an ankle arthrometer and clinical tests of ankle laxity. A posttest-only control group design was used to compare anterior-posterior (AP) displacement in participants with clinically graded laxity (mechanical instability) and a control group. Forty-four individuals with no recent ankle sprains participated in this study. An ankle arthrometer measured AP displacement, and one investigator clinically graded the anterior drawer test. Pearson correlations were significant ($r = 0.48$, $P < .05$) between the anterior drawer and arthrometer measurements of AP displacement. Independent $t$ tests revealed significantly greater AP displacement ($P < .05$) in mechanically unstable ankles on the anterior drawer test. The intraclass correlation coefficients [2,1] for arthrometer AP displacement ranged from 0.44 to 0.87, with reliability decreasing as the laxity grade increased. The ankle arthrometer is a reliable measure of AP laxity and has concurrent validity with a standardized clinical grading system in differentiating levels of joint laxity.

Ankle sprains are currently the most common injury in athletics. Repetitive ankle sprains are common in as many as 50% of patients experiencing ankle sprains, and this can lead to mechanical or functional instability of the ankle joint. Mechanical instability can be defined as joint motion that exceeds normal physiological limits, whereas functional instability is defined as joint motion beyond voluntary control but not necessarily exceeding the physiological limits, leading to sensations of giving way or rolling. Although the precise cause of functional instability remains unclear, ligamentous laxity, muscle weakness, and proprioceptive deficits have all been considered contributors to functional instability. However, the causal relationship between mechanical instability and functional instability is debated with concern because current methods for assessing mechanical instability are inadequate. In addition, recent research has highlighted the role of ligament healing following an acute ankle sprain and considerations of laxity as return-to-sport criteria.

Evaluation of posttraumatic ankle laxity relies primarily on manually performed clinical tests. These include the anterior drawer, an anterior stress of the talus and calcaneus on the ankle mortise; and the talar tilt, an inversion and eversion stress to the ankle joint. The anterior drawer test has been considered one of the most accurate tests for evaluating posttraumatic ankle laxity. Sensitivity and specificity have been reported as high as 96% and 84%, respectively, and have reported strong positive and negative likelihood ratios. Unknown forces, moments, and the clinician’s technique or skill are some extrinsic factors that may negatively influence the validity and reliability of manual testing. Intrinsic factors such as generalized joint mobility and muscle tone may also...
increase the difficulty of side-to-side and between-person comparisons using clinical tests.\textsuperscript{13,18} With the advent of an instrumented ankle arthrometer, valid, quantitative measurements of ankle laxity are available to clinicians and researchers alike for allowing objective evaluation after ankle injuries, rehabilitation, or surgical interventions.

Knee arthrometers are currently available and widely accepted as a method for quantifying knee laxity, but until recently, a similar device for the ankle did not exist.\textsuperscript{19} The first objective, quantitative measurements of ankle laxity were documented using a portable ankle arthrometer (Instrumented Ankle Arthrometer; Blue Bay Research Inc., Milton, Fla.).\textsuperscript{14,22} Kovaleski et al\textsuperscript{14} assessed anterior-posterior (AP) displacement and inversion-eversion rotation in a population of normal healthy ankle complexes, with further studies addressing reliability and validity in a cadaveric model,\textsuperscript{20} and compared healthy participants and those with functional instability\textsuperscript{12} and acute ankle sprains.\textsuperscript{21} In all of these studies, the arthrometer proved a valid and reliable tool for measuring ankle laxity, with high intratester and intertester reliability.\textsuperscript{22,23} In addition, measurements from the arthrometer established an association between ankle laxity and functional instability of the ankle, as well as a relationship between ankle laxity and acute injury to the lateral ligaments.\textsuperscript{10,21} However, in clinical practice, the use of instrumented arthrometers is limited and research to date has not compared data from an arthrometer in parallel with commonly used clinical tests to assess ankle laxity.

Therefore, the purpose of this study was to compare AP displacement measurements using an instrumented ankle arthrometer with the anterior drawer test in a population with and without ankle laxity.

**METHOD**

**Participants**

Forty-four volunteer participants (24 men, 20 women; mean age = 24.45±3.93 years; mean mass = 73.42±15.51 kg; mean height = 67.16±4.17 cm) were tested in this study, for a total of 88 ankles. Participants were excluded if they had been diagnosed with an ankle sprain 4 months prior to testing. Participants’ ankles were stratified into mechanically unstable or control groups via physical examination, with 41 ankles fitting the criteria for the mechanically unstable group and 47 ankles fitting the criteria for the control group. Ankles with mechanical instability were further classified into grade I, grade II, or grade III subgroups based on the results of clinical evaluation, where grade I ankle laxity had very slight laxity with motion from 0–1 mm and a firm endpoint, grade II represented moderate laxity with motion approximately 2–5 mm and a soft endpoint, and grade III had signs of extreme laxity of >5 mm with no endpoint.\textsuperscript{24,25} Participants without laxity were placed into the control group. Informed consent was obtained from all participants in adherence with the university’s institutional review board, which approved the study.

**Instrumentation**

The ankle arthrometer consists of a tibial pad, an adjustable foot plate, a force load handle attached to the foot plate, and a spatial kinetic linkage system (Figure).\textsuperscript{14,20} The foot plate was secured to the dorsum of the foot by 4 pads. A dorsal pad compressed the forefoot until the heel was secure on the heel pad, while the lateral and medial pads secured the calcaneus to the foot plate. A pad was secured, 5 cm above the lateral malleolus, across the tibia to a tibial plate (Figure). Subsequently, the motion of the calcaneus with respect to the tibia was measured, combining the movements of the talocrural joint and subtalar joint. The spatial kinematic linkage system, which measured 6 degrees-of-freedom of motion, was attached to the tibial pad and foot plate. A computer using an analog-to-digital converter recorded data from the load cell and spatial kinematic linkage system, which was displayed graphically on a monitor. A custom computer program using LabVIEW software (National Instruments Corp, Austin, Tex) was used to place the foot in the neutral position. Anterior-posterior force-displacement curves were recorded by the computer as the device was operated.

**Procedures**

Participants reported for a single-testing session and first underwent a clinical orthopedic examination by one investigator to classify their ankles as having either no laxity or some degree of mechanical instability. The degree of ankle laxity was determined using the anterior drawer test.\textsuperscript{26} Arthrometer testing commenced following the procedures established by Kovaleski et al.\textsuperscript{14} Participants were randomly assigned to start testing with either the right or left ankle and were instructed to lie supine on a plinth, with the calf supported in padding. The tibial plate was placed on the shank, the arthrometer was secured to the dorsum of the foot by adjusting
the heel and dorsal clamp, and the tibial plate was secured with hook-and-loop fastener straps to the lower leg. Two hook-and-loop fastener straps were wrapped around the table and the leg 2 and 12 cm above the lateral malleolus, which restricted extraneous leg movement by firmly securing the leg to the table (Figure).

Prior to testing, the load handle was used to position the ankle at the neutral starting point (0 degrees-of-flexion). All force loads and torque levels were positioned at zero in all planes. Anterior translation from the neutral reference point was recorded as anterior displacement, with posterior translation recorded as posterior displacement. The combined range of posterior displacement and anterior displacement from –30 to 125 Newtons (N), as applied through the load handle, was considered total AP displacement. Three trials were conducted per ankle, with the arthrometer removed between each trial. After testing of the first ankle was completed, the entire process was repeated on the opposite ankle.

Data Analysis

Pearson product-moment correlation coefficients were calculated between the arthrometer measures and the 3 clinical test grades of ankle laxity. Independent t tests were used to determine whether significant differences existed in mechanical laxity between subjectively graded mechanically unstable and control groups. Dependent 2-tailed t tests were used to determine whether significant differences existed in AP measurements between ankles in participants with unilateral mechanical instability. Intratester reliability was determined with an intraclass correlation coefficient (ICC) [2,1] conducted between the 3 trials on each ankle. An alpha level of 0.05 was considered significant.

RESULTS

A significant (P < .05) but weak positive Pearson correlation value (0.47) was found between the researchers’ clinical grading of the anterior drawer and the AP displacement measurements. Independent t tests revealed a significantly larger (P < .05) AP displacement in ankles with mechanical instability (11.86 ± 2.68 mm) compared with the control group (10.62 ± 2.62 mm). Intrarater reliability was strong for AP measurements in all participants. However, reliability of the arthrometer measurements decreased as the clinical grade of mechanical instability increased (Table).

DISCUSSION

Concurrent Validity of the Ankle Arthrometer and Clinical Tests

The purpose of this study was to evaluate ankle arthrometer measurements to those of common clinical tests by means of concurrent validity. Manual clinical tests, although subjective in nature, often provide initial outcomes of an injury. As a research instrument, the ankle arthrometer provides precise quantitative data that the subjective tests cannot. The significant difference between mechanically unstable and control ankles, as well as the significant correlation between the researchers’ anterior drawer and the AP measurements of the arthrometer, indicate that the device can distinguish between subjective grades of ankle laxity. Kerkhoffs et al.17 reported that sectioning of the anterior talofibular ligament in a cadaver leads to an increase in AP laxity by 2 mm and further sectioning of the calcaneofibular ligament increased laxity another 2 mm. These values

<table>
<thead>
<tr>
<th>TABLE</th>
<th>Intraclss Correlation Coefficient (ICC) [2,1] Reliability Analysis (Anterior-Posterior Laxity)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLINICAL GROUP</td>
<td>ARTHROMETER</td>
</tr>
<tr>
<td></td>
<td>SEM (mm)</td>
</tr>
<tr>
<td>Overall</td>
<td>1.18</td>
</tr>
<tr>
<td>Control</td>
<td>0.97</td>
</tr>
<tr>
<td>Injured</td>
<td>1.4</td>
</tr>
<tr>
<td>Grade I</td>
<td>1.29</td>
</tr>
<tr>
<td>Grade II</td>
<td>1.61</td>
</tr>
<tr>
<td>Grade III</td>
<td>1.65</td>
</tr>
</tbody>
</table>

Figure. Instrumented Ankle Arthrometer (Blue Bay Research, Inc, Milton, Fla).
are within our reported values of participants with unilateral unstable ankles, where we found a difference of approximately 2 mm between the lax ankle and the ankle without laxity. Overall, our findings are also consistent with those of Kovaleski et al, who found that the ankle arthrometer can detect changes in mechanical laxity produced by gradual sectioning of the anterior talofibular ligament and calcaneofibular ligament in cadaveric specimens. Our study, in conjunction with these 2 studies, supports the concurrent validity between the arthrometer and manual tests of AP laxity.

**Displacement in Mechanical Instability and Control Participants**

Objective assessment of the anterior drawer test has been conducted in an attempt to quantify normal values, but there has been disagreement on what constitutes normal and abnormal values and which methods of testing should be used. The methods of quantifying laxity, with the level of force application considered, have varied and included manual stress tests, sandbags, and stress radiographs. Normative values for anterior displacement measured by other devices have been reported, ranging from 2 to 9 mm. We found an average AP displacement of 11.79±2.78 mm, as opposed to Kovaleski et al who reported average of 18 mm. Both studies used a maximal load of 125 N of force. The manner in which the arthrometer was stabilized could have affected the AP measurements, as Kovaleski et al used only 1 strap 6 cm above the malleoli, whereas our study used 2 straps placed 2 and 12 cm above the malleoli. This can lead to greater extremity stabilization and less overall measured motion at the ankle joint complex. This stabilization procedure may result in increased reliability during testing, as well as more precise measurements. Comparisons to previous research which measured just the talocrural joint is not possible.

Low standard error of measurement in vivo has been reported (1.94 mm), consistent with our values. It was suggested by Kovaleski et al that inconsistencies in measurements seem to occur in an acceptable small range of laxity values, although their findings were limited to 6 cadaveric samples. However, standard error of measurement scores for AP displacement (intratester = 0.58 mm, intertester = 1.02 mm) were determined in the cadaveric study, lending support to the accuracy of the arthrometer measurement of ankle laxity.

Participants in this study had complaints of mechanical instability, functional instability, or both; however, a distinction was not made between the 2 groups and therefore was not examined. Because reliable, quantitative AP measurements were obtained, this instrument may be beneficial in studying the relationship between mechanical instability and functional instability. This association is disputed in the current literature. Previous methods for assessing mechanical instability have been questioned as to their efficacy in establishing a relationship with functional instability. Research examining this connection has relied on subjective measurements or objective instruments with poor reliability. These data lend support to the use of an ankle arthrometer for evaluating posttraumatic ankle laxity assessment and may lead to a greater understanding of the relationship between mechanical instability and functional instability.

**Reliability of Arthrometric Ankle Measures**

Another purpose of our investigation was to determine reliability of an ankle arthrometer in measuring AP displacement among participants with ankles both with mechanical instability and without laxity. Previous research has supported strong intratester and intertester reliability of the ankle arthrometer when measuring normal ankle joint complexes and in detecting changes in mechanical laxity due to anterior talofibular ligament damage to the ankle ligaments, as sequential cadaveric specimens. This phenomenon. One factor could be variability in the damage to the ankle ligaments, as sequential cadaveric sectioning of the lateral ankle ligaments by Bulucu et al demonstrated no single ligament could be isolated as having a dominant stabilizing function. Clinically, knowing what percentage of the ligament is torn is difficult to describe. Therefore, the more damage to the ligaments of the ankle, the more difficult is to precisely evaluate the injury. This factor is removed in cadaver models, and may lead to a greater variability in human participant testing.

Another related issue seen in grade III participants could include muscle guarding, related to articular mechanoreceptor and nociceptor input. Alternately,
there may be changes in the passive stiffness of the ankle ligaments following sprains, with relation to rate of stress application. Decreased laxity may be detected with a faster rate of stretch due the viscous dampening properties of connective tissue; however, when there is not a lot of laxity available, the dampening effect of the ligament may be minimal. As the laxity increases, there may be a greater role or viscous dampening in changing ligamentous strain, as the rate of stress may increase.33 For these reasons, it is important that the tester on the arthrometer uses a standard rate of force application. Clinical tests may also be imprecise as researchers only choose from 3 subjective grades rather than a continuous laxity measurement provided by the ankle arthrometer. A continuous measure of laxity may be more appropriate to both provide a more reliable grade of ankle laxity, as well as for tracking the progression of ligament healing over time.35 The arthrometer also allows for a standard amount of force to be applied to the ankle.

IMPLICATIONS FOR CLINICAL PRACTICE

The use of ankle arthrometry in the research setting has increased over the past decade. However, the use of an arthrometer clinically is rare. The ankle arthrometer offers the ability to obtain a reliable, quantifiable measure of anterior displacement. Our findings showed that values from the ankle arthrometer may correlate with scores of laxity from manual testing by a skilled clinician; therefore, clinicians may be assured that experimental research using an ankle arthrometer will be applicable in the clinical setting.

CONCLUSION

Concurrent validity between the ankle arthrometer and a clinician’s test for AP displacement was described. The device provides an accurate measure of AP displacement, correlating with a standardized clinical grading system in differentiating levels of joint laxity. Research accounting for muscle guarding and rate of force application within the testing protocol would improve the measurement. The results of this investigation demonstrated the ankle arthrometer to be a reliable measure of AP laxity in populations with and without ankle laxity.

REFERENCES

22. Hubbard TJ, Kovaleski JE, Kaminski TW. Reliability of intratester and intertester measurements derived from an instrumented ankle


