

Clinical evaluation of a dynamic test for lateral ankle ligament laxity

J. S. de Vries · G. M. M. J. Kerkhoffs ·
L. Blankevoort · C. N. van Dijk

Received: 23 July 2009 / Accepted: 19 October 2009 / Published online: 19 November 2009
© The Author(s) 2009. This article is published with open access at Springerlink.com

Abstract The dynamic anterior ankle tester (DAAT) has shown a good reliability in testing anterior talar translation in earlier studies. The goal of the present study was first to evaluate the reliability of the DAAT in a clinical setting and second to analyze its ability to detect increased ligament laxity. In 39 patients with unilateral chronic lateral ankle instability, the anterior talar translation of the affected and non-affected side was measured pre and postoperatively using the DAAT, Telos stress radiographs, and the manual anterior drawer test. In contrast to both other tests, the DAAT was not able to accurately detect increased ligament laxity preoperatively or decreased laxity of the affected ankle postoperatively. The DAAT showed a low sensitivity to change (the difference between the mean pre and postoperative value) and a low reliability compared to both other tests. There were no correlations between the three tests. In conclusion, the DAAT showed a low reliability in effectively testing lateral ankle ligament laxity in a clinical setting. This is in contrast to earlier evaluations.

Keywords Ankle · Lateral ligaments · Laxity · Reliability

Introduction

Chronic giving way symptoms in combination with increased lateral ligament laxity develop in ten to twenty percent of the patients sustaining an ankle inversion injury [14]. If conservative measures fail, anatomical reconstruction of the lateral ankle ligament complex provides a good treatment for these patients [1].

The anterior drawer test is the most appropriate clinical test for evaluation of lateral ankle ligament laxity [19]. The manual anterior drawer test is easy to apply but is subjective in nature, and the high intra- and inter-observer variation limits its use, especially for research purposes [7, 21]. Several (radiological) instrumented tests have been developed for objective measurement of ankle instability [19, 20, 32]. Ankle stress radiographs using a Telos stress apparatus is probably the best known and widely used for clinical and scientific evaluation [11, 13, 24, 26]. All these tests have the disadvantage of applying a constant force when testing ankle ligament laxity, allowing for false negative results due to apprehensive muscle contractions and with radiographic stress testing patients are exposed to radiation [16].

Avoiding radiation exposure and to overcome the influence of involuntary muscle contractions on the outcome of an anterior drawer test, the dynamic anterior ankle tester (DAAT) was developed to objectively assess lateral ankle ligament laxity [16, 17]. Its reliability and reproducibility were evaluated on cadaver ankles, healthy subjects, and subjects with known increased ligament laxity [16, 17]. These laboratory studies showed that of the original two parameters, the anterior talar translation is a reliable and reproducible measure with a good intra- and inter-observer reliability, whereas the talar rotation is not.

J. S. de Vries (✉) · G. M. M. J. Kerkhoffs · L. Blankevoort ·
C. N. van Dijk
Department of Orthopedic Surgery, Orthopaedic Research
Center Amsterdam, Academic Medical Center, PO-Box 22660,
1100 DD Amsterdam, The Netherlands
e-mail: j.s.duvries@gmail.com

In a recent prospective study, the clinical outcome of arthroscopic capsular shrinkage for chronic lateral ligament instability of the ankle was evaluated [5]. Postoperatively, both improved functional stability and manually and radiographically tested reduced ligament laxity were found.

The goal of the present study was to clinically evaluate the reliability of the DAAT and its ability to detect increased ligament laxity of an affected ankle joint and the mechanical effect of the shrinkage procedure. Outcome of the DAAT was compared to the manual anterior drawer test and the radiographically measured anterior talar translation. The hypothesis was that the DAAT would prove to be at least as reliable as or have a better reliability than both the manual and radiographic stress test in assessing lateral ankle ligament laxity.

Patients and methods

Design

The study was designed as a prospective longitudinal, intra- and inter-test comparative diagnostic trial. Anterior talar translation in patients with chronic lateral ankle instability scheduled for ankle ligament shortening (arthroscopic capsular shrinkage) was preoperatively and postoperatively measured using the DAAT (D-ATT), ankle stress radiographs (R-ATT), and the manual anterior drawer test (M-ATT). The study period was from February 2002 to February 2005. The Medical Ethical Committee of the hospital approved the study. The clinical results of the arthroscopic capsular shrinkage procedure have been published earlier [5].

Patients

Inclusion criteria were patients older than 18 years of age with recurrent sprains, giving way, and ligament laxity for more than 6 months, who were able to give informed consent. Thirty-nine patients (19 male, 20 female; 16 right ankles, and 23 left ankles) were included. The median age at the time of operation was 27 years (range: 18–66). No patients were lost to follow-up, but one female patient did not allow performing the DAAT and ankle stress radiographs at follow-up because of expected pain.

Increased ligament laxity was defined as anterior talar translation (ATT) ≥ 4 mm or a difference with the contralateral side ≥ 3 mm [12, 13, 24, 27]. Additional exclusion criteria were previous operative therapy for chronic ankle instability, constitutional hyper laxity, systemic diseases affecting the locomotor, system and osteoarthritis grade II or III [34].

Instrumentation

The dynamic anterior ankle tester

The test device has been previously described [16, 17, 34]. The anterior talar translation of the DAAT is measured as the anterior displacement of the talus relative to the tibia in millimeters (D-ATT, millimeters). The subject is seated on a chair with the hip flexed. The foot is placed on a horizontal slide with the back of the heel against a vertical ledge with the hindfoot fixated in a clip. The shin of the tibia is placed against and strapped to a frame which makes an angle with the horizontal, such that the knee is flexed, and the foot is in 15° of plantar flexion. This simulates the optimal position to perform the manual anterior drawer test. The frame prevents anterior displacement and sagittal rotation of the tibia. A 1-kg hammer is placed horizontally and then released with a snap connection. The hammer hits the horizontal slide posterior of the foot and thereby the calcaneus with a velocity of 1.7 m/s. The anterior movement, reflecting the ATT, is measured by a potentiometer. The 35 ms the test takes is within the muscle reflex time [8, 35]. A peak and hold amplifier keeps the highest signal of both potentiometers. The signal is transformed into millimeters and degrees, respectively, and the values can be read from a display. The intrinsic accuracy of the D-ATT with respect to the measured values is 0.1 mm.

Ankle stress radiographs

Radiographic anterior talar translation (R-ATT, millimeters) was measured on lateral ankle views using the Telos GAII/E stress device (ARD Medizin Produkte GmbH, Germany). Radiographs were taken in neutral position and with 150 Newton stress-force. The R-ATT was measured as the difference in anterior displacement of the talus relative to the tibia (shortest distance between the posterior lip of the tibia and the talus) in neutral and in stressed situation [2].

Manual anterior drawer test

The manual anterior drawer test is performed with the patient sitting on a bench with the legs hanging downwards, such that the knee joint is in 90° of flexion; the foot held in 15° plantar flexion. First, the healthy ankle is examined, followed by the affected ankle [33]. The examiner assigned one of four predetermined categories to each examined ankle joint, based on the estimated anterior displacement of the talus relative to the tibia: 0 = 0–2 mm; 1 = 3–5 mm; 2 = 6–10 mm; 3 = 11–15 mm. Hereafter, the manual anterior drawer test will be referred to as manual-ATT (M-ATT, categories).

Procedure

Preoperative and 6-month postoperative, the anterior talar translation of the affected and non-affected ankle was measured manually (M-ATT), radiologically (R-ATT), and with the DAAT (D-ATT). For the D-ATT, the test was repeated five times per side per session with the patient remaining in position. The highest and lowest results of these five measures were discarded, whereas the mean of the three remaining results was taken as the final result per side per session [16]. Both other tests were performed once per side per session.

Statistical analysis

Outcome measures were the preoperative difference between the affected and non-affected side, the difference between pre and postoperative measures of the affected side, and the sensitivity to change, using Cohen's *d*, for the three tests [3]. 'Change' refers to the difference between the mean pre and postoperative value. The formula for Cohen's *d* is (mean preoperative – mean postoperative)/SD, with SD being the pooled SD of both sessions. A value of 0.2–0.3 is regarded as small, around 0.5 as medium and >0.8 as large.

Reliability of the three tests was assessed with the intra-class correlation coefficient (ICC) between the pre and postoperative measures of the non-affected side. ICC values >0.70 were considered as acceptable and values >0.80 as accurate.

The correlations between the D-ATT, R-ATT, and M-ATT were calculated using pre and postoperative measures of both ankles of the three tests.

SPSS 15.0 for Windows was used for statistical analysis because of skewed distributions of most data, and the M-ATT being a test with categorical outcome, non-parametric tests were used to assess statistical significance of differences between means (Wilcoxon signed ranks test) and correlations (Spearman's correlation test). *P* values <0.05 were considered as statistically significant.

Results

The difference between postoperative measures of the affected side was statistically significant for the R-ATT and M-ATT but not for the D-ATT (Table 1; Fig. 1), Cohen's *d* was small for D-ATT and R-ATT and large for M-ATT (Table 1).

There was no statistically significant difference between pre and postoperative values of the D-ATT, R-ATT, and M-ATT for the non-affected side (Table 1). Intra-class correlations between pre and postoperative measures for the unaffected side were all statistically significant, with 0.55 for the D-ATT, 0.71 for the R-ATT, and 0.94 for the M-ATT (Table 1). A scatter plot of the pre versus postoperative measures of the D-ATT of the non-affected side shows that there is no strong linear correlation (Fig. 2). There were no correlations between the D-ATT, R-ATT, and M-ATT as well (Table 2).

Discussion

The most important finding of this study was that, in a clinical setting, the dynamic anterior ankle tester, designed

Table 1 Pre and postoperative measures of D-, R-, and M-ATT of both ankles with statistical significance of the difference between the affected and non-affected side and between preoperative and

postoperative measures, Cohen's *d* for the affected side and intra-class correlation coefficient for the non-affected side

	Pre (SD)	Post (SD)	<i>P</i> value*	Cohen's <i>d</i>	ICC (95% CI)
D-ATT AS (mm)	9.6 (1.6)	9.7 (1.4)	<i>0.833</i>	0.07	
D-ATT NAS (mm)	9.4 (1.4)	9.5 (1.5)	<i>0.643</i>		0.55 (0.28–0.74)
<i>P</i> value*	<i>0.464</i>	<i>0.189</i>			
R-ATT AS (mm)	4.6 (1.5)	4.1 (1.9)	<i>0.045</i>	0.30	
R-ATT NAS (mm)	3.1 (1.7)	3.0 (2.1)	<i>0.906</i>		0.71 (0.51–0.84)
<i>P</i> value*	<i><0.001</i>	<i>0.002</i>			
M-ATT AS (cat)	1.2 (0.4)	0.7 (0.5)	<i><0.001</i>	1.12	
M-ATT NAS (cat)	0.7 (0.7)	0.7 (0.5)	<i>0.317</i>		0.94 (0.88–0.97)
<i>P</i> value*	<i><0.001</i>	<i>0.593</i>			

D-ATT DAAT anterior talar translation, R-ATT radiographic anterior talar translation, M-ATT manual anterior talar translation, AS affected side, NAS non-affected side, Pre preoperative, Post postoperative, SD standard deviation, mm millimeters, cat category, * Wilcoxon signed ranks test, ICC intra-class correlation coefficient, CI confidence interval. All italics in table 1 are *P*-values calculated with the Wilcoxon signed ranks test. Statistically significant values are italic-bold. *P*-values in the fourth column correspond with the 'pre / postoperative' comparison, whereas the *P*-values in the fourth, seventh and tenth row correspond with the 'affected / non-affected side' comparison

Fig. 1 Statistical significance of the difference between pre and postoperative measures for the affected side according to the D-ATT, R-ATT, and M-ATT. *Subscript: D-ATT* DAAT anterior talar translation, *R-ATT* radiologic anterior talar translation, *M-ATT* manual anterior talar translation, *Pre* preoperative, *Post* postoperative, *Wilcoxon signed ranks test

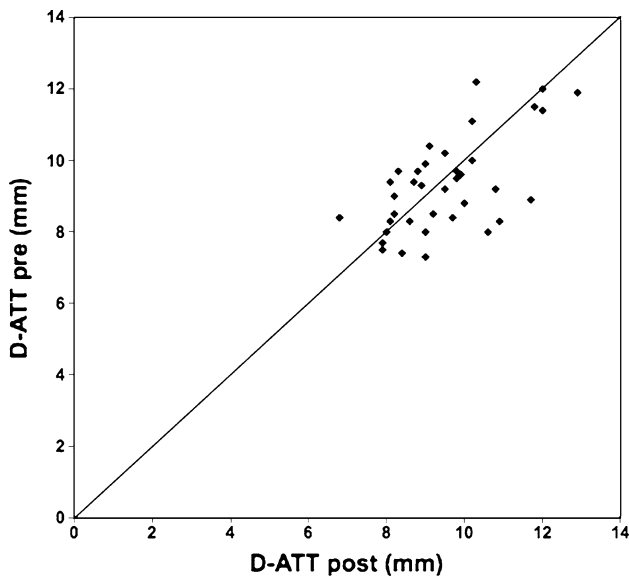
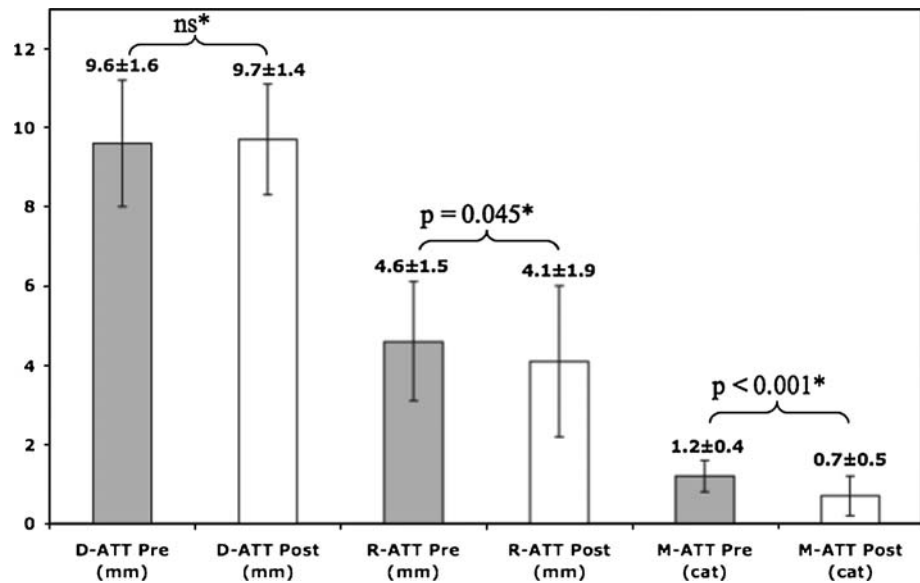


Fig. 2 Scatter plot of pre and postoperative results of the D-ATT of the non-affected side. *Subscript: D-ATT* DAAT anterior talar translation, *Pre* preoperative, *Post* postoperative

Table 2 Correlations between the D-ATT, R-ATT, and M-ATT

	R-ATT <i>R</i> (<i>P</i> value)*	M-ATT <i>R</i> (<i>P</i> value)*
D-ATT	0.19 (0.02)	0.18 (0.03)
R-ATT	NA	0.24 (0.03)

D-ATT DAAT anterior talar translation, *R-ATT* radiographic anterior talar translation, *M-ATT* manual anterior talar translation, * Spearman correlation coefficient, *NA* not applicable

to measure anterolateral ankle ligament laxity, proved not to be as reliable as suggested by earlier studies [16, 17]. ‘Dynamic’ refers to the speed of the test that precludes

reflex muscle contractions that might interfere with the measurement as seen in other (instrumented) tests [16].

The study was conducted to clinically evaluate the dynamic anterior ankle tester (DAAT), concerning the detection of increased ligament laxity, its reliability and to compare the DAAT with radiographic and manual stress testing of the ankle. In a group of 39 patients operated for chronic lateral ankle instability, pre and postoperative measures of anterior talar translation were taken with the DAAT, ankle stress radiographs, and the manual anterior drawer test.

The DAAT did not show increased laxity preoperatively or a reduction in ligament laxity of the affected and operated ankle postoperatively, whereas both the radiographic and the manual test did show a statistically significant increased laxity preoperatively compared to the contralateral side and a statistically significant improvement postoperatively compared to preoperatively. Additionally, the sensitivity to change of the DAAT was low compared to the both other tests. The DAAT also had a low reliability, whereas the radiographic and manual tests had an acceptable and accurate reliability, respectively. No correlations between the three tests were found.

The reliability of the DAAT was lower compared to earlier studies with the same device [16, 17]. The current study confirmed that there is no correlation between the DAAT and radiographic or manual stress testing, as was found earlier [17]. The difference in reliability between the current (ICC 0.55) and the previous study (ICC 0.81–0.93) is probably explained by the different group sizes and the difference in range of the values used for reliability analysis. With the smaller group size used in the previous study, the better reliability was potentially found by change. The smaller range in ligament laxity in this study

(~ 7–13 mm) than in the previous study (~ 5–15 mm) may have led to a lower reliability than would have been found when a larger range in ligament laxity would have been present. Still, even when a higher reliability would have been found, the question remains whether the small preoperative difference between the affected and non-affected side and the small effect size of the intervention as found with the stress radiographs would have been reliably detected.

The better results of the radiographic and manual tests in this study may suggest that they are more appropriate to evaluate ligament laxity, but according to the literature, both tests are not thought to be the best objective measures of the actual state of lateral ankle ligament laxity. Although the inter- and intra-rater reliability of assessing ankle stress radiographs in one study was found to be accurate, there is a great variability in published data for radiographic stress testing [6, 29]. Regarding the anterior talar translation, this may in part be due to the way the translation is measured. According to Beynnon et al. [2], measuring the distance between the posterior lip of the tibia and the talar dome, as was done in the current study, is the most reliable method. Due to its subjective character, manual stress testing of the ankle is thought to be not useful for scientific purpose as well [7, 9]. As with reading ankle stress radiographs, the way the test is performed is important to come to realistic results [4, 23, 33]. Since the presence or absence of increased ligament laxity is the only question to be answered to decide whether surgical treatment of chronic ankle instability is sensible, the manual anterior drawer test probably suffices for clinical practice.

To find more accurate measures for ligament laxity, several ankle stress devices, apart from the DAAT, have been developed. The same investigators that developed the DAAT invented the quasi-static anterior ankle tester (QUAAT) [15, 17, 18]. Although overestimating the ligament laxity by more than 200%, initial evaluation shows good reliability and validity of this device. Further clinical evaluation will be performed. Siegler et al. developed the ankle flexibility meter [25, 28, 30, 31]. Ankle laxity is measured by the degree of anterior displacement or rotation relative to the applied force or moment. In vitro and in vivo reliability was high, but extensive clinical application is not reported so far. Kovalski et al. developed the ankle arthrometer that also showed good reliability with in vitro and in vivo testing [10, 11, 22]. So far, this is the most widely clinically applied device showing consistent results which may reflect reality. Difficulty with all test devices is the lack of a true gold standard to which instruments can be validated.

A limitation of the current study is that only the healthy side was used to analyze reliability. Testing the affected side twice preoperatively with an interval of for example

1 week would probably have led to wider range and higher number of values, probably leading to better reliability assessment. A second limitation is the lack of a gold standard to validate the DAAT. Although the radiographic and in particular the manual test show a good reliability in the current study, this is not in accordance with the literature, and therefore, these tests cannot be regarded as the gold standard to validate the DAAT [6, 7, 9, 29]. A third limitation is that only one observer took the outcome measures. Whereas the DAAT, due to its design, is probably not very sensitive to application by different investigators, the radiographic test and especially the more subjective manual test are more dependent on how the test is performed.

The clinical relevance of the current study is that it shows that lateral ankle ligament laxity, although an important clinical sign that may determine whether a patient will be operated on or not, remains difficult to quantitate objectively.

Conclusions

In contrast to earlier laboratory evaluation in a smaller group, the dynamic anterior ankle tester showed a low reliability in testing ankle ligament laxity in a clinical setting. The outcome warrants re-evaluation of the test device and its application.

Open Access This article is distributed under the terms of the Creative Commons Attribution Noncommercial License which permits any noncommercial use, distribution, and reproduction in any medium, provided the original author(s) and source are credited.

References

1. Becker HP, Rosenbaum D (1999) Chronic recurrent ligament instability on the lateral ankle. *Orthopade* 28:483–492
2. Beynnon BD, Webb G, Huber BM, Pappas CN, Renstrom P, Haugh LD (2005) Radiographic measurement of anterior talar translation in the ankle: determination of the most reliable method. *Clin Biomech (Bristol, Avon)* 20:301–306
3. Cohen J (1988) *Statistical power analysis for the behavioral sciences*, 2nd edn. Lawrence Erlbaum, New Jersey, pp 531–535
4. Corazza F, Leardini A, O'Connor JJ, Parenti Castelli V (2005) Mechanics of the anterior drawer test at the ankle: the effects of ligament viscoelasticity. *J Biomech* 38:2118–2123
5. de Vries JS, Krips R, Blankevoort L, Fievez AW, van Dijk CN (2008) Arthroscopic capsular shrinkage for chronic ankle instability with thermal radiofrequency: prospective multicenter trial. *Orthopedics* 31:655 (full article at: www.orthosupersite.com/view.asp?rID=28896)
6. Frost SC, Amendola A (1999) Is stress radiography necessary in the diagnosis of acute or chronic ankle instability? *Clin J Sport Med* 9:40–45
7. Fujii T, Luo ZP, Kitaoka HB, An KN (2000) The manual stress test may not be sufficient to differentiate ankle ligament injuries. *Clin Biomech (Bristol, Avon)* 15:619–623

8. Gottlieb GL, Agarwal GC (1979) Response to sudden torques about ankle in man: myotatic reflex. *J Neurophysiol* 42:91–106
9. Griffith JF, Brockwell J (2006) Diagnosis and imaging of ankle instability. *Foot Ankle Clin* 11:475–496
10. Hubbard TJ (2008) Ligament laxity following inversion injury with and without chronic ankle instability. *Foot Ankle Int* 29:305–311
11. Hubbard TJ, Kaminski TW, Vander Griend RA, Kovaleski JE (2004) Quantitative assessment of mechanical laxity in the functionally unstable ankle. *Med Sci Sports Exerc* 36:760–766
12. Karlsson J, Bergsten T, Lansinger O, Peterson L (1989) Surgical treatment of chronic lateral instability of the ankle joint. A new procedure. *Am J Sports Med* 17:268–273
13. Karlsson J, Eriksson BI, Bergsten T, Rudholm O, Sward L (1997) Comparison of two anatomic reconstructions for chronic lateral instability of the ankle joint. *Am J Sports Med* 25:48–53
14. Karlsson J, Eriksson BI, Sward L (1996) Early functional treatment for acute ligament injuries of the ankle joint. *Scand J Med Sci Sports* 6:341–345
15. Kerkhoffs G, Blankevoort L, Kingma I, van Dijk CN (2007) Three-dimensional bone kinematics in an anterior laxity test of the ankle joint. *Knee Surg Sports Traumatol Arthrosc* 15:817–824
16. Kerkhoffs GM, Blankevoort L, Schreurs AW, Jaspers JE, van Dijk CN (2002) An instrumented, dynamic test for anterior laxity of the ankle joint complex. *J Biomech* 35:1665–1670
17. Kerkhoffs GM, Blankevoort L, Sierveit IN, Corvelein R, Janssen GH, van Dijk CN (2005) Two ankle joint laxity testers: reliability and validity. *Knee Surg Sports Traumatol Arthrosc* 13:699–705
18. Kerkhoffs GM, Blankevoort L, van Dijk CN (2005) A measurement device for anterior laxity of the ankle joint complex. *Clin Biomech (Bristol, Avon)* 20:218–222
19. Kerkhoffs GM, Blankevoort L, van Poll D, Marti RK, van Dijk CN (2001) Anterior lateral ankle ligament damage and anterior talocrural-joint laxity: an overview of the in vitro reports in literature. *Clin Biomech (Bristol, Avon)* 16:635–643
20. Kirk T, Saha S, Bowman LS (2000) A new ankle laxity tester and its use in the measurement of the effectiveness of taping. *Med Eng Phys* 22:723–731
21. Koval KJ, Egol KA, Cheung Y, Goodwin DW, Spratt KF (2007) Does a positive ankle stress test indicate the need for operative treatment after lateral malleolus fracture? A preliminary report. *J Orthop Trauma* 21:449–455
22. Kovaleski JE, Hollis J, Heitman RJ, Gurchiek LR, Pearsall AW (2002) Assessment of ankle-subtalar-joint-complex laxity using an instrumented ankle arthrometer: an experimental cadaveric investigation. *J Athl Train* 37:467–474
23. Kovaleski JE, Norrell PM, Heitman RJ, Hollis JM, Pearsall AW (2008) Knee and ankle position, anterior drawer laxity, and stiffness of the ankle complex. *J Athl Train* 43:242–248
24. Krips R, van Dijk CN, Halasi T, Lehtonen H, Moyon B, Lanzetta A, Farkas T, Karlsson J (2000) Anatomical reconstruction versus tenodesis for the treatment of chronic anterolateral instability of the ankle joint: a 2- to 10-year follow-up, multicenter study. *Knee Surg Sports Traumatol Arthrosc* 8:173–179
25. Lapointe SJ, Siegler S, Hillstrom H, Nobilini RR, Mlodzienski A, Techner L (1997) Changes in the flexibility characteristics of the ankle complex due to damage to the lateral collateral ligaments: an in vitro and in vivo study. *J Orthop Res* 15:331–341
26. Lee KT, Lee JI, Sung KS, Kim JY, Kim ES, Lee SH, Wang JH (2008) Biomechanical evaluation against calcaneofibular ligament repair in the brostrom procedure: a cadaveric study. *Knee Surg Sports Traumatol Arthrosc* 16:781–786
27. Lindstrand A, Mortensson W (1977) Anterior instability in the ankle joint following acute lateral sprain. *Acta Radiol Diagn (Stockh)* 18:529–539
28. Liu W, Siegler S, Techner L (2001) Quantitative measurement of ankle passive flexibility using an arthrometer on sprained ankles. *Clin Biomech (Bristol, Avon)* 16:237–244
29. Lohrer H, Nauck T, Arentz S, Scholl J (2008) Observer reliability in ankle and calcaneocuboid stress radiography. *Am J Sports Med* 36:1143–1149
30. Siegler S, Lapointe S, Nobilini R, Berman AT (1996) A six-degrees-of-freedom instrumented linkage for measuring the flexibility characteristics of the ankle joint complex. *J Biomech* 29:943–947
31. Siegler S, Wang D, Plasha E, Berman AT (1994) Technique for in vivo measurement of the three-dimensional kinematics and laxity characteristics of the ankle joint complex. *J Orthop Res* 12:421–431
32. Spahn G (2004) The ankle meter: an instrument for evaluation of anterior talar drawer in ankle sprain. *Knee Surg Sports Traumatol Arthrosc* 12:338–342
33. van Dijk CN, Mol BW, Lim LS, Marti RK, Bossuyt PM (1996) Diagnosis of ligament rupture of the ankle joint. Physical examination, arthrography, stress radiography and sonography compared in 160 patients after inversion trauma. *Acta Orthop Scand* 67:566–570
34. van Dijk CN, Tol JL, Verheyen CC (1997) A prospective study of prognostic factors concerning the outcome of arthroscopic surgery for anterior ankle impingement. *Am J Sports Med* 25:737–745
35. Wiersma PH, Dijkhuis T, Klopper PJ (1988) Dynamic response of the leg to sudden varus angulation of the loaded foot: a clinical study in subjects with acute lateral ligament injury. *Eur Surg Res* 20:18