REVIEW

Nr 2024;14 (2):284-291

Clinical Assessment of Ankle Instability: An Update on Which, When, Why

Raffaele Vitiello[1,2,3], Andrea De Fazio[1,2], Angelo Carosini[1,2], Roberto Rossi[3], Matteo Turchetta[4], Giulio Maccauro[1,2], Fabrizio Forconi[3]

[1] *Fondazione Policlinico Universitario A. Gemelli IRCSS, Rome, Italy*
[2] *Università Cattolica Del Sacro Cuore, Rome, Italy*
[3] *Clinic Villa Stuart, Rome, Italy*
[4] *University Hospital Policlinico Vittorio Emanuele, University of Catania, Catania, Italy*

CORRESPONDING AUTHOR:
Angelo Carosini
Fondazione Policlinico Universitario A. Gemelli IRCSS
largo Agostino Gemelli 8
00168 Rome, Italy
E-mail: angelo.carosini@gmail.com

DOI:
10.32098/mltj.02.2024.07

LEVEL OF EVIDENCE: 5

SUMMARY

Background. Ankle sprains and Chronic ankle instability (CAI) are extremely common traumatic conditions that have a negative impact. Today, there is no accredited diagnostic protocol for identify and classify CAI patients. The purpose of this study is to report the most reliable clinical assessments in the literature on ankle instability and to try to propose a reliable and easily reproducible diagnostic algorithm.
Methods. We searched PubMed for articles that included keywords such as: CAI, ankle instability, SEBT, Hop-Test and Functional test. We focused on the most recent articles, selecting those of greatest interest such as meta-analyzes and prospective studies. Finally, we focused on how the next diagnostic process could be constructed.
Results and conclusions. From our research, it could be hypothesized that the most promising tests for a correct diagnosis of CAI are the ALDT, two hop tests, the foot lift, and the SEBT. In the patient with functional instability, a correct classification can derive from neurological Tests. Patient with negative radiological exams but with symptoms and positive clinical and functional tests, it would be advisable to investigate further with ankle arthroscopy. However, the major difficulty for a clinician in diagnosing CAI is represented by the total absence of cut-offs in the various functional tests and by a standardized diagnostic protocol. In our opinion, further studies need to be directed toward this goal.

KEY WORDS
Ankle; instability; CAI; Hop-test; SEBT; Anterior-Draw-Test; electro-myography.

INTRODUCTION

Defining chronic ankle instability (CAI) is not standardized yet. Chronic ankle instability (CAI) has been defined as "a condition characterized by repetitive episodes or perceptions of the ankle giving way; ongoing symptoms such as pain, weakness, or reduced ankle range of motion (ROM); diminished self-reported function; and recurrent ankle sprains that persist for more than 1 year after the initial injury" (1). The most commonly reported symptoms of patients with CAI are ankle failure, pain and swelling, mechanical instability and loss of strength. In addition, patients with CAI are often susceptible to recurrent sprains and functional instability (2). Symptoms can persist for years and up to 72% of people fail to return to previous levels of physical activity (2, 3).
Ankle instability results as one of the complications following an ankle sprain. Ankle sprain is the most common injury in sports medicine (4, 5), accounting for 10% to 15% of all injuries (5, 6). CAI patients are more frequently young and female (7).

Ankle instability should not be confused with ankle joint laxity. Joint laxity is the ability of a synovial joint to exceed the normal range of motion (8).

Joint laxity plays an important role in recurrent postoperative knee and shoulder instabilities (9). Some authors have demonstrated that generalized joint laxity (GJL) is an independent risk factor for poor outcomes and recurrence after surgical procedures in lateral CAI (10). However, there appears to be no association between GJL and the risk of injury in sporting activity, and its role in the CAI is still controversial (11). To evaluate joint laxity the most used and validated score is the Beighton score (BS) (8). However, a recent study has shown that it cannot be used in place of clinical tests and that it should be used with caution for the evaluation of CAI (12).

Ankle sprains account for 7% to 10% of all visits to the emergency room (6, 8-13). Most of these injuries happen to people under the age of 35 (13, 14). Instability is one of the most common complications resulting from an ankle sprain, especially after re-injury. The risk of re-injury or recurrent ankle sprain is between 12% and 47%. Some of these patients with acute or recurrent sprains may develop chronic ankle instability (CAI), making this condition relatively common (6, 13).

Having a dysfunctional ligament complex results in an unstable ankle. Ankle stability is provided by a ligament complex consisting of a medial compartment, a lateral compartment, and the ligaments of the syndesmosis.

The lateral compartment is composed of 3 bundles: anterior talofibular ligament (ATFL), posterior talofibular ligament (PTFL), and calcaneofibular ligament (CFL). ATFL and PTFL give the ankle sagittal and rotational stability while the CFL gives stability in the coronal plane. The most frequent injury of the ankle is the rupture of the ligaments of the lateral compartment secondary to a supination trauma (14, 15). This will result in instability in several planes with a tendency for varus tilt, and the talus will tend to translate anteriorly.

It appears that ATFL is composed of two bundles, one more proximal intra-articular, and one more distal extra-articular; the distal one not only shares a fibular footprint with the CFL but is connected to it via some arciform fibers, forming the Later FibuloTaloCalcaneal Ligament (6, 8-13).

This is the anatomic support for the idea that the repair of the ATFL will produce an indirect re-insertion of the CFL. In addition to this further connection exist between the proximal fiber of ATFL and the Basset ligament. The superior intra-articular fascicle of ATFL is the first and the most often damaged ligament during an ankle inversion sprain and can be responsible for a subtle clinical condition called "microinstability". When the lesion progress through the ATFL inferior fascicle and CFL a major instability occurs.

Medial instability can result from poorly treated isolated deltoid ligament injuries, combined ligament injuries, or inveterate lateral instability (16). The medial ligament complex is composed of 3 main structures: the deltoid ligament, the calcaneonavicular ligament, and the talocalcaneal ligament (6). The deltoid ligament plays a primary role in anteroposterior and rotational stability. It is composed of two main bundles: superficial and deep. The superficial one is composed of an additional four bundles, while the deep one is composed of two. The two deep bundles are composed of posterior and anterior tibiotalar ligaments. The superficial ligaments are composed of the tibiospring, tibionavicular, superficial posterior tibiotalar and tibiocalcaneal ligaments (16). Two clinical pictures may emerge after MLC ruptures: medial instability and rotational instability (17).

Several definitions and models have been proposed over the years to try to include all clinical conditions related to ankle instability. Initially, patients affected were divided by Hertel into two main groups: mechanical instability and functional instability (16, 18). This distinction was made based on the presence or absence of ankle laxity in clinical or radiological tests. Later, Hiller proposed an evolution of Hertel's model, with three different types of patients with CAI:

- Mechanical instability.
- Perceived instability.
- Recurrent sprains (2, 3).

There is an additional group of patients, as we mentioned before, it is the micro unstable. Indeed, micro instability of the ankle can be defined as an occult source of mechanical instability resulting from intra-articular injuries (the superior intraarticular fascicle of ATFL is injured) that can be clearly identified with an arthroscopic examination and can be easily missed un MRI (18).

Another classification regards how to divide conditions into acute and chronic. It is not easy to define a chronic pathology because we do not have the resources to define when the body has stopped trying to repair the acute injury. For this reason, instability lasting more than 3-6 months is usually anecdotally defined as chronic.

Valid diagnostic support comes from radiology. The tests that can help clinicians are radiography, ultrasound and MRI. In stress radiography instability is revealed by the separation of bony structures which reveals a ligamentous inability. An absolute anterior translation > 9 mm or a translation > 5 mm concerning the uninjured side indicates a significant laxity of the ATFL, while an inclination of the talus angle > 10° in total or more than 5° concerning the contralateral indicates pathological laxity of the CF

ligament (19). The medial instability can be evaluated with traditional radiographs.
Moreover, associated lesions such as osteochondral lesions, osteoarthritis and bone conflicts can be shown through lateral displacement of the talus and an increase in medial free space (more than 3 mm of difference compared to the healthy side is considered pathological) (16). Recently some authors questioned the utility of stress radiography suggesting to exclude it from the decision-making algorithm for this exam (6).
Ultrasound is a valuable tool for confirming a CAI. Studies report a sensitivity of 94%-100% and a specificity of 50%-100% in identifying an ATFL lesion (20-23) and a sensitivity of 94% and specificity of 91% in identifying lesions of the CFL (22).
MRI is becoming an increasingly used tool in preoperative diagnosis and planning. MRI can show soft tissue injury and ligament status. Moreover, the MRI could be better tolerated by the patient, especially when in pain. Studies have shown that the diagnostic capacity of MRI in ATFL lesions has a sensitivity of 76%-87% and a specificity of 53%-100%, while in CFL lesions, it has a sensitivity of 40%-47% and a specificity of the 83%-100% (24-27). MRI is very sensitive in detecting lesions of the deltoid ligament, visible as a signal alteration on T2 sequences (16). However, the MRI data must always be associated with the clinical evaluation as it has been highlighted that many healthy subjects have anatomical alterations of the deltoid ligament (28).
Many surgical procedures for ATLF reconstruction have been described. These can be divided into direct anatomical repair/reconstruction (DAR) and non-anatomical repair/reconstruction (NAR) procedures. Both DAR and NAR can involve the use of allograft autografts or synthetic ligaments (29). The gold standard procedure for ATLF reconstruction is the Broström-Gould procedure combined with retinal extensor transfer, although this association has recently been questioned (30).
Regarding the clinical assessment, the statement is based not only on the physical examination of the ankle but also on specifically designed functional tests. The purpose of this study is to report the most reliable clinical process in the literature to define ankle instability and propose to try to propose a reliable and easily reproducible diagnostic algorithm.

PHYSICAL EXAMINATION

It is important to start the clinical evaluation of a patient with CAI starting with a careful inspection and looking for anatomical alterations and signs of misalignment. It is important to recognize and diagnose an underlying former fracture. The typical symptoms of CAI are characterized by widespread pain (which is accentuated by the pressure of the ATFL), edema, swelling, reduced range of motion, and sometimes difficulty in walking (6). It is also important to evaluate the tenderness of the muscles and tendons which can be contracted or stretched (31). Bilateral evaluation is fundamental, always comparing the healthy side with the pathological one. This bilateral evaluation should be performed both in subsequent checks.

RANGE OF MOTION AND STRENGTH

During a clinical evaluation of a patient with CAI is important to evaluate the Range of Motion (ROM) of the ankle joint. One of the risk factors contributing to the onset of CAI is the reduction in dorsiflexion ROM (1, 2). Even though patients have this limitation of ankle range of motion they are still able to perform all daily activities, walking and sports activities but will tend to assume a more injury-prone position (3, 4). During the clinical evaluation, ankle strength is also examined using manual muscle testing or with instrumented dynamometry. Specific deficiencies in ankle strength have been identified as risk factors for Lateral Ankle Sprain (LAS) (8) as well as a characteristic of CAI (32).

ANTERIOR DRAWER TEST

The optimal time to test clinical stability for ligamentous rupture is between 4 and 7 days following the last injury when the acute pain and swelling have subsided, and the patient can relax (31). The anterior drawer test (ADT) is the most clinically important test for identifying ankle instability and is often the first test performed in the patient's physical examination (31). This is used to assess the integrity of the Deltoid ligament, the major contributor to medial instability, and ATFL, the ligament of the lateral compartment of the ankle most frequently involved in LAS. According to Kovaleski *et al.* (23), the most anterior translation of the ATF ligament occurred with the knee flexed to 90° and the ankle at 10° plantar flexion. The test is performed with the patient supine, the knee flexed, the ankle joint in 10-20° flexion, and the heel resting on the palm of the examiner's hand resting on the table, thus stabilizing the heel. The examiner then stabilizes the lower limb while pulling the calcaneus forward, observing the amount of anterior translation. In ATFL rupture an anterior translation of the talus concerning the tibia could be observed, especially if the translation is markedly different from the opposite side. To date, there are still no definite measures in the literature for attributing positivity or non-positivity to the ADT, ranging from 2 mm to 9 mm (32, 33) so comparison with the contralateral ankle is useful if not essential (34). A positive ADT has a sensitivity between 73-96% and a specificity from 84% to 97% (35, 36). An alternative to the ADT test known as the antero-lateral drawer test (ALDT) has been developed in recent years. While the patient is lying supine, the lower limb is stabilized as in the ADT, with the exception that the thumb of the translating hand is positioned above the sinus tarsi and its tip is in contact with the lateral malleolus' anterolateral surface. When ATF instability is present, the physician can see talar movement and the concomitant sulcus formed in the sinus tarsi as anterior translation is given to the calcaneus (37, 39).

Phisitkul *et al.* (38) observed excellent sensitivity (100%) and specificity (100%) with the ALDT but only fair sensitivity (75%) and subpar specificity (50%) with the ADT with 3 mm of anterior talar translation. Based on the cadaveric study of Miller *et al.*, the anterolateral drawer test provoked almost twice the lateral talus displacement found with the anterior drawer test (39).

The posterior drawer test is another ankle instability assessment described by Frost and Hanson. Using the identical position of ADT – but with the foot lying on the couch – the clinician extends the fingers around the medial tibia to feel the displacement of the talus on the tibia, while stabilizing the anterior tibia with the heel of one hand slightly above the ankle. The clinician would simply reverse the forces applied to the ankle during the anterior drawer test, providing a posteriorly directed force (40). No supporting evidence was found in the literature for the posterior drawer test (41).

Some authors report that this test has greater specificity for lesions of the superior fasciculus of the ATFL (42).

HOP TEST (SIDE HOP, TIMED HOPPING, MULTIPLE-HOP, FIGURE-8-HOP, SQUARE HOP, *ETC.*)

Hop tests are a group of functional performance tests that compare the ankle with CAI with the unaffected side. Several variants can be administered to the patient, the main ones are:

1. Side-hop test requires the individual to jump over a 30-cm distance medially and laterally on a single limb. The fastest feasible time is used to complete ten repetitions. The execution time is the outcome.
2. Multiple-hop test: the subjects, in monopodial stance, was asked to jump and land with the same lower limb at 10 different points (grids 20 × 20 cm). During the execution of the test, the subjects were asked to try to balance the landings and avoid postural corrections. The test was assessed using 3 outcome measures: time to complete the test, perceived difficulty performing, and several balance errors.
3. Figure-of-8 hop: two cones are positioned 5 meters apart. The participant was told to hop as quickly as they could twice in a figure-of-eight manner around cones. The result is the turnaround time.
4. Square hop test: hops five times as quickly as they can in and out of a square on the ground that is 40 × 40 cm in size. The result is the execution time.
5. Six-meter timed hop test: a participant hops as quickly as they can on a 6 m long line. The result is the execution time.
6. Six-meter crossover hop test: a participant hops as quickly as they can while changing sides on a 15 cm width by 6 m long line. The result is the execution time.

Few studies in the literature show a difference between the functional tests of CAI and uninjured ankles (43, 44). Individually, the hop tests showed a low sensitivity in detecting patients with CAI, this ranged from 44 to 58%. However, it is also evident that the combination of various hop tests can increase the sensitivity, which on average goes from 50% to 62%, respectively, for one or two tests, but that the difference between two and four tests is negligible (45).

The side hop and timed hop test provided the best ability to discriminate patients with CAI. In particular, side hope was found to be the best, probably because this test puts the lateral ligament structures under greater stress (43). Some studies have also evaluated these tests in individual patients by comparing the result obtained from the injured side and the uninjured side. These studies demonstrated worse performance on the injured side with a difference in the time of execution of the tests. This difference is 0.37 seconds for the Figure 8 test, 0.57 seconds for the side hop test, 0.42 seconds for the 6-meter crossover hop test and 2.22 seconds for the square hop test (46).

FOOT-LIFT

The foot-lift test involves a single-legged stance on a firm surface and is used to assess static balance. The test involves counting how many times the foot raises off the ground in 30 seconds. One mistake was committed for every rise of the grounded foot counted on each side (47). Using a higher frequency of test-foot lifts throughout the course of a 30-second trial, this test was able to distinguish between people with and without CAI.

STAR EXCURSION BALANCE TEST (SEBT)

The Star Excursion Balance Test (SEBT) is a dynamic test described by Gray (48), as a rehabilitation tool consisting of a series of squats with only one limb to reach 8 points placed on 8 lines placed at 45° from each other. The directions are called anterior, anteromedial, anterolateral, medial, lateral, posterior, posteromedial and posterolateral. The measurement or result of the SEBT performance is the distance the participant can reach. A test was invalid if the balance was lost, the foot was lifted or moved from the center, the hands leave the hip, or the reach leg provided support upon touching down. A standardized protocol of 4 practice trials followed by 3 test trials was performed in each of the eight directions to minimize the learning effect. The average of the three test trials normalized for the length of the stance leg was used for analysis.

Not all directions of SEBT for CAI evaluation have a similar prognostic value, in the studies there is consensus in attributing the greatest diagnostic capacity to the anteromedial, medial, and posteromedial direction (48, 49).

Some authors compared the injured and uninjured sides of participants with unilateral CAI and showed worse results in the unstable side, especially in the anterior, medial, anteromedial, and posterolateral directions (49, 50). Other authors have shown that healthy patients have a better total score when compared with patients with CAI (51).

Y-BALANCE TEST

Y-balance test is nothing more than a simplification of SEBT. It includes anterior, posteromedial, and posterolateral direction (52, 54). It has been shown that posteromedial distance achieved are those with higher prognostic value for CAI and therefore more clinically useful (53).

TALAR TILT TEST AND EVERSION TALAR TILT TEST

The talar tilt test was first described by Dehme in 1993 (54). This is a clinical maneuver to identify lateral ligament insufficiency of the ankle. The test is performed by holding the hindfoot by the calcaneus and applying varus stress while performing counterpressure with the other hand on the medial distal tibia (55).

Rosen *et al*. showed that the talar tilt test has good specificity (72-94%) but poor sensitivity (23-52%). The positive likelihood ratio (+LR) values for the talar tilt test are 2.23-4.14, the negative LRs are 0.58-0.66. The diagnostic odds ratios ranged from 1.43 to 8.96. It would thus appear that this test alone has little clinical utility, but may be useful when combined with a test with high sensitivity. It may be useful in the exclusion of a CAI (56).

The Eversion Stress test allows assessment of the stability of the deltoid ligament complex and thus the medial compartment. It is also known as Eversion Talar tilt Test. The patient is positioned in sitting or supine lying with the knee in full extension. The physician lifts and abducts the heel while stabilizing the distal tibia simultaneously. The test should be performed on each side. Greater laxity and pain on the injured side than on the uninjured side indicate a positive test (57).

NEUROLOGICAL EVALUATION OF FUNCTIONAL INSTABILITY

Superficial electromyography (EMG): the rationale behind this test is the fact that functional instability could result from some lesions in proprioception and the muscular response to nerve activation. Some authors have instead associated with CAI a delayed response of activation of the ankle muscles (58, 59).

In particular, the Peroneus Longus (PL) and the short Peroneus Brevis (PB) seem to have a longer reaction time (RT) of about 1 ms in patients with CAI when the ankle is subjected to an inversion of about 30° (60), while if subjected to an inversion greater than 50° there would not seem to be a significant difference (61). There would not even seem to be any differences in the RTs of gluteus medius (GM) and erector spine (ES) thus excluding involvement of the proximal muscles (58).

As part of the neurological evaluation of the ankle in functional CAI, a very simple test that evaluates the proprioceptive capacity is the Romberg test. To perform the test, the patient must remain in an upright position leaning only on the limb to be examined, this position must first be maintained with the eyes open and then with the eyes closed. The test is positive if the position becomes unstable when the eyes are closed (61).

DISCUSSION

CAI is an extremely common post-traumatic condition that has a negative impact, especially on athletic patients' outcomes. Most of the CAI can be attributed to the lateral compartment (62).

Medial ankle instability is rarer than lateral instability, in fact isolated deltoid ligament injury accounts for approximately 3-4% of ankle ligament injuries and is often associated with fractures (6).

Today, there is no accredited diagnostic protocol to follow to identify and classify CAI patients and assess their eventual return to sports activity.

Each test considered in this study has a consensus on the method of performance and efficacy, but there are no cutoffs to identify the CAI-affected population from the non-injured population. Based on our experience, we believe that in a suspect of CAI, the diagnostic algorithm should begin with a clinical and anamnestic evaluation of the ankle involved. Asking about the traumatic mechanism of later injuries to identify the structures involved, which should be given priority during the clinical evaluation. We also need to investigate the time passed since the first episode of an ankle sprain. Previous episodes of lateral ankle sprains increase the risk of recurrence (63).

Having to formulate a diagnosis we can rely on clinical and radiological tests. Radiological exams have high specificity but not complete sensitivity. They could miss to diagnose the most suspect forms of CAI like the micro or functional instability. That's why is mandatory to spend time and attention on clinical and functional examination. There are many clinical trials. Certainly, the most used, even in the acute phase, is the anterior drawer test which, however, only shows us the dislocation on the anterior plane and does not reproduce the classic traumatic movement in pronation. The ADLT variant overcomes this problem by neutralizing the effect of the medial ligaments. Besides, those tests are dependent on the skill of the examiner and the compliance of the patient. The subjective nature of this kind of approach needs to be integrated by standardized functional examination able to gain results as a sharp numerical score in a reproducible execution.

Hop tests appear to be a promising functional test suite for the identification of CAI. The difference in the time taken to perform the exercise between the healthy side and the injured side is significant. Using them individually, they do not have a high sensitivity. However, when used in combination with each other and when used to compare the two ankles of an individual with suspected CAI they appear to have a good diagnostic capability. However, their standardization in terms of outcome and cutoff is missing.

The SEBT is a very useful functional test, especially in some particular trajectories. As for the hop tests, also for the SEBT, the main problem consists in not having cutoffs that distinguish the healthy patient from the patient with CAI.

The test with the greatest sensitivity is the ALDT, and so it would seem logical to start with that in any diagnostic protocol. Later tests with higher specificity such as hope tests and the SEBT can be used as confirmation of CAI. Talar tilt test may be useful in ruling out CAI.

It should also be kept in mind that these tests can be used in the follow-up of patients with ankle ligament injuries treated conservatively or surgically (64).

CONCLUSIONS

From our research, it could be hypothesized that the most promising tests for a correct diagnosis of CAI are the ALDT, two hop tests chosen by the clinician, the foot lift, and the SEBT also in the simplified Y-Balance version.

In the patient with functional instability, a correct classification can derive from neurological tests such as the Romberg and EMG of the PB and PL. Patient with negative radiological exams but with symptoms and positive clinical and functional tests, it would be advisable to investigate further with ankle arthroscopy.

However, the major difficulty for a clinician in diagnosing CAI, is represented by the total absence of cut-offs in the various functional tests and by a standardized diagnostic protocol. In our opinion, further studies need to be directed toward this goal.

FUNDINGS

N/A.

DATA AVAILABILITY

N/A.

CONTRIBUTIONS

RV, ADF, AC: conceptualization, methodology, writing – original draft. GM, FF: validation. RV, ADF, AC, MT: investigation. MT: writing – review & editing. FF: supervision.

CONFLICT OF INTERESTS

The authors declare that they have no conflict of interests.

REFERENCES

1. Hiller CE, Kilbreath SL, Refshauge KM. Chronic Ankle Instability: Evolution of the Model. J Athl Train. 2011;46(2):133-41. doi: 10.4085/1062-6050-46.2.133.
2. Delahunt E, Coughlan GF, Caulfield B, Nightingale EJ, Lin CWC, Hiller CE. Inclusion Criteria When Investigating Insufficiencies in Chronic Ankle Instability. Med Sci Sports Exerc. 2010;42(11):2106-21. doi: 10.1249/MSS.0b013e3181de7a8a.
3. Lassiter TE, Malone TR, Garrett WE. Injury to the lateral ligaments of the ankle. Orthop Clin North Am. 1989;20(4):629-40.
4. McConkey JP. Ankle sprains, consequences and mimics. Med Sport Sci. 1987;23:39-55. doi: doi: 10.1159/000413988.
5. MacAuley D. The European Perspective: Ankle injuries: same joint, different sports. Med Sci Sports Exerc. 1999;31(Supplement):S409-11. doi: 10.1097/00005768-199907001-00001.

6. Corte-Real N, Caetano J. Ankle and syndesmosis instability: consensus and controversies. EFORT Open Rev. 2021;6(6):420-31. doi: 10.1302/2058-5241.6.21001.
7. de Britto Costa LP, Gonzalez Corrêa F, Monteiro Cunha HC, et al. Epidemiological Study of Foot and Ankle Injuries in Athletes: A Multivariate Logistic Regression. Muscles Ligaments Tendons J. 2023;13(3):430-5. doi: 10.32098/mltj.03.2023.11.
8. Sacks HA, Prabhakar P, Wessel LE, et al. Generalized Joint Laxity in Orthopaedic Patients: Clinical Manifestations, Radiographic Correlates, and Management. J Bone Joint Surg Am. 2019;101(6):558-66. doi: 10.2106/JBJS.18.00458.
9. Lim JR, Lee HM, Yoon TH, Lee HM, Chun YM. Association Between Excessive Joint Laxity and a Wider Hill-Sachs Lesion in Anterior Shoulder Instability. Am J Sports Med. 2021;49(14):3981-7. doi: 10.1177/03635465211049221.
10. Park KH, Lee JW, Suh JW, Shin MH, Choi WJ. Generalized Ligamentous Laxity Is an Independent Predictor of Poor Outcomes After the Modified Broström Procedure for Chronic Lateral Ankle Instability. Am J Sports Med. 2016;44(11):2975-83. doi: 10.1177/0363546516656183.
11. Pacey V, Nicholson LL, Adams RD, Munn J, Munns CF. Generalized joint hypermobility and risk of lower limb joint injury during sport: a systematic review with meta-analysis. Am J Sports Med. 2010;38(7):1487-97. doi: 10.1177/0363546510364838.
12. Yokoe T, Tajima T, Yamaguchi N, Morita Y, Chosa E. Association between the Beighton Score and Stress Ultrasonographic Findings of the Anterior Talofibular Ligament in Healthy Young Women: A Cross-Sectional Study. J Clin Med. 2022;11(7):1759. doi: 10.3390/jcm11071759.
13. Viljakka T, Rokkanen P. The treatment of ankle sprain by bandaging and antiphlogistic drugs. Ann Chir Gynaecol. 1983;72(2):66-70.
14. Fong DTP, Hong Y, Chan LK, Yung PSH, Chan KM. A Systematic Review on Ankle Injury and Ankle Sprain in Sports: Sports Med. 2007;37(1):73-94. doi: 10.2165/00007256-200737010-00006.
15. Hertel J. Functional Anatomy, Pathomechanics, and Pathophysiology of Lateral Ankle Instability. J Athl Train. 2002;37(4):364-75.
16. Loozen L, Veljkovic A, Younger A. Deltoid ligament injury and repair. J Orthop Surg (Hong Kong). 2023;31(2):10225536231182345. doi: 10.1177/10225536231182345.
17. Aicale R, Maffulli N. Rotational ankle instability: A current concept review. J Orthop Surg (Hong Kong). 2023;31(2):10225536231182347. doi: 10.1177/10225536231182347.
18. Gopinath R, Pigott M, Lindsey B, et al. Medial Ankle Instability: Review of Anatomy, Evaluation, and Treatment. Foot Ankle Spec. 2022;15(6):573-8. doi: 10.1177/1938640021992915.
19. Shakked R, Sheskier S. Acute and Chronic Lateral Ankle Instability Diagnosis, Management, and New Concepts. Bull Hosp Jt Dis 2013. 2017;75(1):71-80.
20. Oae K, Takao M, Uchio Y, Ochi M. Evaluation of anterior talofibular ligament injury with stress radiography, ultrasonography and MR imaging. Skeletal Radiol. 2010;39(1):41-7. doi: 10.1007/s00256-009-0767-x.
21. Gün C, Unlüer EE, Vandenberk N, Karagöz A, Sentürk GO, Oyar O. Bedside ultrasonography by emergency physicians for anterior talofibular ligament injury. J Emerg Trauma Shock. 2013;6(3):195-8. doi: 10.4103/0974-2700.115340.
22. Cheng Y, Cai Y, Wang Y. Value of ultrasonography for detecting chronic injury of the lateral ligaments of the ankle joint compared with ultrasonography findings. Br J Radiol. 2014;87(1033):20130406. doi: 10.1259/bjr.20130406.
23. Hua Y, Yang Y, Chen S, Cai Y. Ultrasound examination for the diagnosis of chronic anterior talofibular ligament injury. Acta Radiol Stockh Swed 1987. 2012;53(10):1142-5. doi: 10.1258/ar.2012.120171.
24. Kim YS, Kim YB, Kim TG, et al. Reliability and Validity of Magnetic Resonance Imaging for the Evaluation of the Anterior Talofibular Ligament in Patients Undergoing Ankle Arthroscopy. Arthrosc J Arthrosc Relat Surg Off Publ Arthrosc Assoc N Am Int Arthrosc Assoc. 2015;31(8):1540-7. doi: 10.1016/j.arthro.2015.02.024.
25. Joshy S, Abdulkadir U, Chaganti S, Sullivan B, Hariharan K. Accuracy of MRI scan in the diagnosis of ligamentous and chondral pathology in the ankle. Foot Ankle Surg Off J Eur Soc Foot Ankle Surg. 2010;16(2):78-80. doi: 10.1016/j.fas.2009.05.012.
26. Kumar V, Triantafyllopoulos I, Panagopoulos A, Fitzgerald S, Van Niekerk L. Deficiencies of MRI in the diagnosis of chronic symptomatic lateral ankle ligament injuries. Foot Ankle Surg. 2007;13(4):171-6. doi: 10.1016/J.FAS.2007.04.002.
27. Jolman S, Robbins J, Lewis L, Wilkes M, Ryan P. Comparison of Magnetic Resonance Imaging and Stress Radiographs in the Evaluation of Chronic Lateral Ankle Instability. Foot Ankle Int. 2017;38(4):397-404. doi: 10.1177/1071100716685526.
28. Mengiardi B, Pfirrmann CW, Vienne P, Hodler J, Zanetti M. Medial collateral ligament complex of the ankle: MR appearance in asymptomatic subjects. Radiology. 2007;242(3):817-24. doi: 10.1148/radiol.2423060055.
29. Pintore E, Cipollaro L, Pintore R, Oliva F, Maffulli N. Extensor Retinaculum Flap and Fibular Periosteum Ligamentoplasty After Failed Surgery for Chronic Lateral Ankle Instability. Foot Ankle Int. 2020;41(12):1546-52. doi: 10.1177/1071100720945703.
30. Feng SM, Maffulli N, Ma C, Oliva F. All-inside arthroscopic modified Broström-Gould procedure for chronic lateral ankle instability with and without anterior talofibular ligament remnant repair produced similar functional results. Knee Surg Sports Traumatol Arthrosc. 2021;29(8):2453-61. doi: 10.1007/s00167-020-06361-2.
31. Gribble PA. Evaluating and Differentiating Ankle Instability. J Athl Train. 2019;54(6):617-27. doi: 10.4085/1062-6050-484-17.
32. Van Dijk CN, Lim LSL, Bossuyt PMM, Marti RK. Physical Examination Is Sufficient For The Diagnosis Of Sprained Ankles. J Bone Joint Surg Br. 1996;78-B(6):958-62. doi: 10.1302/0301-620x78b6.1283.
33. Kovaleski JE, Norrell PM, Heitman RJ, Hollis JM, Pearsall AW. Knee and ankle position, anterior drawer laxity, and stiffness of the ankle complex. J Athl Train. 2008;43(3):242-8. doi: 10.4085/1062-6050-43.3.242.
34. Karlsson J, Bergsten T, Lansinger O, Peterson L. Surgical treatment of chronic lateral instability of the ankle joint. A new

procedure. Am J Sports Med. 1989;17(2):268-73; discussion 273-274. doi: 10.1177/036354658901700220.
35. Lynch SA. Assessment of the Injured Ankle in the Athlete. J Athl Train. 2002;37(4):406-12.
36. Krips R, De Vries J, Van Dijk CN. Ankle Instability. Foot Ankle Clin. 2006;11(2):311-29. doi: 10.1016/j.fcl.2006.02.003.
37. Vaseenon T, Gao Y, Phisitkul P. Comparison of two manual tests for ankle laxity due to rupture of the lateral ankle ligaments. Iowa Orthop J. 2012;32:9-16.
38. Phisitkul P, Chaichankul C, Sripongsai R, Prasitdamrong I, Tengtrakulcharoen P, Suarchawaratana S. Accuracy of Anterolateral Drawer Test in Lateral Ankle Instability: A Cadaveric Study. Foot Ankle Int. 2009;30(7):690-5.
39. Miller AG, Myers SH, Parks BG, Guyton GP. Anterolateral Drawer Versus Anterior Drawer Test for Ankle Instability: A Biomechanical Model. Foot Ankle Int. 2016;37(4):407-10. doi: 10.1177/1071100715620854.
40. Frost HM, Hanson CA. Technique for testing the drawer sign in the ankle. Clin Orthop. 1977;(123):49-51.
41. Larkins LW, Baker RT, Baker JG. Physical Examination of the Ankle: A Review of the Original Orthopedic Special Test Description and Scientific Validity of Common Tests for Ankle Examination. Arch Rehabil Res Clin Transl. 2020;2(3):100072. doi: 10.1016/j.arrct.2020.100072.
42. Pereira H, Guillo S, Glazebrook M, et al. Lateral ankle instability: an international approach by the Ankle Instability Group. Berlin (Heidelberg): Springer; 2021, p. 392.
43. Rosen AB, Needle AR, Ko J. Ability of Functional Performance Tests to Identify Individuals With Chronic Ankle Instability: A Systematic Review With Meta-Analysis. Clin J Sport Med. 2019;29(6):509-22. doi: 10.1097/JSM.0000000000000535.
44. Buchanan AS, Docherty CL, Schrader J. Functional Performance Testing in Participants With Functional Ankle Instability and in a Healthy Control Group. J Athl Train. 2008;43(4):342-6. doi: 10.4085/1062-6050-43.4.342.
45. Davies WT, Myer GD, Read PJ. Is It Time We Better Understood the Tests We are Using for Return to Sport Decision Making Following ACL Reconstruction? A Critical Review of the Hop Tests. Sports Med. 2020;50(3):485-95. doi: 10.1007/s40279-019-01221-7.
46. Caffrey E, Docherty CL, Schrader J, Klossnner J. The Ability of 4 Single-Limb Hopping Tests to Detect Functional Performance Deficits in Individuals With Functional Ankle Instability. J Orthop Sports Phys Ther. 2009;39(11):799-806. doi: 10.2519/jospt.2009.3042.
47. Hiller CE, Refshauge KM, Herbert RD, Kilbreath SL. Balance and Recovery From a Perturbation are Impaired in People With Functional Ankle Instability. Clin J Sport Med. 2007;17(4):269-75. doi: 10.1097/JSM.0b013e3180f60b12.
48. Kaminski TW, Gribble P. The Star Excursion Balance Test as a Measurement Tool. Athl Ther Today. 2003;8(2):46-7. doi: 10.1123/att.8.2.46.
49. Gribble PA, Hertel J, Plisky P. Using the Star Excursion Balance Test to Assess Dynamic Postural-Control Deficits and Outcomes in Lower Extremity Injury: A Literature and Systematic Review. J Athl Train. 2012;47(3):339-57 doi: 10.4085/1062-6050-47.3.08.
50. Hertel J, Braham RA, Hale SA, Olmsted-Kramer LC. Simplifying the Star Excursion Balance Test: Analyses of Subjects With and Without Chronic Ankle Instability. J Orthop Sports Phys Ther. 2006;36(3):131-7. doi: 10.2519/jospt.2006.36.3.131.
51. Nakagawa L, Hoffman M. Performance in Static, Dynamic, and Clinical Tests of Postural Control in Individuals with Recurrent Ankle Sprains. J Sport Rehabil. 2004;13(3):255-68. doi: 10.1123/jsr.13.3.255.
52. Chimera NJ, Smith CA, Warren M. Injury History, Sex, and Performance on the Functional Movement Screen and Y Balance Test. J Athl Train. 2015;50(5):475-85. doi: 10.4085/1062-6050-49.6.02.
53. Kang MH, Lee DK, Park KH, Oh JS. Association of Ankle Kinematics and Performance on the Y-Balance Test With Inclinometer Measurements on the Weight-Bearing-Lunge Test. J Sport Rehabil. 2015;24(1):62-7. doi: 10.1123/jsr.2013-0117.
54. Cox JS, Hewes TF. "Normal" talar tilt angle. Clin Orthop Relat Res. 1979;(140):37-41.
55. Guerra-Pinto F, Côrte-Real N, Gomes TM, Consciência JG, Glazebrook M, Oliva XM. Varus talar tilt combined with an internal rotation pivot stress assesses the supination instability vector in lateral ankle ligaments' injury - cadaver study. Foot Ankle Surg. 2020;26(3):258-64. doi: 10.1016/j.fas.2019.03.007.
56. Rosen AB, Ko J, Brown CN. Diagnostic accuracy of instrumented and manual talar tilt tests in chronic ankle instability populations. Scand J Med Sci Sports. 2015;25(2):e214-21. doi: 10.1111/sms.12288.
57. Aslan A, Sofu H, Kirdemir V. Ankle Ligament Injury: Current concept. OA Orthopaedics. 2014;2(1):5.
58. Donahue MS, Docherty CL, Riley ZA. Decreased fibularis reflex response during inversion perturbations in FAI subjects. J Electromyogr Kinesiol. 2014;24(1):84-9. doi: 10.1016/j.jelekin.2013.08.012.
59. Hoch MC, Mckeon PO. Peroneal Reaction Time after Ankle Sprain: A Systematic Review and Meta-analysis. Med Sci Sports Exerc. 2014;46(3):546-56. doi: 10.1249/MSS.0b013e3182a6a93b.
60. Eechaute C, Vaes P, Duquet W, Van Gheluwe B. Reliability and discriminative validity of sudden ankle inversion measurements in patients with chronic ankle instability. Gait Posture. 2009;30(1):82-6. doi: 10.1016/j.gaitpost.2009.03.006.
61. Ryan L. Mechanical stability, muscle strength and proprioception in the functionally unstable ankle. Aust J Physiother. 1994;40(1):41-7. doi: 10.1016/S0004-9514(14)60453-0.
62. Cerezal A, Ocampo R, Llopis E, Cerezal L. Ankle Instability Update. Semin Musculoskelet Radiol. 2023;27(3):231-44. doi: 10.1055/s-0043-1767767.
63. Hubbard TJ, Wikstrom EA. Ankle sprain: pathophysiology, predisposing factors, and management strategies. Open Access J Sports Med. 2010;1:115-22. doi: 10.2147/oajsm.s9060.
64. Lalevée M, Anderson DD, Wilken JM. Current Challenges in Chronic Ankle Instability: Review and Perspective. Foot Ankle Clin. 2023;28(1):129-43. doi: 10.1016/j.fcl.2022.11.003.