A New Paradigm for Rehabilitation of Patients with Chronic Ankle Instability

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Abstract: Lateral ankle sprains have been shown to be one of the most common musculoskeletal injuries in both athletes and the recreationally active population. Moreover, it is estimated that approximately 30% of people who incur a lateral ankle sprain will ssustain recurrent ankle sprains and experience symptoms of pain and instability that last > 1 year. Chronic ankle instability (CAI) is the term used to describe cases involving repetitive ankle sprains, multiple episodes of the ankle "giving way," persistent symptoms, and diminished self-reported function for > 1 year after the initial ankle sprain. The optimal conservative treatment for CAI is yet to be determined; however, comparison between patients with CAI and individuals showing no history of ankle sprain has revealed several characteristic features of CAI. These include diminished range of motion, decreased strength, impaired neuromuscular control, and altered functional movement patterns. We propose a new treatment paradigm for conservative management of CAI with the aim of assessing and treating specific deficits exhibited by individual patients with CAI.

Keywords: ankle sprain; chronic ankle instability; arthrokinematics; balance training; rehabilitation; therapeutic exercise

Introduction

According to the National Collegiate Athletic Association (NCAA) injury surveillance system (ISS), ankle sprains are the most common injuries in collegiate athletes and account for 15% of all injuries.[1] Furthermore, the NCAA ISS estimates that approximately 11 000 ankle sprains occur per year in collegiate athletes at a rate of 0.83 per 1000 exposures.[1] In an epidemiological study that examined high school athletes, it was estimated that 326 396 ankle injuries occur per year with an injury rate of 0.52 ankle injuries per 1000 exposures.[2] Waterman et al[3] studied the incidence of ankle sprains in the general population by collecting data through the National Electronic Injury Surveillance System (NEISS) for a 5-year period and found an incident rate of 2.15 per 1000 person-years.[3] These studies show that ankle sprains are a common musculoskeletal injury sustained by both athletes and recreationally active individuals in the United States. However, more interestingly, it is estimated that ≤ 30% of people who sustain an ankle sprain will experience a recurrent sprain and residual symptoms, such as pain and instability that last for > 1 year.[4,5]

The most common mechanism of injury in lateral ankle sprains (LAS) is excessive inversion and plantar flexion of the foot coupled with external rotation of the lower leg.[6] Traditionally, LAS are diagnosed by a grading system.[7] Grade I LAS are the most common type of sprains, and patients with grade I LAS typically present with mild pain and swelling over the anterior talofibular ligament (ATFL) with no joint instability.[7] Patients with grade II LAS present with greater disability, moderate

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pain, and swelling over both the ATFL and the calcaneofibular ligament (CFL).[7] Furthermore, grade II LAS typically involve complete rupture of the ATFL and stretching of the CFL fibers.[7] The most severe sprains are classified as grade III, but these are relatively uncommon in athletes and result in extreme disability.[7] This type of injury involves damage to the ATFL, CFL, and posterior talofibular ligament (PTFL).[7] It is commonly thought that the grade of LAS may be a predictor of the patient's future outcomes and risk of reinjury.[5] However, a systematic review by van Rijn et al[5] found that patients with varying degrees of sprains showed no difference in outcomes after 3 years. Therefore, we believe more emphasis should be placed on determining other factors that may lead to poor prognosis, such as pain management, as well as incorporating a more extensive evaluation process that may expose potential deficits and allow the addition of specific rehabilitation techniques to address these deficits.

Chronic ankle instability (CAI) is the term used to describe cases showing residual symptoms of ankle instability and a feeling of the ankle "giving way" that lasts > 1 year after the initial ankle sprain.[8] In 2002, Hertel[9] proposed a model that included both mechanical and functional insufficiencies that may contribute to CAI. Over the past decade, this model has been revised by Hiller et al[10] to better represent the varied presentations of individual patients with CAI. Hertel[11] has also proposed a newer model delineating the full spectrum of sensorimotor alterations that have been demonstrated in patients with CAI, which alludes to a more robust framework of the etiology of the sensorimotor deficits associated with CAI. Although these previous models provide a theoretical basis for the potential contributing factors to CAI, they fail to link patient-specific deficits with optimal interventions. Therefore, our purpose is to present a new paradigm consisting of an evaluation and treatment algorithm to help guide the conservative management of patients with CAI.

Management of Acute Ankle Sprains

Before addressing the management of CAI, it is important to briefly discuss the typical protocol for care of acute ankle sprains. In addition, it is important to understand that the phases of ankle rehabilitation may overlap. Immediate care of acute ankle sprains includes protection of the lateral ligaments, rest from physical activity, application of ice, compression, and elevation, also known as the PRICE treatment. The goals of this phase are to protect the damaged soft tissues, decrease pain, and control inflammation. Pain management may include different therapeutic modalities, such as application of ice and transcutaneous electrical stimulation, as well as administration of analgesic modalities. Use of a compression bandage to control swelling and application of an orthosis, such as an Aircast (DJO Global Inc.) or walking boot, should also be used to partially immobilize the injured ankle and protect the sprained ligaments. Care should be taken to prevent patients from ambulating with an antalgic gait. Patients who are unable to walk without a limp should use crutches to limit painful weight bearing. As the pain and swelling resolve, exercises to restore normal range of motion (ROM), strength, and balance should be implemented. Finally, endurance and sport-specific tasks should be added to the rehabilitation protocol. Each phase of rehabilitation should be continued until the goals of the phase are reached and maintained. Proper acute management may reduce the possibility of CAI development; however, many people who sustain acute ankle sprains do not seek medical attention.[12]

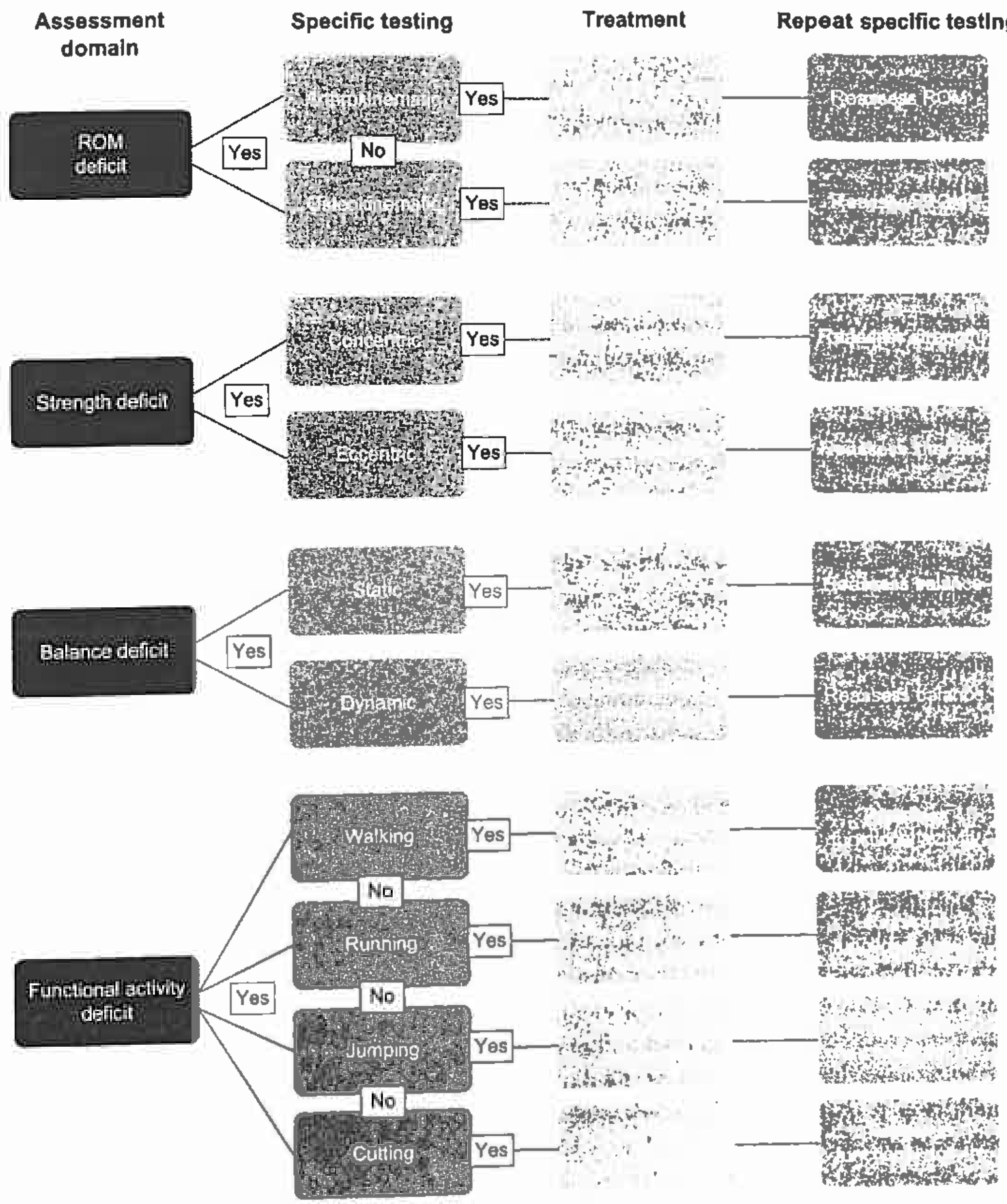
Management of CAI

Patients with CAI show various types of deficits, including decreased ROM[13–17] and strength,[18,19] impaired proprioception[19–24] and neuromuscular control,[25–28] and altered gait patterns.[29,30] To address these deficits, we believe it is important to assess and treat each specific symptom domain individually because the interactive effects across the symptom domains are unclear. Therefore, we propose that using the 4 broad assessment domains of ROM, strength, balance, and functional activities, with a superseding principle of pain control, can provide clinicians with a systematic method of treating CAI-associated deficiencies and enable patients to return to full function (Figure 1). We believe that these 4 broad assessment domains encompass the mechanical and functional insufficiencies described by Hertel.[9]

Pain as a Guide During Rehabilitation

Many patients seek treatment for CAI with the primary complaint of functional deficit; however, pain must also be an important consideration guiding rehabilitation goals and progressions. In addition to pharmacological management,[31] analgesic modalities such as cryotherapy,[32,33] thermotherapy, and electrical stimulation[32] can be used to help mitigate pain in patients with CAI. Likewise, manual therapeutic techniques, such as grade I and II joint mobilizations, can be used for pain relief. Although these modalities and techniques may be used prior to

Figure 1. An assessment and treatment paradigm for patients with chronic ankle instability.



Abbreviation: ROM, range of motion.

therapeutic exercise, exercises that cause pain should be discontinued until they can be performed without pain. If persistent ankle pain does not resolve with conservative management, further diagnostic imaging (eg, conventional weightbearing radiographs, magnetic resonance imaging [MRI],[34] and/or single-photon emission computed tomography [SPECT])[35] should be considered to identify potential causes, such as soft tissue impingement (ie, sinus tarsi syndrome, anterolateral impingement, or osteochondral lesions), that may require care from a foot and ankle orthopedic specialist.

ROM

Multiple studies have shown a decrease in dorsiflexion ROM in patients who sustain ankle sprains,[13-17] and this is thought to be a contributing factor in the development of CAI.[36] The anterior positional fault theory of the talus and fibula has been suggested to be a major contributor to the decreased

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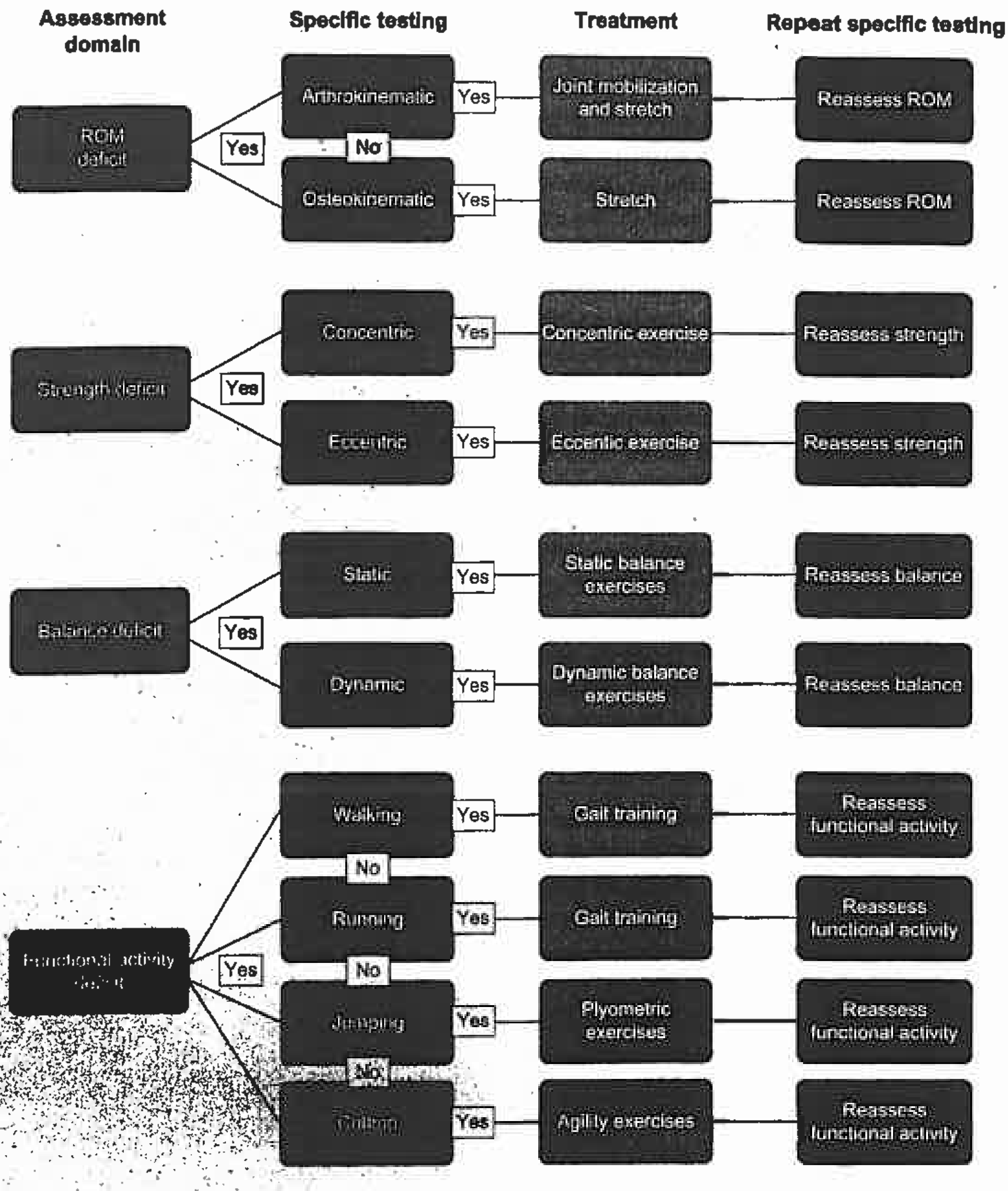


Abbreviation: ROM, range of motion.

dorsiflexion associated with CAI.[37–40] It has also been shown that individuals with CAI have a more anteriorly positioned talus with regard to the tibia[17] and a more anteriorly positioned fibula with regard to the tibia[38–40] when compared with the healthy population. Decreased dorsiflexion ROM may result in the foot being in a more plantar flexed position during the gait cycle, which reduces the stability of the joint and increases the risk of recurrent inversion injury.[16,41] Dorsiflexion ROM deficit may be caused by either an arthrokinematic restriction, an osteokinematic restriction, or a combination of both. Therefore, when assessing ankle ROM, it is important to test both the arthrokinematics and the osteokinematics of the ankle. We recommend that arthrokinematic restrictions be assessed before osteokinematic motion because arthrokinematic restrictions may mask the findings of osteokinematic tests.

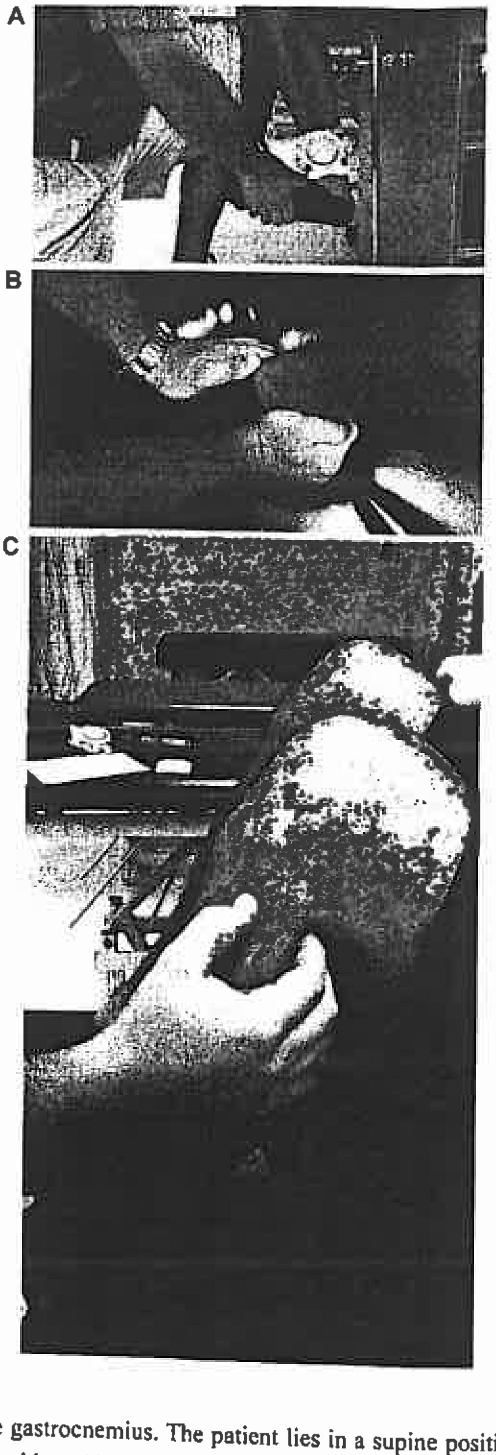
A common test used to assess the arthrokinematics of the talocrural joint is the posterior talar glide test (Figure 2A).[14] When performing this test, it is best to have the patient seated with the knees at 90° and the feet unrestricted. The clinician then places the foot in a neutral position and places his or her thumbs on the dome of the talus. While maintaining the position of the foot, the clinician then the glides feet posteriorly until a firm end feel is felt. The findings for both feet are then compared. Unilateral restriction of posterior talar glide is indicative of an arthrokinematic restriction of the talocrural joint that may be limiting dorsiflexion ROM. The posterior talar glide test has been shown to have high intrarater reliability, with intraclass correlation estimates ranging from 0.85 to 0.99 and standard error of measurement values ranging from 0.34° to 2.71°.[14,42,43]

In addition to assessing the arthrokinematics of the talocrural joint, the clinician should also assess the distal and proximal tibiofibular joint.[17,38,44] This can be done by gliding the lateral malleolus and then the fibular head anteriorly to posteriorly to determine any bilateral differences in the mobility of the joint. Limited posterior glide of the lateral malleolus or anterior glide of the fibular head may be associated with dorsiflexion ROM restriction (Figures 2B, C). The arthrokinematics of distal joints, including the subtalar and calcaneocuboidal joints, should also be assessed because hypomobility at these joints may also influence talocrural joint mechanics.

There are 4 positions that should be used to assess osteokinematic dorsiflexion of the talocrural joint; these positions can be measured by either a bubble inclinometer or a goniometer, and the measurements must be performed for both sides. The first position tests restrictions caused by the gastrocnemius. The patient lies in a supine position on the table and is instructed to dorsiflex the foot (Figure 3A). This can be done both actively and passively by the clinician. The second position tests for soleus tightness and involves the patient lying in the prone position with the knee flexed to 90°

Figure 2. A) The posterior talar glide test can be used to test the arthrokinematics of the talocrural joint. B) In addition, the posterior distal fibula glide and C) the anterior proximal fibula glide can be useful tests to detect arthrokinematic restrictions.

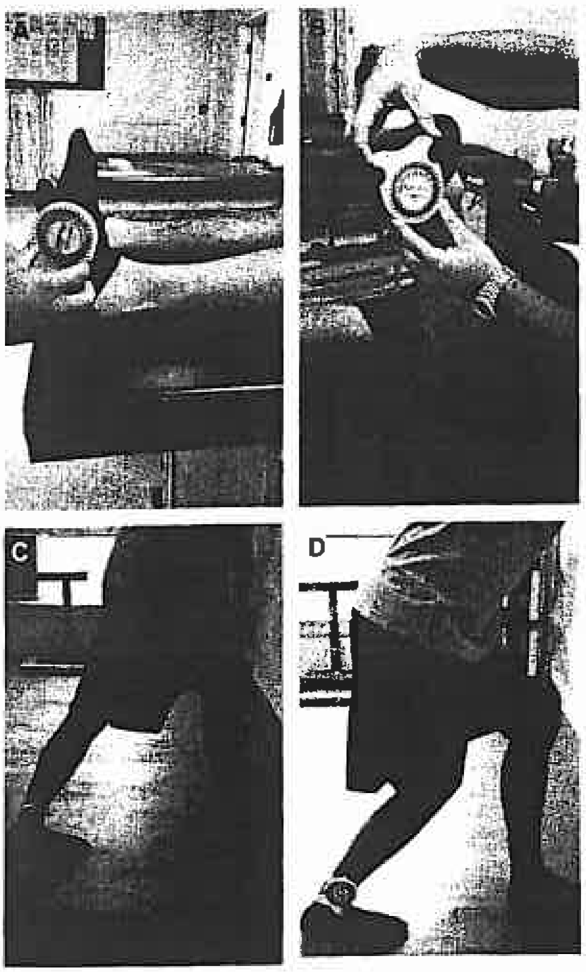
A B C



(Figure 3B). From this position, the patient is instructed to perform foot dorsiflexion. Once again, this test should be completed both actively and passively by the clinician.

The other 2 positions used to test osteokinematic dorsiflexion are employed in closed kinetic chain tests. The third position has the patient standing, starting with both feet next to each other. The patient steps forward with 1 of the legs and then begins to lean forward as far as possible, while keeping the back leg straight and completely on the ground (Figure 3C). This test also assesses gastrocnemius tightness. The final position tests for soleus tightness and is similar to the test previously described; however, the patient bends the back leg and tries to push the knee as far over the toes as possible (Figure 3D). An alternative to this technique is the weightbearing lunge test, which also assesses ankle dorsiflexion ROM with a bent knee in the closed kinetic chain.[45,46]

Figure 3. There are 4 positions that should be used to test the osteokinematic dorsiflexion range of motion of the talocrural joint, which include A) seated straight knee, B) prone bent knee, C) standing straight knee, and D) standing bent knee.



The treatments for arthrokinematic and osteokinematic restrictions are different and should be based on the clinical findings of the physical examination. If the tests for an arthrokinematic restriction are positive, the clinician should begin therapeutic techniques to treat both arthrokinematic and osteokinematic restriction of the joint. These treatments should include joint mobilizations (grade III or higher) to enact ROM changes. In addition, mobilization with movement techniques has been shown by Vicenzino et al[42] to increase posterior talar glide and dorsiflexion in those with recurrent ankle sprains and should be considered a useful treatment in addition to passive accessory joint mobilization techniques. Osteokinematic restriction treatments include stretching of the muscles that are found to be tight. In addition, therapeutic modalities may be indicated before the various stretches. It is important to continue to reassess ROM deficits by either a goniometer or a bubble inclinometer to see if the treatment needs to be adjusted. Once all ROM deficits have been eliminated, the clinician may put less emphasis on these exercises and focus on the other domains. We believe that ROM should be restored to a level equaling that of the uninvolved contralateral limb or, in the case of bilateral CAI that causes a decrease in ROM in both ankles, to established normal values. In patients with CAI, ankle ROM that is limited by articular pain should be considered a red flag and warrant referral to a specialist.

Strength

Both concentric and eccentric strength deficits of the ankle musculature have been shown to be potential contributing factors in cases of CAI.[18,24,47–52] The 4 major muscle groups that cross the ankle (anterior compartment, lateral compartment, deep posterior compartment, and superficial posterior compartment) act as dynamic stabilizers during functional tasks. In patients with CAI, weakness of the evertor muscles may contribute to the foot being more inverted during gait. Furthermore, it is hypothesized that a decrease in the strength of the muscles that cross the more proximal joints, such as the knee and hip, may play a role in CAI. Therefore, it is important to assess the potential weakness of all muscles that cross the ankle, knee, and hip joints. These muscles should be tested for both concentric and eccentric deficits by way of manual muscle testing. If any deficits are established, the clinician should implement strengthening exercises to address these deficits.

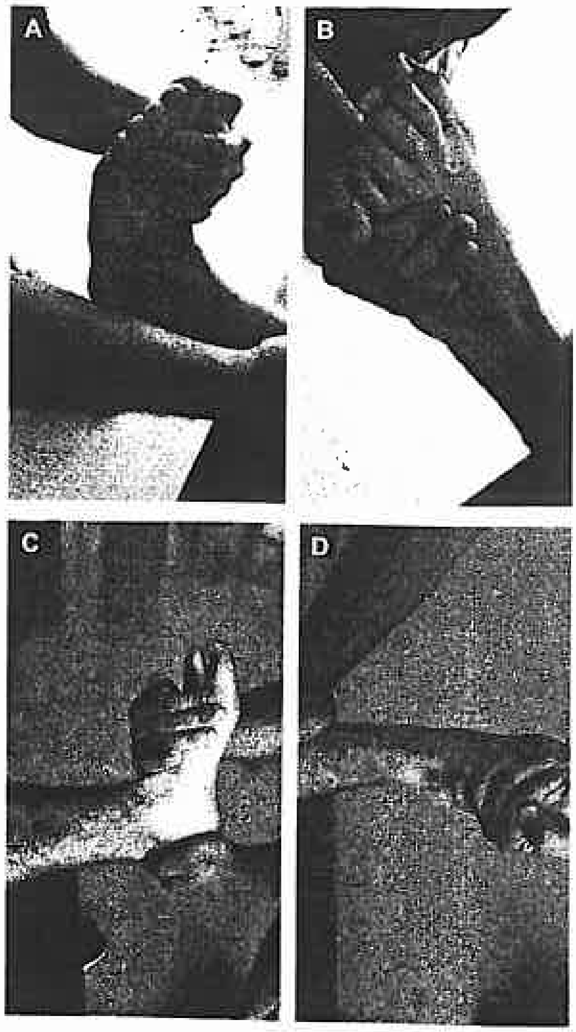
Common ankle-strengthening exercises include, but are not limited to, towel curls, short foot exercise, 4-way resistive band exercises, manual resistance exercises, calf raises, and 4-way walks. When implementing strength exercises at the ankle, it is important to use both the Specific Adaptations to Imposed Demands (SAID) and overload principles. To produce strength gains, exercises need to be performed ≥ 3 days per week for ≥ 4 consecutive weeks. Compliance with a home exercise program is essential for acheiving strength gains.

Compensation with other muscles is a common finding in patients performing 4-way resistive band exercises. For example, patients often compensate for weak evertor muscles by using the hip external rotator muscles instead. Therefore, we suggest proper patient education and positioning to isolate the targeted muscles. This can be completed more easily by using manual resistance from the clinician as opposed to band resistance. With manual resistance, the clinician can provide enough force throughout the ROM to produce strength gains in the targeted muscles. In addition, the clinician can provide enough force to stress the muscles both concentrically and eccentrically. It is important to note that because muscles are much stronger when they contract eccentrically, the force that the clinician provides must be greater than that which the individual can resist concentrically.

An example of a concentric/eccentric manual exercise for eversion involves the patient being seated on a treatment table with the leg straight. The clinician can take the patient through inversion and eversion to clarify the proper positioning. Once the patient understands the motion and can replicate the movement, the clinician can begin to add manual resistance. The patient should start with the foot inverted and push it into the clinician's hand while he or she is being guided into eversion. Once maximum eversion is reached, the clinician should begin to push the foot back into inversion as the patient resists that motion. This can be replicated for all 4 main motions of the ankle and can be progressed to more complicated patterns, such as D1 and D2 proprioceptive neuromuscular facilitation (PNF). These patterns have the patient go through inversion and dorsiflexion and then plantar flexion and eversion simultaneously (D1 pattern) (Figures 4A, B). The D2 pattern consists of eversion and dorsiflexion, followed by plantar flexion and inversion (Figures 4C, D). Once again, the clinician can load these muscles concentrically, eccentrically, or use a combination of both, depending on hand placement.

With regard to CAI, it has been shown that strength exercises at the ankle cause an increase in force production in the muscles surrounding the ankle joint[47,53] and may increase joint position sense[47] and lower extremity function.[48] Resistive bands should be used for home exercise programs; however, it is essential that patients understand the specific motions that are needed to strengthen the targeted muscles. Patient education is critical to the efficacy of any home exercise program. As with ROM, strength should be reassessed manually or with a handheld dynamometer, and these assessments should be continued until the deficit is no longer present. Similar to painful ROM testing, ankle-strengthening exercises that result in joint pain in a patient with CAI should be considered a red flag and warrant referral to a specialist.

Figure 4. A) The D1 pattern consists of the ankle going through inversion and dorsiflexion and B) then plantar flexion and eversion simultaneously. C) The D2 pattern consists of eversion and dorsiflexion, followed by D) plantar flexion and inversion.

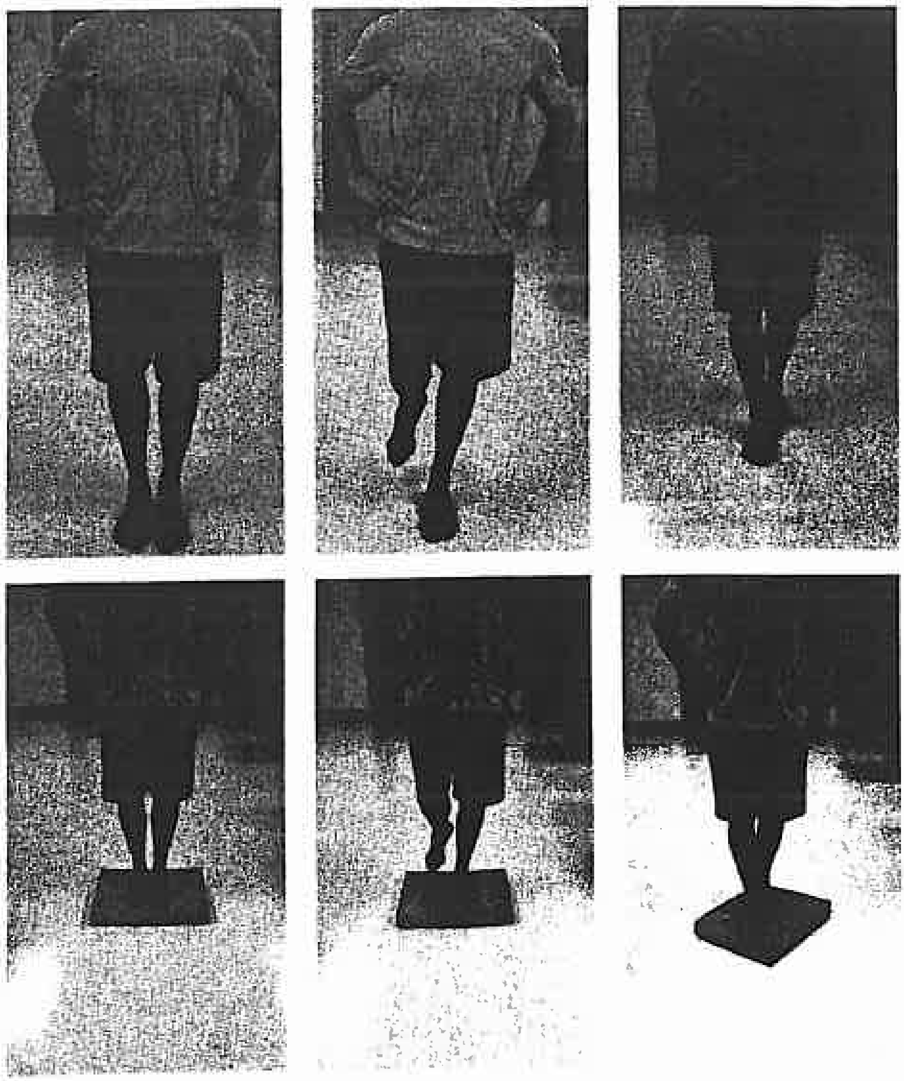


Balance

Patients with CAI have been shown to have diminished proprioception[19-24] and neuromuscular control[29,30,49] compared with healthy controls. Although proprioception and neuromuscular control differ in their physiologic definitions, balance exercises may improve both. Multiple studies have shown that balance training programs decrease the incidence of ankle sprains[50–52,54] and improve postural control in patients with CAI.[26] Furthermore, a Cochrane review[55] concluded that neuromuscular training is an effective method for short-term improvement in CAI-associated symptoms. Balance deficits can be clinically detected in individuals by using both the balance error scoring system (BESS) and the star excursion balance test (SEBT).

The BESS uses 6 different eyes-closed conditions: double-legged stance, single-legged stance, and tandem stance on a firm surface, and double-legged stance, single-legged stance, and tandem stance on a foam surface (Figure 5). It is important to note that when using the BESS to assess balance deficits in patients with CAI, unlike when using the test to evaluate mild head trauma,[56] limb dominance does not need to be established to determine the testing position. The test should be completed twice to compare differences between the healthy limb and the injured limb. During the first test, the patient should stand on the healthy limb during the single-legged stance and have the healthy limb in the back during the tandem stance. For the second test, the patient should stand on the injured limb during the single-legged stance and have the injured limb in the back during the tandem stance. The BESS has been shown to be a valid

Figure 5. The balance error scoring system test consists of 3 different positions (double-legged stance, single-legged stance, and tandem stance) on both a firm and foam surface.



Abbreviation: BESS, balance error scoring system.

test to detect postural control deficits in patients with CAI[57] and has been shown to have an interrater reliability ranging from 0.78 to 0.96.[46] The SEBT is a more functional test that can detect postural control deficits in those with CAI[28] and is reported to have high intertester (0.81–0.93) and intratester reliability (0.82–0.96).[58,59] The SEBT (sometimes referred to as the Y Balance Test) uses 3 different positions in which the patient stands first on the healthy limb and then on the injured limb, with the hands on the hips, reaching out as far as possible with the opposite leg in the anterior direction, posterior medial direction, and posterior lateral direction (Figure 6).[60] Each reach distance is compared with the distance achieved when the patient is balancing on the healthy limb. Because the BESS and SEBT can both be used to detect differences in postural control,[28,57] we believe that it is important to note that the BESS is not a functional test, and when assessing postural control, the domain can be divided into static and dynamic balance.

Static balance can be assessed by using the BESS. If static balance deficits are detected (ie, the patient cannot perform a task as well on the involved limb as on the healthy limb), the clinician should implement static balance exercises to improve postural control. These exercises are similar to those that would be performed for acute ankle sprains. The clinician should use the information gathered from the BESS to determine the starting point of balance exercises and progress the exercises as the patient is able to complete each task. In addition to assessing static balance, the clinician may also assess dynamic balance by using the SEBT. If dynamic balance deficits are detected, the clinician may implement dynamic balance exercises, such as the SEBT, in conjunction with static balance exercises.

Patients can also begin doing other functional balance exercises such as forward, lateral, and diagonal hops in which the goal is to regain balance after landing on the foot. These exercises can be made more difficult by using unstable surfaces, adding another constraint, such as catching a ball, increasing the length of excursions or hops, and increasing the duration of exercise sets. More advanced exercise can also include exercises that require the patient to hop, balance on the landing leg, and then reach back to where he or she started with the contralateral limb.

Balance deficits should continue to be reassessed until they are no longer present. Balance exercises that cause pain should be avoided, and less stressful exercises should be implemented instead. As previously stated, joint pain that does not subside should be a reason for referral to a specialist.

Functional Activities

The final rehabilitation domain is functional activities, which can be further broken down into walking, running, jumping, and cutting activities. Although all domains are important in treating CAI, this domain has been studied the least. However, it has been shown that people with CAI have an altered gait pattern during walking.[13,29,30,50] Specifically, when compared with healthy individuals, patients with CAI show greater inversion during the swing phase and spend a

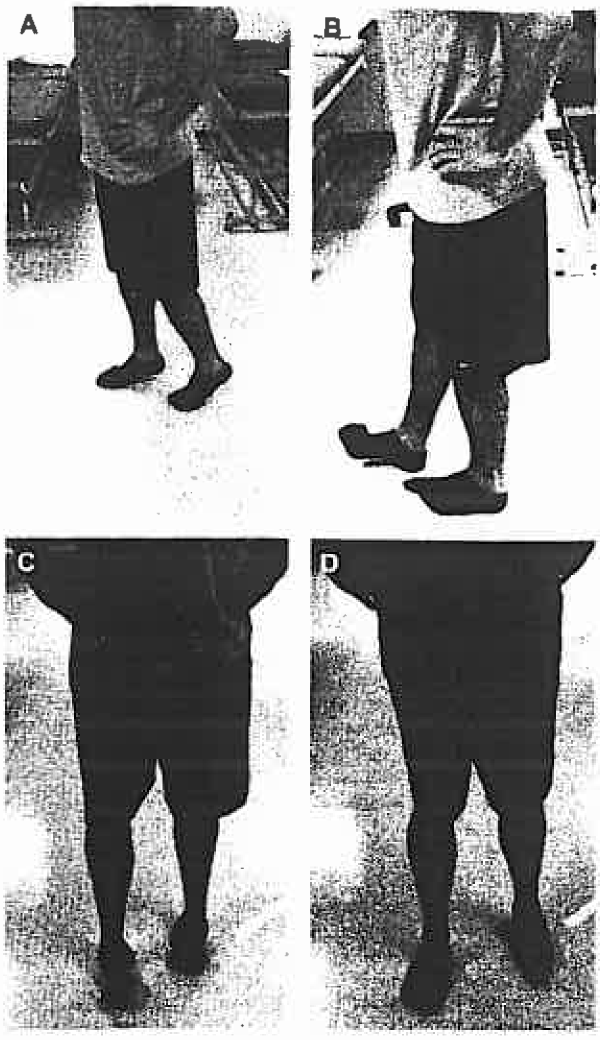
Figure 6. The star excursion balance test uses 3 different positions in which the patient stands on the involved leg with the hands on the hips and reaches as far as possible with the opposite leg in the A) anterior direction, B) posterior medial direction, and C) posterior lateral direction.

longer time on the lateral aspect of the foot during the stance phase, which may predispose them to ankle sprains.[29,30,50] It is hypothesized that preactivation of the peroneals prior to heel strike may help to correct this vulnerable position.[30,61,62]

To detect changes in gait clinically can be challenging because the motions are small and happen quickly. Therefore, we believe that clinicians should try to break the gait cycle into smaller parts and educate their patients with regard to proper walking and running mechanics. This can be done by slow treadmill walking, during which the clinician has the patient exaggerate the deficient motions. Once patients begin to demonstrate proper gait, they can progress to jogging and then running. In addition, the clinician can promote functional eccentric strength by incorporating 4-way walks, in which the person walks on the toes, heels, outside of the feet, and inside of the feet for an extended period of time (Figure 7). However, patients doing these exercises should be made to understand that these are not normal ways to walk, and that these exercises are being performed to strengthen the dynamic stabilizers of the ankle.

A similar approach can be carried out with regard to jumping mechanics. Patients should start with small hops and progresses to more advanced plyometrics (eg, exercises that involve a high-velocity eccentric contraction immediately followed by a concentric contraction of the same muscle) once they feel and look like they are not inverting excessively when landing. Finally, cutting and sport-specific activities should be completed after normal walking, running, and jumping mechanics have been restored. As with other larger joints, it may be useful to use mirrors and biofeedback in this domain. As with the other domains, pain must also be used as a guiding factor during functional exercises.

Figure 7. Eccentric strengthening can be carried out by having the patient walk on the A) toes, B) heels, C) outsides of the feet, and D) insides of the feet for an extended period of time.



Further Considerations

In addition to the clinician-reported assessments highlighted in our paradigm, we also recommend the use of patient self-reported function outcomes, such as the Foot and Ankle Ability Measure[63] or the Lower Extremity Functional Scale[64] to track patient progress. We recommend that progressive therapeutic exercise be completed for a minimum of 4 weeks. Furthermore, ankle bracing has been shown to be an effective method to decrease the incidence of ankle sprains during athletic competition[65] and could be used during both the rehabilitation process and upon return to play. Patients with CAI who do not make a concerted effort at conservative management should be referred to a foot and ankle surgeon to determine if they are candidates for lateral ligament reconstruction. As with any new treatment algorithm, the efficacy of our proposed approach needs to be subjected to the scrutiny of clinical trial research to determine if the use of this algorithm can improve clinical outcomes in patients with CAI.

Conclusion

Patients with CAI may possess multiple deficits that distinguish them from individuals with healthy ankles, and the makes it crucial for clinicians to properly detect these deficiencies on an individual basis to provide appropriate care. The 4 domains of ROM, strength, balance, and functional activities, along with the overarching tenet of pain-free exercise, provide a framework to assess and treat each of the potential deficits associated with CAI. It is important to note that there may be some overlap and influence between domains, and clinicians may have patients work simultaneously across multiple domains. However, it is imperative to individually assess and reassess each of these characteristics while treating patients with CAI.

Conflict of Interest Statement

Luke Donovan, MEd, ATC, and Jay Hertel, PhD, ATC, disclose no conflicts of interest.

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