ABSTRACT

SYSTEMATIC REVIEW AND META ANALYSIS COMPARING PROPRIOCEPTIVE TRAINING AND REPOSITION TAPING ON DYNAMIC POSTURAL CONTROL IN CHRONIC ANKLE INSTABILITY

Background: Chronic ankle instability (CAI) results from a lateral ankle sprain (LAS) and is defined as recurrent sprains, giving way, and feelings of instability. Athletes have a high risk of developing CAI, ranging 33-73%, after LAS. Athletes with CAI display frontal plane instability leading to deficits in dynamic postural control measured by the posterolateral (PL) reach on the Star Excursion Balance Test (SEBT). Balance training (BT) and fibular repositioning tape (FRT) both have demonstrated improvements on the SEBT in recent literature, yet not compared. Purpose with Hypothesis: The purpose of this study is to review whether BT or FRT is more favorable in improving PL control during the SEBT. It is hypothesized that BT will demonstrate a greater improvement. Methods: This study was carried out using the PRISMA guidelines. Inclusion criteria included experimental studies using BT or FRT examining PL reach on the SEBT. Analysis completed using PEDro scale, critical appraisal sheet, and Microsoft Excel for effect size, chi squared, and Q-value measures at a 95% confidence interval. Results: Six studies were used to complete the review, 4 studies with BT and 2 studies with FRT. The PEDro scale score ranged from 2 to 7. The effect size of the pooled studies on the SEBT was large (1.45±0.27; p<0.01) favoring BT. Conclusion: BT yielded greater improvement in PL reach on the SEBT, indicating it may be the better choice when creating frontal plane stability.

Ross Piche
May 2016
SYSTEMATIC REVIEW AND META ANALYSIS COMPARING PROPRIOCEPTIVE TRAINING AND REPOSITION TAPING ON DYNAMIC POSTURAL CONTROL IN CHRONIC ANKLE INSTABILITY

by
Ross Piche

A project submitted in partial fulfillment of the requirements for the degree of Doctor of Physical Therapy in the Department of Physical Therapy College of Health and Human Services California State University, Fresno
May 2016
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BACKGROUND

Incidence and Prevalence of Chronic Ankle Instability

A lateral ankle sprain (LAS) is the only precursor to developing chronic ankle instability (CAI). LASs are a common occurrence in recreational and professional athletes. This injury occurs in one-third of the non-athletic individuals and increases significantly to 1 in 2 individuals in the athlete population.\(^1\) The incidence of LAS is 2.15 per 1,000 person-years, indicating that in a given year there will be 2 LAS regardless of sample size. The risk for ankle sprain and CAI are intimately related to activity levels; as much as 50% of injuries occur during a sporting event, which is consistent with the incidence rate of 11.55 per 1000 sporting hours to any sporting activity.\(^2\)\(^3\) Court sports, such as basketball, report a higher incidence of injury compared to outdoor activities like running.

LAS results in joint laxity and can lead to CAI after one severe episode of sprain or multiple sprains. Following a LAS, symptoms can persist for 18 months in up to 72% of athletes after initial injury, and young males demonstrate a higher risk for CAI.\(^1\)\(^6\) Re-sprain is a hallmark feature of CAI. Re-sprain rates vary from sport to sport, yet most will happen within a 2-year period.\(^2\) Within the first year after injury, CAI can develop in 33-72% of individuals after only their first sprain.\(^7\) If untreated CAI can develop fibular longus tendinopathy and increase the rate at which the athlete will develop osteoarthritic changes.\(^2\)
Lateral Ankle Sprain

Mechanism of Injury

A LAS is a precursor to developing CAI, therefore, it is important to understand its pathoanatomy. The typical mechanism of injury during a LAS is the weight bearing position and forced plantarflexion, combined with subtalar hyperinversion resulting in lateral translation of the talus. The fibrous capsule of the subtalar joint is first to resist talus translation during movement, but it is weakest at its anterior portion. Now the capsule cannot provide support needed as a result the anterior talofibular ligament (ATFL) and calcaneofibular ligament (CFL) will resist this anterior talus translation.

The ligamentous structures that resist translation of the talus are the lateral ligaments of the ankle, including the ATFL and CFL. These ligaments prevent the anterolateral translation of the talus in normal circumstances; however, as the translation of the talus moves beyond the elastic properties into the plastic properties, in the case of a LAS, they fail in 73% of cases. Musculotendinous mechanism used to offset lateral translation is the peroneal longus tendon. During the LAS moment this ankle evertor does not have the mechanical advantage to resist this external force or the reaction time needed to counter the inversion impulse. This results in damage to the surrounding ligaments and tendons.

Grades of Severity

Chronic ankle instability develops from a LAS grade II and III, where microtearing and complete tear, respectively, occur. The tearing leads to greater instability of the talus due to ligament laxity and subsequent loss in proprioceptive feedback. After injury the talus shifts anterolaterally and places stress on the
remaining intact ligaments, ATFL and CFL. This leads to decreased dorsiflexion range of motion, but an increase in frontal plane instability.

More severe grades result in less articular congruency in the subtalar joint, which will ultimately lead to early joint degeneration.\textsuperscript{10} The fibula displaces anteroinferiorly in relation to the tibia, resulting in slack on the ATFL with a decrease in dorsiflexion range and increase in frontal plane instability.\textsuperscript{6,11} An additional complication results from the role of the ligaments and tendons. The ATFL and peroneal longus tendon, following injury, present with impaired mechanoreceptor and golgi tendon unit function for generation of proprioceptive feedback. As the ligament is stretched, torn, and scarred down, the afferent receptors will become less effective. With disruption of the ligaments at the ankle, the athlete will lose proprioceptive feedback, therefore, altering function of the joint.\textsuperscript{9} The loss of proprioceptive feedback in combination with joint laxity increases the risk of re-injury during athletic performance.

**Impairments**

Symptoms in LAS are immediate swelling, instability, crepitus, weakness, stiffness, and pain, which is consistent with impairments in CAI.\textsuperscript{2} These impairments affect the postural control needed to return to normal activity, specifically, frontal plane movements such as cutting. It is difficult to determine the clinical course of the recovery due to the complex nature of the injury; for example, athletes tend to return to play without rehabilitation, increasing damage to the joint.

Thirty-six to 85% of individuals will report full recovery within a period of 3 years. However, athletes often do not wait for full recovery to occur and return to sport with instability still present, within 3 days.\textsuperscript{12} Within the first year after
initial injury, re-sprain, pain and feelings of instability continue in 33-72% of non-athletes and athletes, respectively.\textsuperscript{7} This clinical syndrome is known as CAI.

**Chronic Ankle Instability**

**Definition and Risk Factors**

Chronic ankle instability (CAI) is defined as recurrent complaints of giving way and subjective complaints of instability up to 1 year after LAS.\textsuperscript{14} Risk factors leading to CAI include joint laxity, bony incongruency, proprioceptive deficits, muscular imbalance between ankle evertors to invertors, increased BMI, and taller individuals.\textsuperscript{15-18}

CAI is a result of mechanical and functional ankle instability. The original proposal in 1965 consisted of only functional instability, where proprioception and peroneal muscle function was disrupted in individuals with chronic complaints after LAS.\textsuperscript{8} However, observational studies demonstrated that these individuals also had a degree of ligament laxity and pathologic arthrokinematics at the ankle. Thus these impairments of joint laxity, synovial changes, and bony incongruence were termed mechanical instability.\textsuperscript{6}

Each individual is placed on a continuum between mechanical and functional instability, which makes it difficult to diagnose and treat this condition. The literature does not clearly delineate when symptoms of LAS become CAI, therefore, it is important to understand both pathologies and their impairments when attempting to treat. Since CAI presents on a continuum between individuals, there is difficulty in assigning subjects to similar groups within literature. Thus a new model was developed in 2011 to take into account recurrent sprains, as well as functional and mechanical instability. The new model contains 7 categories, where an individual with CAI can be placed into one category based on their
symptoms. This model demonstrates a much more complex syndrome into which an individual is graded. The subcategories of this model include mechanical instability, functional instability, recurrent sprains or any combination of the 3.

**Mechanical Instability of Chronic Ankle Instability**

This type of instability is described as anatomic in nature. Pathogenic ligament laxity predisposes the joint to further damage during single-leg weight bearing positions. Laxity can be measured through an anterior drawer and talar tilt test, which showed good reliability when compared to flouroscopy examination.

Arthokinematic changes occur within the joint due to positional faults of the talus and fibula and lead to a decrease in range of motion and feelings of instability. Synovial inflammation and impingement can result in pain with increased instability within the joint. It has been reported that CAI can lead to early osteoarthritic changes. As an end result of this new articular imbalance, CAI makes it difficult to attain and maintain good postural control needed for dynamic single-limb balance.

**Functional Instability of Chronic Ankle Instability**

Functional instability is ultimately the major culprit over time. Its associated mechanism becomes abnormal afferent input to key lateral movement control muscles. A consequent lack of musculature defense in protecting the lateral ankle when a quick reaction is required leaves the ankle defenseless against injury. Specifically, mechanoreceptor damage following a severe LAS or, under the conditions of repeated sprains, can manifest in the ATFL and peroneus longus tendon loss or slowing of afferent information to the central nervous system.
Individuals with CAI present with slowed neuromuscular response and reflexes to perturbations. This lack of response increases the risk of re-sprains. A combination of proprioceptive deficits, altered neuromuscular firing patterns, and muscle weakness lead to a decrease in center of pressure control and ultimately dynamic postural control.  

**Interventions in CAI**

Current treatments for chronic ankle instability are surgical and conservative. Only 10% of individuals will require surgery for chronic ankle instability and tend to have the same long term outcomes as conservative treatment over a 1-year period. Conservative treatment is typically the first option for treating CAI. Treatment includes balance training, bracing, external support, mobilization, and strengthening programs.  

The goal of conservative treatment is to improve proprioception, joint position sense, correct positional faults, and improve postural stability to prevent recurring sprains. Physical therapy treatment aims to correct the impairments in functional and mechanical instability to allow the individual return to activity or sport. During the rehabilitation process, the Star Excursion Balance Test (SEBT) is used clinically to assess progress in the rehabilitation process, as it is useful in determining proprioceptive and muscular feedback at the ankle through performance. It is also an important measure for safe return to sport because of its required single-leg dynamic postural stability position. Poor performance on SEBT places an athlete at 2.5 times greater risk for re-injury, according to research by Gribble et al. In Division I athletes, the risk for re-injury can increase to 3.5 times greater risk when they cannot meet the cutoff score of 89%, most likely due to increase exposure to moment forces. The Star Excursion Balance Test’s 3-
direction version is valid and reliable for dynamic postural stability with use on the CAI population.\textsuperscript{25} However, the important movement associated with determining CAI and balance deficits is the posterolateral direction.\textsuperscript{26} This direction on the SEBT is most similar to a side-cut maneuver in athletics. Due to athletes with CAI displaying increased frontal plane instability during cutting tasks, this functional test becomes increasingly important in assessing if an intervention is effective in rehabilitating control of this directional instability.\textsuperscript{27,28}

**Strengthening.** Functional ankle instability presents with a decrease in the strength ratio between the peroneal longus and posterior tibialis muscle.\textsuperscript{8} Strengthening can be accomplished through isometric, isokinetic, and eccentric methods.\textsuperscript{2} However, strengthening has demonstrated inconsistent results in treatment in CAI because it does not address position sense and postural control.\textsuperscript{29} Although this type of strengthening can improve overall torque force of muscle units outputs, it cannot improve neuromuscular recruitment speed due to loss of proprioceptive detection capability due to structural damage at the cellular level. Muscles strengthening therefore cannot protect the individual from subsequent damage, as LAS becomes more and more a reaction timing issue.

**Mobilizations.** Mobilization is used to increase dorsiflexion range of motion and postural control. With CAI pathology there is a mechanical restriction in posterior glide due to joint incongruity.\textsuperscript{6} There is evidence that dorsiflexion range of motion and dynamic postural control have a linear relationship.\textsuperscript{30} Furthermore, research demonstrates that one session of posterior mobilization improves dorsiflexion range of motion temporarily.\textsuperscript{31} However, research is lacking on mobilization’s ability to improve dynamic postural control as measured by the SEBT.
**External support.** Use of over-the-counter braces and taping on joint position sense and recurrent sprains are typical examples of external bracing. Bracing does not make a change in joint position sense. Taping is more effective than no treatment in athletes to prevent re-occurring sprains. Fibular repositioning tape also known as Mulligan’s taping, which holds the fibula in a more neutral position in relation to the tibia, improves single leg balance in individuals with CAI. Research suggests taping may also play a role in proprioception function in the CAI population. It is believed that tape stimulates the cutaneous mechanoreceptors that influence joint positional sense to enhance balance.

**Balance training.** Balance training often uses a combination of range of motion, strength, and proprioception to build stability around a joint. This is carried out statically or dynamically to restore normal movement. Balance training is a common technique used by physical therapists to help athletes improve postural stability to return to sport. Balance training is effective in preventing recurrent sprains and increasing self-perceived stability compared to no treatment as measured by the Cumberland Ankle Instability Test or Functional Ankle Disability Index. Balance training also demonstrates improvements in SEBT over a 4-week period.

**Purpose and Hypothesis**

Balance and taping have been the most explored treatment interventions in the past 15 years for athletes and active individuals with CAI. These 2 interventions have been compared for proprioceptive awareness, but not when examining the functional outcome of dynamic postural stability. Therefore, the purpose of this systematic-review and meta-analysis is to review the effect of
balance training versus fibular repositioning taping on athletic individuals for
dynamic postural stability through the SEBT, specifically in the posterolateral
direction. The null hypothesis is balance training and fibular repositioning taping
will yield no difference in the posterolateral direction on the SEBT. The
alternative hypothesis is balance training will yield a statistically significant
improvement to the posterolateral direction on the SEBT compared to fibular
repositioning taping.
METHODS

Literature Search Strategy

This study was carried out using the PRISMA guidelines for systematic reviews and meta-analyses. A search was performed in August 2015 in PubMed, Elsevier, CINAHL, Cochrane, Web of Science, Google scholar (through proxy), Physiotherapy Evidence Database (PEDro) and SAGE Research methods to identify studies examining the effects of proprioceptive training or tape in athletes with chronic ankle instability. The following MESH terms were used for the search: proprioceptive training OR balance training AND postural stability, chronic ankle instability OR recurring ankle sprain AND proprioceptive training, chronic ankle instability AND balance, chronic ankle instability OR recurrent ankle sprain AND tape, chronic ankle instability AND athletes. Articles accepted in review must be full text articles within the years 2000 to 2015. Additional filters added the search were human species and written in the English language. Four studies were identified within acquired articles that fit the target population. For systematic study inclusion and exclusion see the consort (Figure 1). As indicated by the graph, studies were eliminated based on not meeting the inclusion criteria and lack of experimental design.

The inclusion criteria consisted of the following: (1) healthy athletes or recreational individuals between ages 18-40 with chronic ankle instability as determined by self-report, FADI, CAIT, FAAM, AII, or referral by a doctor; (2) limited to studies that described the proprioception training in single-limb or double-limb stance on unstable conditions and surfaces; (3) outcome measurement Star Excursion Balance Test (SEBT) using the posterolateral direction; and (4) subjects receiving fibular repositioning taping method as an intervention.
Exclusion criterion included neurological or endocrine disorder, which effected balance and subjects who received lateral ankle ligament repair surgery.

**Assessment of Studies**

Risk of bias and validity threats across studies were measured using the PEDro scale. This scale reports 11 items that examine the level of internal validity in the study. The first item focuses on external validity; therefore, it is not included in the final tally. The PEDro scale is a valid and reliable measure for determining methodological quality of studies examining physical therapy interventions.\(^{36}\) Quality of each individual article was further determined through the use of a critical appraisal sheet adapted from Duke University. The critical appraisal process consisted of examining experiment groups, study methodology, and results for risk of bias and threats to validity.

**Summary of Measures**

The Star Excursion Balance Test (SEBT) is an outcome measure of dynamic postural stability commonly used in physical therapy throughout the rehabilitation process. This test consists of a balance task requiring the individual to maintain single limb balance while reaching with noninvolved limb in 8-directions. Measurements are taken pre and post intervention or may compare involved limb to uninvolved. Recent literature provides support for a 3-direction test that shows similar reliability when compared to the 8-direction test.\(^{39}\) The 3-test directions are anterior, posteromedial, and posterolateral. The test scores are normalized by dividing reach distance by leg-length then multiplying by 100. Research has shown the inter-rater (ICC=0.86-0.92), intra-rater (ICC=0.94), and test-retest (ICC=0.84-0.92) reliability of the SEBT to be good.\(^{39-41}\) The MDIC for posterolateral direction is 5.3%.\(^{23}\)
**Statistical Analysis**

For the statistical analysis the posterolateral SEBT normalized measure was used in a fixed 2-group analysis from both proprioception and taping groups in Microsoft Excel 2003 sheet. From the analysis an individual and pooled effect size was determined with an assumed 95% confidence interval. The data were assessed for heterogeneity using the same Microsoft Excel 2003 worksheet examining the Q-value and Chi-squared distribution set at <0.05. Then a comparison of effect sizes was conducted comparing balance training to fibular repositioning taping in studies with athletic individuals as defined by the included studies using a 95% confidence interval.
RESULTS

Study Selection
A search of the literature across the designated databases yielded 339 studies. A review of the titles and abstracts for the PICO components narrowed the pool to 53 studies. An independent review for inclusion and exclusion criteria yielded 6 studies for use in this systematic review and meta-analysis (see Figure 1). Four studies included the intervention balance training and 2 included fibular repositioning tape.

Study Characteristics
Four studies were randomized control trials and 2 were repeated measure designs. All studies used a pre-test and post-test immediately after intervention with no long-term follow-up period. The population used in each study varied in inclusion criteria. Two studies used active individuals, 3 studies used recreational athletes, and 1 study used semiprofessional athletes. Four studies included balance training as their intervention, while 2 studies used fibular repositioning taping. All studies using a balance-training program used a no-intervention control group. The outcome measure used in all studies included the posterolateral direction using the Star Excursion Balance Test. For detailed information of the studies refer to Table 1.

Taping Studies Characteristics
Two studies examining fibular repositioning taping were included within this meta-analysis. Study quality for both used a single group repeated measure design. One study defined their population as recreationally active individuals while another study used recreational athletes for their population. Both studies
used a pre-test post-test design for each variable. One study showed a statistically significant change in posterolateral reach distance on the SEBT, while the other did not.

**Balance Studies Characteristics**

Four studies for balance programs were identified to analyze within this study. All 4 studies were randomized control trials. One study included recreationally active individuals, 2 included recreational athletes, and 1 study used semiprofessional athletes. All 4 studies showed statistically significant improvement in posterolateral reach distance on the SEBT.

**Article Assessment**

The mean score of the 6 studies was 4.83 on the PEDro. The mean score of the studies using a balance program was 5.25, ranging from 4 to 7. The mean of the studies using fibular repositioning tape was 4, with a range of 2 to 6. There was no blinding of subjects or therapists across all studies and 2 studies blinded the assessor. Four of the 6 studies had similar groups at baseline. For detailed information on which criterion were met for each study, refer to Table 2.

**Statistical Analysis**

The null hypothesis of no statistically significant difference between balance and taping was rejected. Effect sizes across studies ranged from 0.50 to 2.36. The pooled effect size was 1.45 with $Q=20.65$ and $p$ value of $<0.05$ demonstrating a large effect size for balance training with a heterogeneous grouping of studies. A secondary analysis comparing participants based on athlete status as defined by the studies yielded a large effect size of 1.10 with $Q=3.30$ and
p value=0.19. Refer to Figures 2 and 3 for representation of effect sizes by forest plot.
DISCUSSION

Purpose and Hypothesis
The purpose of this study was to examine the effect of a balance program versus fibular repositioning taping on posterolateral reach during the SEBT. The rejected null hypothesis was balance training and fibular repositioning taping would yield no difference in the posterolateral direction on the SEBT. The alternative hypothesis was accepted, as balance training had a large effect on posterolateral reach compared to fibular repositioning taping in athletes.

Summary of Evidence
The finding of this meta-analysis was in favor of a 4-6 week balance program to improve posterolateral reach in active adults and recreational athletes. The effect size of this study was large with a heterogeneous grouping of studies. The heterogeneity is consistent with other meta analyses examining balance training and taping.\(^4^2\) One reason could be that the definition of CAI was interpreted differently by each author. In 2014, the International Ankle Consortium created a statement for the definition of CAI. This statement was meant to help researchers recruit homogeneous cohorts within studies, as recently reviewed studies yielded inconsistent results from their intervention. Only 2 studies included in this meta-analysis contained the consortium positional statement definition of CAI. Another reason for heterogeneity among the measured studies could be that CAI presents differently between individuals when examining impairment severity and disability. The current model proposed in 2011 separated CAI into 7 different subcategories that can be interpreted differently by each authors\(^1^9\) Due to the large spectrum of severity and disability
created by so many subcategories of instability, there is a resultant problem in developing a homogeneous cohort to study.

It is difficult to generalize the results due to the difference in skill level of participants between the studies. Each study within this meta-analysis defined their population as active individuals, recreational athlete, or semi-professional athlete. Only one study was able to comment on the amount of activity, whether sport or exercise, the participant completed each week. Therefore, it is unclear if the active individual can be considered equal to a semiprofessional athlete in terms of functional ability within the SEBT. Thus a secondary analysis was performed to examine athletes only between balance and taping. After conducting a secondary analysis examining athletes only, as indicated by the study descriptor of their population, there was a large effect size with a homogeneous grouping. There was a difference between the 2 skill levels on how the interventions interacted with their CAI. Further studies should consider developing an identifier of athletic level with CAI similar to that of the Tegner Score for anterior cruciate ligament repair literature. The Tegner score is an 11-point ordinal scale used to rate the individuals athletic level. A new measure for CAI could improve the ability to determine the effectiveness of interventions within different skill levels. This is important consideration as competition increases frequency of exposure increases.

The largest limitation within this is the study participants’ baseline characteristics on determining severity of CAI. One study had a mean age of 10 years older compared to the other 5 studies. The mean age difference can play a detrimental role on dynamic postural control due to the difference in the level of experience of the athlete or severity of CAI. There is evidence that experience may play a role on balance performance in individuals with CAI. For example,
Paillard et al. found that higher professional athletes are able to utilize more proprioceptive feedback compared to recreational athletes.\textsuperscript{45} The reason for this could be due to professionals’ exposure to more dynamically unstable conditions and increased training regimen as compared to the typical athlete. This is a contradictory idea, as it is known when exposure-rates to activity increase the risk for injury also increases.\textsuperscript{1} Yet higher level athletes are exposed more to dynamic instability movements and report better scores on the SEBT.

There was no one universal subjective outcome measure used between the studies. While there are currently 6 accepted subjective questionnaires validated for CAI, it is difficult to compare results between different questionnaires. Each study used a different set of questionnaires and reported different means pre-intervention. Between the 6 studies there were 4 different outcome measures used to measure severity of CAI. This makes it difficult to determine the severity of the CAI within cohorts from each study. However, the outcome measures and study inclusion criteria for the cutoff score to determine CAI for each measure are acceptable according to the International Ankle Consortium positional statement indicating the studies may be comparable.\textsuperscript{46} Although each measure is acceptable, the measure that is most appropriate for athletes is the FADI-sport.\textsuperscript{46} Of the 2 studies that used the FADI-Sport, one group of participants had a mean score difference of 11% suggesting that these participants had a significantly lower perceived functional level to begin. These participants that had a lower functional score may have demonstrated a greater improvement on the SEBT due to new perceived stability from the intervention. However, after examination of perceived stability to actual stability, there did not seem to be a connection. This may indicate that while the patients may feel more stable, in reality, they are not and could be at higher risk for re-injury when returning to sport.
Balance Training

The specific protocol for each study varied but used the same general principle by tapping into the central nervous system with proprioception and reactive postural control. The studies that demonstrated the greatest change in SEBT score used an unstable surface and reactive postural recovery. Research shows that unstable surfaces such as a wobble board or foam pad simulate kinematics similar to that of an ankle sprain. As participants progress with the level of exercise, they are effectively training their neuromuscular system to protect the joint from perturbations that challenge the proprioceptive mechanisms and reactive control of the peroneal longus. All balance training studies in this meta-analysis included utilized the theory of training the neuromuscular feedback loop, which demonstrated improvements in dynamic postural control. This is consistent with Forestier’s 2015 study explaining that neuromuscular control is improved through creation of a new motor plan in response to these perturbations about the subtalar joint.

The improvements to postural control are limited by the amount of damage to the proprioceptive receptors around the joint. For example, a recent meta-analysis examining balance training to no training found that effectiveness of the intervention can decrease in individuals with a history of multiple sprains. However, the participants from that study were younger and may not have had the same training level of the current study participants, in terms of highly competitive exposure. Only 2 studies within this meta-analysis reported history of recurrent sprains, yet it could be implied all studies’ participants experienced recurrent sprains if the definition of CAI adhered to the positional statement according to the International Ankle Consortium. This may contribute to the lack of improvement to meet the MCID of 5.3% after the interventions.
Even with the recurrent nature of chronic instability there was a large effect size in favor of balance training. This suggests that age and level of experience may play a role, while number of sprains may not. No research has examined the correlation of number of sprains to performance in dynamic postural control. However, there is evidence that level of experience can positively affect postural control, whereas a study that examined elite and recreational soccer players demonstrated that the elite players have better use of afferent information for postural stability.\(^{45}\)

**Fibular Repositioning Tape**

While the effect size favors balance training, a review of the fibular repositioning tape studies demonstrated a statistically significant improvement in postural stability for one study.\(^{48}\) Research studies on taping to improve mechanical instability is lacking. The intervention of fibular repositioning tape is that 1 Grade-IV posterosuperior mobilization to the distal fibula, once performed, can be held in place by tape.\(^{49}\)

When the fibula is in the correct anatomical position, this allows the joint to move in the correct plan of motion.\(^{6}\) However, there is no evidence that indicates that the fibular repositioning taping technique can keep the fibula from returning to the anteroinferior positional fault after being applied. Consequently, it is not known if the tape mechanism will perform under dynamic stresses applied to the fibula.

The proposed mechanism for improving balance is via activation of proprioceptors in the skin that improves perceived stability, thereby, improving dynamic postural control.\(^{49}\) However, there is inconsistent data whether taping can actually improve joint position sense and movement.\(^{31-33}\) One reason could be
that receptors located in the skin around the ankle are damaged in CAI due to recurrent sprains. The recurrent sprains created excessive swelling and stretching of the skin inhibiting the function of the mechanoreceptors’ ability to sense proprioception.\textsuperscript{10} Nonetheless, there is still a small improvement with one application of fibular repositioning tape.\textsuperscript{48} This improvement may be more due to the fact that the tape serves as a visual reminder. A preliminary study in 2009 found the addition of tape influences the ankle position before and during initial contact, which can influence stability.\textsuperscript{51}

Recent literature for taping is focusing on perceived stability gained from taping and prophylactic prevention of re-sprains. There is inconsistent correlation of improved scores on the SEBT and improved sense of stability.\textsuperscript{49, 52} This improvement is believed to be the result of the placebo effect after the clinician explains to the client the benefit of the intervention. Fibular repositioning taping improved subjective feelings of stability based on a 3-question perception Likert-scale in a taping study completed in 2007 with no improvements in dynamic postural control.\textsuperscript{52} Since there is no actual change on dynamic postural control, tape may be setting up athletes up for a greater chance of re-injury.

In a pilot study examining the prophylactic effects of fibular repositioning taping throughout a basketball season, taping was found to reduce the amount of re-sprains.\textsuperscript{53} However, it only reduced the number of re-sprains by 2 throughout the entire season. Also, caution must be taken due to the small sample size and poor number needed to treat of 22; indicating that 22 people must be receive the intervention to see a positive effect in just 1 person.\textsuperscript{53} The prophylactic effect of fibular repositioning tape may not be appropriate for all athletes with CAI to reduce recurrent sprains.
Star Excursion Balance Test

The SEBT is a good measure of dynamic postural stability to determine if an athlete is at risk for re-injury. Current literature suggests a score below 89% on the SEBT would be put a collegiate-level athlete at risk for re-injury.\textsuperscript{24} None of the study means with athletes achieved this 89% threshold indicating the participants from these studies may have more severe-unstable ankles due to mechanical or functional instabilities. Five of the 6 studies achieved statistical significant differences due to the intervention, yet the changes were small. The MCID for posterolateral direction is 5.3%.\textsuperscript{23} Only 2 studies achieved the MCID, which were both 4-week balance training studies.\textsuperscript{34, 54} However, 1 study methodology was not exclusive to the sole treatment of balance training.\textsuperscript{34} This study included a comprehensive program with strengthening, balance training, and home exercise program. Therefore, it is inconclusive whether balance training alone can meet the MCID in the posterolateral direction on the SEBT or if it requires training in conjunction with other interventions. This meta-analysis suggests balance training has moderate evidence and taping has low evidence quality based on PEDro scale, critical appraisal, and qualitative measures to improve dynamic postural stability in the posterolateral direction.

Limitations

Within-Study Validity

The average score on the PEDro was 4.83 demonstrating a risk for bias within studies. While there was a specific inclusion criteria for each study, the sampling procedure was a sample of convenience using self-reported instability as the criteria to screen. Therefore, it is difficult to know where the participants lie within the spectrum of CAI. As most studies occurred before the International
Ankle Consortium position statement, the requirements needed to determine the type of instability did not include a physical examination of laxity and a subjective questionnaire before testing, as indicated by the positional statement. Only 1 balance training study and 1 taping study performed a physical exam for laxity. This makes it difficult to determine if all athletes included were similar at baseline in terms of mechanical and functional instabilities.

There was no blinding of subjects or therapists in any of the studies; however, 2 studies blinded the assessor. This is a threat for bias as participants believe they are receiving or not receiving the best intervention available. Also, therapists may be biased to believe their application of the intervention may improve testing and affect measurement recording post-intervention. There was no comment in how the remaining 4 studies attempted to reduce risk of bias when there was no blinding of the assessor.

**Between-Study Validity**

A balance training program and fibular repositioning tape are very different types of interventions used to treat CAI. While their mechanisms are different, the goal is to create stability within the joint to improve functional performance. Balance training intends to use the intrinsic forces of the muscles to maintain stability around the ankle, thus improving functional stability. Fibular repositioning tape attempts to secure the fibula mechanically. When the joint becomes mechanically secured low-threshold sensory fibers activate to illicit a motor response to create stability and improve functional stability. The better outcome in dynamic postural control would be due to the motor plan training found within balance training protocols, not resistance by tape and latent response to input to the inversion impulse experienced.
Treatment times between studies are very different. The effects of balance training in athletes with CAI is commonly reported on using prolonged times ranging from 4 weeks to entire seasons.\textsuperscript{42} Effects of taping on postural stability has only been reported on after one application and demonstrated inconsistencies on improvements.\textsuperscript{39,40,49,51,52} There is currently no research on dynamic postural stability over a prolonged period.

Limitations of the Meta-Analysis

The average of the methodological quality is moderate level determined by the PEDro scale, critical appraisals, and qualitative measures. A possible limitation is only 1 assessor measured the methodological quality for the included studies. Another limitation within this meta-analysis is the small number of studies and participants included to determine effect size. Perhaps the effect size would decrease with a larger group of studies. The largest limitation within this meta-analysis is the baseline characteristics of the athletes with CAI. To improve the similarity between group studies, a definition of athleticism should be determined with the CAI population. Currently there is not a reliable and valid measure to determine athletic level in athletes with CAI.

Conclusions

Balance training is favored compared to fibular reposition taping for improvements to dynamic postural stability in athletes. Based on moderate level evidence, balance training can show improvement to dynamic postural control in athletes. Care must be taken when analyzing active individuals due to the wide spectrum of CAI presentations. Due to the small sample size in this analysis it is difficult to determine if the interventions can be applied across the spectrum of CAI.
Clinical Implications

The use of a comprehensive 4-week balance training program, which includes conditions that mimic impulses of a LAS, can be beneficial for individuals with CAI when used in conjunction with other interventions. Fibular repositioning taping may have a beneficial role in improving perceived stability that may improve actual dynamic stability training. There is no evidence on the combination interaction effect that would be created by the use of these 2 interventions simultaneously, yet it would be possible to include both in a treatment intervention for athletes.

Future Research

Future research should focus on developing a standard measure for athleticism level. A suggestion to the research community would be developing a measure similar to the Tegner Score (11-point ordinal scale) for knee pain in order to create more homogeneous athlete cohorts within studies. There is a need for higher quality evidence in balance training studies focusing on standardizing the balance training protocol. There is also a need for higher quality taping studies with larger samples examining the effects over a 4-6 week interval.
REFERENCES


TABLES
<table>
<thead>
<tr>
<th>Author/ Year</th>
<th>Study Design</th>
<th>N</th>
<th>Population</th>
<th>Intervention</th>
<th>Pre SEBT Mean (sd)</th>
<th>Post SEBT Mean (sd)</th>
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<tr>
<td>McKeon 2008</td>
<td>RCT</td>
<td>16</td>
<td>Recreational athletes: 1) history of &gt;1 LAS 2) subsequent episodes of the ankle giving way as quantified by &gt;4 &quot;yes&quot; on All. 3) self report of disability due to ankle sprains qualified by a score of &lt;90% on the FADI and the FADI Sport.</td>
<td>Balance Training: 4 wk (12 sessions at 20 min each) activities included 1) progressive hop to stabilization 2) progressive SLS with eyes open to closed.</td>
<td>77% (15)</td>
<td>87% (13)</td>
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<td>Delahunt 2010</td>
<td>RM</td>
<td>16</td>
<td>Recreational athletes and physically active individuals: 1) history of &gt;2 LAS to the same ankle joint 2) subjective history of episodes of giving way of the ankle joint 3) subjective reporting of feelings of ankle joint instability during sporting participation 4) CAIT score of &lt;24.</td>
<td>Taping: Each participant went thru 1) no tape, 2) subtalar sling, 3) fibular repositioning</td>
<td>71.38% (10.19)</td>
<td>74.98% (10.16)</td>
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<tr>
<td>Cruz-Diaz 2014</td>
<td>RCT</td>
<td>35</td>
<td>Recreational athletes: 1) history of &gt;1 LAS 2) self-report of instability &gt;6 mo 3) CAIT &lt;27</td>
<td>Balance Training: 6 wk using DLS and SLS on: 1) exercise mats, 2) dynair, 3) Bosu, 4) minitramp, 5) foam roller</td>
<td>78.99% (1.51)</td>
<td>83.47% (2.44)</td>
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<tr>
<td>Hale 2007</td>
<td>RCT</td>
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<td>Physically active individuals: 1) history of &gt;1 LAS with limping &gt;1 day 2) chronic ankle pain, instability, giving way, or weakness attributed to LAS for 6mo</td>
<td>Balance Training: 4 wk (6 supervised-sessions) comprehensive-balance, stretching, strength, and HEP (5x/wk)</td>
<td>74% (10)</td>
<td>86% (6)</td>
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<td>Cloak 2013</td>
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<td>Semi-professional footballers: 1) history of &gt;1 LAS within past 2 years 2) recurrent feelings of giving way 3) CAIT &gt;23.</td>
<td>Balance Training: 6 wk (12 sessions) supervised wobble board (W) or wobble board (WV) with vibration . Difficulty modified by researcher</td>
<td>(W):78% (2)</td>
<td>(W):79% (2)</td>
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<td>Wheeler 2013</td>
<td>RM</td>
<td>22</td>
<td>Physically active individuals: 1) history of &gt;1 ankle sprain 2) recurrent episodes of ankle instability 3) &gt;85% on FAAM or &gt;3 on AII, 4) lacking &gt;5dg DF difference</td>
<td>Fibular Repositioning Tape: 1) baseline testing 2) immediate allocation tape vs. no tape 3) followed by intervention 4) immediate post-intervention testing. 5) 24 hr rest period then receive other treatment.</td>
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Key: RCT-Randomized Control Trial; RM-Repeated Measure; LAS-Lateral Ankle Sprain; SEBT-Star Excursion Balance Test; SLS-Single Leg Stance; FADI-Functional Ankle Disability Index; CAIT-Cumberland Ankle Instability Tool; FAAM-Foot and Ankle Ability Measure; AII-Ankle Instability Instrument; DF-Dorsflexion;
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<th>PEDro Criteria</th>
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<td>171.6 (12.4)</td>
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Figure 1. Consort

Records identified through database searching (n= 339)

Excluded based on relevancy of title and abstract. (n=286)

Records Screened (n=53)

Excluded: Non-experimental studies. (n=18)

Potentially relevant trials (n=35)

Excluded: Studies did not include the SEBT outcome. (n=25)

Potentially relevant trials...

Excluded: Statistics without clear means or standard deviations; did not include the posterolateral direction of the SEBT; different taping method. (n= 4)

Studies included in Quantitative Synthesis, Meta-Analysis (n=6)
Figure 2. Pooled forest plot for posterolateral reach on SEBT

Figure 3. Athlete forest plot for posterolateral reach on SEBT
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Date