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**THE EFFICACY OF NON-SURGICAL INTERVENTIONS IN THE TREATMENT AND  
PREVENTION OF ANKLE SPRAINS AND INSTABILITY: A REVIEW OF THE  
LITERATURE**

**A MASTER'S (Capstone Project)  
SUBMITTED TO THE GRADUATE FACULTY  
OF THE GRADUATE SCHOOL  
BETHEL UNIVERSITY**

**BY  
KYLE Z. PELZER**

**IN PARTIAL FULFILLMENT OF THE REQUIREMENTS  
FOR THE DEGREE OF  
MASTER OF ARTS IN ATHLETIC TRAINING LEADERSHIP**

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THE EFFICACY OF NON-SURGICAL INTERVENTIONS IN THE TREATMENT AND  
PREVENTION OF ANKLE SPRAINS AND INSTABILITY: A REVIEW OF THE  
LITERATURE

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### Abstract for Critical Review of Literature

**Background:** Ankle sprains are a common injury among the high school-aged athletic population. With recurrent ankle sprains leading to chronic ankle instability (CAI), additional research is needed to determine the efficacy of non-surgical interventions for the high school-aged athletic population.

**Purpose:** The purpose of this critical review of literature is to determine the efficacy of proprioception training and/or ankle bracing in the treatment of ankle sprains and the prevention of CAI.

**Methods/Results:** 20 research articles were selected for review. The included topics are proprioception training and the use of an ankle bracing in regard to the non-surgical treatment of ankle sprains and CAI. The literature indicates results that support the use of a proprioception training program and the use of an ankle brace/tape in combination for the prevention of recurrent ankle sprains and the development of CAI.

**Conclusion:** A review of the literature indicates the use of proprioception training and ankle bracing are both effective in lessening the incidence of ankle sprains and CAI. While there is adequate research in each of these interventions, more research is needed to include high school-aged athletes as well as specificity in proprioception programs and ankle bracing/taping. Research supports the continued use of proprioception training and ankle bracing or taping following an ankle sprain to lessen the incidence of recurrent ankle sprains and CAI.

**Implications for Athletic Training:** Athletic trainers in the secondary setting can support the use of quality prevention measures that will affect the lives of student-athletes. Evidence-based practice can be demonstrated by utilizing an ankle brace as an effective prevention measure

following an ankle sprain and implementing a proprioception training program in the reduction of ankle sprains and the development of CAI.

**Keywords:** Ankle sprain, chronic ankle instability, proprioception, ankle brace, and ankle tape

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## Chapter One: Introduction

Ankle sprains and chronic ankle instability are musculoskeletal conditions that are present in nearly every sport and activity. With lateral ankle sprains (LAS) being the most common injury sustained in sports activities, there is certainly a need to evaluate the many interventions that could potentially lower the incidence of ankle sprains and CAI (Cho & Park, 2019).

Tsikopoulos et al. (2018) describe chronic ankle instability as an “encompassing term used to describe ongoing ‘giving-way’ episodes in the affected ankle, as well as physical and subjective functional limitations” (p. 873). Due to the chronic nature of ankle instability being partially exacerbated by subsequent ankle sprains, looking at interventions in the high school athletic population is vital. Preventing ankle sprains and consequently chronic ankle instability will certainly affect those individuals later in life.

The importance of research in the high school-aged athletic population for any joint instability is to determine the effectiveness of prevention and treatment methods. The prevention and treatment methods utilized will later impact the performance and overall health of the individual whether they continue to participate in athletic activities or not. For healthcare professionals, there is a significant responsibility to provide the best care for the youth population, especially considering those who sustain injuries at a younger age may not fully understand the possible consequences of not properly caring for an injury. There is a critical need for athletic trainers to educate student-athletes regarding how their injuries will affect their daily lives in the short term, and most significantly the long term. This is also an opportunity to demonstrate the need for leadership in secondary athletic trainers to provide the best care available to youth athletics.

## **Statement of Purpose**

Tsikopoulos et al. (2018) point out that there is up to an 80% recurrence rate for LAS for those in high-risk sports and 32-74% of those LAS patients develop chronic ankle instability. The purpose of researching this topic is to determine the effectiveness of interventions that may lessen the incidence of ankle sprains and instability. As stated in the previous section, there is a need for early intervention to prevent future ankle injuries and the development of CAI, which overall can compromise the patient's athletic career as well as their quality of life going forward. Early intervention and prevention of ankle ailments in the youth population will be the clinical focus by which athletic trainers can provide a high level of evidence-based care.

For student-athletes in the high school population with chronic ankle instability, does proprioception or bracing lessen the incidence of ankle sprains and instability for those involved in a sport? To answer this question, research literature was evaluated to determine the effectiveness of both proprioception training and ankle bracing/taping in preventing ankle sprains and ankle instability. Using a literature review, research was used to determine the answer to the previously stated clinical question to provide athletic trainers and other healthcare professionals with knowledge that can be used to properly care for individuals who have sustained ankle sprains or have developed CAI.

## **Need for Review**

While the importance of preventing ankle sprains and ankle instability may be obvious, the most effective treatment or rehabilitation for these conditions may not be. In the National Athletic Training Association's (NATA) position statement on the management and prevention of ankle sprains, it is indicated that athletic trainers should treat ankles sprains through the use of

nonsteroidal anti-inflammatory medications, functional rehabilitation, and proprioception training (Kaminski et al., 2013). Considering that evidence-based care is ever-changing, it is crucial to gather relevant and current research that either supports the latest recommendations or advises changes to the current treatment of ankle sprains and CAI.

Athletic trainers are the driving force to care for the young athletic population. Athletic trainers typically work closely with student-athletes when an injury occurs and manage the subsequent treatment and rehabilitation. The significance of research in this area is for athletic trainers to better understand the best methods to prevent an injury such as an ankle sprain from occurring. If such an injury does occur, the athletic trainer should provide up-to-date, evidence-based practice methods to treat the injury and safely bring the individual back to their sport to prevent future injuries. With student-athletes being particularly vulnerable, leaders in the secondary school athletic training setting have an opportunity to advocate for the well-being of their student-athletes by providing the best available care and by developing preventative habits before conditions such as chronic ankle instability can occur.

Tsikopoulos et al. (2018) explain that there is currently no consensus of the most effective method to improve proprioception. Regarding another intervention, Raymond et al. (2012) concluded that there is no significant effect on proprioception acuity in patients who use an ankle brace or tape when compared to no ankle brace or tape. Given these findings, it suggests that there is a lack of consensus on how to properly administer interventions that are proven to reduce the incidence of ankle sprains and consequently ankle instability. This topic has a wide array of research that needs to be analyzed to determine if proprioception and/or using an ankle brace/tape should continue to be used as effective forms of rehabilitation and/or prevention

measures. Once this has been determined, it will be important for athletic trainers to understand if these interventions are the most effective ways to manage a patient with an ankle sprain or instability. Furthermore, it will be important to establish additional research that should be performed either in proprioception and/or ankle bracing/taping.

### **Significance to Athletic Training**

There is a need for consensus among the athletic training profession in the care of ankle injuries, and in the case of treatment interventions there remains questions on how to care for ankle injuries most effectively. Although consensus on the treatment interventions of ankle sprains and instability may be undecided, there is adequate research to determine how effective proprioception and the use of ankle bracing/tape can be to conclude their reliability and value. This can give athletic trainers and other healthcare professionals the knowledge needed to make an evidence-based decision for their patients.

The need for research to lessen the incidence of any injury is crucial to moving the field of athletic training forward. Athletic trainers must recognize the need for making evidence-based decisions when providing care to their patients. This includes being able to interpret and utilize current research to answer clinical questions when needed. While many injuries or conditions should be reviewed regarding treatment interventions, ankle sprains and ankle instability are among the most common injuries as they are seen in virtually every sporting activity. Such an injury can ultimately affect a person's overall quality of life as they age and impact their ability to be active. Since a majority of student-athletes will not move on to collegiate level sports and even fewer will participate at a professional level, athletic trainers must do everything possible to

prevent an injury such as an ankle sprain and especially recurrent ankle sprains that can lead to chronic ankle instability.

## **Chapter Two: Methods**

This section will provide a review of the literature to determine if proprioception or bracing/taping can lessen the incidence of ankle sprains and instability. The chapter will review the parameters for the search strategies used to obtain the literature, a discussion of inclusion and exclusion criteria to narrow the literature. In addition, the number and type of studies for the literature, and the criteria for evaluating the studies will be included. This information can provide the basis for answering the clinical question listed in chapter one as well as specifying the parameters for other researchers to replicate the literature findings.

### **Search Strategies**

To obtain the appropriate literature for the prevention of ankle sprains and ankle instability using either proprioception or ankle bracing/taping, a search was performed using CINAHL, PubMed, SCOPUS, ScienceDirect Journals, and the Cochrane Database of Systematic Reviews. The keywords used were “ankle sprain”, “ankle instability”, “chronic ankle instability”, “proprioception”, “balance training”, “bracing”, and “ankle brace.” Limiters used in the literature search were studies within 10 years for all, except for two articles within 20 years. Some searches were limited to subjects in a high school athletic population. The range of literature publication dates was from 2003 to 2019.

### **Inclusion and Exclusion Criteria**

A majority of studies included in the review of the literature were those that focused on ankle sprains and chronic ankle instability with interventions of proprioception and/or ankle bracing. Additional terms were accepted for the proprioception intervention, which included the

terms neuromuscular and balance training. Articles that used bracing as an intervention included both semi-rigid ankle braces and ankle taping. The broader spectrum of intervention inclusion was due to a similarity between different terms (e.g. neuromuscular training and balance training) and comparable interventions (e.g. ankle brace and ankle tape). Due to a lack of studies that focused specifically on subjects in contact sports with ankle instability, all sports and activities were included. Studies that included used cadavers to obtain outcome measures were excluded from the literature review. In addition, to maintain relevance to the current ankle sprain and ankle instability treatments, a majority of the included studies were within 10 years on the date of publication, with the exception of two research articles that were included due to large populations of adolescent subjects that were specific to the clinical question.

### **Number and Type of Studies**

Several different types of studies were found during the search including: randomized control trials (RCT), systematic reviews/meta-analysis, cohort studies, case-control studies, and cross-sectional studies. Using a literature matrix, a total of 20 articles were obtained and reviewed. Of the 20 articles found, there were seven RCTs, eight systematic reviews/meta-analysis, two cohort studies, one case-control study, and two cross-sectional studies. The subjects included in the search ranged in age from 15-70 years, however, most studies reported a mean age of approximately 20 years old. There were a varying number of subjects for each study with as little as 14 subjects in a randomized control trial and as many as 7195 subjects in a systematic review.

## Criteria for Evaluation of Studies

Using the hierarchy of evidence for intervention studies, each study can be categorized based on the type of study, with level I being the highest (Fineout-Overholt et al., 2010). The seven RCT studies were considered level II, the eight systematic reviews were of level I, the two cohort studies and one case-control study were valued at level IV, and the two cross-sectional studies were considered level VI. Each of the 20 studies was reviewed using the PEDro scale for RCTs (The George Institute for Global Health, n.d.), The Foundations of Evidence Critical Appraisal for systematic reviews/meta-analysis, the Quality Assessment of Diagnostic Accuracy Studies for diagnostic research (QUADAS), and the Critical Appraisal Skills Program for prognostic research (CASP) (Raab and Craig, 2016). The evaluation tools were used to determine the methodological quality of each study, specifically those that contain high-quality evidence to support the research question. Each critical appraisal criteria scales can be seen in Appendices B-E.

While all of the studies have an emphasis on ankle sprains and ankle instability, several were focused on proprioception alone, ankle bracing alone, or a combination of the two interventions. Eight of the studies evaluated if proprioception training is effective in reducing ankle sprains and ankle instability, while five studies determined the effectiveness of ankle bracing in lessening ankle sprains and instability. In addition, four studies compared both proprioception training and ankle bracing used alone or together. In each study, there were various measures used to determine the outcome measures, which includes: an isokinetic dynamometer for joint position sense, the Romberg's test and Star Excursion Balance Test



(SEBT) for postural control, and the hop test and Foot and Ankle Ability Measure (FAAM) for functional control.

A review of the literature reveals several strengths and weaknesses within each study. Weaknesses were reported for studies with small sample sizes, those that did not specify the type of proprioception intervention provided in the clinical trial, and studies that did not specify the year(s) data was collected. Strengths for these studies included those with a large sample size, a detailed review of the interventions and results from the trial, objective measurements to determine outcome measures, and a comprehensive literature review. In addition, the eight systematic reviews have evaluated a large number of subjects, and each includes reliable results and high-quality conclusions.

## **Summary**

Multiple databases were searched for a literature review to answer the following question: For student-athletes in the high school population with chronic ankle instability, does proprioception or bracing lessen the incidence of ankle sprains and instability for those involved in a contact sport? A review of each study will reveal the effectiveness of each intervention and an analysis can be formulated to determine the best evidence-based treatment available to prevent and treat ankle sprains and ankle instability.

### **Chapter Three: Literature Review and Analysis**

The purpose of chapter three is to present the significant and meaningful findings of the literature review that were utilized to answer the aforementioned research question. The research literature was organized in a literature review matrix and categorized by research that is deemed high-quality, moderate-quality, and low-quality based on various assessment tools. This chapter will include reviewing the synthesis of the matrix, a synthesis of the major findings, strengths, and weaknesses of the studies, and finally a summary of the chapter.

#### **Synthesis of Matrix**

The matrix, which can be observed in Appendix A, was chosen for a review of the literature and is based on the Bethel University graduate template. This matrix was selected after evaluating and utilizing three different style matrix designs. The final matrix was chosen based on its simple layout design and relative ease of use when compared with other matrix designs. The matrix is listed by source so that all of the literature can be easily identified by the author as well as for the reader to further investigate. The matrix is then split into four columns, which include: design methodology/purpose, sample/setting, design instruments, and results. Each of these columns provides concise information on the selected literature that will be used to answer the research question. At the bottom section of each article matrix, there is a recommendation that represents meaningful information from the study's findings.

There is a total of 20 research studies that are included in the literature review matrix and each will be incorporated into the synthesis of the major findings. There are eight systematic review studies, of which five are also a meta-analysis, seven randomized control trials (RCT), two cohort studies, two cross-sectional studies, and one case-control study.

## **Synthesis of Major Findings**

To review, the research question being considered for this critical review is as follows: For student-athletes in the high school population with chronic ankle instability, does proprioception or bracing lessen the incidence of ankle sprains and instability for those involved in a sport? Many of the research articles had compelling results, however, the quality of the research should be examined to determine if the findings can be considered reliable evidence-based research. In addition, the research may lack aspects that make it credible enough to consider the findings. The following results are separated by high-quality, moderate-quality, and low-quality evidence. The research that was deemed high-quality had a PEDro score of seven or higher out of ten, a Foundations of Evidence Critical Appraisal score of four out of four, a QUADAS score of 10 or higher out of 14, or a CASP score of nine or higher out of 12. The moderate-quality research had a PEDro score of four to six, a Foundations of Evidence Critical Appraisal score of two to three, a QUADAS score of six to nine, or a CASP score of five to eight. Lastly, the low-quality research had a PEDro score of three or less, a Foundations of Evidence Critical Appraisal score of one or less, a QUADAS score of five or less, or a CASP score of four or less.

### **High-Quality Evidence**

In a prospective study, Cho, and Park (2019) reviewed 35 male and female subjects, ages 20-42, who were scheduled for the Brostrom procedure and were tested for factors contributing to functional ankle instability (FAI). Cho and Park (2019) tested the subjects for the following: joint position sense and peroneal strength using an isokinetic dynamometer, postural control using a modified Romberg's test, and functional performance using a 1-leg hop test, a 6-meter

hop test, and cross 3-m hop test. From these evaluations, it was determined that a majority of the tests indicated the side-to-side movement of the ankle joint when compared to the unaffected ankle (Cho and Park, 2019). Besides peroneal strength and postural control stability, all other components were correlated with FAI. These aspects of ankle instability are important to consider as they are the area of focus with the proposed treatments of proprioception and ankle bracing. Using the QUADAS assessment, this study scored a 10 out of 14 to be considered high-quality.

In a systematic review and meta-analysis, eight studies were reviewed with 152 males and females, ages 17-35, who have sprained an ankle at least once or have CAI. The goal of this study was to determine the effect of an ankle brace or taping the ankle, compared to no brace or tape (Raymond et al., 2012). The results were separated into either functional ankle instability or mechanical ankle instability subgroups (Raymond et al., 2012). It was determined that there is no significant effect on proprioceptive acuity regarding joint position sense and passive movement detection when using an ankle brace or tape in patients with recurrent ankle sprains or CAI (Raymond et al., 2012). These findings suggest that proprioceptive acuity is not affected by the use of an ankle brace or tape, however, the use of an ankle brace or tape should not be discouraged because of this finding. This systematic review was given a score of four out of four on the Foundations of Evidence Critical Appraisal questionnaire.

A systematic review and meta-analysis of 19 different studies reviewed 547 subjects, aged 16-33, to determine the effectiveness of non-surgical techniques in the improvement of dynamic postural control in patients with chronic ankle instability by using the STAR excursion balance test (Tsikopoulos et al., 2018). The review found that a 4-6-week proprioception

training program and strengthening program both saw improvement in dynamic postural control when compared to the control groups (Tsikopoulos, et al., 2018). The review found that eight studies resulted in a standard mean difference (SMD) of -.75, 95% with confidence intervals (CI) of -1.28 to -0.23 for the proprioception training and two studies with an SMD of -1.2, 95% with CIs of -2.36 to -0.08 (Tsikopoulos, et al., 2018). The results indicate that the use of both a proprioception training program and a strength training program can improve the dynamic postural control of patients with CAI. This systematic review was given a score of four out of four on the Foundations of Evidence Critical Appraisal questionnaire.

A systematic review and meta-analysis evaluated the effectiveness of proprioception compared to bracing in reducing the recurrence rate in subjects with CAI by reviewing three different studies (Burger et al., 2018). The study examined groups of 220, 40, and 34 subjects for each study with proprioception and bracing groups who used similar proprioception training and the use of a semi-rigid orthosis during sporting activities (Burger et al., 2018). The results of the study showed that evidence does not suggest the use of proprioception training over bracing with the indication for the use of both proprioception and bracing rather than proprioception alone in patients with CAI (Burger et al., 2018). The conclusion of this study provides evidence that proprioception training alone may not be enough to prevent recurrent ankle sprains versus the use of both proprioception training and the use of an ankle brace. With the use of the Foundations of Evidence Critical Appraisal, this systematic review was given a score of four out of four. The three articles included range from four out of 10 to seven out of 10 on the PEDro scale.

In a retrospective cross-sectional study, 81 subjects with CAI and 42 uninjured control subjects were tested to determine impairments in the Hertel model of CAI (Hiller et al., 2011). The subjects were tested using balance testing with foot lift, single-leg balance, and motor control after perturbation to determine if the subjects fit the data for the current Hertel model. The current Hertel model includes the subgroups of mechanical instability and functional instability whereas the proposed Hertel model would include recurrent ankle sprains for a combination of the prior two subgroups (Hiller, et al., 2011). Outcomes were based on the subject's Cumberland Ankle Instability Tool score, anterior drawer test results, and the total number of sprains. This resulted in 56.5% of ankles fitting the current Hertel model and 100% of ankles fitting the proposed Hertel model (Hiller, et al., 2011). With data supporting the modified Hertel model for CAI, there is an indication to use the updated model to properly classify patients and address current ankle deficits. Using the CASP assessment, this study rated nine out of 12 to be considered high-quality.

In a RCT, 186 subjects with severe (Grade III) lateral ankle sprains, ages 15-65 years old were included to determine functional impairments and the incidence of residual ankle instability following conservative treatment of an initial lateral ankle sprain (Prado et al., 2014). The subjects were randomly placed in one of two groups, with one group using a walking boot, ice, elevation, and joint mobilization for three weeks, while the second group had the subjects wear a functional brace for three weeks (Prado et al., 2014). The subjects were tested using a visual analog scale for pain, general clinical status, AOFAS (American Orthopaedic Foot and Ankle Society) score, and an anterior drawer stress x-ray (Prado et al., 2014). The results indicated that patients treated with a functional ankle brace alone for three weeks resulted in a better outcome than those that were treated with a walking boot, ice, elevation, and joint mobilization for three

weeks before application of a functional ankle brace (Prado et al., 2014). The results of this RCT indicate a progressive course of treatment using a functional ankle brace versus conservative treatment using a walking boot for patients with an initial ankle sprain. This study was awarded a nine out of 10 on the PEDro scale with the only missing finding being no blinding to the subjects due to different treatments.

In a systematic review and meta-analysis, seven RCTs, with a total of 3725 subjects, determined the effectiveness of proprioception training in reducing the incidence of ankle sprains in athletes when compared to other common treatments (Schiftan, et al., 2015). The review determined the effectiveness of proprioception, which concluded that proprioception training was effective at reducing the incidence of ankle sprains compared to other interventions in subjects with a history of ankle sprains as well as subjects no history of ankle sprains (Schiftan et al., 2015). While the evidence supports proprioception training in reducing the incidence in patients with a history of ankle sprains, more research is needed to determine the effectiveness of proprioception in patients with no history of ankle sprains. Using the Foundations of Evidence Critical Appraisal, this systematic review was given a score of four out of four with moderate to high-quality studies included in the review.

Bellows and Wong (2018) reviewed eight different RCTs to determine the effectiveness of balance training and bracing in the reduction of ankle sprains in athletes with and without prior ankle injury. The systematic review and meta-analysis included a total of 7195 athletes ranging from high school to professional sports with 3581 subjects in the bracing studies and 3577 subjects in the balance training studies (Bellows and Wong, 2018). The incidence of ankle sprains and relative risk was used to determine the effectiveness of balance training compared to the bracing groups and the control groups (Bellows and Wong, 2018). The bracing studies

resulted in a 64% reduced risk of ankle sprains compared to the control groups, while the balance training studies resulted in a 46% reduced risk of ankle sprains when compared to the control groups (Bellows and Wong, 2018). This review concludes that both balance training and bracing are effective in reducing the risk of ankle sprains, although it did not determine if one or both are the most effective forms of interventions. This systematic review was given a four out of four using the Foundations of Evidence Critical Appraisal with moderate to high-quality studies in the review based on the PEDro scale.

In a RCT, 384 total subjects were included to determine the effectiveness of bracing and proprioception training, alone and together for the prevention of recurrent ankle sprains. Subjects were randomized into either a proprioception training group, a bracing group, or a combination of the two with a one-year follow-up (Janssen et al., 2014). The outcome measure was determined by the subject's self-reported rate of recurrent ankle sprain (Janssen et al., 2014). After a one-year follow-up, 20% of all subjects reported recurrent ankle sprains, including 27% of the proprioception training group, 15% of the brace group, and 19% of the combination group (Janssen et al., 2014). This resulted in a relative risk of 0.53 with 95% CI (0.29 to 0.97) (Janssen et al., 2014). This study indicates that the use of a brace after an ankle sprain is more effective in decreasing the rate of recurrence, although not in self-reported severity. This study was appraised using the PEDro scale for a score of seven out of 10. There was no blinding to the subjects, therapists, or assessors due to awareness of the subjects belonging to either the proprioception, bracing, or combination groups.

Swiontkowski (2011) reviewed eight RCTs to determine the effectiveness of bracing versus other functional treatments. The review included 1250 total subjects with 358 using an ankle brace and an unidentified number of other functional prevention methods such as an air



cast or Tubigrip compression sleeve (Swiontkowski, 2011). The results were determined by the outcome of recurrent ankle sprains, reported symptoms, and outcome in return to work/sports (Swiontkowski, 2011). The study concluded that ankle braces are the most effective form of functional treatment compared to other functional treatments, although more research is needed to determine the most effective type of brace (Swiontkowski, 2011). The Foundations of Evidence Appraisal was used to obtain a score of 4 out of 4 with the consideration that 7 out of 8 articles in the review were considered high quality based on the PEDro scale.

### **Moderate Quality Evidence**

A cohort study reviewing proprioception in patients with unilateral ankle instability, examined 44 males and females, with a mean age of 21.8 in patients with an ankle sprain and CAI (Sousa et al., 2017). The study used an isokinetic dynamometer to evaluate the patient's active and passive ankle joint position sense, kinesthesia, and force sense (Sousa et al., 2017). The results of the study indicated an increased error in patients with inversion-movement detection and bilateral evertor force sense (Sousa et al., 2017). Because of these findings, poor ipsilateral inversion movement detection and bilateral evertor force sense may contribute to further injury due to proprioceptive errors. These results are meaningful for the justification of administering proprioception training for a patient with either an ankle sprain or CAI. This cohort study was given a score of nine out of 14 on the QUADAS assessment to be considered moderate-quality.

A secondary analysis of an RCT was done by Wikstrom and Mckeon (2017) to research the predictors of successful postural control training for patients with chronic ankle instability. The RCT consisted of 59 subjects, male and female, with a mean age of 22 and

subjects randomized into either a plantar massage group, an ankle joint mobilization group or a calf stretching group (Wikstrom and Mckeon, 2017) The subjects were treated with six, two-minute treatment sessions over the course of two weeks and tested using a clinician-oriented single-leg balance test (Wikstrom and Mckeon, 2017). The results of the study indicate that subjects with  $\geq 3$  errors on the single-leg balance test, had a 73% probability of improvement in proprioception in the ankle joint mobilization group (Wikstrom and Mckeon, 2017). Subjects with  $\geq 11$  ankle sprains had a 94% probability of treatment success in the calf stretching group (Wikstrom and Mckeon, 2017). The results of this study demonstrate treatment success predictors for patients with ankle sprains and CAI, which could be incorporated into the treatment plan for a proprioception training program. Based on the PEDro scale, this study was given a five out of 10 to be considered moderate-quality.

A single-blinded RCT reviewed the effects of a progressive hopto-stabilization balance (PHSB) program compared to a single leg balance (SLB) program (Anguish and Sandrey, 2018). In the study, 18 subjects aged  $18.38 \pm 1.81$  years, were randomly assigned to either the PHSB or SLB program for two weeks (Anguish and Sandrey, 2018). The subjects were tested using the foot and ankle ability measure (FAAM) activities of daily living subscale, FAAM-Sports subscale, the star excursion balance test, and weight-bearing joint position sense (JPS) blocks (Anguish and Sandrey, 2018). Improvements were seen in FAAM-ADL and FAAM-Sports for both groups, however, there was no clinically important difference made (Anguish and Sandrey, 2018). Each group equally improved scores of dynamic postural control and JPS (Anguish and Sandrey, 2018). Given these results, the PHSB and SLB groups saw similar improvements and should be considered in addressing proprioception in subjects with an ankle

sprain or CAI. Using the PEDro scale, this study was given a six out of 10 to be considered moderate-quality.

A case-control study reviewed 24 subjects with CAI and 20 uninjured subjects to evaluate compensatory postural responses using a unilateral simulated ankle-sprain mechanism (Sousa et al., 2018). The study used bilateral electromyography of agonist muscle activity during a unilateral sudden inversion perturbation to determine muscle onset activations of short-latency responses (SLRs) and medium latency responses (MLRs) (Sousa et al., 2018). The results revealed that subjects with CAI had a later-onset of tibialis anterior (TA) and soleus activation in their uninjured ankle and decreased bilateral TA MLR in a supported position (Sousa et al., 2018). The bilateral limitations and deficits for patients with CAI express a need for bilateral ankle rehabilitation to address the proposed deficits in the uninjured ankle for subjects with CAI. This study was given the QUADAS score of six out of 14 to be considered moderate-quality.

Dizon and Reyes (2010) reviewed 4723 total subjects in a systematic review of seven different trials to determine the effectiveness of various external ankle supports in the prevention of inversion ankle sprains. The review included those with ankle sprains and control subjects, which included a mix of adolescents and adults involved in recreational and competitive athletic activities (Dizon and Reyes, 2010). The outcomes were determined by the incidence of ankle sprains in subjects who were previously injured and uninjured (Dizon and Reyes, 2010). The results indicate a reduction in ankle sprains by 69% in those using an ankle brace and 71% in those using ankle tape, with no conclusive evidence determining a superior type of brace/tape

(Dizon and Reyes, 2010). Using the Foundations of Evidence Critical Appraisal, this study was given a three out of four with moderate-quality studies included in the review.

An RCT evaluated a total of 382 subjects with an ankle sprain two months prior to the study to determine the effect of combining ankle braces and neuromuscular training compared to the individual use of either ankle braces or neuromuscular training alone in the prevention of ankle sprains (Janssen et al., 2012). The subjects were given a monthly questionnaire to determine the incidence of ankle sprains after the interventions (Janssen et al., 2012). The results from the questionnaire indicated that bracing is at least equal to neuromuscular training and may be superior (Janssen et al., 2012). Bracing is a cost-effective form of ankle sprain and CAI prevention (Janssen et al., 2012). The PEDro scale was used to rate this study six out of 10 with the finding of no blinding of subjects due to different tests being used for each group.

In a RCT, McGuine and Keene (2006) determined the effectiveness of a balance training program in reducing the risk of ankle sprains with 765 high school athletes. The subjects were randomized into either an intervention group that involved balance training or a control group with only standard conditioning exercises (McGuine and Keene, 2006). The outcome measure was determined using an ankle sprain rate when comparing the intervention group to the control group (McGuine and Keene, 2006). The results indicate the rate of ankle sprains for the injured intervention group was 6.1 versus 9.1 for the injured control group and the rate of sprains for the uninjured intervention group was 4.3 versus 7.7 in the uninjured control group (McGuine and Keene, 2006). The evidence indicates a reduction of ankle sprains by 38% for subjects with previous ankle injuries, however, more research is needed to determine if a balance training program can produce a significant reduction in ankle sprains (McGuine and Keene, 2006). With

a score of six out of 10 on the PEDro scale, this RCT was considered moderate-quality. In this study, there was no blinding of subjects, the therapists, or assessors due to different interventions as well as no concealment for allocation.

A RCT studied 31 male and female subjects with 16 subjects in the balance training group with a mean age of  $22.2 \pm 4.5$  and 15 subjects in the control group with a mean age of  $19.6 \pm 1.3$  (Mettler et al., 2015). This study determined the effectiveness of a four-week balance-training program and its effects on the spatial locations of the center of pressure (COP) data points in subjects with CAI (Mettler et al., 2015). The subjects were tested using COP data collected with an AccuSway force platform (Mettler et al., 2015). The COP data indicated the movement of COP from anterolateral to posterolateral, which may result in a better functioning sensorimotor system (Mettler et al., 2015). The results of this study indicate that balance training may be beneficial to improving JPS. This study was given four out of 10 on the PEDro scale with the major finding being that the research did not contain eligibility criteria.

### **Low-Quality Evidence**

In a systematic review, ten RCTs with a total of 388 subjects were included to compare neuromuscular control and surgical intervention for subjects with CAI (Vries et al., 2003). The subjects were tested using the ankle joint functional assessment tool and the foot and ankle disability index (Vries, 2003). The results indicated that neuromuscular training versus no training resulted in better ankle function after four weeks of intervention, however, there was insufficient evidence to support one surgical intervention over another (Vries, 2003). Based on these results, a longer-term follow-up is needed to determine the effectiveness of neuromuscular control, however, four weeks of neuromuscular training was effective. After an evaluation using

the Foundations of Evidence Critical Appraisal, this study was given a one out of four with moderate to high bias, placing this study in the low-quality consideration.

In a cross-sectional study, 14 male subjects with CAI and a mean age of  $21.1 \pm 2.5$  were evaluated to determine the effectiveness of a semi-rigid brace or taping of the ankle during weight-bearing kinematics and ankle internal rotation in plantar flexion (Kobayashi et al., 2014). The subjects were tested using single weight-bearing fluoroscopy and computed tomography (CT) scans to evaluate ankle kinematics (Kobayashi et al., 2014). The results indicate that the application of a semi-rigid brace or taping had limited effects on anterior translation and internal rotation (Kobayashi et al., 2014). The results of this study may be useful to improve brace design and taping techniques to prevent recurrent ankle sprains. The CASP appraisal was used to appraise this research for a score of four out of 12.

### **Strengths and Weaknesses**

Reviewing the strengths and weaknesses of the literature is important to understand how strong the evidence can be at determining an evidence-based answer to the research question. Many of the strengths in the literature lie unmistakably in the quality research section, while a majority of the weaknesses are likely to be found in the low-quality section. A mixed variety of strengths and weaknesses were found in the moderate quality section, which included moderate to high bias, small subject size, or a lack of blinding in the studies.

A common strength value presented in the high-quality research was large sample groups, especially with the systematic reviews. Two examples were the research by Schiffan et al. (2015), which included 3725 subjects and the research by Bellows and Wong (2018), which included 7195 subjects. Another strength in the research is the large portion of systematic

reviews that were considered high-quality with this type of research reviewing a wide array of RCTs.

Conversely, the weakness presented in the research included many subject populations that were outside of the desired population for the original research question. Additionally, the research does not include a standard proprioception program to be used across all studies as well as a specific ankle support or tape. These weaknesses may not allow for an accurate interpretation of the results if there is not a standard treatment between various studies.

### **Summary**

A review of the previous literature has provided the results needed to obtain a reasonable justification for the answer to the research question. Having categorized the results and considered its strengths and weaknesses, this section will contribute to the discussion that follows regarding the research implications.

## **Chapter Four: Discussion, Implications, and Conclusions**

This fourth and final chapter will include a synthesis of the literature from the previous chapter, which will provide the gaps and trends in the literature. This chapter will finish by evaluating the implications in the practice of athletic training and recommendations for further research. This section will then conclude with a definitive answer to the following research question. For student-athletes in the high school population with chronic ankle instability, does proprioception or bracing lessen the incidence of ankle sprains and instability for those involved in a sport?

### **Literature Synthesis**

The research that was presented in chapter three provides evidence that will contribute to a comprehensive interpretation of whether proprioception and/or bracing can lessen the incidence of ankle sprains and instability. Of the 20 research articles reviewed, seven articles included a focus on proprioception and/or balance training, while five articles included a focus on only bracing and/or taping. Additionally, of the 20 research articles, four articles compared both proprioception and/or balance training to bracing and/or taping in their effectiveness to lessen the incidence of an ankle sprain and/or CAI.

Evaluating the quality of the research was necessary to determine if the results have a high level of reliability or if results should be used with caution if the quality of the research is considered low. Of the 20 research articles, 10 were considered high-quality using the foundations of evidence critical appraisal questions for systematic reviews and meta-analysis research, the PEDro scale for RCTs, and the QUADAS scale for diagnostic studies. While half of the included studies are considered high-quality, only four of the high-quality studies included



subjects that were of a high school-aged population (between 14-18 years old). The majority of the remaining studies included a high school-aged population, however, many studies did not provide age-specific results to interpret the results based on age.

Regarding the research findings that focused exclusively on proprioception training as an intervention, five out of seven research articles supported the use of a proprioception program. Two articles had mixed results, which reported evidence supporting the use of proprioception training in reducing ankle sprains in the subjects with a history of ankle sprains. Both articles determined that more research is needed to determine the effectiveness of proprioception training in subjects with no prior history of an ankle sprain. Additional research may include analyzing proprioceptive acuity in subjects before and after an initial ankle sprain.

Out of the five research articles that addressed the use of an ankle brace or tape, three supported the use as an effective prevention measure. Of the two research articles that did not support the use of an ankle brace, one indicated no significant effect on proprioceptive acuity while using an ankle brace or tape (Raymond et al., 2012). It was indicated in the second article that more research is needed to determine the effectiveness of joint kinematics in subjects with CAI (Kobayashi et al., 2014). It should be noted that with all of the included articles, none of the research discouraged the use of an ankle support. Additionally, there was not a consensus on the type of ankle brace or tape that is most effective.

When evaluating the four research studies that directly compared proprioception training to bracing, the results were mixed with bracing being at least equal in the reduction of ankle sprains as compared to proprioception training. Nevertheless, each article that compared both

interventions recommended the combination of both proprioception training along with the use of a brace/tape for patients following an ankle sprain or those with CAI.

### **Trends and Gaps**

One of the most common results among the research that included bracing was evidence to support the use of an ankle brace. This included seven of the nine in favor of ankle bracing as an effective prevention measure for the reduction of ankle sprains and/or CAI. Out of 11 research articles that included proprioception, nine supported the use of proprioception as an effective treatment in reducing ankle sprains and/or CAI. The research that compared both proprioception and ankle braces/tape supported the use of both a proprioception training program with the use of an ankle brace/tape, while two out of the four articles noted that bracing is equal if not more effective than proprioception.

The largest gap seen in the research is the lack of studies that include high school-aged subjects aged 14-18. The research does contain studies in which the subjects of the high school-aged population are included in the data, but the author(s) did not provide age-specific results to make conclusions for that population. There are limitations in research when involving a high school-aged population, including: obtaining parent/guardian consent, providing widely known ineffective treatments or no treatment at all in a control group, and the vulnerability of subjects under 18 years of age.

Another gap in the research is the lack of a standard proprioception program as well as a standard specific brand or type of ankle brace/tape. This would provide more reliability and specificity to the results that will allow for broader evidence-based comparisons across multiple research studies. Additionally, there was a lack of quality research that compared both

proprioception training and ankle bracing in the same study, which was the specific focus for the research question examined in this literature review.

### **Athletic Training Implications**

Considering the overall body of research found for this literature review, there is strong evidence to support the use of an ankle brace or ankle tape following an ankle sprain for the continued prevention of recurrent ankle sprains and thus the development of CAI. Proprioception was overall considered equal or slightly less effective than an ankle brace, however, all research that compared both treatments concluded concurrent use of a proprioception training program and ankle brace as the most effective. One of the best high-quality studies demonstrating this was a systematic review and meta-analysis with 7195 athletes, in which it was determined that bracing resulted in a 64% reduced risk of ankle sprains compared to the control group and balance training resulted in a 46% reduced risk of ankle sprains when compared to the control group (Bellows and Wong, 2018).

Given the research findings in this literature review, it can be reasonably concluded that the use of an ankle brace is very effective, and a proprioception training program is nearly as effective in the reduction of ankle sprains and the development of CAI. Since secondary high school athletic trainers care for athletes in one of their most vulnerable states, there must be a standard of care for effective, evidence-based treatment for ankle injuries. There is a need for leadership among athletic trainers to support quality prevention measures that will ultimately affect the lives of student-athletes in the future regardless of athletic ability as many high school student-athletes will not go on to compete competitively in college or professionally. The current evidence-based research on ankle sprains and CAI provides the tools for athletic trainers

to advocate for the health of their patients regardless of the stress placed on them by coaches, parents, and the student-athletes themselves.

### **Future Research Recommendations**

Further research is needed in many areas as there is a crucial shortage of research that focuses solely on the ankle proprioception and/or the use of an ankle brace in the high school population. Given that only two articles in this literature review focused solely on subjects of 18 years and younger, more research is needed to focus on younger populations. Additionally, further research is needed to include the use of a standard proprioception training program and specific type of ankle brace, in which each can be compared and contrasted across different research studies. Related to the research on proprioception and ankle braces, there are additional treatments that should be included and compared in these studies, which include: core and hip strengthening, gait training, or manual therapy treatments.

### **Conclusion**

Evidence-based research is the basis for athletic trainers to provide the utmost care for their patients that is proven by high-quality research. After thorough and deliberate review of the literature, the use of proprioception and an ankle brace are both deemed effective forms of treatment to lessen the incidence of ankle sprains and CAI. While more research is certainly needed, especially in the adolescent population of 14-18-year-old high school student-athletes, secondary school athletic trainers should continue the use of a combination of proprioception training and ankle bracing/taping following an ankle sprain.

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## Appendix A

## Evidence Synthesis Matrix

**Source:** Cho, B.-K., & Park, J.-K. (2019). Correlation Between Joint-Position Sense, Peroneal Strength, Postural Control, and Functional Performance Ability in Patients With Chronic Lateral Ankle Instability. *Foot & Ankle International*, 40(8), 961–968. doi: 10.1177/1071100719846114

Design Methodology/Purpose	Sample/Setting	Design Instruments	Results
Cohort study <b>Purpose:</b> To compare the difference of joint-position sense, peroneal strength, postural control, functional performance, and the correlation between each that contribute to functional ankle instability <b>Method:</b> Subjects tested for FAI by joint position sense and peroneal strength, postural control, and functional performance.	35 male and female subjects aged 20-42 who were scheduled for Brostrom procedure.  QUADAS Score of 10/14	Testing using isokinetic dynamometer, Romberg's test, 1-leg hop test, 6-meter hop test, and cross 3-m hop test.	The majority of examination tests indicate side-to-side ankle joint movement when compared to the unaffected ankle. Besides peroneal strength and postural control stability, the components were correlated to each other.
<b>Recommendations:</b> Strongly correlated components of FAI can be used to detect patients with FAI.			

**Source:** Raymond, J., Nicholson, L. L., Hiller, C. E., & Refshauge, K. M. (2012). The effect of ankle taping or bracing on proprioception in functional ankle instability: A systematic review and meta-analysis. *Journal of Science and Medicine in Sport*, 15(5), 386-392. doi:10.1016/j.jsams.2012.03.008

Design Methodology/Purpose	Sample/Setting	Design Instruments	Results
Systematic review and meta-analysis <b>Purpose:</b> To determine the effect of subjects wearing an ankle brace or taping the ankle, compared to no brace or tape in subjects with a history of ankle sprain or instability. <b>Method:</b> Joint position sense testing with and without ankle brace or tape.	152 males and females, ages 17-35. 2 subgroups for those with ankle instability (functional ankle instability and mechanical ankle instability)  Foundations of Evidence Critical Appraisal: 4/4	Joint position sense and passive movement detection.	There is no significant effect on proprioceptive acuity while using an ankle brace or tape
<b>Recommendations:</b> Proprioceptive acuity is not affected by the use of an ankle brace or tape in a patient with recurrent ankle sprains or CAI.			

**Source:** Sousa, A. S., Leite, J., Costa, B., & Santos, R. (2017). Bilateral Proprioceptive Evaluation in Individuals With Unilateral Chronic Ankle Instability. *Journal of Athletic Training*, 52(4), 360-367.

Design Methodology/Purpose	Sample/Setting	Design Instruments	Results
Cohort study <b>Purpose:</b> To research ankle proprioception in patients with unilateral ankle instability.	44 males and females, with a mean age of 21.8 in patients with a unilateral ankle sprain and CAI.	Isokinetic dynamometer	Increased error in patients with inversion-movement detection and bilateral evertor force sense.

<b>Method:</b> Active and passive ankle joint position sense, kinesthesia, and force sensing	QUADAS Score of 9/14		
<b>Recommendations:</b> Poor ipsilateral inversion movement detection and bilateral evertor force sense may contribute to further injury due to proprioceptive errors.			

<b>Source:</b> Tsikopoulos, K., Mavridis, D., Georgiannos, D., & Cain, M. S. (2018). Efficacy of non-surgical interventions on dynamic balance in patients with ankle instability: A network meta-analysis. <i>Journal of Science and Medicine in Sport</i> , 21(9), 873-879. doi:10.1016/j.jsams.2018.01.017			
<b>Design Methodology/Purpose</b>	<b>Sample/Setting</b>	<b>Design Instruments</b>	<b>Results</b>
Systematic review and meta-analysis of 19 trials <b>Purpose:</b> To research the effectiveness of non-surgical techniques in the improvement of dynamic postural control in patients with chronic ankle instability <b>Method:</b> Testing of dynamic postural control using the star-excursion balance test in the posteromedial direction at the end of a 4-6 week rehab protocol and 6 months follow up	547 subjects, male and female, aged 16.5-33.6  Foundations of Evidence Critical Appraisal: 4/4	Balance training using STAR excursion balance test	A 4-6 week proprioception training program and strengthening program both saw improvement in dynamic postural control when compared to the control groups.
<b>Recommendations:</b> Results indicate that the use of both proprioception training and strength training can improve the dynamic postural control of patients with CAI.			

<b>Source:</b> Wikstrom, E. A., & Mckeon, P. O. (2017). Predicting balance improvements following STARS treatments in chronic ankle instability participants. <i>Journal of Science and Medicine in Sport</i> , 20(4), 356-361. doi:10.1016/j.jsams.2016.09.003			
<b>Design Methodology/Purpose</b>	<b>Sample/Setting</b>	<b>Design Instruments</b>	<b>Results</b>
Secondary analysis of randomized control trial <b>Purpose:</b> To research the predictors of successful postural control training for patients with chronic ankle instability <b>Method:</b> Subjects randomized into either a plantar massage, an ankle joint mobilization, or a calf stretching group	59 subjects, male and female, with a mean age of 22  PEDro score of 5/10	Single limb balance test and testing errors	Subjects with $\geq 3$ errors on the single-leg balance test, had a 73% probability of improvement in proprioception in the ankle joint mobilization group. Subjects with $\geq 11$ ankle sprains had a 94% probability of treatment success in the calf stretching group
<b>Recommendations:</b> Indicates success predictors for patients with ankle sprains and CAI, which could be incorporated into the treatment plan for a proprioception training program. It can also be used for clinical decision making.			

<b>Source:</b> Anguish, B., & Sandrey, M. A. (2018). Two 4-Week Balance-Training Programs for Chronic Ankle Instability. <i>Journal of Athletic Training</i> , 53(7), 662-671. doi: 10.4085/1062-6050-555-16			
<b>Design Methodology/Purpose</b>	<b>Sample/Setting</b>	<b>Design Instruments</b>	<b>Results</b>

<p>RCT</p> <p><b>Purpose:</b> Review the effects of a progressive hopto-stabilization balance (PHSB) program compared to a single leg balance (SLB) program in subjects with CAI.</p> <p><b>Method:</b> Subjects randomly assigned to the PHSB or SLB program</p>	<p>18 subjects aged 18.38 ± 1.81 years</p> <p>PEDro score of 6/10</p>	<p>Foot and Ankle Ability Measure (FAAM) Activities of Daily Living subscale, FAAM-Sports subscale, Star Excursion Balance Test, and weight-bearing JPS blocks.</p>	<p>Both PHSB and SLB groups saw improvement and should be considered for all athletes.</p>
<p><b>Recommendations:</b> Incorporation of one or both balance training programs for patients with CAI.</p>			

<p><b>Source:</b> Burger, M., Dreyer, D., Fisher, R., Foot, D., O'Connor, D., Galante, M., &amp; Zaltaonkir, S. (2018). The effectiveness of proprioceptive and neuromuscular training compared to bracing in reducing the recurrence rate of ankle sprains in athletes: A systematic review and meta-analysis. <i>Journal of Back and Musculoskeletal Rehabilitation</i>, 31(2), 221–229. doi: 10.3233/bmr-170804</p>			
<p><b>Design Methodology/Purpose</b></p>	<p><b>Sample/Setting</b></p>	<p><b>Design Instruments</b></p>	<p><b>Results</b></p>
<p>Systematic review and meta-analysis</p> <p><b>Purpose:</b> Determine the effectiveness of proprioception compared to bracing in reducing the recurrence rate of subjects with CAI</p> <p><b>Method:</b> 3 different studies with proprioception and bracing groups</p>	<p>Groups of 220, 40, and 34 subjects for each study with proprioception and bracing groups</p> <p>Foundations of Evidence Critical Appraisal: 4/4 3 articles included a PEDro scale range from 4/10 to 7/10</p>	<p>Similar proprioception training and semi-rigid orthosis worn during sporting activity</p>	<p>Evidence does not suggest the use of proprioception training over bracing.</p>
<p><b>Recommendations:</b> Indications for the use of both proprioception and bracing rather than proprioception alone.</p>			

<p><b>Source:</b> Hiller, C. E., Kilbreath, S. L., &amp; Refshauge, K. M. (2011). Chronic Ankle Instability: Evolution of the Model. <i>Journal of Athletic Training</i>, 46(2), 133–141. doi: 10.4085/1062-6050-46.2.133</p>			
<p><b>Design Methodology/Purpose</b></p>	<p><b>Sample/Setting</b></p>	<p><b>Design Instruments</b></p>	<p><b>Results</b></p>
<p>Cross-sectional study</p> <p><b>Purpose:</b> To evaluate data to fit between 2 different models for ankle instability.</p> <p><b>Method:</b> Retrospective with CAI subjects and case-control subjects</p>	<p>108 total subjects with 81 subjects with CAI and 42 uninjured control subjects.</p> <p>CASP score of 9/12</p>	<p>Balance testing with foot lift and single-leg balance and motor control after perturbation</p> <p>Outcomes were based on Cumberland Ankle Instability Tool score, anterior drawer test results, and a total number of sprains.</p>	<p>The modified Hertel model for CAI is supported by the data.</p>
<p><b>Recommendations:</b> Indication for modified Hertel model of CAI.</p>			

<p><b>Source:</b> Sousa, A. S. P., Valente, I., Pinto, A., Soutelo, T., &amp; Silva, M. (2018). Short and Medium Latency Responses in Participants With Chronic Ankle Instability. <i>Journal of Athletic Training</i>, 53(7), 679–686. doi: 10.4085/1062-6050-120-17</p>			
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<b>Design Methodology/Purpose</b>	<b>Sample/Setting</b>	<b>Design Instruments</b>	<b>Results</b>
Case-control study <b>Purpose:</b> To determine Bilateral compensatory postural responses using a unilateral simulated ankle-sprain mechanism in subjects with CAI <b>Method:</b> Bilateral electromyography of agonist muscle.	24 subjects with CAI (age $20.6 \pm 2.52$ ) and 20 uninjured subjects (age $21.8 \pm 2.21$ )  QUADAS Score of 6/14	Bilateral electromyography of agonist muscle activity during a unilateral sudden inversion perturbation of $30^\circ$	Subjects with CAI had later tibialis anterior (TA) and soleus activation in the uninjured ankle and decreased bilateral TA
<b>Recommendations:</b> Bilateral ankle limitations and deficits for patients with CAI.			

**Source:** Dizon, J. M. R., & Reyes, J. J. B. (2010). A systematic review of the effectiveness of external ankle supports in the prevention of inversion ankle sprains among elite and recreational players. *Journal of Science and Medicine in Sport*, 13(3), 309–317. doi: 10.1016/j.jsams.2009.05.002

<b>Design Methodology/Purpose</b>	<b>Sample/Setting</b>	<b>Design Instruments</b>	<b>Results</b>
Systematic Review <b>Purpose:</b> Determine the effectiveness of external ankle supports in the prevention of inversion ankle sprains and which ankle support is most effective. <b>Method:</b> 7 different trials reviewed a variety of adolescents and adults involved in recreational and competitive athletic activities	4723 total subjects that include those with ankle sprains and control subjects.  Foundations of Evidence Critical Appraisal: 3/4 Moderate quality RCTs	Incidence of ankle sprains in subjects who are previously injured and uninjured	Reduction in ankle sprains with both ankle bracing and taping
<b>Recommendations:</b> No findings for a superior type of brace/tape			

**Source:** Vries, J. D., Krips, R., Sierevelt, I., & Blankevoort, L. (2003). Interventions for treating chronic ankle instability. *Cochrane Database of Systematic Reviews*. doi:10.1002/14651858.cd004124

<b>Design Methodology/Purpose</b>	<b>Sample/Setting</b>	<b>Design Instruments</b>	<b>Results</b>
Systematic Review <b>Purpose:</b> To compare non-surgical and surgical treatments for chronic ankle instability <b>Method:</b> Ten randomized control trials comparing neuromuscular control and surgical intervention	Total of 388 subjects in RCTs  Foundations of Evidence Critical Appraisal:3/4 Moderate to high bias in included RCTs	Ankle joint functional assessment tool and foot and ankle disability index	Neuromuscular training versus no training resulting in better ankle function after 4 weeks of intervention.  Insufficient evidence to support one surgical intervention over another. Rehabilitation is more effective than immobilization following ankle reconstruction.
<b>Recommendations:</b> Rehabilitation should be more functional following ankle surgery versus immobilization.			

<b>Source:</b> Janssen, K., Verhagen, E., & Mechelen, W. V. (2012). Ankle sprains in a randomized controlled trial (ABrCt): Braces versus neuromuscular exercises for the secondary prevention of ankle sprains. <i>Journal of Science and Medicine in Sport</i> , 15. doi: 10.1016/j.jsams.2012.11.030			
<b>Design Methodology/Purpose</b>	<b>Sample/Setting</b>	<b>Design Instruments</b>	<b>Results</b>
RCT <b>Purpose:</b> Determine the effect of combining ankle braces and neuromuscular training compared to the individual use of either braces or neuromuscular training alone in preventing ankle sprains. <b>Method:</b> Subjects with ankle sprain within 2 months before the study	382 subjects. Males and females aged 18-70  PEDro score of 6/10 No blinding of subjects due to the nature of different tests	Incidence of ankle sprain after interventions and monthly follow up questionnaire	Evidence indicates that bracing is at least equal to neuromuscular training and may be superior.
<b>Recommendations:</b> Bracing is considered a cost-effective form of ankle sprain and CAI prevention			

<b>Source:</b> Kobayashi, T., Saka, M., Suzuki, E., Yamazaki, N., Suzukawa, M., Akaike, A., & Gamada, K. (2014). The Effects of a Semi-Rigid Brace or Taping on Talocrural and Subtalar Kinematics in Chronic Ankle Instability. <i>Foot &amp; Ankle Specialist</i> , 7(6), 471–477. doi: 10.1177/1938640014543357			
<b>Design Methodology/Purpose</b>	<b>Sample/Setting</b>	<b>Design Instruments</b>	<b>Results</b>
Cross-sectional study <b>Purpose:</b> Determine the effectiveness of a semi-rigid brace or taping of the ankle during weight-bearing kinematics during ankle internal rotation in plantar flexion in subjects with CAI <b>Method:</b> Subjects recruited with unilateral ankle sprains	14 subjects with CAI Males with a mean age of $21.1 \pm 2.5$  CASP score of 4/12	Single weight-bearing fluoroscopy and computed tomography (CT) scan to evaluate ankle kinematics	Application of a semi-rigid brace or taping had limited effects on anterior translation and internal rotation
<b>Recommendations:</b> Further evidence is needed to determine the effectiveness of semi-rigid bracing/taping on joint kinematics in subjects with CAI			

<b>Source:</b> Mettler, A., Chinn, L., Saliba, S. A., Mckeon, P. O., & Hertel, J. (2015). Balance Training and Center-of-Pressure Location in Participants With Chronic Ankle Instability. <i>Journal of Athletic Training</i> , 50(4), 343–349. doi: 10.4085/1062-6050-49.3.94			
<b>Design Methodology/Purpose</b>	<b>Sample/Setting</b>	<b>Design Instruments</b>	<b>Results</b>
RCT <b>Purpose:</b> To determine how a 4-week balance training program affects the spatial locations of the center of pressure (COP) data points in subjects with CAI. <b>Method:</b> COP data points collected while subjects balanced using a single limb on a force plate during a 10-second trial.	31 total subjects. Balance training group with mean age $22.2 \pm 4.5$ and control group with age $19.6 \pm 1.3$  PEDro score of 4/10 No eligibility criteria	COP data measured using AccuSway force platform	COP data indicates the movement of COP position from anterolateral to posterolateral. This may result in a better functioning sensorimotor system

<b>Recommendations:</b> Indicates that balance training has positive effects on the sensorimotor system.			
<b>Source:</b> Prado, M. P., Mendes, A. A. M., Amodio, D. T., Camanho, G. L., Smyth, N. A., & Fernandes, T. D. (2014). A Comparative, Prospective, and Randomized Study of Two Conservative Treatment Protocols for first-episode Lateral Ankle Ligament Injuries. <i>Foot &amp; Ankle International</i> , 35(3), 201–206. doi: 10.1177/1071100713519776			
<b>Design Methodology/Purpose</b>	<b>Sample/Setting</b>	<b>Design Instruments</b>	<b>Results</b>
RCT <b>Purpose:</b> To determine functional impairments and the incidence of residual ankle instability following conservative treatment of a first lateral ankle sprain <b>Method:</b> Subjects randomly selected into either a walking boot with weight-bearing allowed, mobilization for 3 weeks or a second group had patients wear a functional brace for 3 weeks,	186 subjects with severe (Grade III) lateral ankle sprains. Male and female, ages 15-65 years old  PEDro score of 9/10 No blinding of subjects due to different treatments	Visual Analog Scale for pain, clinical general status, AOFAS score, and anterior drawer stress x-ray	Patients treated with a functional ankle brace alone results in a better outcome than those that are treated with a walking boot for 3 weeks before application of functional ankle brace
<b>Recommendations:</b> Treatment using a functional ankle brace versus conservative treatment using a walking boot for patients with an initial ankle sprain.			

<b>Source:</b> Schiftan, G. S., Ross, L. A., & Hahne, A. J. (2015). The effectiveness of proprioceptive training in preventing ankle sprains in sporting populations: A systematic review and meta-analysis. <i>Journal of Science and Medicine in Sport</i> , 18(3), 238–244. doi: 10.1016/j.jsams.2014.04.005			
<b>Design Methodology/Purpose</b>	<b>Sample/Setting</b>	<b>Design Instruments</b>	<b>Results</b>
Systematic review and meta-analysis <b>Purpose:</b> To determine the effectiveness of proprioception training in reducing the incidence of ankle sprains in athletes <b>Method:</b> Review of 7 RCT in subjects who had performed proprioception training compared to other treatments	3725 total subjects in 7 RCTs  Foundations of Evidence Critical Appraisal:4/4 Moderate to high-quality studies	Results gained from a pooled estimate of the effectiveness of proprioception	Proprioception training was effective at reducing the incidence of ankle sprains compared to other interventions. Proprioception training was effective in the reduction of ankle sprains in subjects with a history of ankle sprains as well as no history of ankle sprains.
<b>Recommendations:</b> While evidence supports proprioception training in reducing the incidence in patients with a history of ankle sprains, more research is needed to determine the effectiveness of proprioception in patients with no history of ankle sprains.			

<b>Source:</b> Bellows, R., & Wong, C. K. (2018). The Effect of Bracing and Balance Training on Ankle Sprain Incidence Among Athletes: A Systematic Review with Meta-Analysis. <i>International Journal of Sports Physical Therapy</i> , 13(3), 379–388. doi: 10.26603/ijsp20180379			
<b>Design Methodology/Purpose</b>	<b>Sample/Setting</b>	<b>Design Instruments</b>	<b>Results</b>

<p>Systematic review and meta-analysis</p> <p><b>Purpose:</b> To determine the effectiveness of balance training and bracing in the reduction of ankle sprains in athletes with and without prior ankle injury.</p> <p><b>Method:</b> 8 different RCT studies with 5 studies looking at balance training and 5 studies evaluating bracing</p>	<p>7195 athletes included as subjects from high school to professional sports 3581 subjects in the bracing studies and 3577 subjects in the balance training studies</p> <p>Foundations of Evidence Critical Appraisal:4/4 Moderate to high-quality studies based on PEDro scale</p>	<p>Incidence of ankle sprains and relative risk used to determine the effectiveness of balance training compared to bracing groups and the control groups.</p>	<p>The bracing studies resulted in a 64% reduced risk of ankle sprains compared to the control groups and the balance training. This resulted in a 46% reduced risk of ankle sprains when compared to the control groups.</p>
<p><b>Recommendations:</b> Both balance training and bracing are effective in reducing the risk of ankle sprains. It is not determined if one or both are the most effective forms of intervention.</p>			

<p><b>Source:</b> McGuine, T. A., &amp; Keene, J. S. (2006). The Effect of a Balance Training Program on the Risk of Ankle Sprains in High School Athletes. <i>The American Journal of Sports Medicine</i>, 34(7), 1103–1111. doi: 10.1177/0363546505284191</p>			
Design Methodology/Purpose	Sample/Setting	Design Instruments	Results
<p>RCT</p> <p><b>Purpose:</b> To determine the effectiveness of a balance training program in reducing the risk of ankle sprains in high school athletes</p> <p><b>Method:</b> Randomized into either intervention group that involved balance training and control group with only standard conditioning exercises</p>	<p>765 total subjects, high school athletes 523 female, 373 males</p> <p>PEDro score of 6/10 No blinding of subjects, therapist, or assessors due to different treatments Allocation not concealed</p>	<p>Ankle sprain rate when comparing the intervention group to control group</p>	<p>The rate of ankle sprains for the injured intervention group was 6.1 versus 9.1 for the injured control group. The rate of sprains for the uninjured intervention group was 4.3 versus 7.7 in the uninjured control group.</p>
<p><b>Recommendations:</b> Evidence indicates a reduction of ankle sprains for subjects with previous ankle injuries, however more research is needed to determine if a balance training program can produce a significant reduction in ankle sprains.</p>			

<p><b>Source:</b> Janssen, K. W., Mechelen, W. V., &amp; Verhagen, E. A. L. M. (2014). Bracing superior to neuromuscular training for the prevention of self-reported recurrent ankle sprains a three-arm randomized controlled trial. <i>British Journal of Sports Medicine</i>, 48(16), 1235–1239. doi: 10.1136/bjsports-2013-092947</p>			
Design Methodology/Purpose	Sample/Setting	Design Instruments	Results
<p>RCT</p> <p><b>Purpose:</b> To determine the effectiveness of bracing and proprioception training, alone and together for the prevention of recurrent ankle sprains</p> <p><b>Method:</b> Subjects randomized into either</p>	<p>384 total subjects, 120 in a proprioception training group, 126 in bracing group, and 138 in the combination group</p> <p>PEDro score of 7/10 No blinding of subjects, therapist, or assessors</p>	<p>Subjects self-reported rate of a recurrent ankle sprain</p>	<p>After a one-year follow-up, 20% of all subjects reported recurrent ankle sprains, 27% of the proprioception training group, 15% of the brace group, and 19% of the combination group.</p>

proprioception training group, bracing group, or combination of the two with a 1-year follow-up	due to different treatments		Relative risk: 0.53 with 95% CI (0.29 to 0.97).
<b>Recommendations:</b> The use of a brace after an ankle sprain is more effective in the rate of recurrence although not in self-reported severity.			

<b>Source:</b> Swiontkowski, M. (2011). A Systematic Review on the Treatment of Acute Ankle Sprain: Brace versus Other Functional Treatment Types. <i>Yearbook of Orthopedics</i> , 2011, 93–96. doi: 10.1016/j.yort.2011.05.062			
<b>Design Methodology/Purpose</b>	<b>Sample/Setting</b>	<b>Design Instruments</b>	<b>Results</b>
Systematic review <b>Purpose:</b> To determine the effectiveness of bracing versus other functional treatments <b>Method:</b> Review of 8 studies regarding functional treatment for lateral ankle sprains.	1250 total subjects included 358 with the use of ankle brace An unidentified number of other functional prevention methods such as air cast or Tubigrip compression sleeve.  Foundations of Evidence Critical Appraisal:4/4 7 out of 8 studies considered high quality based on PEDro scale	The outcome of recurrent ankle sprains, report symptoms, and outcome in return to work/sports.	Ankle braces are the most effective form of functional treatment compared to other methods.
<b>Recommendations:</b> The use of ankle brace is the most effective form of functional treatment although more research is needed to determine the most effective type of brace.			



## Appendix B

## PEDro scale Criteria (The George Institute for Global Health, n.d.)

Graded on a 10 point scale with question number one not included in the score.

1. Eligibility criteria were specified.
2. Subjects were randomly allocated to groups (in a crossover study, subjects were randomly allocated an order in which treatments were received).
3. The allocation was concealed.
4. The groups were similar at baseline regarding the most important prognostic indicators.
5. There was blinding of all subjects.
6. There was blinding of all therapists who administered the therapy.
7. There was blinding of all assessors who measured at least one key outcome.
8. Measures of at least one key outcome were obtained from more than 85% of the subjects initially allocated to groups.
9. All subjects for whom outcome measures were available received the treatment or control condition as allocated or, where this was not the case, data for at least one key outcome was analyzed by “intention to treat.”
10. The results of between-group statistical comparisons are reported for at least one key outcome.

11. The study provides both point measures and measures of variability for at least one key outcome.

## Appendix C

Foundations of Evidence Critical Appraisal (Raab and Craig, 2016):

Graded on a four-point scale.

1. Is the clinical question focused?
2. Was the literature search thorough and exhaustive?
3. Are the included studies of high quality and valid?
4. Is the selection of the included studies reproducible?

## Appendix D

Quality Assessment of Diagnostic Accuracy Studies (QUADAS) (Raab and Craig, 2016):

Graded on a 14 point scale.

1. Was the spectrum of athletes representative of the athletes who will receive the test in practice?
2. Were selection criteria clearly described?
3. Is the reference standard likely to correctly classify the target condition?
4. Is the time period between reference standard and index test short enough to be reasonably sure that the target condition did not change between the two tests?
5. Did the whole sample or a random selection of the sample receive verification using a reference standard of diagnosis?
6. Did athletes receive the same reference standard regardless of the index test result?
7. Was the reference standard independent of the index test (i.e., the index test did not form part of the reference standard)?
8. Was the execution of the index test described in sufficient detail to permit replication of the test?
9. Was the execution of the reference standard described in sufficient detail to permit its replication?

10. Were the index test results interpreted without knowledge of the results of the reference standard?
11. Were the reference standard results interpreted without knowledge of the results of the index test?
12. Were the same clinical data available when test results were interpreted as would be available when the test is used in practice?
13. Were uninterpretable or intermediate test results reported?
14. Were withdrawals from the study explained?

## Appendix E

## Critical Appraisal Skills Programme (CASP) (Raab and Craig, 2016):

Graded on a 12 point scale.

1. Did the study address a clearly focused issue?
2. Did the authors use an appropriate method to answer their question?
3. Was the cohort recruited in an acceptable way?
4. Was the exposure accurately measured to minimize bias?
5. Was the outcome accurately measured to minimize bias?
6. (a) Have the authors identified all important confounding factors? (b) Have they taken account of the confounding factors in the design or analysis?
7. (a) Was the follow-up of subjects complete enough? (b) Was the follow-up long enough?  
Was follow-up thorough, and was it long enough to allow symptoms to present or resolve?
8. Are the results of this study clearly stated?
9. Are the results precise?
10. Do you believe the results?
11. Can the results be applied to the local population?
12. Do the results of this study fit with other available evidence?