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EPIDEMIOLOGY, RISK FACTORS AND CONSERVATIVE TREATMENT OF CHRONIC ANKLE INSTABILITY: A REVIEW OF SYSTEMATIC REVIEWS

EPIDEMIOLOGIJA, DEJAVNIKI TVEGANJA IN KONZERVATIVNO ZDRAVLJENJE KRONIČNE NESTABILNOSTI GLEŽNJA: PREGLED PREGLEDNIH ČLANKOV

ABSTRACT

Chronic ankle instability is a condition that often occurs after a lateral ankle sprain. It affects daily activities, quality of life and can cause further ankle injuries. The purpose of this article is to systematically review and compare the effectiveness of physiotherapy methods and techniques, epidemiology, and risk factors of chronic ankle instability. A literature search was performed using the PubMed database for existing systematic reviews and meta-analyses. The results show that the prevalence of chronic ankle instability is 46% in people with a history of ankle sprains and is highest in adolescents. In addition, risk factors are poorly understood. Balance training has been shown to be the most effective among standalone treatments. It improves functionality, instability, dynamic balance, and health-related quality of life. Furthermore, a multimodal program is effective in improving self-reported ankle function. Vibration is a useful adjunct to exercise because it improves sensorimotor deficits. Joint mobilization is effective in increasing ankle dorsiflexion and improving balance. Despite the frequent use of external support, it has not been supported as a sole intervention.

Keywords: ankle instability, chronic pain, ankle joint, foot injury, sports injury

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IZVLEČEK

Kronična nestabilnost gležnja je stanje, ki se pogosto pojavi po lateralnem zvinu gležnja. Vpliva na vsakodnevne dejavnosti ter kakovost življenja in lahko povzroči nadaljnje poškodbe gležnja. Namen tega članka je sistematično pregledati in primerjati učinkovitost fizioterapevtskih metod in tehnik, epidemiologijo in dejavnike tveganja kronične nestabilnosti gležnja. S pomočjo podatkovne zbirke PubMed je bilo opravljeno iskanje literature za obstoječe sistematične preglede in metaanalize. Rezultati kažejo, da je razširjenost kronične nestabilnosti gležnja 46-odstotna pri ljudeh, ki so si v preteklosti zvijali gleženj, najvišja pa je pri mladostnikih. Poleg tega so dejavniki tveganja slabo poznani. Vadba za ravnotežje se je izkazala za najučinkovitejši način zdravljenja, saj izboljša funkcionalnost, odpravi nestabilnost, izboljša dinamično ravnotežje in pozitivno vpliva na poročano kakovost življenja. Poleg tega so multimodalni programi zelo učinkoviti za izboljšanje samoporočane funkcije gležnja. Vibracije so koristen dodatek k vadbi, saj izboljšujejo senzomotorične primanjkljaje. Mobilizacija sklepov je učinkovita pri povečanju obsega giba gležnja in pripomore k izboljšanju ravnotežja. Kljub pogosti uporabi opornic in drugih sorodnih pripomočkov, le-ti niso podprti kot samostojni ukrep.

Ključne besede: nestabilnost gležnja, kronična bolečina, gleženjski sklep, poškodba stopala, športna poškodba

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INTRODUCTION

Ankle sprains are one of the most common musculoskeletal injuries in both athletes and the general population, accounting for 16 to 40% of all sports-related injuries (Halabchi & Hassabi, 2020; Prieto-González et al., 2021; Waterman, Owens, Davey, Zacchilli, & Belmont, 2010). Lateral ankle sprain (LAS) is the most prevalent type of sprain (Doherty et al., 2014). It has a high recurrence rate and many people develop long-lasting symptoms that contribute to the development of chronic ankle instability (CAI) (Gribble et al., 2016). CAI is a condition characterized by a history of at least one LAS with inflammatory symptoms, frequent episodes of ankle joint "giving way", persistent symptoms of pain, swelling and muscle weakness, limited range of motion, diminished self-reported function and recurrent sprains that persist for more than a year after the initial injury (Gribble et al., 2013; Hertel & Corbett, 2019). Mild ankle pain, which usually occurs during vigorous physical activity, is present in 50 to 79% of patients with CAI (Al Adal, Pourkazemi, Mackey, & Hiller, 2019). Patients are especially cautious about putting weight on the injured ankle and walking on uneven surfaces, with braces providing only partial relief (Al-Mohrej & Al-Kenani, 2016). Limited range of motion in the direction of dorsiflexion is often present due to decreased posterior talar glide, anterior displacement of the talus, or an anteriorly positioned fibula (Denegar, Hertel, & Fonseca, 2002; Hubbard, Hertel, & Sherbondy, 2006). Furthermore, kinesthesia and joint position sense are impaired in patients with CAI when compared with uninjured limbs and healthy controls (Xue, Ma, Li, Song, & Hua, 2021). Associated lesions that frequently accompany CAI are sinus tarsi syndrome, osteochondral defects, peroneal tendinopathy, and subtalar instability (Al-Mohrej & Al-Kenani, 2016).

CAI develops as a result of mechanical instability, functional instability, or a combination of both (Hertel, 2002). Mechanical instability is caused by ligament laxity, arthrokinematic, degenerative, and synovial changes, whereas functional instability is caused by proprioceptive and neuromuscular deficits, postural control deficits, and muscle weakness (Hertel, 2002; Kobayashi & Gamada, 2014). Hertel & Corbett (2019) described a model that provides a theoretical framework for understanding the causes of CAI. Their model is based on a biopsychosocial approach and explains how initial LAS leads to a collection of pathomechanical, sensory-perceptual, and motor-behavioral impairments, that influence the patient's clinical outcome.

Ankle examination does not differ between individuals with the first ankle sprain and those who have experienced multiple or recurrent sprains (Gribble, 2019). In the case of mechanical instability, clinical examination is particularly important for diagnosis, while in the case of functional instability balance tests, strength testing, and analysis of posture, gait, and running are examined (Wenning & Schmal, 2022). The examination should include inspection of the lower limb, noting the possible presence of hindfoot varus misalignment, midfoot cavus, assessment of the injured soft tissues, especially the lateral ligaments of the ankle, assessment of peroneal muscle strength and ankle range of motion (Al-Mohrej & Al-Kenani, 2016; Chen, 2020). To test the lateral ligaments, the anterior drawer test, and the talus tilt test may be performed (Gribble, 2019). Furthermore, the ankle arthrometer and ultrasonography have been found to have very good diagnostic accuracy (Radwan et al., 2016; Rodriguez-Merchan, 2012).

Treatment of CAI is primarily conservative, with a focus on physiotherapy and the use of external support (Al-Mohrej & Al-Kenani, 2016; Rodriguez-Merchan, 2012). Hertel & Corbett (2019) state that it is necessary to develop a holistic care plan, which addresses the primary condition and identified impairments along with the relevant component interactions, personal and environmental factors. In cases where patients do not recover after three to six months of conservative treatment, surgical intervention is recommended (Camacho, Roward, Deng, & Latt, 2019). There is no consensus regarding optimal surgical treatment for CAI but all techniques often have good results (Rodriguez-Merchan, 2012).

Return to sport can be considered when the patient is no longer experiencing pain or swelling and has normal ankle stability, strength, neuromuscular control, and ankle function (Camacho et al., 2019). Picot et al. (2022) have proposed a set of functional tests for assessing the suitability of return to sport after CAI, including the single-leg stance test, the modified version of the star excursion balance test, the side hop test, and the figure-of-eight test. For assessment of the self-reported function, the Foot and Ankle Ability Measure and the Ankle Ligament Reconstruction-return to Sport After Injury questionnaires are suggested as the most relevant measures. Moreover, CAI significantly affects the quality of life, the ability to perform daily activities, and the development of post-traumatic ankle osteoarthritis (Carbone & Rodeo, 2017; Hubbard-Turner & Turner, 2015). It is thus important to provide patients with effective and evidence-based treatment. Although there is a wide range of techniques for the treatment of CAI, such as exercise therapy, manual therapy, and the use of external support, there is no consensus regarding the most effective treatment intervention. In addition, epidemiology and risk factors are poorly understood. This report aims to review, analyze and present the

epidemiology, risk factors, and treatment of CAI, with an emphasis on physiotherapeutic methods and techniques.

METHODS

A systematic search was performed in March 2023 in the PubMed database. The database was searched using "Chronic ankle instability" as the search string. In addition, manual search of reference lists of retrieved articles, as well as all citations (using Google Scholar function “cited by”) was conducted to ensure no studies were missed. To provide a broad overview of the field, we included all existing systematic review articles that concerned the epidemiology, risk or prognostic factors, and conservative treatment in individuals with CAI. We only included systematic reviews and meta-analyses. Studies that focused on the aforementioned areas concerning other pathologies, surgical interventions, measurement methods, and consequences of CAI were excluded.

RESULTS

After screening 132 hits in the PubMed database, 39 studies were initially included. After the abstract examination, we excluded 14 studies, and after the full-text examination, we additionally excluded one study. An additional study was incorporated through manual retrieval. The PRISMA diagram shown in Figure 1, illustrates the process of research and selection of studies. From the final pool of included articles, three investigated epidemiology, four studies risk factors, and 17 focused on conservative treatment of CAI. Among all included studies on treatment, three studies investigated the use of external support, three studies manual therapy, six studies exercise therapy or exercise therapy with whole-body vibration, and five studies explored various conservative interventions. A summary of the articles focusing on treatment is presented in Table 1, while findings on epidemiology and risk factors are narratively integrated into the discussion section.

Figure 1. The study search and selection process.

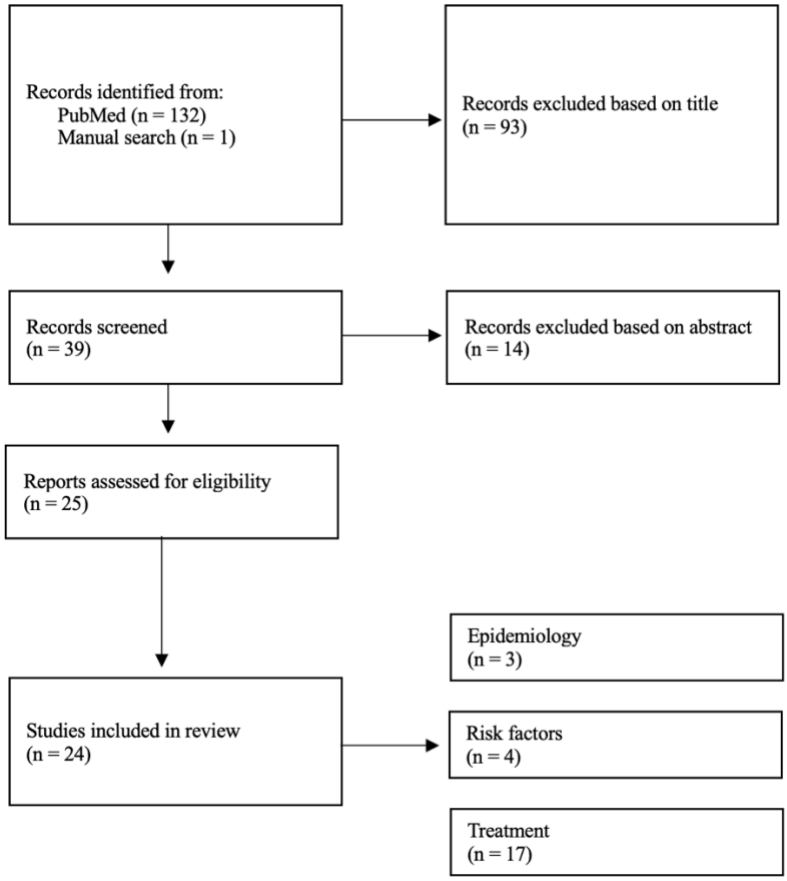

Table 1. Characteristics of the selected studies.

Study	Purpose	Number of included studies/ participants	Intervention	Results and conclusions
Mollà-Casanova, Inglés, & Serra-Añó (2021)	To identify the effects of balance and strength training on function, ankle instability, and dynamic balance in people with CAI	15/457	Balance and strength training	Based on fair-to-high-quality evidence, balance training significantly improves functionality, instability, and dynamic balance in people with CAI. However, when compared to strength training, balance training was only greater in terms of the functional outcome.
Luan, Adams, Witchalls, Ganderton, & Han (2021)	To evaluate the effects of strength training compared with no exercise and neuromuscular control training on balance and self-reported function in people with CAI	11/428 – in a systematic review 8/No data – in a meta-analysis	Strength training and neuromuscular control training	Strength training did not produce any detectable changes on Star Excursion Balance Test (balance) and Foot and Ankle Ability Measure scores in comparison to the control group among patients with CAI. Neuromuscular control training was significantly better at improving Cumberland Ankle Instability Tool scores and Star Excursion Balance test scores when compared to strength training.
Han et al. (2022)	To assess exercise therapies that aim to enhance proprioception in individuals with CAI	11/333	Exercise therapy	Foot and ankle muscle strengthening exercises showed the highest probability of being among the best treatments for improving joint position sense in individuals with CAI. Static balance exercise and corrective exercise also showed good results. On the other hand, proprioceptive exercise, dynamic balance exercise only, aquatic exercise, rehabilitation exercise with a brace, mixed static and dynamic balance exercise, and control were less effective. As the complexity of the balance exercise intervention increases, the effectiveness of the proprioceptive outcome decreases.

Jiang et al. (2022)	To synthesize current evidence regarding the effect of balance training on dynamic postural stability in CAI patients	12/No data	Balance training	Balance training was significantly effective in improving the dynamic posture stability (Star Excursion Balance Test) of CAI patients. Compared to other exercise interventions, balance training revealed a small negative effect size but was not statistically significant. Balance training demonstrated greater improvement in dynamic postural stability compared to no exercise intervention.
Tan et al. (2022)	To investigate the effects of whole-body vibration on associated sensorimotor deficits in balance, strength, joint position sense, and muscle activity in patients with CAI	8/315 recreationally active individuals and athletes	Whole-body vibration with balance training	Whole-body vibration has a significant effect on balance – on the posterolateral and medial direction of the Star Excursion Balance Test. Additionally, it significantly improves the peak torque, joint position sense, and muscle activity in the tibialis anterior and gastrocnemius. Results support the use of whole-body vibration with balance training to improve sensorimotor deficits, including balance, strength, joint position sense, and muscle activity in people with CAI.
Xue et al. (2023)	To determine whether existing exercise therapies can restore the joint position sense deficits of patients with CAI when compared with non-training controls	7/257	Exercise therapy – muscle strengthening, balance, coordination, and vibration	Meta-analyses revealed significantly higher improvements in passive joint position sense during inversion and eversion after exercise therapies when compared to non-training controls. No significant changes in active joint position sense were observed with regard to inversion and eversion.
Vallandingham, Gaven, & Powden (2019)	To assess the effectiveness of joint mobilizations for improving dorsiflexion range of motion and dynamic postural control in individuals with CAI	10/374	Joint mobilizations, manipulation, mobilizations with movement and traction	Meta-analysis revealed that joint mobilizations targeted at increasing the posterior glide of the talus may have weak to moderate positive effects on both dorsiflexion range of motion and dynamic postural control in people with CAI compared to controls and preintervention. Maitland mobilization and Mulligan mobilizations with movement demonstrated the greatest efficiency in improving the aforementioned clinical outcomes with Mulligan mobilizations being superior for enhancing the dorsiflexion range of motion. Traction and high-velocity manipulations to the tibiofibular joints were not supported for improving dynamic balance and range of motion.
Kim & Moon, (2022)	To quantify the effect of joint mobilization on the range of motion, dynamic balance, and function in individuals with CAI	9/364	Joint mobilizations, manipulation, non-weight-bearing and weight-bearing mobilizations	Mobilizations with or without voluntary movement both showed significant and immediate improvement in the dorsiflexion range of motion and dynamic balance, but not in function (patient-oriented outcomes).
Shi, Han, Witchalls, Waddington, & Adams (2019)	To determine whether manual therapy can improve functional outcomes and determine its optimal duration for individuals with CAI	4/208	Joint mobilization and mobilization with movement	Six sessions rather than one session of manual therapy significantly improve ankle functional performance for individuals with CAI. Moderate to low evidence suggests that six sessions of manual therapy can improve ankle dorsiflexion range of motion and motor control.
Kim et al. (2023)	To identify, critically appraise, and synthesize the existing evidence regarding the effects of therapeutic interventions on arthrogenic muscle inhibition in patients with CAI	9/181	Focal ankle joint cooling, manual therapy, fibular reposition taping, whole-body vibration, and transcranial direct current stimulation	Focal joint cooling has shown moderate effects on spinal excitability in ankle muscles for the soleus and the fibularis longus. Four weeks of transcranial direct current stimulation combined with eccentric exercise showed large effects on corticospinal excitability in two weeks after the intervention for the fibularis longus and tibialis anterior. On the other hand, manual therapy, fibular reposition taping, and whole-body vibration were not effective. Focal joint cooling and transcranial stimulation may be effective in the treatment of arthrogenic muscle inhibition but the current evidence is too limited to draw definitive conclusions.
Koshino & Kobayashi (2023)	To determine which conservative interventions are effective for improving static and dynamic balance in patients with CAI	48/1906	Various conservative interventions; whole-body vibration training, balance training, joint mobilization, strength training, taping, multimodal intervention, transcranial direct current stimulation	The results show, that whole-body vibration training was significantly more effective than controls for both static (moderate-certainty evidence) and dynamic balance (low-certainty evidence). Balance training and joint mobilization were significantly more effective than controls for dynamic balance but not for static balance (very low to low-certainty evidence). On the other hand, adding other interventions to balance training had no significant effect on either type of balance compared with balance training alone (moderate to low-certainty evidence). Strength training and taping had no significant effect on either type of balance (very low- to low-certainty evidence). Multimodal interventions were significantly effective in improving dynamic balance (low-certainty evidence). Adding transcranial direct current stimulation to strength training was significantly more

				effective for dynamic balance than strength training alone (moderate-certainty evidence).
Tsikopoulos, Mavridis, Georgiannos, & Vasiliadis, (2018)	To compare the results of different standalone and/or combined nonsurgical interventions on CAI as measured by the Cumberland Ankle Instability Tool at 0 to 6 months after treatment and treatment-related complications	21/789 – in a systematic review 19/No data – in a meta-analysis	Various conservative interventions; balance training, strengthening exercises, a combination of the balance and strengthening, manual therapy, and multimodal treatment	A four-week supervised rehabilitation program, which included balance training, strengthening, functional tasks, and range of motion exercises was significantly better in improving ankle function compared to control. Among the standalone interventions, only balance training showed better results than control. Additionally, the adverse events associated with interventions were transient, mild, and uncommon.
Tsikopoulos, Mavridis, Georgiannos, & Cain (2018)	To identify the effectiveness of non-surgical treatments for improving dynamic postural control in patients with CAI.	19/No data – in a systematic review 16/547 – in a meta-analysis	Various conservative interventions; balance training, strength training, balance training with sensory-targeted ankle rehabilitation strategies, vibration training, manual therapy and multimodal rehabilitation	A four to six-week supervised balance training program and a four to six-week strengthening rehabilitation protocol showed significant improvements in dynamic postural control when compared to control. A six-week combined intervention that addressed balance and strength had the highest probability of being among the best treatment options, but it was only represented in one study.
Powden, Hoch, & Hoch (2017)	To assess the effectiveness of conservative rehabilitation programs for improving health-related quality of life in individuals with CAI	15/ 584	Conservative interventions; balance training, manual therapy, or a combination of both	Conservative rehabilitation produces large improvements in health-related quality of life in people with CAI. Balance training demonstrated a high level of evidence and the largest summary effect, indicating it may be the most appropriate rehabilitation strategy to improve health-related quality of life. Additionally, manual therapy can also improve health-related quality of life.
Biz et al. (2022)	To evaluate the effects of Kinesio Taping on sports performances and ankle functions in athletes with CAI	8/270 adult athletes	Kinesio Taping	The application of Kinesio Taping showed significant improvements in gait functions (step velocity, step, and stride length, and reduction in the base of support in dynamics), reduction in joint range of motion in inversion and eversion, decrease in muscle activation of the long peroneus and decrease in postural sway in movement in the mid-lateral direction. Based on these findings, Kinesio Taping has a moderate stabilizing effect on the ankles of the athletes with CAI participating in popular contact sports.
Tsikopoulos et al. (2020)	To assess the impact of taping and orthotic devices on dynamic postural control in individuals with CAI, the presence of a placebo effect in participants treated with sham taping, and the presence of complications	21/469 – in a systematic review 13/262 – in a meta-analysis	Kinesio Taping, rigid taping, elastic athletic taping, fibular reposition taping, nonelastic taping, sham taping, and the use of orthosis	Based on the evidence of moderate strength, the findings suggest that external supports, regardless of their type, do not exhibit greater effectiveness than control measures in improving dynamic postural control among patients with at least one ankle sprain and residual functional or mechanical deficits. Consequently, utilizing these external supports as a standalone treatment approach does not seem to be a viable strategy for the primary management of CAI. Additionally, there is no evidence of a placebo effect or adverse effects in patients treated with sham taping.
Xue, Chen, Xu, Tao, & Hua (2022)	To investigate whether external support could enhance the proprioception of injured ankles in patients with CAI	8/No data	External support	External support has shown significantly higher joint position sense on inversion and plantar flexion and lower kinesthesia in eversion in patients with CAI. The study does not support the use of external support for improving proprioception deficits and preventing injuries, since there were negative effects on kinesthesia, clinically small changes in proprioception, and poor methodologic quality of existing studies.

DISCUSSION

This report aims to examine the epidemiology, risk factors, and effectiveness of various physiotherapeutic methods and techniques for CAI. CAI frequently occurs after an acute injury of the ankle. Despite a wide range of methods and techniques, there is still no consensus regarding the most effective physiotherapeutic management. Furthermore, the epidemiology and risk factors are poorly studied.

Epidemiology

Three studies that examine the epidemiology of CAI were included in this systematic review. Lin, Houtenbos, Lu, Mayer, & Wippert (2021) conducted a systematic review using valid and reliable self-reporting tools to assess the epidemiology of CAI. They included 3804 physically active individuals, including soldiers, students, athletes, and physically active individuals with a history of ankle sprains. The findings revealed that the prevalence of CAI was 25% (ranging from 7% to 53%), whereas among participants with a history of ankle sprains the prevalence was 46% (ranging from 9% to 76%). The sample in Lin et al.' (2021) study consisted of individuals aged between 15 to 32 years, with the highest prevalence observed among individuals with a history of ankle sprains under the age of 18, reaching 63%. Gruskay, Brusalis, Heath, & Fabricant (2019) stated that CAI is a common consequence of lower extremity injuries in young athletes, with the incidence increasing due to inadequate management of the initial ankle sprain and increased participation in organized and competitive sports or early sport specialization. Additionally, in a systematic review, Mandarakas, Pourkazemi, Sman, Burns, & Hiller (2014) examined the prevalence of CAI in children. They found that perceived instability was present in 23% to 71% of children with a history of ankle sprains, mechanical instability in 18% to 47%, and a history of recurrent sprains in 22%.

The results of the systematic review by Lin et al. (2021) showed the highest prevalence of CAI in netball, dance, and water sports, followed by basketball, volleyball, and rowing. Attenborough et al. (2014) conducted a systematic review to investigate the most common aspects of CAI in individual sports. They reported that football had the highest proportion of participants with recurrent ankle sprains (61%) and mechanical instability (38%), followed by basketball, where 60% of participants reported recurrent ankle sprains, while athletics had the highest proportion of participants with perceived instability (41%). Basketball, netball, soccer, and volleyball are multidirectional sports, that involve running, changes of direction, and jumping, therefore the high prevalence of recurrent sprains is not surprising (Taylor, Wright,

Dischiavi, Townsend, & Marmon, 2017). It may be expected that the prevalence would be similar in other sports involving these movement patterns. More surprising is the high prevalence of CAI in water sports and rowing, where the upper limbs and back are predominantly more stressed and injured (Hosea & Hannafin, 2012; Wanivenhaus, Fox, Chaudhury, & Rodeo, 2012). The small sample size in the swimming and rowing category, with ten to twenty individuals, could be a contributing factor to the observed prevalence.

The prevalence of CAI in studies shows a wide range, which can be attributed to different inclusion and exclusion criteria, age groups, sports, or small sample sizes. Further research is needed to identify and investigate factors that influence the prevalence of CAI, such as gender, body mass index, and rehabilitation history. The studies conducted so far have primarily focused on physically active individuals up to the age of 32, which does not represent the entire population. Therefore, conducting epidemiological studies on the overall population would be necessary.

Risk factors

Understanding the risk factors is crucial for designing prevention and treatment programs (Collings et al., 2021). In this literature review four studies that examined risk factors for CAI were included. Pourkazemi, Hiller, Raymond, Nightingale, & Refshauge (2014) conducted a systematic review to identify the predictors of CAI after an index lateral ankle sprain. The factors investigated were postural control, perceived instability, and severity of the index sprain. Among the three examined potential predictors, only the severity of the initial sprain (grade 2) predicted re-sprain. Due to concerns about the validity of the grading system used for ankle sprains, these findings should be interpreted with caution. Pacheco et al. (2021) compared the prognosis of the combined anterior talofibular ligament (ATFL) and calcaneofibular ligament (CFL) injury with ATFL injury alone according to the progression of the injury to the CAI. The study revealed that there is no statistically significant correlation between the severity of ligament injuries and the progression to CAI. Furthermore, the prognosis for combined ATFL and CFL injury is worse, as there is a higher risk of developing osteochondral injuries, tendon injuries, and other injuries that affect treatment outcomes and later return to sports activities. Conflicting findings exist regarding the influence of the sprain grade on the progression of CAI. Pourkazemi et al. (2014) reported that grade 2 sprain predicted recurrent sprains, whereas Pacheco et al. (2021) did not find a statistically significant correlation between ligament injury severity and progression in CAI. However, in their recent retrospective analysis, Zhang et al.

(2023) discovered that injury to the posterior talofibular ligament, which occurs in grade 3 sprain is a predictive factor for CAI. Additionally, they reported that higher body mass index, young age, large bone marrow lesions, and grade 2 effusion of the tibiotalar joint were as well prognostic factors for CAI.

Thompson et al. (2018) conducted a systematic review and meta-analysis of systematic reviews to investigate the statistical significance and effect size of primary factors contributing to the development of CAI. They reported that poor dynamic balance, delayed peroneal reaction time, and deficiencies in evertor strength are factors with strong evidence contributing to CAI. Factors with moderate evidence include impaired proprioception and deficits in static balance. Since muscles serve as active stabilizers of the joint, reduced strength and slower reaction time of the evertors diminish the ankle's stabilization ability (Lambert, Falconer, & Mason, 2020).

Individuals with CAI experience muscle weakness beyond the ankle level. Khalaj, Vicenzino, Heales, & Smith (2020) conducted a meta-analysis to investigate whether impairments in lower limb muscle strength exist in individuals with chronic CAI compared with uninjured controls. The results showed deficiencies in the strength of ankle invertors, ankle evertors, and knee extensors. Furthermore, some of the included studies reported deficits in the strength of hip flexors, hip abductors, and hip external rotators. However, due to included cross-sectional studies, it cannot be conclusively determined whether these factors are the cause or the consequence of the injury.

One of the limitations of systematic reviews assessing risk factors is the failure to meet inclusion criteria for participants in individual studies. Furthermore, there is a scarcity of prospective studies investigating risk factors for CAI. Most of the literature merely identifies variables that distinguish individuals with CAI from uninjured individuals or those with LAS.

Treatment

This literature review includes studies examining various types of exercise therapy, manual therapy, external support, whole-body vibration, transcranial direct current stimulation, and focal ankle cooling.

Among the exercise therapy interventions, balance training and neuromuscular control training received stronger support as standalone interventions compared to strength training. These were found to be more effective in improving self-reported ankle function and balance (Luan et al., 2021; Mollà-Casanova et al., 2021). Balance training has demonstrated effectiveness in

improving functionality, instability, and dynamic balance and was shown to be the most suitable rehabilitation strategy for enhancing the health-related quality of life in individuals with CAI (Jiang et al., 2022; Mollà-Casanova et al., 2021; Powden et al., 2017). According to Mollà-Casanova et al. (2021), greater improvements in functionality were achieved through balance training involving hop-to-stabilization exercises rather than the single-leg stance on unstable surfaces. Han et al. (2022) found that strength training exercises targeting the muscles of the foot and ankle have a positive impact on improving joint position sense. There is no consensus on the effectiveness of strength training for improving balance, as Luan et al. (2021) and Koshino & Kobayashi (2023) state that strength training was not effective in improving balance, while Tsikopoulos, Mavridis, Georgiannos, & Cain (2018) reported a significant improvement in balance with a four-week strength training protocol. Strength training as a standalone intervention has not been shown to be highly effective. However, it would be worth considering its inclusion in multimodal programs, since muscle weakness is a common issue among individuals with CAI (Khalaj et al., 2020). This is supported by the findings of Tsikopoulos, Mavridis, Georgiannos, & Vasiliadis (2018), who reported that a multimodal program incorporating balance exercises, muscle strengthening, functional tasks, and flexibility exercises is effective in improving self-reported ankle function. Strength training has not been proven as very effective since most of the studies rather focused only on strengthening the ankle muscles. According to Khalaj et al. (2020), muscle weakness is also present in the hips and knees, therefore it would be reasonable to include the entire lower kinetic chain in the exercise program.

Whole-body vibrations combined with physical therapy have been proven to be an effective intervention for improving sensorimotor deficits. The sinusoidal mechanical oscillation of the body created by a vibration platform elicits various physiological responses that enhance neuromuscular function (Rittweger, 2010). Whole-body vibrations, when combined with balance training, significantly improve balance, joint position sense, and muscle activation of the tibialis anterior and gastrocnemius muscle in individuals with CAI (Tan et al., 2022). Passive joint position sense was also improved by whole-body vibration training that included strength, balance, and coordination exercises (Xue et al., 2023). Tan et al. (2022) suggest that a suitable duration for vibratory training to improve sensorimotor deficits is between four and eight weeks.

Arthrokinematic restrictions are present in individuals with CAI; there is a limitation of posterior talar glide, which affects the osteokinematic movement in the direction of dorsiflexion

(Hertel & Corbett, 2019). In existing systematic reviews, joint mobilization has been shown to be an effective intervention for increasing posterior talar glide and subsequently improving dorsiflexion (Kim & Moon, 2022; Shi et al., 2019; Vallandingham et al., 2019). Moreover, it significantly improves dynamic balance (Kim & Moon, 2022; Koshino & Kobayashi, 2023; Vallandingham et al., 2019). According to Vallandingham et al. (2019), there is a greater improvement in dynamic postural control following Mulligan mobilization with movement compared to Maitland mobilization, which indicates a preference for the former method in the treatment. Powden et al. (2017) reported that manual therapy can be clinically effective in improving health-related quality of life in patients with CAI. To achieve significant changes in function, six sessions rather than one session of manual therapy are needed (Shi et al., 2019). On the contrary, joint mobilization did not have a significant impact on ankle function (Kim & Moon, 2022; Shi et al., 2019). Traction and high-velocity manipulations on the tibiofibular joint were not supported as interventions to improve dynamic balance and mobility in patients with CAI (Vallandingham et al., 2019).

External ankle support is commonly used in the prevention and during the treatment or recovery of ligamentous injuries (Miller, Needle, Swanik, Gustavsen, & Kaminski, 2012). In this systematic review, the use of braces, various taping methods, and orthotic insoles did not prove to be effective neither in improving dynamic postural control nor proprioceptive deficits (Tsikopoulos et al., 2020; Xue et al., 2022). Therefore, it is not recommended as a standalone intervention for treating CAI. Conversely, Zwiers, Vuurberg, Blankevoort, & Kerkhoffs, (2016) suggest that braces and supports have a preventive effect on ankle sprains in sports activities. The use of kinesiology tape has garnered some more support in research. Although it has not been effective in improving dynamic balance, lateral landing from an unilateral jump, and agility tests, it has shown significant improvements in gait function, reduction in the joint range of motion in inversion and eversion, decrease in the muscle activation of the long peroneus and decrease in the postural sway in movement in the mid-lateral direction (Biz et al., 2022). According to the aforementioned source, kinesiology tape has a moderate stabilizing effect on the ankle in athletes with CAI. The effectiveness of the kinesiology tape application may be further enhanced when accompanied by a properly designed exercise program (Doherty, Bleakley, Delahunt, & Holden, 2017).

A common issue regarding CAI is arthrogenic muscle inhibition, which hinders rehabilitation by preventing high voluntary muscle activation (Lepley & Lepley, 2022). When addressing arthrogenic muscle inhibition, the most effective approaches are transcranial direct current

stimulation combined with eccentric exercise and focal ankle joint cooling (Kim et al., 2023). The first intervention resulted in significant effects on corticospinal excitability of the long peroneal and anterior tibial muscles and the second intervention showed moderate effects on spinal excitability of the long peroneal and gastrocnemius muscles. Furthermore, Koshino & Kobayashi (2023) state, that transcranial direct current stimulation combined with strength training, is effective in improving dynamic balance. Current evidence on these techniques is still insufficient to draw definitive conclusions as it is primarily based on short-term studies. As noted by Needle, Lepley, & Grooms (2017) ankle lateral ligament injuries extend beyond mechanical changes and peripheral sensory deficits, and have significant effects on the somatosensory and motor cortices. Therefore, further research is needed to explore therapeutic interventions that can target the central nervous system to address CAI.

This systematic review is the first to provide a comprehensive overview of the available evidence on the epidemiology, risk factors, and effectiveness of different conservative treatment methods and techniques for CAI. Through the review, we have identified interventions that effectively influence certain outcome measures, but it is challenging to determine the most effective method overall. The interventions with the most support include balance training, multimodal exercise programs incorporating balance training, muscle strengthening, functional tasks, and mobility exercises, joint mobilization targeting increased posterior glide of the talus, and whole-body vibration. On the other hand, external support has received the least support. Given the high prevalence of CAI among physically active individuals and those with a history of ankle sprain, it would be sensible to educate patients about the potential progression from acute to a chronic condition, as education is the component of high-quality care (Lin et al., 2020).

Limitations

As a limitation of this literature review, we can highlight the diversity of included studies, which encompass various methodologies, populations, outcome measures, types, and durations of interventions. Therefore, it is challenging to directly compare the effectiveness of individual interventions with one another. A challenge also arises from the inclusion of studies in systematic reviews before 2014, as during that time the inclusion and exclusion criteria for patients with CAI in research studies were not yet well-established. Our review was also limited to studies published in English, which may introduce language bias. While we primarily focused on systematic reviews and meta-analyses to ensure a broader overview of the existing

evidence, the exclusion of primary research studies may have resulted in the omission of valuable insights. Additionally, the potential impact of publication bias must always be acknowledged, as studies with significant findings may be more likely to be published, potentially skewing the overall conclusions.

CONCLUSION

CAI is a pathological condition that often occurs after LAS. In the physically active population, the prevalence of CAI is 25%, while in individuals with a history of LAS it reaches 46%. The highest prevalence is found in adolescents and in sports such as netball, dancing, and water sports. Recurrent ankle sprains are common in soccer and basketball. Risk factors are poorly understood, as most existing studies examine the variables that distinguish individuals with CAI from uninjured individuals with cross-sectional designs. However, prognostic factors for CAI include poorer static and dynamic balance, slower peroneal reaction time, evertor muscle weakness, and impaired proprioception. In contrast, there is no consensus on the influence of the degree of sprain on progression to CAI. Among treatments, balance training has been shown to be the most effective standalone intervention. It has been shown to elicit improvements in functionality, instability, dynamic balance, and health-related quality of life. In addition, a multimodal program that improves self-assessed ankle function and the use of vibration as an adjunct to physical therapy to influence joint position sensation and ankle muscle activation have also been shown to be effective. Joint mobilization is effective in increasing dorsiflexion and improving dynamic balance. On the other hand, the efficacy of external bracing as a sole intervention in the treatment of CAI has not yet been proven, despite its frequent use. Further research is needed on newer methods and techniques to treat arthritic muscle inhibition, such as transcranial direct current stimulation and focal ankle cooling.

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