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Clinical Exercise Science

THE SURVEY OF THE PREVALENCE OF CHRONIC ANKLE INSTABILITY IN ELITE TAIWANESE BASKETBALL ATHLETES

Dissertation

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Abbreviations

AE: athletic exposure

AII: The Ankle Instability Instrument

CAI: Chronic Ankle Instability

IAC: The International Ankle Consortium

ICC: Intraclass Correlation Coefficient

IdFAI: The Identification Functional Ankle Instability

LEFS: The Lower Extremity Functional Scale

LEFS-TW: The Taiwan-Chinese version of Lower Extremity Functional Score

NRS: Numeric Rating Scale

ROC: Receiver operating characteristic

VAS: Visual analog scale

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The survey of the prevalence of chronic ankle instability in elite Taiwanese basketball athletes

Abstract

BACKGROUND: Ankle sprains are common in basketball. It could develop into Chronic Ankle Instability (CAI) causing decreased quality of life, functional performance, early osteoarthritis, and increased risk of other injuries. To develop a strategy of CAI prevention, localized epidemiology data and a valid/reliable tool are essential. However, the epidemiological data of CAI is not conclusive from previous studies and the prevalence of CAI in Taiwanese basketball athletes are not clear. In addition, a valid and reliable tool among the Taiwan-Chinese version to evaluate ankle instability is missing.

PURPOSE: The aims were to have an overview of the prevalence of CAI in sports population using a systematic review, to develop a valid and reliable cross-cultural adapted Cumberland Ankle Instability Tool Questionnaire (CAIT) in Taiwan-Chinese (CAIT-TW), and to survey the prevalence of CAI in elite basketball athletes in Taiwan using CAIT-TW.

METHODS: Firstly, a systematic search was conducted. Research articles applying CAI related questionnaires in order to survey the prevalence of CAI were included in the review. Second, the English version of CAIT was translated and cross-culturally adapted into the CAIT-TW. The construct validity, test-retest reliability, internal consistency, and cutoff score of CAIT-TW were evaluated in an athletic population (N=135). Finally, the cross-sectional data of CAI prevalence in 388 elite Taiwanese basketball athletes were presented. Demographics, presence of CAI, and difference of prevalence between gender, different competitive levels and play positions were evaluated.

RESULTS: The prevalence of CAI was 25%, ranging between 7% and 53%. The prevalence of CAI among participants with a history of ankle sprains was 46%, ranging between 9% and 76%. In addition, the cross-cultural adapted CAIT-TW showed a moderate to strong construct validity, an excellent test-retest reliability, a good internal consistency, and a cutoff score of 21.5 for the Taiwanese athletic population. Finally, 26% of Taiwanese basketball athletes had unilateral CAI while 50% of them had bilateral CAI. In addition, women athletes in the investigated cohort had a higher prevalence of CAI than men. There was no difference in prevalence between competitive levels and among play positions.

CONCLUSION: The systematic review shows that the prevalence of CAI has a wide range among included studies. This could be due to the different exclusion criteria, age, sports discipline, or other factors among the included studies. For future studies, standardized criteria to investigate the epidemiology of CAI are required. The CAI epidemiological study should be prospective. Factors affecting the prevalence of CAI ability should be investigated and described. The translated CAIT-TW is a valid and reliable tool to differentiate between stable and unstable ankles in athletes and may further apply for research or daily practice in Taiwan. In the Taiwanese basketball population, CAI is highly prevalent. This might relate to the research method, preexisting ankle instability, and training-related issues. Women showed a higher prevalence of CAI than men. When applying the preventive measure, gender should be taken into consideration.

Keywords: chronic ankle instability, ankle sprain, sports injury, Cumberland Ankle Instability Tool, prevalence

Studie zur Prävalenz von chronischer Sprunggelenkinstabilität bei taiwaneschen Elite-Basketball-Athleten*innen

Zusammenfassung

HINTERGRUND: Verstauchungen des Sprunggelenks sind beim Basketball häufig. Daraus kann sich eine chronische Sprunggelenkinstabilität (Chronic Ankle Instability, CAI) entwickeln, die zu verminderter Lebensqualität, funktioneller Leistung, früher Arthrose und einem erhöhten Risiko für andere Verletzungen führt. Um eine Strategie zur CAI-Prävention zu entwickeln, sind lokalisierte epidemiologische Daten und ein valides/zuverlässiges Instrument erforderlich. Allerdings sind die epidemiologischen Daten von CAI aus früheren Studien nicht schlüssig und die Prävalenz von CAI bei taiwanesischen BasketballsportlerInnen ist nicht klar. Darüber hinaus fehlt ein valides und zuverlässiges Werkzeug in der taiwanesisch-chinesischen Version zur Beurteilung der Sprunggelenkinstabilität.

ZIEL: Die Ziele waren, anhand einer systematischen Übersichtsarbeit einen Überblick über die Prävalenz von CAI in der Leistungssportlerpopulation zu erhalten. Zudem sollte ein valides, reliables und kulturübergreifendes Tool für Umfragen der Sprunggelenkinstabilität, in Form des Cumberland Ankle Instability Tool Questionnaire (CAIT) in Taiwan-Chinesisch (CAIT-TW) entwickelt, sowie die Prävalenz von CAI bei Elite-Basketball- Athleten*innen in Taiwan mit Hilfe des CAIT-TW erhoben werden.

METHODEN: Zunächst wurde eine systematische Suche durchgeführt. Forschungsartikel, die CAI-bezogene Fragebögen verwenden, um die Prävalenz von CAI zu erheben, wurden in den Reviews aufgenommen. Als nächster Schritt wurde die englische Version des CAIT übersetzt und kulturübergreifend in den CAIT-TW adaptiert. Die Konstruktvalidität, die Test-Retest-Reliabilität, die interne Konsistenz und der Schwellenwert des CAIT-TW wurden in einer

Leistungssportlerpopulation (N=135) evaluiert. Schließlich wurden die Querschnittsdaten der CAI-Prävalenz bei 388 taiwanesischen Elite-Basketball-Athleten vorgestellt. Es wurden demografische Daten, das Vorhandensein von CAI und der Unterschied der Prävalenz zwischen den Geschlechtern in verschiedenen Wettkampfniveaus und Spielpositionen ausgewertet.

ERGEBNISSE: Die Prävalenz von CAI betrug 25 % und lag zwischen 7 % und 53 %. Die Prävalenz von CAI unter den Teilnehmern mit einer Vorgeschichte von Sprunggelenksverstauchungen lag bei 46 % und reichte von 9 % bis 76 %. Darüber hinaus zeigte der kulturübergreifend adaptierte CAIT-TW eine mäßige bis starke Konstruktvalidität, eine ausgezeichnete Test-Retest-Reliabilität, eine gute interne Konsistenz und einen Grenzwert von 21,5 für die taiwanesische Sportlerpopulation. Schließlich wiesen 26% der taiwanesischen Basketball-Athletinnen ein unilaterales CAI auf, während 50% von ihnen ein bilaterales CAI hatten. Darüber hinaus hatten weibliche Sportler in der untersuchten Kohorte eine höhere Prävalenz von CAI als Männer. Es gab keinen Unterschied in der Prävalenz zwischen den Leistungsniveaus und zwischen den Spielpositionen.

SCHLUSSFOLGERUNG: Der systematische Review zeigt, dass die Prävalenz von CAI unter den eingeschlossenen Studien eine große Bandbreite aufweist. Dies könnte auf die unterschiedlichen Ausschlusskriterien, das Alter, die Sportdisziplin oder andere Faktoren in den berücksichtigten Studien zurückzuführen sein. Für zukünftige Studien werden standardisierte Kriterien zur Untersuchung der Epidemiologie von CAI benötigt. Epidemiologische Studien zu CAI sollten daher prospektiv angelegt sein. Zudem sollten Faktoren, die die Prävalenz der CAI-Fähigkeit beeinflussen, untersucht und beschrieben werden. Der übersetzte CAIT-TW ist ein valides und zuverlässiges Instrument zur Unterscheidung zwischen stabilen und instabilen Sprunggelenken bei Sportlerinnen und kann für die Forschung oder die tägliche Praxis in Taiwan weiterverwendet werden. In der taiwanesischen Basketballpopulation ist CAI stark verbreitet. Dies könnte mit der Untersuchungsmethode, einer vorbestehenden Sprunggelenksinstabilität und trainingsbedingten Problemen zusammenhängen. Frauen zeigten eine höhere Prävalenz von CAI als Männer. Bei der Anwendung der Präventionsmaßnahme sollte das Geschlecht berücksichtigt werden.

Schlüsselwörter: chronische Sprunggelenkinstabilität, Verstauchungen des Sprunggelenks, Sportverletzung, Cumberland Ankle Instability Tool, Prävalenz

1. Introduction

Ankle sprain is one of the most common sports injuries in active populations [1]. Sports, involving repetitive cutting, rapid stop, directional change, jumping and landing, (ex: basketball, ice hockey, soccer, and gymnastics) are prone to ankle sprains with an incidence of 0.5 per 1000 athletic exposures (AEs) [1]. Ankle sprain is not only an acute injury but also causes residual symptoms [2]. These can include recurrent ankle sprain, pain, swelling, perceived ankle instability and weakness [2]. The residual symptoms from an acute ankle sprain can last more than two years [3]. The term to describe the consequence caused by an acute ankle sprain is chronic ankle instability (CAI) [4]. CAI affects ankle functions and alters the neuromuscular control in the knee, hip and trunk bilaterally [5-8]. This could cause further injuries, such as early developed osteoarthritis, loading on the anterior cruciate ligament, recurrent ankle sprain, decreased quality of life and reduced level of physical activity in the long term [2, 9-11].

The signs and symptoms of CAI are varying [3]. Previous studies investigating CAI applied different criteria to define CAI [12]. Therefore, in 2014 the International Ankle Consortium (IAC) suggested standard criteria to define CAI for controlled research [4]. The criteria to identify CAI can include a history of significant ankle sprains, recurrent ankle sprains, and/or perceived ankle instability, and/or experiencing uncontrolled ankle sudden inversion [4]. There are three suggested tools to evaluate the presence of perceived ankle instability: the Ankle Instability Instrument (AII), the Cumberland Ankle Instability Tool (CAIT), and Identification of Functional Ankle Instability (IdFAI) [13-15].

Before IAC published the standard criteria for participants selection in CAI related studies, a systematic review that investigated the presence of CAI in sporting populations defined participants with CAI as having a history of ankle sprain while perceiving ankle instability or mechanical ankle instability or persisting symptoms or recurrent ankle sprain [16]. After IAC published the statement, late studies applied the standard of IAC using questionnaires to investigate the epidemiology of CAI [17, 18].

To develop prevention strategies for CAI, epidemiology data is essential and CAI-related risk factors should be investigated [19]. However, the epidemiological data of CAI is not conclusive from previous studies. The studies investigating CAI-related factors are limited. The epidemiological data of CAI in Taiwan is scarce. In addition, there is no tool in the Taiwan-Chinese version to evaluate the perceived ankle instability. Furthermore, in the basketball population ankle sprain is the most common injury [20]. A high rate of ankle sprain could indirectly increase the prevalence of CAI. The prevalence of CAI has been evaluated in basketball athletes [17, 21, 22], however, the sample size is small.

Therefore, the study aims to investigate the prevalence of CAI in sports populations using a systematic review, to cross-cultural adapt the Cumberland Ankle Instability Tool Questionnaire to Taiwan-Chinese version (CAIT-TW), to survey the prevalence of CAI in elite basketball athletes in Taiwan using CAIT-TW, and to investigate the association between CAI prevalence and gender, competitive level and play position. This cumulative thesis comprises three recent studies that were published (under review) in peer-reviewed journals.

2. Literature Review

2.1 The epidemiology of ankle sprain and residual symptoms

Ankle sprain is one of the most common sports injuries in active populations [1, 23]. In 2010 the US Emergency Departments showed that the incidence of ankle sprain was 3.29 per 1000 person per year [24]. Sports involving jumping, landing and repetitive direction changing are prone to ankle sprain [1]. The incidence of ankle sprain was 3.1 per 1000 athlete-exposures (AEs) in sub-elite football athletes [25]. The incidence of lateral ligament complex ankle sprain was 0.5 per 1000 AEs in US collegiate student-athletes [1]. The incidences of ankle sprain were between 0.4 and 3.1 per 1000 AEs in high-school athletes [26-28].

Ankle sprain is not only an acute injury but can also leads to residual symptoms [2]. Anandacoomarasamy and Barnsley (2005) found that 74% of the participants showed residual symptoms after an acute ankle sprain [29]. During an average 29-month follow-up after an acute ankle sprain, residual symptoms include pain, swelling, giving way or weakness [29]. Yeung et al. (1994) found that 59% of the surveyed athletes sustained residual symptoms, such as pain (30%), instability (20%), crepitus (18%), weakness (17%), stiffness (15%), swelling (14%) and others (8%) [30]. Braun (1999) found that after 6 to 18 months of ankle sprain, 72.6% in a general clinic population showed residual symptoms (ankle instability, weakness, pain, and swelling) and limited physical activity (unable to turn or jump on ankle without symptoms (43%) or walk a mile without pain or limping (40%)) [31]. In short, more than half of the participants (59%-72.6%) suffer from residual symptoms after an acute ankle sprain.

A history of a previous ankle sprain is a risk factor for developing recurrent ankle sprains [32]. Delahunt and Remu showed that college students with a history of previous ankle sprain sustained about twice as likely to suffer a subsequent ankle sprain (hazard ratio =2.21, 95%CI=

1.07-4.57) [33]. de Noronha showed that athletes with previous ankle sprain had a 6.5 times higher incidence of non-contact ankle sprain than athletes without a history of ankle sprain [34]. Acute ankle sprains can cause recurrent ankle sprain and develop into CAI [2].

2.2 Chronic ankle instability

The residual symptoms resulting from an ankle sprain are heterogeneous and the terms to describe the sequelae of acute ankle sprains are also diverse (e.g. functional instability [35-37], functional ankle instability [38], chronic lateral ankle instability [39, 40], chronic ankle sprain [41], recurrent lateral instability [42] and chronic ankle instability (CAI)) [4]. The residual symptoms of ankle sprain/CAI have been investigated since 1955 and the definition and description of CAI are evolving with time.

In 1955 Bosien, StaplesIn and Russel found that after 27-month of ankle sprain, 36% of participants showed recurrent ankle sprains, 33% had residual symptoms and 60% showed persistent abnormal changes on the ankle [3].

In 1965 Freeman et al. applied the term “functional instability” describing the phenomenon of individuals of the foot to giving way to an ankle sprain and mechanical instability or an ankle joint laxity after an ankle sprain [35-37].

In 2002 Hertel described CAI as the condition of repetitive bouts of lateral ankle instability resulting in numerous ankle sprains. In Hertel’s model, CAI includes mechanical insufficiencies, functional insufficiencies or both (Figure 1A) [43].

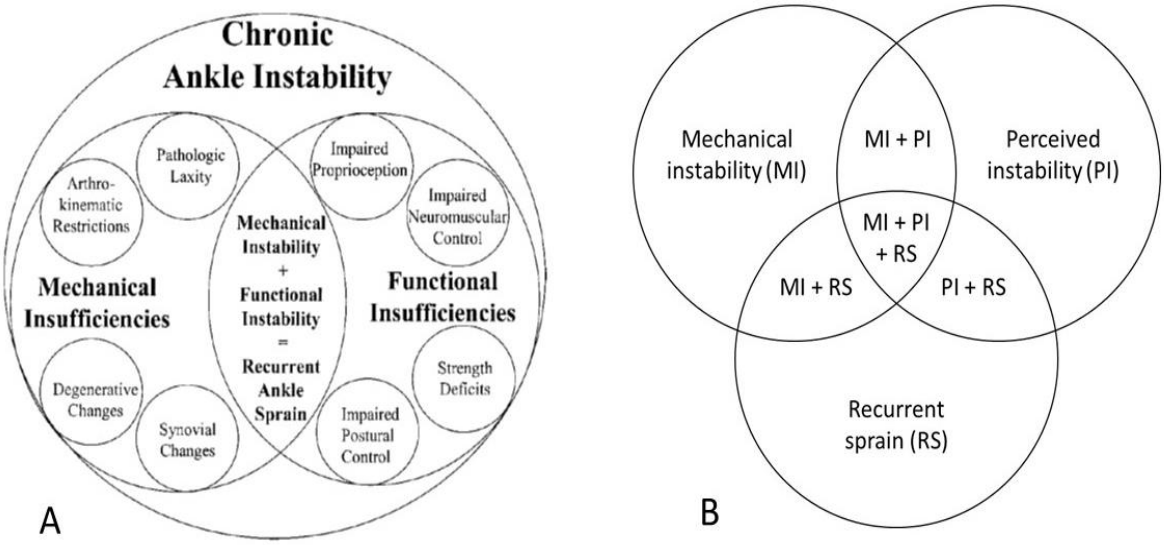
In 2011 Hiller, Kilbreath and Refshauge proposed a model for CAI. They displayed that participants with residual symptoms after an ankle sprain could be placed into three categories: mechanical instability, perceived instability and recurrent ankle sprain (Figure 1B) [44].

In 2013 the International Ankle Consortium published selection criteria for participants with CAI for research purposes [4]. The inclusion criteria are (1) with a history of at least one significant ankle sprain, and (2) with a history of giving way, recurrent ankle sprain or feeling of ankle joint instability [4]. "A significant ankle sprain" should be associated with inflammatory symptoms and must have occurred 12 months before the study. "Giving way" means the uncontrolled and unpredictable episode of excessive ankle inversion and must occur at least twice in the past six months. "Recurrent ankle sprain" is defined as two or more ankle sprains to the ankle with a history of a significant ankle sprain. "Feeling of ankle joint instability" can be confirmed using self-reported ankle instability tools: the Ankle Instability Instrument (answering more than five "yes"), the Cumberland Ankle Instability Tool (CAIT) (the score is less than 24) and the Identification of Functional Ankle Instability (the score is more than 11) [4].

In 2019 Hertel and Revay presented an updated model of CAI. The model showed the impairments (pathomechanical, sensory-perceptual and motor-behavioral) after an ankle sprain, the interaction of personal and environmental factors to the impairment and the outcome after 12 months of the initial ankle sprain [5].

To date, the description and definition for CAI are concrete and specified [5]. For research purposes, standard selection criteria and questionnaires measuring ankle instability are available [4].

Figure 1 Models of chronic ankle instability



A. Paradigm of mechanical and functional insufficiencies that contribute to chronic ankle instability [42]. B. The model of chronic ankle instability developed by Hiller, Kilbreath, and Refshauge [43]

2.3 The consequence of chronic ankle instability

Post-traumatic osteoarthritis

Ankle injury can cause younger and faster functional loss osteoarthritis, which will impact the quality of life [2, 45]. A single acute ankle sprain also results in osteochondral lesions [5] and it can gradually develop into post-traumatic osteoarthritis [46]. CAI has been associated with post-traumatic osteoarthritis [2]. Studies showed that patients with CAI had osteochondral lesions and degenerative cartilage in the injured ankle [47, 48].

Neuromuscular change

CAI is not only an ankle issue, it can also affect the proximal joints, for example, the knee, hip, and trunk [8, 49].

In the ankle joint, the altered neuromuscular control makes participants with CAI walk and run with an inverted and plantar-flexed ankle before heel contact. This is a vulnerable ankle posture facilitating further lateral ankle sprains [50].

In the knee joint, participants with CAI showed changed knee kinematics when landing, which is a risk factor for knee injuries [10], and showed increased muscle activation of rectus femoris before heel contact while walking, which might be the compensation for the deficit ankle shock absorption [51].

In the hip joint, CAI is related to decreased hip strength (external rotator, abductor and extensor), changed hip muscle activation (gluteus medius) and altered hip kinematics (increased hip flexion during functional tasks) [8, 52-55].

Decreased trunk stability has been found in participants with CAI [6, 56]. Marshall, Mckee, and Murphy (2009) found that CAI delays the trunk muscle reflex activities in a trunk perturbed task [6], and Terad, Kosik, Mccann and Gribble (2016) found that CAI decreases hemidiaphragm contractility [56].

Decreased physical activities and quality of life

Ankle sprain is an acute injury that causes pain, swelling, limited range of motion and loss of ankle function [57]. The residual symptoms from an ankle sprain limit ankle function and general physical function [9, 58] . The limited ankle function not only affects the health-related quality of life [11, 59] but also declines physical activity [9].

Decreased ankle function caused by CAI is associated with a deteriorated health-related quality of life [58]. Besides limited ankle function also lowers physical activity in both the short-term and long-term [60, 61]. In the short term, an acute ankle sprain restricts running speed and distance in a mice model [60]. In the long-term, one year after an acute ankle sprain participants showed lower physical activity compared to pre-injury level and matched controls [61]. A low level of physical activity is connected to further potential chronic illness or injuries [62]. In sum, CAI is related to post-traumatic osteoarthritis, neuromuscular change, decreased physical activities and quality of life that causes long-term ankle problems provokes further injuries and potential lifelong chronic illness.

2.4 The epidemiology of chronic ankle instability

Since CAI causes lifelong negative consequences, it is essential to have a comprehensive view of its epidemiology. The prevalence of CAI has been systematically reviewed in children [63]. The prevalence of the perceived ankle instability with a history of previous ankle sprain was 23% to 71% in dancers, adolescent soccer players, obese kids and kids with previous severe ankle injuries [64-67]. The prevalence of mechanical instability was 18% to 47% in dancers and adolescent soccer players [64]. The prevalence of recurrent ankle sprain was 22% in dancers, kids with normal weight and physical education students [34, 64, 67-70].

In sports populations, the epidemiology was summarized by Attenborough and colleagues [16]. The recurrent ankle sprain (61%) and mechanical instability (38%) are the most prevalent in soccer [16]. The highest rate of perceived ankle instability was in netball (39%) and track and field (41%) with a history of ankle sprain [16, 71, 72]. Gymnastics and basketball had the highest percentage of persisting symptoms (64% and 51% respectively) after an ankle sprain [16, 73, 74].

In a young general population (17-year-old), Hershkovich et al. (2015) defined CAI as " an individual had recurrent ankle sprains, ankle functional impairment, mechanical ankle instability or residual symptoms after one year of ankle sprain [75]. They found that the prevalence of CAI was 1% in Israel citizens (N=829,791) who were recruited into mandatory military service [75].

In brief, the prevalence of CAI is diverse in different populations. In children and the athletic population with a history of ankle sprain, the prevalence of CAI ranged from 18%-71%. In the young general population, the prevalence is only 1%. The range of the prevalence is wide (1% to 71%), which is related to the research method. Studies investigated the prevalence of CAI applied to different criteria for identifying CAI, targeted in different populations (e.g. children, athletes and the general population) and without using recommended tools (e.g. CAIT, IdFAI and AII). Since the IAC provided standard criteria for the research of CAI, studies conducted based on the criteria need to be summarized. Therefore, a comprehensive overview of the epidemiology of CAI can be presented.

2.5 The prevalence of chronic ankle instability in basketball athletes

Epidemiology of ankle sprain in basketball

Ankle sprain is the most common injury in basketball [1, 76, 77]. The epidemiology of ankle sprain in basketball athletes is summarized in Table 1. Of all injuries in basketball ankle sprain was 14% to 36% (0.33-1.29/1000 athletic exposures (AEs)) in high-school-athletes [1, 28, 78], 16%-25% (0.88-2.15/1000AEs) in collegiate athletes [76, 78, 79] and 13%-26% (1.3-3.5/1000 AEs) in professional athletes [80-82]. The injured timings are rebounding (25-33%) followed by defending (13-15%) and general playing (16-28%) [83, 84]. The majority mechanism is due to contact with another person (50-57%) [78, 79, 84].

Epidemiology of chronic ankle instability in basketball

Of all injuries, 19%-22% of injuries were recurrent ankle sprain in basketball athletes [1, 28, 84]. The prevalence of CAI in the basketball population has been investigated. A systematic review concluded that in basketball 60% of the participants have recurrent ankle sprains, 28% perceived ankle instability with a history of an ankle sprain and 30% suffered from persisting symptoms after an ankle sprain [16]. Besides, one study found that 30% (17/57) of basketball student-athletes were having CAI in the US [17]. Two studies found that in Japan 4%-64% (1/24, 8/22 and 14/22) of the collegiate basketball athletes had CAI [21, 22]. In a word, the prevalence of CAI in basketball athletes with a history of ankle sprain could range from 4% to 64%.

Although the prevalence of CAI in the basketball population has been investigated, the sample sizes are small (N=22-57). Becides, previous studies excluded athletes with a history of fracture and injury in the lower extremities. Athletes with the previous injury may also have CAI, the prevalence of CAI may be underestimated. Therefore, a survey for basketball athletes should be conducted and the athletes with other ankle issues should also be included in the surveillance.

Table 1 The epidemiology of ankle sprain in basketball athletes

Author	country	Year	Participant	Methods	Results
Borowski et al., 2008 [83]	USA	2005-2007	High school basketball players	RIO	The most common body sites injured ankle/foot (39.7%) Boy: 43.2% (n= 196829) Girl: 35.9% (n= 211535)
Pasanen et al., 2017 [28]	Finland	2011-2014	Nine adolescent basketball U18 teams Male: 100 Female: 101	Questionnaire Coach physician	Lateral ankle sprain n= 72 All player: 1.20 (0.93-1.48) Girl: n= 33, 1.29/1000AE (0.85-1.74) Boy: n=39, 1.14/1000AE (0.78-1.49)
Ross et al., 2016 [1]	USA	2009/2010-2014/2015	25 sports from the NCAA	NCAA-ISP	Lateral Ligament Complex Ankle Sprains Mem: 15%, 1.2/1000 (10.70-13.22) Women: 14%, 1.0/1000 (8.29-10.71)
Zuckerman et al., 2018 [76]	USA	2009/2010–2014/2015	NCAA basketball teams men's team: 78 women's team: 74	NCAA-ISP	The most common injury in men's and women's basketball was ankle sprain Men:17.9% (n=141), 1.43/1000AE (1.29-1.57) Women: 16.6% (n=270), 1.08/1000AE (0.95-1.21)
Clifton, Onate et al., 2018 [79]	USA	2005/2006-2013/2014 2004/2005-2013/2014	Basketball male athletes in High school and college	RIO NCAA-ISP	Commonly injured body parts were the ankle High school athletes: - Practices: 35.9%, 0.39/1000AE (0.36, 0.43) - Competitions: 32.6%, 0.85/1000AE (0.77-0.92) Collegial athletes: - Practices: 25.0%, 1.10/1000AE (1.02, 1.18) - Competitions: 24.3%, 2.15/1000AE (1.93-2.36)
Clifton, Hertel et al., [78]	USA	2005/2006-2013/2014 2004/2005-2013/2014	Basketball female athletes in high school and college	RIO NCAA-ISP	Commonly injured body parts were the ankle High school athletes: - Practices: 29.3%, 0.33/1000AE (0.30-0.36) - Competitions: 28.9%, 0.98/1000AE (0.90, 1.07) Collegial athletes: - Practices: 21.7%, 0.88 (0.81-0.96) - Competitions: 21.2%, 1.71 (1.52-1.90)

Tummala et al., 2018 [84]	USA	2004-2014	NCAA Men's and Women's Basketball teams	NCAA-ISP	Men: 1.49/1000 AEs Women: 1.21/1000 AEs
Rodas et al., 2019 [81]	Spain	2007-2015	59 professional male basketball players	a validated electronic medical record system	Ankle sprain: 1.3/1000 AEs (1.0-1.7)
Herzog et al., 2019 [82]	USA	2013/2014-2016/2017	30 NBA teams	the NBA electronic medical record system	Single-season risk of ankle sprain was 25.8%
Starkey, 2000 [77]	USA	1988-1997	1094 NBA athletes	NBTA	Ankle was the most common site of musculoskeletal trauma 10.7%(n=1062) Ankle sprains were the most frequently occurring orthopedic injury 9.4%(n=942)
Deitch et al., 2006 [80]	USA	1996-2002	N= 1145 NBA 702 (61%) WNBA 443 (39%)	NBTA	A lateral ankle sprain was the most common diagnosis Total: 13.7% (n=611) NBA: 14.3% (n=412), 3.5/1000AE WNBA: 12.7% (n=199), 4.3/1000AE
Drakos et al., 2010 [85]	USA	1988/1989-2004/2005	NBA N=1094	NBTA	Lateral ankle sprains were found most common: 13.2% (n=1658)
Baker et al., 2020 [86]	USA	2015- 2019	WNBA	WNBA database	Lateral ankle sprains were noted to be the most common injury: 20%(n=39)

NCAA: The National Collegiate Athletic Association, NBA: National Basketball Association, WNBA: Women's National Basketball Association, RIO: High-School Reporting Information Online; NCAA-ISP: The National Collegiate Athletic Association Injury Surveillance Program; NBTA: The data base from the National Basketball [Athletic] Trainers' Association, AE: athletic exposures

2.6 The influence of gender, competitive level and play position on the injury rate of ankle sprain and chronic ankle instability

Gender, level of competition, and played position have been considered as factors that impact the injury rate of ankle sprain in basketball. However, the evidence is not conclusive. This section provides a brief overview of how the above factors: gender, level of competition, and play position, influences the injury rate of ankle sprain and chronic ankle instability in basketball.

2.6.1 Gender difference on the incidence of ankle injury

Gender affects the ankle injury rate in basketball (see Table 2). However, there have been other researches that prove otherwise. Despite three studies presented evidence that females suffer fewer ankle injuries than males [76, 83, 84]. There are two that indicate opposite results [87, 88]. In addition, the two researches pointed out that there are no indistinguishable gender differences in ankle injury [28, 80] .

The differences between ankle injury rates could be the result of varying anatomical structures, joint laxity and menstrual cycles [88-92]. Regarding the structural differences between genders, Beynnon and colleagues (2001) found that female college athletes with an increased tibial varum and calcaneal eversion range of motion have a greater risk of ankle sprains [93].

Wilkerson and Mason (2000) investigated the dissimilarities of ankle joint laxity between men and women. They tested the angle of inverted talar tilt in female and male athletes who have no history of significant ankle ligamentous injury. The results stated that women's inverted talar tilt is 2.9 times higher than men's (women: 3.20 degrees and men: 1.07 degrees, $p < 0.01$) [89]. The study suggested that women had a greater ligamentous laxity of the lateral ankle than men [89].

Menstrual cycles, especially ovulation, alter muscle activities and mechanical property around the ankle joint, further affect ankle joint stability and postural stability [90-92]. Lee and Yim (2016) found that healthy young women have altered muscle activation in the ankle joint in the ovulate phase yet worse postural stability in ovulation than in the follicular phase [90]. Similarly, Yim, Jerrold, Petrofsky, and Lee (2018) stated that muscle tone of muscles around the ankle (tibilais anterior, peroneal longus, and lateral gastrocnemius) and dynamic stiffness are significantly lower in the ovulating phase than in the menstruating phase; the decreased muscle tone and stiffness are correlated to postural stability [91]. In addition, Khowailed and Lee pointed that ovulated women have greater postural sway than menstruated women and men [92]. Women in the ovulate phase of menstrual cycles showed less postural stability than that in the follicular phase. This could be the factor causing the different injury rates between genders.

To sum up, women have overall different ankle structural, greater joint laxity and in the ovulation phase less postural stability in comparison to men. These may be the reasons how gender plays an important role in the ankle injury rate.

2.6.2 Level of competition and injury ankle injury rate

The relation between competitive level and rate of ankle sprains is not clear yet [78, 88, 94] (see Table 3). Previous studies suggested that athletes at a higher competitive level seem to have a higher rate of ankle injury than those at a lower level [95]. Athletes' body composition [34, 96], play intensity [78, 97], athletic exposure [95], and prevalence of a history of previous ankle sprain [97, 98] are possible explanations to this assumption.

The greater body mass and body mass index (BMI) are risk factors for ankle sprain in high school, collegiate, professional athletes and military recruits [32, 34, 96]. In general, athletes in a higher competitive level are taller and heavier than those in a less competitive level, which is related to a different rate of ankle sprain [71]. When playing, higher competitive level athletes create greater force and intensity than athletes in a lower competitive level, which may increase the risk of injury [78, 79, 97]. Because of more practice sessions/time for higher competitive level athletes than lower competitive level athletes, the recovery period between sessions is relatively less for highly competitive athletes [95]. Less recovery period causing tiredness and muscle fatigue in lower extremities negatively affect postural control which is related to a risk of ankle sprain [32, 99, 100]. In addition, athletes in a higher competitive level have had a greater number of previous ankle sprain than that in a lower competitive level, which is one of the risk factors of recurrent ankle sprain [98, 101].

2.6.3 Play position and ankle injury rate

Basketball athletes in different positions (guard, forward and center) do different tasks [102]. Therefore, physiological profiles are distinct among play positions [103, 104]. Guard with good aerobic and anaerobic capacity performs high-intensive tasks, for example, transitioning from defense to offense, creating chances for teammates to score, and do many turning, shuffling and direction change [102, 105]. Forward runs a lot during competition [102]. Center, the tallest, heaviest and strongest among all play positions, carries out rebounding and contacting other opponents during boxout [103, 105].

Different characteristics may be associated with different injury rates. The injury rates among play positions have been investigated. , Meeuwisse, Sellmer, and Hagel (2003) noted center suffer the most contact and noncontact injuries among all play positions because centers are with the heaviest body mass performs move around a high concentrate area with other athletes and jump great amount for rebound [106]. Yet, Vanderlei et al. (2013) suggested that the guard sustains the most physiological demanding compare to other paly positions, which may cause fatigue affecting neuromuscular control and predispose to ankle sprain [103, 105]. However, the correlations of play positions and ankle injury rate are not consistent (see Table 4). It is important to identify if there is a different injury rate of ankle sprain among different play positions because a prevention strategy can be integrated into daily training based on play positions.

Table 2 Injury rate of ankle sprain and gender

Authors, year	Participants	Investigate duration/study design	Method	Results
Borowski et al., 2006 [83]	USA high school basketball athletes	2-Year (2005-2007) Descriptive epidemiology study	HS-RIO	Ankle/foot injury: **girl < boy** (36% vs 43%) IPR, 1.20 [95% CI, 1.04-1.40], P = .01
Tummala et al., 2018 [84]	USA men's & women's collegiate basketball players	10-Year (2004-2014) Descriptive epidemiology study	NCAA-ISP	Ankle injury: **women < men** IPR: 0.81 [95% CI, 0.75-0.88 Competition: IPR, 0.80 [95% CI, 0.69-0.92] Practice: IPR, 0.80 [95%CI, 0.69-0.92] Preseason: IPR, 0.72 [95% CI, 0.62-0.84] In-season: IPR, 0.87 [95% CI, 0.78-0.96] Postseason: IPR, 0.53 [95% CI, 0.30-0.96] Recurrent injury: women > men IPR: 1.77 [95% CI, 1.22-2.57]
Zuckerman et al., 2018 [76]	USA men's & women's collegiate basketball players	5-Year (2009/2010–2014/2015) Descriptive epidemiology study	NCAA-ISP	Basketball injury rates: **women < men** Women: 6.54 (6.22 to 6.85) Men: 7.97 (7.65 to 8.30)
Hosea et al., 2000 [87]	USA 125 high schools/colleges/ universities basketball athletes N=11780, Women: 4940 Men: 6840	2-Year Prospect epidemiologic study	Athletic exposure	Ankle injury: **women > men** (1.25:1) P<.001
Beynnon et al., 2005 [88]	USA high school and college athletes	4-Year (1999-2003) Cohort study	Athletic exposure	Ankle sprain in basketball players **Women > men** RR: 4.11; [95% CI, 0.91-18.60], P = .046

Deitch et al., 2006 [80]	USA WNBA: 433 NBA: 702	WNBA: 5-Year (1997-2002) NBA: 6-Year (1996-2002) Cohort study (prevalence)	Athlete exposures	lower extremity injuries: **women > men** (p=.01) Women: n=1031,66% [95% CI, 13.1-16.2] Men: n=1857, 65% [95% CI, 10.8-12.4] Ankle injury: **no difference** Women: n=235, 15%, [95% CI, 4.1-5.9] Men: n=486, 17%, [95% CI, 3.6-4.5]
Pasanen et al., 2017 [28]	Finland adolescent basketball	3-Year (2011-2014) Prospective follow-up study	Questionnaire Coach Physician	Injury rate of high ankle injury: **no difference** Women: n= 36, 1.41 (0.95-1.87) Men: n= 39, 1.14 (0.78-1.49) IRR: 1.24 (0.79-1.95), p=.35

IRR: Incidence rate ratio, IPR: Injury proportion ratios, NCAA-ISP the National Collegiate Athletic Association Injury Surveillance Program/System,

HS-RIO: High School Reporting Information Online

Table 3 Injury rate of ankle sprain and competitive levels

Authors, year	Participants	Investigate duration/ study design	Method	Results
Clifton, Onate, et al., 2018 [79]	USA High school/collegiate basketball male athletes	High school 8-Year (2005/2006-2013/2014) College 9-Year (2004/2005–2013/2014) Descriptive epidemiology study	HS-RIO NCAA-ISP	Total injury rate:**college > high school** IRR: 3.43, [95% CI, 3.28-3.59]
Clifton, Hertel, et al., 2018 [78]	USA High school/collegiate basketball female athletes	High school 8-Year (2005/2006-2013/2014) College 9-Year (2004/2005–2013/2014) Descriptive epidemiology study	HS-RIO NCAA-ISP	Total injury rate:**college > high school** 4.96 vs 1.82 AE/1000 The estimated national number: **college < high school** college: 72 264 high school: 775 942
Clifton et al., 2016 [95]	American football athletes in youth, high school , and college	2-Year (2012-2014)	YFSS NATION NCAA-ISP	The lateral ligament complex sprain rate: **College > high school & youth** (RR = 1.30; 95% CI, 1.14-1.47) (RR = 1.54, 95% CI, 1.23-1.92) The high ankle sprain rate: College> high school > youth (RR = 1.97; 95% CI, 1.59-2.44) (RR = 10.12; 95% CI, 4.48-22.87) (RR = 5.13; 95% CI, 2.27-11.56).
Beynnon et al., 2005 [88]	high school and college athletes	4-Year (1999-2003) Cohort study	Exposure rate	The risk of ankle injury: **No difference** RR: 1.16 [95% CI, 0.61-2.21], P =.64 College: n=238, 4.4%, 0.99 (0.54 -1.65) /1000 person-days High school: n=663, 5.9%, 0.80 (0.53-1.14)/1000 person-days

NCAA-ISP the National Collegiate Athletic Association Injury Surveillance Program/System, HS-RIO: High School Reporting Information Online, YFSS: the Youth Football Safety Study, NATION: the National Athletic Treatment, Injury and Outcomes Network

Table 4 Injury rate of ankle sprain and basketball played positions

Authors, year	Participants	Investigate duration/ study design	Method	Results
Starkey, 2000 [77]	USA NBA athletes N= 1094	10-Year (1988/1989–1997/1998)	NBTA	Game-related injury rate: **Forward > guard > center** Forward: 21.7/1000 AEs Guard: 21.3/1000 AEs Center: 21.0/1000 AEs
Meeuwisse et al., 2003 [106]	Canada Athletes participated in the Canada West Division of Canadian Intercollegiate Athletic Union men's basketball,	2-Year	CISIR	**Center > forward & guard** Center: n=6, 11% Forward: n=16, 2% Guard: n=23, 3%
Kofotolis & Kellis, 2007 [107]	Greece 18 professional basketball facilities N=204	2-Year (2 consecutive seasons) Prospective cohort study.	Athletic exposure rate	**Center > forward, guard** (26%, 20% 12%)
Borowski et al., 2008 [83]	USA high school basketball athletes	2-Year (2005-2007) Descriptive epidemiology study	HS-RIO	**Guard > forward > center** Girl vs boy: Guard: 50% 50% Forward: 35% 41% Center: 14% 13%
Tummala et al., 2018 [84]	USA men's & women's collegiate basketball players	10-Year (2004-2014) Descriptive epidemiology study	NCAA-ISP	Ankle sprain in competition: **Guard > forward > center** (n=194, 43%, n=155, 35%, n=80, 18%) IPR, 1.73 [95% CI, 1.43-2.11] IPR, 3.11 [95% CI, 2.40-4.03] IPR, 1.79 [95% CI, 1.34-2.39]

Sitler et al., 1994 [108]	USA United States Military Academy cadets' ankle sprains in Basketball intramural basketball seasons. N=1061	2-Year (1990 & 1991) randomized clinical study	Athletic exposure rate	**No difference among positions** Guard: n=20, 43%, Forward: n= 18, 39% Center: n= 8, 18% The incidence of ankle injury by position was independent of brace assignment (X^2 = 0.9311, P >0.30).
Cumps et al., 2007 [109]	14 basketball teams Professional: 2 men's teams National: 8 Regional: 4 N=164	one competitive season	Athletic exposure rate	Ankle sprain **No difference** among positions in offense
McKay, Goldie, Payne, & Oakes, 2001 [98]	Australia Elite/recreational basketball athletes N=10 393	an elite competition three recreational competitions cross-sectional study	Questionnaire	**Position played was not related to the occurrence of ankle injury**
Clifton, Hertel, et al., 2018 [78]	USA High school/collegiate basketball male athletes	High school 8-Year (2005/2006-2013/2014) College 9-Year (2004/2005–2013/2014) Descriptive epidemiology study	HS-RIO NCAA-ISP	Ankle sprain in High school athletes Center: 35% Forward: 30% Guard: 30% Ankle sprain in Collegiate athletes Center: 30% Forward: 24% Guard: 21%
Clifton, Onate, et al., 2018 [79]	USA High school/collegiate basketball female athletes	High school 8-Year (2005/2006-2013/2014) College 9-Year (2004/2005–2013/2014) Descriptive epidemiology study	HS-RIO NCAA-ISP	Ankle sprain in High school athletes Center: 25% Forward: 30% Guard: 26% Ankle sprain in Collegiate athletes

NCAA-ISP the National Collegiate Athletic Association Injury Surveillance Program/System, HS-RIO: High School Reporting Information Online, NBTA: The data base from the National Basketball [Athletic] Trainers' Association, AE: athletic exposures, CISIR: The Canadian Hospitals Injury Reporting and

3. Research Objectives

CAI is a chronic issue and predisposes to further degenerative ankle issues (post-traumatic osteoarthritis), other injuries due to maladaptive neuromuscular control, deteriorated quality of life and diminished physical activity. Epidemiology of CAI is essential for the strategy of CAI prevention [18]. However, the prevalence of CAI presented by the previous studies is with a wide range. To have a comprehensive overview of the epidemiology of CAI and to figure out the underlying reason for the wide range of prevalence, a systematic review is needed.

Besides, the epidemiological data of CAI in Taiwan is scarce, because all tools evaluating perceived ankle instability are developed in English, and there is no Taiwan-Chinese version of that. Furthermore, basketball is a population at a high risk of ankle sprain, but the epidemiological data of CAI in this population is insufficient. The difference in the prevalence of CAI between different competitive levels, genders and play positions in the basketball population is not clear.

Therefore, the aims of this Ph.D. project were to investigate the prevalence of chronic ankle instability in Taiwanese elite basketball athletes. To achieve so, the research questions are the followings:

1. To identify the prevalence of chronic ankle instability through a valid and reliable self-reported tool in active populations and to identify the limitation of the current studies using a systematic review (study 1).
2. To cross-cultural translate the Cumberland Ankle Instability Tool (CAIT) to the Taiwan-Chinese version (CAIT-TW), and to evaluate the validity, reliability, and cutoff score of CAIT-TW for the Taiwan-Chinese athletic population (Study 2).
3. To investigate the prevalence of chronic ankle instability in a basketball population and to study if the gender and competitive level affect the prevalence of chronic ankle instability (Study 3).

4. Studies

Table 5 Characteristics of the studies included in the present thesis

Study	Journal	Design	Participants	Measures	Chapter
1	Journal of Foot and Ankle Research	Systematic review	nine research articles were included	epidemiological data of CAI	4.1
2	Disability and Rehabilitation	Cross-cultural adaptation and psychometric properties evaluation	Competitive athletes CAI (n=77) 21±2 year, 172±10 cm, 69±15 kg CON (n=58) 20±1 year, 174±9 cm, 66±14 kg	cross-cultural adaptation construct validity test-retest reliability internal consistency cutoff score	4.2
3	BMC Sports Science, Medicine and Rehabilitation	Cross sectional	Basketball athletes (N=388) Semi-pro athletes (n=133) 26.5 ± 3.4 collegiate athletes (n=255) 20.1 ± 1.6	The prevalence of CAI The association of prevalence of CAI and gender/competitive level/play position	4.3

4.1 Study 1

Title: The epidemiology of chronic ankle instability with perceived ankle instability- a systematic review

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4.1.1 Abstract

Background: Chronic ankle instability, developing from ankle sprain, is one of the most common sports injuries. Besides it being an ankle issue, chronic ankle instability can also cause additional injuries. Investigating the epidemiology of chronic ankle instability is an essential step to develop an adequate injury prevention strategy. However, the epidemiology of chronic ankle instability remains unknown. Therefore, the purpose of this study was to investigate the epidemiology of chronic ankle instability through valid and reliable self-reported tools in active populations.

Methods: An electronic search was performed on PubMed and Web of Science in July 2020. The inclusion criteria for articles were peer-reviewed, published between 2006 and 2020, using one of the valid and reliable tools to evaluate ankle instability, determining chronic ankle instability based on the criteria of the International Ankle Consortium, and including the outcome of epidemiology of chronic ankle instability. The risk of bias of the included studies was evaluated with an adapted tool for the sports injury review method.

Results: After removing duplicated studies, 593 articles were screened for eligibility. Twenty full-texts were screened and finally nine studies were included, assessing 3804 participants in total. The participants were between 15 and 32 years old and represented soldiers, students, athletes and active individuals with a history of ankle sprain. The prevalence of chronic ankle instability was 25%, ranging between 7% and 53%. The prevalence of chronic ankle instability within participants with a history of ankle sprains was 46%, ranging between 9% and 76%. Five included studies identified chronic ankle instability based on the standard criteria, and four studies applied adapted exclusion criteria to conduct the study. Five out of nine included studies showed a low risk of bias.

Conclusions: The prevalence of chronic ankle instability shows a wide range. This could be due to the different exclusion criteria, age, sports discipline, or other factors among the included studies. For future studies, standardized criteria to investigate the epidemiology of chronic ankle instability are required. The epidemiology of CAI should be prospective. Factors affecting the prevalence of chronic ankle instability should be investigated and clearly described.

Keywords: ankle sprain, sports injury, functional ankle instability

4.1.2 Introduction

Ankle sprain is one of the most common sports injuries in physically active individuals and causes a high financial burden on the healthcare system [1, 2, 110]. The incidence of ankle sprain from the US emergency departments in 2010 was 3.29 per 1000 person per year [24]. In an athletic population, a cohort of the sub-elite Australian football athletes showed an incidence of ankle sprain of 3.1 per 1000 athlete-exposures during the 2016 season [25]. In addition, 25 US collegiate sports presented an incidence of lateral ligament complex ankle sprain of 0.5 per 1000 athlete-exposures [1]. Regarding the substantial financial burden resulting from ankle sprain, Gribble et al. summarized that ankle sprains generated $6.2 billion in healthcare costs for US high-school athletes and €208 million in the Netherlands annually [2, 111]. In the US emergency department, $1029 per event of ankle sprain was charged [24].

Ankle sprain also predisposes athletes to recurrent ankle sprains and leads to residual symptoms [2, 112]. In soccer, basketball and volleyball, 61%, 60% and 46% of the ankle sprain was recurrent ankle sprain [16]. Seventy-four percent of patients with an acute ankle sprain suffered from residual symptoms lasting 29 months after the initial ankle sprain, such as pain, perceived instability, weakness and swelling [29]. The International Ankle Consortium defines the pathology of residual symptoms after a significant ankle sprain as chronic ankle instability (CAI) [4]. The International Ankle

Consortium characterized CAI as a condition in which an individual has a significant ankle sprain and/or experienced recurrent ankle sprain on the sprained ankle, and/or feels ankle instability, and/or experienced giving way at least twice in the past six months [4]. To determine the subjective ankle instability, three tools with a critical cutoff score are recommended by the International Ankle Consortium: The Ankle Instability Instrument (AII), The Cumberland Ankle Instability Tool (CAIT), and The Identification of Functional Ankle Instability (IdFAI) [4]. The criteria published by the International Ankle Consortium have been applied in research widely.

CAI is not only an ankle issue but also systematically affects other joints, causing further physical issues [5]. In the ankle structure, individuals with CAI show a decreased range of motion, secondary tissue injury, restricted osteokinematics and post-traumatic osteoarthritis [5]. CAI systematically impairs proprioception, balance, movement pattern, and invokes muscle weakness and altered H-reflex bilaterally [5]. CAI can cause further injuries, for example: recurrent ankle sprain, early development of osteoarthritis and increased loading on the anterior cruciate ligament [2, 46, 113]. Since CAI can lead to numerous negative consequences, it is important to develop a preventative strategy for this ankle problem. To develop a prevention strategy, the clarification of epidemiological data is essential [114].

To identify the prevalence of CAI in sporting populations, Attenborough and colleagues conducted a systematic review which defined CAI based on a CAI model published in 2011 [44] and reported the prevalence of the perceived ankle instability (28%), the recurrent ankle sprain (50%) and the persistent symptoms (30%-45%) in basketball, soccer and volleyball [16]. However, the prevalence of CAI using the standardized criteria published in 2014 from the International Ankle Consortium has not been reported conclusively. Therefore, the purpose of this review was to identify the epidemiology of chronic ankle instability through valid and reliable self-reported tools in a physically active population.

4.1.3 Methods

Search strategy

The systematic search was performed in the online search engines PubMed and Web of Science in July 2020 using the keywords and MeSH terms ("ankle instab*" OR CAIT OR IDFAI OR AII) AND (prevalence OR frequency OR epidemiology). Articles published between 2006 and 2020 were screened, since the three tools (AII, CAIT and IdFAI) evaluating perceived ankle instability recommended by the International Ankle Consortium were published in 2006, 2006 and 2012 respectively.

Inclusion and exclusion criteria

Studies that met the following criteria were included: (1) peer reviewed studies, (2) using one of the valid and reliable tools (AII, IdFAI, and CAIT) to evaluate chronic ankle instability, (3) determining chronic ankle instability based on the criteria of the International Ankle Consortium, (4) and the outcome represented the epidemiology of CAI. If the studies were not written in English, a review article or the full-text unavailable, they were excluded.

Study selection and the data collection process

The study selection process was performed by two independent reviewers. After removing the duplicated articles, titles and abstracts of the articles were screened based on the pre-determined criteria. The remaining full-texts were reviewed for eligibility and either included or excluded for the current review. A third reviewer was consulted when the two authors could not reach agreements. Authors, published year, studied population, sample size, demographics, the criteria of determining CAI, inclusion criteria, exclusion criteria, and the epidemiological data of CAI were extracted.

Risk of bias in individual studies

Two independent reviewers assessed the bias of included studies using an adapted risk assessment tool [115, 116]. There are seven items in the adapted bias assessment tool, including the definition of CAI, the study design, the description of participants' demographics, the sampling method, the analysis rate of included data, the method of identifying CAI and the period of follow up (see Table 6). Each item was scored with a "Yes" or "No", representing a high or low risk of bias respectively. The item was noted "No" if the information was not clear or the study did not meet the criteria of the specific item. When the score of risk of bias more than 75%, the risk of bias was considered low [117]. In case of different conclusions on scoring a certain item by the two reviewers, the discrepancies were discussed to reach an agreement.

Table 6 Risk of bias assessment

	Criterion	Schmitt et al.[118]	Donovan et al.[119]	Koshino et al. [21]	Holland et al.[120]	Doherty et al.[121]	Attenborough et al [122]	Simon et al.[18]	Tanen et al.[17]	Kobayashi et al. [22]	% Studies with 'yes' response
1	That a clear definition of chronic ankle instability is clearly described	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	100%
2	Study design is cross-sectional or prospective	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	56%
3	Description of participants demographics are given	No	No	Yes	Yes	Yes	Yes	No	No	Yes	56%
4	Studies that conducted the random selection process or the studies that analyzed the entire target population receive	No	No	No	No	NA	No	Yes	No	No	13%
5	Prospective studies that collected the data of at least 80% of the participants included in the study. The cross-sectional and retrospective studies receive N/A for this criterion.	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
6	The injury diagnosis was conducted by health professionals or using valid and reliable tools	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	100%
7	The follow up period: For the prospective studies at least 6 months follow up, for retrospective studies up tp 12	NA	NA	NA	NA	Yes	NA	NA	NA	NA	NA

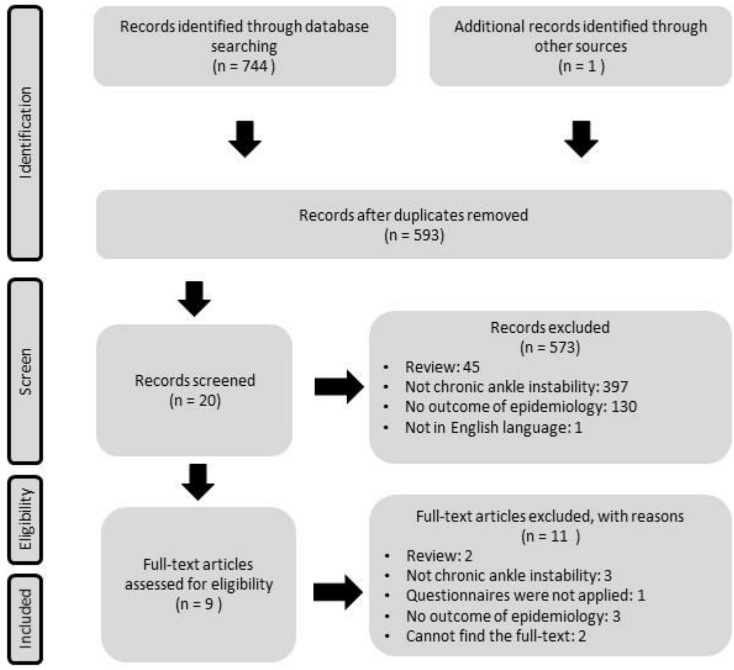
NA: Not applicable

4.1.4 Results

Study selection

The conducted systematic searches resulted in a total of 744 studies (Figure 2). After removing the 152 duplicates, the titles and abstracts of the 592 remaining articles were screened. Twenty articles entered the phase of full-text review and their references were screened for possible eligible articles. Although no other studies were found through this method in June 2020, one study published in September 2020 was included. Eventually, nine articles were included.

Figure 2 Flow chart of included and excluded studies.



Study characteristics and the results of individual studies

Table 7 provides a summary of the characteristics of the included studies. Three study types were included: seven cross-sectional studies [17, 18, 21, 22, 119, 120, 122], one longitudinal descriptive study [118] and one cohort study [121]. The total sample size was 3804 participants. The sample size of each study ranged from 70 to 1238 participants.

The summarized prevalence of CAI was 25% (ranging from 7 to 53%). The data from one study was not integrated into the overall result because the study applied the prevalence of 65 included participants who sought medical care to estimate the prevalence for the whole population (N=1238) [118]. Forty-six percent of participants with a history of ankle sprains were diagnosed with CAI (ranging from 9-76%).

The age of the participants among the different study populations ranged from 15 to 32 years. The number of participants aged younger than 18 years was 1399 [17, 120, 121], for adult participants (18-24 years) it was 1167 [17, 18, 21, 22, 119, 122] and the number of participants for the military population (average age was 32 years) was 1238 [118]. The prevalence of CAI in participants aged younger than 18 years, aged between 18 and 24 years and aged over 25 years were 26% (320/1399) [17, 119, 120], 25% (237/959) [17, 18, 21, 122], and 2% (28/1238) [118] respectively. The prevalence of CAI in participants with a history of ankle sprain in each age category was 63%, 36% and 43%.

Table 7 Summary of the included studies

Authors	Country	Study type	Mode of data collection	Study population	Defining CAI	Exclusion criteria	Prevalence of CAI, n(%)	Prevalence of CAI within participants with history of ankle sprains, n(%)	Participants with history of ankle sprain, n(%)
Schmitt et al. [118]	France	Descriptive longitudinal study	Questionnaires	French soldiers aged 32.2 (N=1238) with a history of ankle sprain (n=65)	Based on IAC using IdFAI	IAC	28(2)	28/65(43)	65(5)
Donovan et al. [119]	USA	Cross-sectional study	Questionnaires	Athletes 8 from sports clubs and high Athletes in high schools in Wisconsin (N=1002) - Female (n=505): 15.7 ± 1.7 years - Male (n=497): 15.6 ± 1.9 years	A history of ankle sprain and perceived ankle instability (evaluated using IdFAI)	Without history of injury	200(20)	200/262(76)	262(26)
Koshino et al. [21]	Japan	Cross-sectional study	Questionnaires	Japanese Collegiate athletes with LAS (N=470) CAI (n=47): 20.0 ± 1.2 years, 1.70 ± 0.7 m, 65.5 ± 11.5 kg Coper (n=20): 20.5 ± 1.4 years, 1.68 ± 0.06 m, 63.8 ± 10.3 kg	Based on IAC using CAIT	Research criteria: IAC Clinical criteria: IAC without exclusion criteria	47(10) 93(20)	47/212(22) 93/212(44)	212(45)
Holland et al. [120]	USA	Cross-sectional study	Questionnaires	Students in western North Carolina(N=201) - Uninjured (n=86): 16.0 years, 1.69 m, 62.0 kg - Coper (n=16): 15.38 years, 1.66 m, 65.2 kg - Potentially unstable (n=40): 15.6 years, 1.65 m, 60.9 kg - Unstable (n=59): 15.68 years, 1.68 m, 62.5 kg	Based on IAC using IdFAI	Missing data	59(29)	59/115(51)	115(57)

Doherty et al. [121]	Ireland	Cohort study	Questionnaires	Physical active individuals with LAS (N=70) - CAI (n=28): 23.2 years, 75.5 kg, 1.72 m - LAS coper (n=42): 22.7 years, 73.4 kg, 1.73 m	Based on IAC using CAIT	IAC	NA	28/70 (40)	NA
Attenborough et al. [122]	Australia	Cross-sectional study	Questionnaires Ankle joint laxity	Female netball players in Sydney(N=96) - Club (n=42): 24.1±7.9 years, 1.67±0.05 m, 68.5±15.9 kg - Inter-district (n=54): 19.4±3.5 years, 1.73±0.06 m, 72.0±12.7 kg	Previous ankle sprain + Recurrent ankle sprain, perceived ankle instability (CAIT), mechanical ankle instability	A lower limb injury in the six months prior to testing a history of ankle surgery or ankle fracture all previous ankle sprains occurred a minimum of six months prior	44(46)	44/69(64)	69(72)
Simon et al. [18]	USA	Exploratory study	Questionnaires	Dancer (N=77) 19.61± 2.53 years, dance experience: 13.61 ± 3.16 years	perceived ankle instability (IdFAI)	A history of fracture or surgery in the lower extremities.	41(53)	41/54(76)	54(70)
Tanen et al. [17]	USA	Descriptive epidemiological survey	Questionnaires	Athletes (N=512) Collegiate athletes (n=316) 19.6 ± 1.2 years high school athletes (n=196) 15.9 ± 1.2 years	Perceived ankle instability (CAIT and AII)	A history of an ankle fracture, ankle surgery, neurological disorder such as, Parkinson's disease, amyotrophic lateral sclerosis, or multiple sclerosis, or failed to completely answer the questionnaires.	120(23)	120/391(31)	391(76)
Kobayashi et al. [22]	Japan	Cross-sectional study	Questionnaires	Female athletes (N=138) Aged 18-23 21.8±0.4 years, 1.66 m, 57.0 kg	Based on IAC using CAIT	IAC	10(7)	10/106(9)	106(77)

IAC: The International Ankle Consortium, CAIT: The Cumberland Ankle Instability Tool, AII: The ankle Instability Instrument, IdFAI: The Identification of functional Ankle Instability, NA: not applicable

The study population consists of military personnel [118], athletes [17, 21, 22, 119, 122], dancers [18], and physically active individuals [120, 121]. The prevalence of CAI within each sport is shown in Table 8.

The definitions of CAI in the included studies were homogeneous, but the exclusion criteria diverse. Four articles applied the inclusion and exclusion criteria from the International Ankle Consortium to define the presence of CAI (2.3-40%) [21, 22, 118, 121]. Two studies only applied inclusion criteria from the International Ankle Consortium (10% and 49%) [21, 120]. One study identified CAI by the history of a significant ankle sprain, mechanical ankle instability and the perceived ankle instability (46%) [122]. Three studies used the history of ankle sprains and perceived ankle instability to identify CAI (20-53%) [17, 18, 119].

Table 8 Prevalence of chronic ankle instability in different sports

Sport	Total	CAI		Having history of ankle sprain	
	n	n	%	n	%
Netball [122]	96	44	46%	69	72%
Dance [18, 22]	99	45	45%	69	70%
Aquatics [17]	50	16	32%	28	56%

Basketball [17, 21, 22]	105	32	30%	85	81%
Volleyball [17, 21, 22]	79	24	30%	53	67%
Rowing/Crew [17]	10	3	30%	8	80%
Field Hockey [17]	11	3	27%	7	64%
Wrestling [17]	23	6	26%	16	70%
Rugby [21]	35	9	26%	22	63%
Acrobatics [17]	35	9	26%	22	6%
Baseball [17]	38	9	24%	34	89%
Judo [21]	18	4	22%	6	33%
Running [17]	66	14	21%	29	44%
Soccer [17, 21, 22]	108	22	20%	77	71%
Gymnastics [21]	15	3	20%	9	60%
Handball [21]	5	1	20%	2	40%
Golf [17]	11	2	18%	5	45%
Lacrosse [21]	60	9	15%	23	38%
Ice hockey [21]	31	3	10%	11	35%
Swimming [22]	11	1	9%	6	55%
Tennis [17, 21]	55	4	7%	20	36%
Badminton [21]	14	1	7%	7	50%
Track and field [21, 22]	63	5	8%	23	37%
Table tennis [21]	55	2	4%	12	22%
Total	1093	99	25%	643	47%

CAI: chronic ankle instability

Risk of bias across studies

The results of the critical appraisal are displayed in Table 6. Two studies scored less than 60% [118], two studies scored 60% [17, 18, 119] and five studies scored ≥ 80% [21, 22, 120-122] on the bias assessment tool. Seven included studies showed clear criteria to define CAI by the same or similar to the criteria from the International Ankle Consortium [17, 21, 22, 118, 121, 122]. The criteria for the two studies were unclear but clarified after contacting the corresponding authors [119, 120]. In regards to the study design, five studies were cross-sectional studies, and the other studies were a longitudinal descriptive study [118], a cohort study [121], an exploratory study [18] and a descriptive epidemiological survey [17]. For the demographics of the participants, four studies only provided age [18, 118-120]. None of the included studies applied random selection to sampling. One study defined the target population clearly at a university and analyzed all data they received [18]. Three included studies clearly defined the target population but did not analyze the entire target population [118-120]. Four studies did not either define the target population precisely or report the sampling process [17, 21, 22, 122]. Only one study followed up participants with first-time ankle sprain for 12 months [121]. All studies applied standard tools to evaluate ankle instability.

4.1.5 Discussion

The current review included nine studies and the results showed that the prevalence of CAI was 25%, ranging from 7% to 53% and the prevalence of CAI within participants with a history of ankle sprains was 46%, ranging from 9% to 76%. Five out of nine included studies had a low risk of bias.

The prevalence of CAI from eight included studies ranged from 7% to 53%. The results from one study were not integrated because of the high risk of bias [118]. The wide range of prevalence may be caused by the varying research methods, different characteristics of participants and other factors. In regards to varying research methods, the included studies applied different exclusion criteria to investigate the prevalence of CAI (Table 7), although the International Ankle Consortium published standard inclusion and exclusion criteria aimed at controlled research [4]. Based on the criteria participants with CAI and other conditions (e.g. history of a fracture and surgeries in lower extremities) will be excluded because the conditions confound the CAI symptoms (e.g. giving way and perceived ankle instability) [4]. In this case, the prevalence might be underestimated. Yet, if studies defined CAI based on inclusion criteria only (a history of one or more significant ankle sprain and experienced ‘‘giving way'' and/or recurrent sprain and/or ''feelings of instability'') and do not exclude the participants without CAI but with the conditions in the exclusion criteria, the prevalence might be overestimated.

Most of the included studies investigated CAI using a questionnaire and excluded participants with the conditions confounding the presence of ankle instability (Table **7**). Without history-taking or physical examination, it is difficult to differentiate CAI from other possible conditions in the exclusion criteria. Koshino et al. found that by applying both inclusion and exclusion criteria from the International Ankle Consortium to determine the prevalence of chronic ankle instability the prevalence was 10.0% [21]. Yet, by only applying the inclusion criteria the prevalence was doubled (19.8%) [21]. Thus, a comprehensive method should be established for the research of CAI epidemiology which can differentiate between CAI and other issues confounding the symptoms of CAI.

In addition, different characteristics of participants, for example age and population, also vary the prevalence of CAI. Regarding to age, the samples from the included studies come with a wide range of ages (15-32 years). A previous study showed that a younger age is one of the risk factors for recurrent ankle sprain, which in turn is one of the risk factors of CAI [123]. Tanen et al. showed that high school athletes had a higher prevalence of CAI compared to collegiate athletes (31% and 19% respectively)

[17]. In the current review, the prevalence of CAI with a history of ankle sprain seems higher in participants aged younger than 18 years (63%) compared to those aged between 18 and 25 years (36%). The included studies represent a wide range of ages that may be responsible for the wide range of prevalence.

Furthermore, different sports disciplines show a varying prevalence of ankle sprain and CAI. Doherty et al. found that indoor/court sports showed the highest prevalence and incidence of ankle sprain (7 ankle sprains per 1000 athletic exposure [95 % CI 6.8–7.2], 12.17 % [95 % CI 12.01–12.33]) among water/ice sports (3.7/1000 athletic exposure [95 % CI 3.3–4.17], 4.36%[95 % CI 3.92–4.79]), filed-based sports (1.0/1000 athletic exposure [95 % CI 0.95–1.05], 11.3 % [95 % CI 11.15–11.44]) and outdoor pursuits sports (0.88/1000 athletic exposure [95 % CI 0.73–1.02], 11.65 % [95 % CI 11.33–11.97]) [110]. Roos et al. discovered that basketball had the highest rate of lateral ankle sprain from 25 sports [1]. Regarding the recurrent ankle sprain, athletes showed the highest rate of recurrent ankle sprain in basketball, women's outdoor track and women's hockey from 25 sports disciplines [1]. Besides, a systematic review revealed that soccer, basketball and volleyball reported the highest rate of recurrent ankle sprain, and track and field showed the most participants perceived ankle instability with a history of ankle sprain [16]. Similarly, Koshino et al found that athletes who play basketball (63%, 14/22), volleyball (42%, 11/26) or soccer (37%, 15/40) had a high rate of CAI [21]. In the included studies from the current review, netball, dance and aquatics show the highest prevalence of CAI followed by basketball, volleyball and rowing/crew (Table 8).

Additionally, the investigated populations and the sample size of each sport discipline varied among the included studies. For example, the sample size in the various included sports ranged between five and 163 participants. There were only 10 to 20 participants overall in the categories of swimming, golf, gymnastics, field hockey and rowing/crew, and there were 96 to 108 participants in netball, dance, basketball and soccer (Table 8). It is difficult to generalize the result due to the varying age, sports disciplines and wide range of sample sizes in each sports discipline of the participating populations. Therefore, clear description of the factors (for example, age [123] and sports discipline [110]) in epidemiological study of CAI can facilitate a comprehensive understanding of CAI prevalence.

Some articles investigating the epidemiology of CAI were excluded CAI due to the mismatched definition from the current review. Two systematic reviews defined CAI as self-reported perceived ankle instability, mechanical instability, repetitive ankle sprain and persisting symptoms lasting over six months after an acute ankle sprain and surveyed the epidemiology of CAI in sporting populations and children [16, 63]. In sporting populations, the recurrent ankle sprain (61%) was the most prevalent in soccer athletes and the highest rate of perceived ankle instability (41%) was in track and field athletes with a history of ankle sprain [16]. Children with a history of ankle sprain and perceived ankle instability/recurrent ankle sprain was 22-71% [63]. The other excluded study defined CAI as recurrent ankle sprain or ankle functional impairment or mechanical ankle instability or residual symptoms after one year of ankle sprain and found the prevalence of CAI was 1% in a 17-year-old general population (N=829,791) who were recruited into mandatory military service [75]. Again, with the heterogeneous population and definition of CAI, the rate of CAI can range from 1% to 71% which is a wider range than in the current results (7% to 53%).

Regarding other factors affecting the prevalence of CAI, accessibility of rehabilitation can affect the development of CAI. Exercise therapy showed moderate evidence to treat/prevent recurrent ankle sprain [124]. For instance, proprioception training reduces 36% of the risk in recurrent ankle sprain in the participants with a history of ankle sprain [125]. Balance training can also improve the perceived ankle instability of the patients with CAI [126]. However, Hubbard-Turner discovered that 64% (112/175) of the participants did not seek medical care after lateral ankle sprain injuries, and within the 36% (63/175) who seek treatment, only 10% (6/63) of them performed balance training [127]. Similarly, Schmitt et al. found that 47.6% of participants did not receive physiotherapy after the first ankle sprain [118] and Tanen et al. found that

45% of the investigated athletes did not seek medical care [17]. Doherty et al. showed that 40% of the participants who did not seek exercise/physical therapy developed CAI, whereas 60% of the participants who received rehabilitation did not develop CAI, although there was no significant association between rehabilitation and the development of CAI [128]. The availability of exercise/physical therapy may differ from areas and institutions. However, most of the included studies did not present the history of rehabilitation for ankle sprains, which may confound the results [4].

Additionally, there are some other influencing factors that have been discussed in previous studies, for example, body size, gender and competition level. Unfortunately, the evidence is not conclusive. For body size, one cross-sectional study found that participants' body mass index and height are associated with the presence of mechanical and functional ankle instability in a general population (N=829,791) [75]. However, a prospective study found that body mass index is not associated with the recovery of ankle function six months after an acute ankle sprain [129]. The difference in the prevalence of CAI between genders also remains unclear. Regarding gender, one of the included studies found that female athletes showed a higher prevalence of CAI than male athletes (32% vs. 17% respectively, $p<0.05$) [17]. In addition, Donovan et al. found that the prevalence for boys was 23.5% and for girls it was 26.2% [119]. In contrast, Hershkovich et al. found that men had a 2.33 fold-greater incidence of CAI than women (1.1% vs. 0.7%, N=829,791) [75].

Competition levels may play an essential role on the prevalence of CAI, but the direction is controversial in the current evidence. Tanen et al. found that the prevalence of CAI was higher in the athletes in a lower competitive level (high school athletes) than that in a higher competitive level (collegiate athletes) [17]. Although Attenborough et al. further showed that athletes in the lower competition levels (club athletes) had a higher prevalence of CAI than that in the higher competition levels (inter-district athletes), the average age for club and inter-district athletes being 19 and 24 years [122]. It is not clear if the difference in the prevalence between these two populations were from the age, the competitive level, or both. In future studies, body size, gender, competitive level and history of rehabilitation after an acute ankle sprain should be identified to understand their effects on the prevalence of CAI and the above factors should be clearly described to depict the characteristics of the surveyed cohort.

Risk of bias

The criteria to define CAI were applied in each study. Although all studies define CAI based on the standard criteria of the International Ankle Consortium, the inclusion and exclusion criteria were distinct among the included studies. This causes a misestimating of the prevalence of CAI. As mentioned in the previous paragraph, the standard from the International Ankle Consortium is for controlled research, which excludes the participants with other issues confounding identification of CAI. The participants with other conditions (history of a fracture or surgeries or acute injury in previous three months) and CAI cannot be clarified. This will definitely affect the results of the CAI prevalence. Therefore, to establish the standard criteria is a prerequisite for conducting epidemiological studies.

In regards to the study design, to investigate the epidemiology of chronic injuries, Bahr suggested applying a prospective study design with continuous or serial measurements [130]. However, none of the included studies applied the prospective study design. The prevalence would fluctuate among different game seasons. Therefore, the data from each study can only represent the prevalence in a certain period. Future studies should be prospective designed to measure the symptoms of CAI at regular intervals and to portray the presence of CAI among whole seasons.

Participants' characteristics were missing in four included studies [17, 18, 118, 119]. Height, body mass index and age are associated with CAI [75]. Without the characteristics of the sample, it is difficult to generalize the data. Seven included studies did not analyze the whole target population or clearly define the target population [17, 21, 22, 118-120, 122]. This could affect the representation and the generalization of the data.

There were some limitations in the current review. First of all, only nine studies were included. The prevalence might not be representative because of the small sample size. In addition, the included studies were heterogeneous. The surveyed population, countries, competitive level and sports were varying. Three studies presented the prevalence of CAI in different sports [17, 21, 22]. Furthermore, the criteria to define CAI were different among the included studies. A clear standard to define CAI in future epidemiological studies should be defined. Finally, it is not clear if the pre-existing ankle instability affects the development of CAI after a significant ankle sprain. Some individuals have perceived ankle instability or giving way without a history of ankle sprain. Do the individuals have CAI because of the pre-existing instability, or do they really develop CAI after a significant ankle sprain?

4.1.6 Conclusion

The prevalence of chronic ankle instability in the active population was 25%, ranging between 7% and 53% in different populations. The prevalence of chronic ankle instability within the participants with a history of an ankle sprain was 46%, ranging from 9% to 76%. The wide range of the prevalence was mainly caused by exclusion criteria, age, sports discipline, and other factors. In order to obtain comprehensive epidemiological information about CAI, first of all, prospective studies should be conducted to the symptoms of CAI with valid and reliable tools at regular intervals [130]. To report the injury risk of CAI, prevalence should be used, because athletes with CAI still participate in practice and competitions [130]. In addition, the thorough method to well identify the participants with CAI and other lower limbs condition should be developed. Finally, the risk factors of ankle sprain or CAI including age and sports discipline should be clearly reported to depict the surveyed population. Factors which remains unclear of ankle sprain/CAI (e.g. gender, body size and history of rehabilitation) should be clarified and described in further epidemiology studies of CAI.

List of abbreviations

CAI: Chronic ankle instability

AII: The Ankle Instability Instrument

CAIT: The Cumberland Ankle Instability Tool

IdFAI: The Identification of Functional Ankle Instability

IAC: The International Ankle Consortium

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable

Availability of data and material

Not applicable

Competing interests

The authors declare that they have no competing interests

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Authors' contributions

Chaio-I Lin participated in conceptualization, data curation, formal analysis, funding acquisition, visualization and writing the original draft. Sanne Houtenbos was involved in electronic searching, screening, selecting the review studies and review and editing of the manuscript. Yu-Hsien Lu was involved in the bias appraisal and review and editing the manuscript. Frank Mayer assisted in funding acquisition and reviewing the manuscript. Pia-Maria Wippert supervised this study, was involved in reviewing the manuscript and assisted in funding acquisition. All authors read and approved the final manuscript.

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4.2 Study2

Title: Cross-cultural adaptation, reliability, and validation of the Taiwan-Chinese version of Cumberland Ankle Instability Tool

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4.2.1 Abstract

Purpose: To cross-cultural translate the Cumberland Ankle Instability Tool (CAIT) to Taiwan-Chinese version (CAIT-TW), and to evaluate the validity, reliability and cutoff score of CAIT-TW for Taiwan-Chinese athletic population.

Materials and methods: The English version of CAIT was translated to CAIT-TW based on a guideline of cross-cultural adaptation. 77 and 58 Taiwanese collegial athletes with and without chronic ankle instability filled out CAIT-TW, Taiwan-Chinese version of Lower Extremity Functional Score (LEFS-TW) and Numeric Rating Scale (NRS). The construct validity, test-retest reliability, internal consistency and cutoff score of CAIT-TW were evaluated.

Results: In construct validity, the Spearman's correlation coefficients were moderate (CAIT-TW vs LEFS-TW: Rho=0.39, $p < .001$) and strong (CAIT-TW vs NRS: Rho= 0.76, $p < .001$). The test retest reliability was excellent (ICC2.1 = 0.91, 95%, confidential interval = 0.87-0.94, $p < .001$) with a good internal consistency (Cronbach's α: 0.87). Receiver operating characteristic curve showed a cutoff score of 21.5 (Youden index: 0.73, sensitivity: 0.87, specificity 0.85).

Conclusions: The CAIT-TW is a valid and reliable tool to differentiate between stable and instable ankles in athletes and may further apply for research or daily practice in Taiwan.

Keywords: chronic ankle instability; functional ankle instability; CAIT; self-report questionnaire; validity and reliability

4.2.2 Introduction

Ankle sprain is the most common injury in the athletic population accounting for 6.9 - 14.5% of all reported injuries in sports, such as American football, soccer, volleyball, gymnastics, lacrosse, basketball, and cross country [110]. Sports that demand running, cutting, jumping, landing accelerating and decelerating cause a high rate of ankle sprain [2]. After an acute ankle sprain 35% of individuals suffer from residual symptoms, pain, swelling, recurrent ankle sprain, loss of ankle function, giving way, and strength decreasing [5]. Different descriptions of this phenomenon had been suggested, chronic lateral ankle instability, recurrent lateral ankle instability, ankle instability, residual ankle instability, chronic instability, and chronic ankle sprain [5, 131]. However, in 2014 International Ankle Consortium termed that as Chronic Ankle Instability (CAI) and characterized CAI as an individual that had endured a significant ankle sprain, and experienced episodes of giving way and/or recurrent ankle sprain and/or subjective ankle instability [4]. 40 % of first-time acute ankle sprain developed into CAI, which caused a high rate of recurrent ankle sprain (12-80%), lowered the quality of daily life, affected functional performance, and may cause post-traumatic osteoarthritis [4, 58, 128, 132, 133].

To qualify for subjective ankle instability, International Ankle Consortium recommended three valid and reliable self-report questionnaires with cutoff scores:

the Ankle Instability Instrument (AII), the Cumberland Ankle Instability Tool (CAIT) and the Identification Functional Ankle Instability (IdFAI) [4]. The CAIT has been translated into different languages: Brazilian-Portuguese, Spanish, Korean, Japanese, Persian, Dutch, French, and Greek which is then applied towards research and clinical practice [134-143]. A valid and reliable self-report questionnaire is low cost and able researchers and clinicians to evaluate the ankle instability and to access improvements to the rehabilitation [136].

The prevalence of CAI has been investigated in different countries and different populations [16-18, 122]. A systematic review indicated that 61% of soccer athletes, 60% of basketball athletes and 46% of volleyball athletes suffered from recurrent ankle sprain; and 28% of basketball athletes experienced perceived ankle instability while 30% experienced other residual symptoms [16]. Attenborough et al. applied CAIT to investigate the prevalence of CAI in Australian netballs athletes, and they found that 88.4 % of them had CAI [122]. Simon et al. found 75.9% (41/54) of professional dancer had CAI using IdFAI [18]. Tanen and colleagues applied CAIT to survey the prevalence of CAI in US high schools and colleges, and the result showed that 23.4% of athletes had CAI [17]. The prevalence of CAI is varying in different sport populations and areas. In terms of sports injury prevention and management, it is important to recognize the prevalence of CAI in the athletic population in different areas and provide an efficient and specific intervention protocol or strategy to improve the quality of sports performance.

Chinese is a widely used language, and it is the official language in Taiwan. However, there is no Taiwan-Chinese version of CAIT that has been evaluated for validity and reliability. A valid and reliable self-reporting questionnaire in Taiwan-Chinese would be helpful for monitoring and injury prevention in athletes who speak Mandarin Chinese in Taiwan. Therefore, the objective of this study was to develop a valid and reliable cross-cultural adapted Taiwan-Chinese version of CAIT (CAIT-TW).

4.2.3 Material and Methods

The current study was a cross-sectional study of cross-cultural adaption and validation of a self-report questionnaire. This study was conducted from June to October 2018 for a total of 5 months.

Cross-cultural translation

We informed the developer of CAIT about this study and also obtained the license of using CAIT in the current study from Elsevier (license number: 4758770436837) [14]. The English version of the CAIT was translated to a Taiwan-Chinese version referring to the guidelines for the process of cross-cultural adaptation [144]. There are six steps:

Initial translation (step I): Two bilingual translators, a certified athletic trainer and a non-medical background translator, translated the English CAIT into CAIT-TW individually.

Synthesis of The Translations (step II): The differences of translations between the two translators were synthesized in a consensus meeting.

Back translation (step III): The primary CAIT-TW was translated back to English by two English native speakers without any medical background. The translators were unaware of the existence of the original English CAIT.

Expert Committee (step IV): The expert committee consisted of a methodologist, a health professional, a language professional, and the translators (forward and back translators). Then, they discussed the discrepancies of all versions of translations and reach an agreement based on semantic, idiomatic, experiential, and conceptual equivalence to consolidate the prefinal version of CAIT-TW.

Test of the prefinal version (step V): To examine the meaning and subjects' understanding of each item, 33 athletes filled out the prefinal version of CAIT-TW (172.1 ± 9.6 cm, 64 ± 12.2 kg, 14.1 ± 10.1 hours of training per week, and 7.3 ± 3.0 years of training experience, the score of CAIT-TW was 22.6 ± 6.0). Identified problems in the questionnaire were reported and revised in preparing the final CAIT-TW-version.

Submission of documentation to coordinating committee for appraisal of the adaptation process (step VI): The questionnaire developer reviewed the final version of CAIT-TW, all reports about the step I to V, and appraised the process of adaption.

Participants

For sample size determination Terwee et al. suggested that to evaluate internal consistency at least 100 subjects are required, and to assess the Intraclass Correlation Coefficient a minimum of 50 participants are required [145]. We applied convenience by contacting coaches and athletic trainers on the campus to recruit participants in sports teams. In total, 135 native Mandarin speakers (98 males and 37 females), who were over the age of 18 were regularly attending to trained athletes (≥ 10 hours per week), whom were recruited from sports teams from two universities in Taiwan. Athletes with CAI were allocated in the CAI group and athletes without any ankle issues were assigned to a control group (CON). Subjects in the CAI group met the following criteria: a history of at least one significant ankle sprain; and/or a history of the previously injured ankle joint ‘giving way’, and/or recurrent sprain and/or ‘feelings of instability’ in their daily or sports activity [4]. Subjects with bilateral CAI were included in this study too. The subjects were excluded if they (1) had a history of previous surgeries or a fracture to the musculoskeletal structures in either lower extremity requiring realignment; or (2) had acute musculoskeletal injuries of the lower extremity in the previous 3 months, which affect joint integrity and function (e.g. sprains or fractures) disturbing their desired physical activity in at least 1 day (3) were attending regular balance training; or (4) were not able to complete the questionnaire.[4] All participants read and signed the informed consent document. This study procedure was approved by the Ethics Committee of the University of Potsdam in Germany (Number: 25/2018).

Instruments

Cumberland Ankle Instability Tool Questionnaire: The CAIT questionnaire contains nine questions to evaluate both ankles concerning pain in each ankle for daily activities, ankle instability in different types of physical activities, ankle control when recurrent sprain occurring and recovery period after recurrent ankle sprains [14]. The maximum score is 30, and the cutoff point to identify the subject with or without CAI is 24 in the original English version [4, 146].

Lower Extremity Functional Scale (LEFS): LEFS contained 20 items to evaluate the function of lower extremity in patients with orthopedic problems [147]. LEFS has been translated to a Taiwan-Chinese version of LEFS (LEFS-TW) with satisfactory validity and reliability (internal consistency: Cronbach α was 0.98 and test-retest reliability: $ICC_{2,1}$ was 0.97) [148].

Numeric Rating Scale (NRS): The maximum score of NRS is 10, meaning extremely instable in the ankles, and the minimum score is 0, indicating very stable ankles. NRS has been applied to evaluate the degree of each ankle's instability and perception of effort in isometric exercise [140, 149].

Analysis of psychometric properties

For psychometric properties examination, the construct validity, test-retest reliability, and internal consistency reliability of CAIT-TW were analyzed. The cutoff score between participating athletes with or without CAI was built up by testing discriminating ability.

Construct validity: Due to the lack of a gold standard, construct validity is to evaluate if ankle function is truly measured by CAIT-TW. To confirm it, the correlations between similar tools were evaluated [145]. To examine the construct validity of CAIT-TW, Spearman's correlation coefficient were used to examine the correlation between CAIT-TW and LEFS-TW [148] and between CAIT-TW and NRS [140, 149]. The Spearman's correlation coefficient is ≤ 0.30 considered as poor, 0.30-0.60 as moderate, > 0.60 as strong [135, 140, 143, 145].

Test-retest reliability: Participants filled out this questionnaire twice, with a week period in between testing. The test-retest reliability was examined by the intraclass correlation coefficient ($ICC_{1,2}$). The test-retest reliability of the questionnaire was considered excellent when the ICC value is > 0.90, good as 0.75–0.90, moderate as 0.50-0.75 and <0.50 as poor [150].

Internal consistency: For internal consistency reliability examination, Cronbach's α coefficient was applied to the testing of the internal consistency of CAIT-TW. Cronbach's alpha of a good questionnaire should be between 0.70 and 0.95 [145].

Discriminating ability: The position statement of the International Ankle Consortium suggested that the 24 points of CAIT is the cutoff point to distinguish the subject with or without CAI. To determine the cutoff score of CAIT-TW in an athletic population, a receiver operating characteristic (ROC) curve was utilized to find the highest Youden index [151].

Statistical Analysis

All data analysis was performed using IBM SPSS 22.0 (Chicago, Illinois, USA). Construct validity tested the correlation between CAIT-TW and LEFS-TW and between CAIT-TW and NRS using Spearman's correlation. Test-retest reliability was conducted by the intraclass correlation coefficient ($ICC_{1.2}$), and internal consistency reliability was performed by Cronbach's α coefficient. Discriminating ability was determined using ROC to find the highest Youden index.

4.2.4 Results

The English version of CAIT was adapted to a Taiwan-Chinese version based on the guidelines [144]. No specific problem of semantic, idiomatic, experiential, and conceptual equivalence was relevant during the translation process. The most frequently asked question when testing the prefinal version was about item 9: after a TYPICAL incident of my ankle rolling over, my ankle returns to "normal". According to the athletes' experience, there were different degrees of rolling over, which affects the duration of recovery. Without a specific definition of that, it was difficult for some athletes to answer this question. For this item, we decided to follow the original CAIT guidelines without any changes due to being a translated version.

In total 292 athletes filled out the questionnaires (Table 9). After excluding invalid questionnaires and participants who did not meet the inclusion criteria, 135 questionnaires were included to assess psychometric properties (Figure 3). In total, 77 were athletes with CAI and 58 were athletes without CAI. 116 of 135 questionnaires were used to evaluate construct validity (Table 10) and 87 of 135 questionnaires were applied to examine test-retest reliability, internal consistency, and discriminating ability (Table 11). There was no difference in demographics between two groups, but the score of CAIT-TW, LEFS-TW and NRS showed a statistical difference between the CAI and the CON groups (see Table 10 and Table 11).

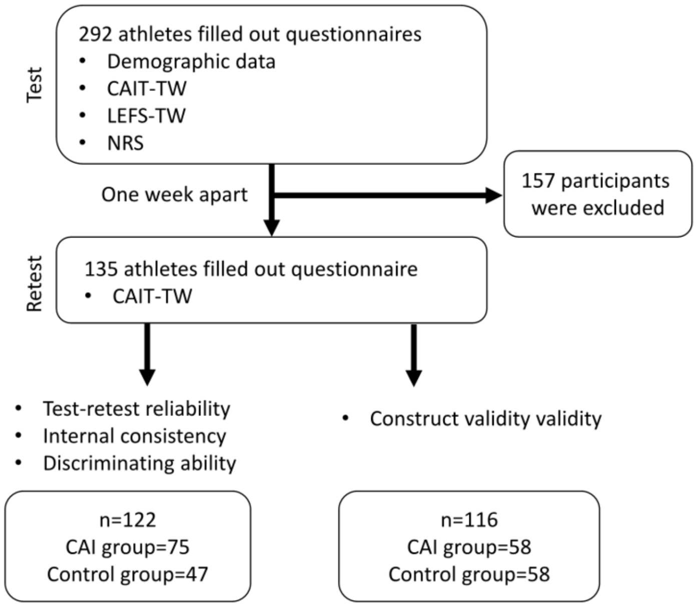
Table 9 Taiwan-Chinese version of Cumberland Ankle instability Tool

康柏蘭腳踝穩定性評估量表 在以下問題中，請選擇最能描述您腳踝狀況的選項:

1. 我有腳踝疼痛	**左踝**	**右踝**
A 從來沒有 5		
B 在運動的過程中 4		
C 在**不平坦**的路面跑步 3		
D 在**平坦**的路面跑步 2		
E 在**不平坦**的路面行走 1		
F 在**平坦**的路面行走 0		
2. 我感覺到腳踝不穩定	**左踝**	**右踝**
A 從來沒有 4		
B **偶爾**發生在運動過程中(並非每次運動)3		
C **經常**發生在運動過程中(每次運動)2		
D **偶爾**發生在日常活動中 1		
E **經常**發生在日常活動中 0		
3. 快速轉換方向時，我會感覺到腳踝不穩定	**左踝**	**右踝**
A 從來沒有 3		
B **偶爾**發生在跑步過程中 2		
C **經常**發生在跑步過程中 1		
D 發生在走路時 0		
4. 下樓梯時，我會感覺到腳踝不穩定	**左踝**	**右踝**
A 從來沒有 3		
B 只有快速下樓時 2		
C 偶爾發生 1		
D 總是發生 0		
5. **單腳站立**時, 我會感覺到腳踝不穩定	**左踝**	**右踝**
A 從來沒有 2		
B 墊腳尖站立時 1		
C 全腳掌平貼地面時 0		
6. 做下列哪個動作時，我感覺到腳踝不穩定?	**左踝**	**右踝**
A 從來沒有 3		
B 單腳左右來回跳 2		
C 單腳原地反覆向上跳 1		
D 雙腳向上跳 0		
7. 做下列哪個動作時，我感覺到腳踝不穩定?	**左踝**	**右踝**
A 從來沒有 4		
B 在不平坦的路面**跑步** 3		
C 在不平坦的路面**慢跑** 2		
D 在不平坦的路面**行走** 1		
E 在平坦的路面**行走** 0		
8. 當腳踝快要扭傷(翻腳刀)時，	**左踝**	**右踝**
A 我都能**立刻**阻止扭傷發生 3		
B 我**時常**能阻止扭傷發生 2		
C 我**偶爾**能阻止扭傷發生 1		

D 我**無法**阻止扭傷發生 0		
E 我**不曾**扭傷腳踝 3		
9.　在扭傷之後，我的腳踝通常需要多久才能恢復正常？	**左踝**	**右踝**
A 立刻恢復 3		
B 一天以內 2		
C 一到兩天 1		
D 兩天以上 0		
E 我不曾扭傷腳踝 3		

Figure 3 The flow chart of data collection.



CAIT-TW means Taiwan-Chinese version of Cumberland Ankle Instability Tool, LEFS-TW means Taiwan-Chinese version of Lower Extremity Function Scale, NRS means Numeric Rating Scale, and CAI means chronic ankle instability.

Table 10 Participants' characteristics for testing construct validity

	CAI			CON			Homogeneity
N (Men/Women)	58 (36/22)			58 (51/7)			
Age (year)	20.5	±	1.5	20.1	±	1.3	*p* = 0.56
Height (m)	171.7	±	9.9	173.1	±	8.5	*p* = 0.05
Weight (kg)	68.5	±	14.9	65.5	±	14.2	*p* = 0.40
Training hours per week	20.6	±	7.0	18.1	±	5.6	*p* = 0.63
Training experience (year)	9.8	±	3.1	9.3	±	3.1	*p* = 0.55
CAIT-TW	16.4	±	4.1	25.6	±	4.4	*p* < .001[a]
LEFS-TW	76.2	±	4.8	78.7	±	2.9	*p* < .001[a]
NRS	4.9	±	1.8	1.7	±	1.9	*p* < .001[a]

CAI: group of Chronic ankle instability, CON: control group, CAIT-TW: Taiwan-Chinese version of Cumberland Ankle Instability Tool, LEFS-TW: Taiwan-Chinese version of Lower Extremity Function Scale, NRS: Numeric Rating Scale, [a] indicates $p < 0.05$

Table 11 Participants' characteristics in evaluating test-retest reliability, internal consistency, and discriminating ability

	CAI	CON	Homogeneity
N (Men/Women)	75 (47/28)	47 (40/7)	
Age (year)	20.5 ± 1.5	20.1 ± 1.4	p = 0.11
Height (cm)	171.4 ± 9.5	173.0 ± 9.0	p = 0.26
Weight (kg)	66.9 ± 14.1	66.0 ± 15.5	p = 0.82
Training hours per week	19.2 ± 7.0	18.9 ± 5.6	p = 0.79
Training experience (year)	9.7 ± 3.6	9.4 ± 3.2	P = 0.89
CAIT-TW score	16.6 ± 4.3	26.1 ± 4.0	p < .001[a]
CAIT-TW retest score	17.2 ± 5.2	26.6 ± 4.3	p < .001[a]
LEFS-TW	76.3 ± 4.8	78.8 ± 3.0	p < .001[a]
NRS	5.0 ± 1.8	1.5 ± 1.9	p < .001[a]

CAI: group of Chronic ankle instability, CON: control group, CAIT-TW: Taiwan-Chinese version of Cumberland Ankle Instability Tool, LEFS-TW: Taiwan-Chinese version of Lower Extremity Function Scale, NRS: Numeric Rating Scale, [a] indicates $p < 0.05$

Construct validity: The correlation between CAIT-TW and LEFS-TW was moderate (Rho = 0.39, p < .001) and the correlation between CAIT-TW and NRS was strong (Rho = 0.76, p < .001).

Test-retest reliability: CAIT-TW had excellent test-retest reliability ($ICC_{2.1}$ = 0.91, 95% confidence interval: 0.87-0.94, p < .001) overall. The test and retest scores of CAIT-TW were 20.3 ± 6.3 and 20.8 ± 6.6. For each item test-retest reliability were moderate to good ($ICC_{2.1}$ = 0.60-0.85) (see Table 12). The drop-out rate was 9.6% (13/135) (see Figure 3). The reasons for this drop-out rate were the absence of practice or incomplete questionnaires.

Table 12 Test-retest of Taiwan-Chinese version of Cumberland Ankle Instability Tool

Items	$ICC_{2.1}$	95%CI	*p* value
Item 1	0.82	0.75-0.88	<.001
Item 2	0.60	0.43-0.73	<.001
Item 3	0.71	0.59-0.80	<.001
Item 4	0.68	0.58-0.78	<.001
Item 5	0.73	0.62-0.81	<.001
Item 6	0.71	0.59-0.80	<.001
Item 7	0.83	0.76-0.88	<.001
Item 8	0.82	0.74-0.87	<.001
Item 9	0.85	0.78-0.89	<.001
Total score	0.91	0.87-0.94	<.001

Internal consistency: CAIT-TW had good internal consistency. Cronbach's α coefficient of CAIT-TW was 0.87. There was no improvement if any item of CAIT-TW was deleted (Table 13).

Table 13 Internal consistency of Taiwan-Chinese version of Cumberland Ankle Instability Tool

	Corrected item: total correlation	Cronbach's α if item was deleted
Item 1	0.67	0.85
Item 2	0.58	0.85
Item 3	0.64	0.85
Item 4	0.63	0.85
Item 5	0.48	0.86
Item 6	0.65	0.85
Item 7	0.68	0.84
Item 8	0.59	0.85
Item 9	0.65	0.85

No improvement was observed if any item was deleted

Discriminating ability: The mean score of CAIT-TW in the CAI group was 16.6 ± 4.3 and in the CON group was 26.1 ± 4.0. ROC showed that the cutoff score of CAIT-TW was 21.5 according to the maximum Youden index (0.73) (Figure 4 and Table 14). The sensitivity and specificity were 0.87 and 0.85 respectively.

Figure 4 The receiver operating characteristic (ROC) curve of Taiwan-Chinese version of Cumberland Ankle instability Tool. The area under the curve was 0.94.

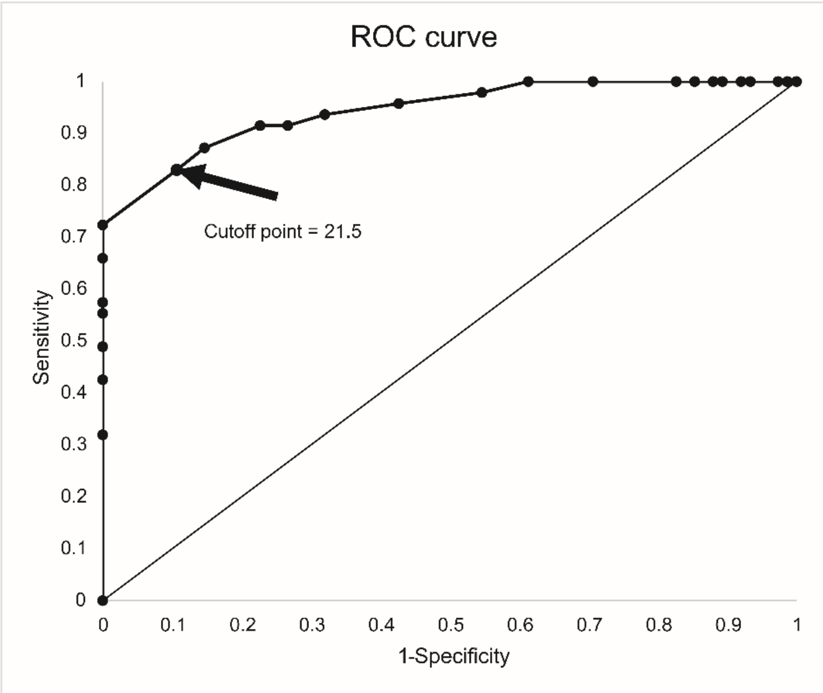


Table 14 Sensitivity, specificity and Youden index of Taiwan-Chinese version of Cumberland Ankle instability Tool

CAIT score	sensitivity	specificity	Youden index
3.0	1.00	0.00	0.00
5.5	1.00	0.01	0.01
7.5	1.00	0.03	0.03
8.5	1.00	0.07	0.07
9.5	1.00	0.08	0.08
10.5	1.00	0.11	0.11
11.5	1.00	0.12	0.12
12.5	1.00	0.15	0.15
13.5	1.00	0.17	0.17
14.5	1.00	0.29	0.29
15.5	1.00	0.39	0.39
16.5	0.98	0.45	0.43
17.5	0.96	0.57	0.53
18.5	0.94	0.68	0.62
19.5	0.91	0.73	0.65
20.5	0.91	0.77	0.69
21.5	**0.87**	**0.85**	**0.73**
22.5	0.83	0.89	0.72
23.5	0.72	1.00	0.72
24.5	0.66	1.00	0.66
25.5	0.57	1.00	0.57
26.5	0.55	1.00	0.55
27.5	0.49	1.00	0.49
28.5	0.43	1.00	0.43
29.5	0.32	1.00	0.32
31.0	0.00	1.00	0.00

4.2.5 Discussion

The current study translated and cross-culturally adapted CAIT from English to Taiwan-Chinese version. The CAIT-TW assessed the validity, reliability and cutoff score using an athletic population. In construct validity CAIT-TW showed a strong correlation with NRS and moderate correlation with LEFS-TW. CAIT-TW had overall excellent test-retest reliability, good internal consistency and was with a 21 cutoff score to discriminate between a stable ankle and an unstable ankle.

In construct validity, the Spearman's correlation coefficient between CAIT-TW and LEFS-TW was not optimal but acceptable. This may be caused by the testing population and property of the questionnaires. The correlation between the English version of CAIT and LEFS was moderate (0.50, $p < .01$), and the correlation between the Greek version of CAIT and LEFS was strong (0.71, $p < .001$), and their participants were from the general community, dancers in an art school, and students from a physiotherapy's school [14, 143]. The participants in this current study were all competitive athletes, attending 18-20 hours of high-intensity training every week. The athletes with CAI did not drop out of their daily training because of their ankle condition, and they performed their sports-specific tasks every day. Most of the questions in Lower Extremity Functional Scale (LEFS) is based on activities in daily life (15 items out of 20), which may not be sensitive enough to detect ankle instability for highly competitive athletes. In addition, LEFS focus on general functional in lower extremities instead of specialization in ankle condition. This may cause the correlation between LEFS-TW and CAIT-TW resulting in not optimal in competitive athletes. On the other hand, the Spearman's correlation coefficient between CAIT-TW and NRS showed strong correlation (Rho= 0.76, $p < 0.001$). This result is comparable with previous studies [14, 139, 140]. The correlation between English, Iranian and Dutch version of CAIT and Visual Analogue Scale or NRS were 0.64-0.80. [14, 139, 140]

For test-retest reliability, although the test-retest of CAIT-TW on each item was moderate to good, the overall test-retest reliability was excellent, which is consistent with previous studies ($ICC_{2,1}$ were from 0.83-0.98) [14, 134-140, 143]. The current study applied a one-week interval to examine the overall test-retest reliability, which was similar with the Brazilian-Portuguese version ($ICC_{2,1}$ = 0.98), two Spanish versions ($ICC_{2,1}$ = 0.98 and 0.95), the French version (ICC2,1 = 0.96), the Persian version ($ICC_{2,1}$ = 0.91-0.95) and the Korean version ($ICC_{2,1}$ = 0.95) of CAIT [134-137, 139, 142]. The Greek version showed 0.95 to 97 of $ICC_{2,1}$ with seven to ten days in between testing [143]. In the English version and the Japanese versions of CAIT, the test-retest intervals were between two and three weeks respectively and the $ICC_{2,1}$ were 0.96 and 0.83 [14, 138]. The current result should be interpreted carefully, because the test-retest reliabilities in five out of nine items were moderate ($ICC_{2.1}$ = 0.60-0.73), which is not perfect but acceptable. Compared to the French and the Greek version of CAIT, the test-retest reliabilities of each item were excellent ($ICC_{2.1}$ = 0.95-0.99 and 0.84-0.91). The differences may cause by the athletes' dynamic status. Athletes may have a different level of fatigue between test and retest, which may affect posture stability and then affect the score of each item [152].

In CAIT-TW the Cronbach's α coefficient was 0.87 indicating good internal consistency. The Cronbach's α coefficient would not improve if any item was omitted. This result is comparable with the French version of CAIT, which is with the Cronbach's α coefficient of 0.89 and there is no improvement if any item was deleted [142]. The result was comparable with previous studies. In the original English version Cronbach's α coefficient was 0.83. The Cronbach's α coefficient of Brazilin-Portuguese, Korean, Japanese, Persian, Dutch and Greek versions ranged from 0.73-0.97 [134, 137-140, 143]. In the Spanish version, published by Cruz-Duaz et al., the Cronbach's α coefficient was 0.77, and if items 5 or 6 were deleted, the Cronbach's α coefficient would be 0.79 and 0.78 respectively [135]. In the other Spanish version of CAIT, the Cronbach's α coefficient was 0.84 of the right ankle and 0.80 of the left ankle, and if item 9 was deleted the Cronbach's α coefficient would increase [136].

The current study showed that the cutoff score of CAIT-TW was 21.5 based on 0.73 of the Youden index. It is lower than the English, Japanese, French and Greek versions of

CAIT [14, 138, 142, 143, 146]. The original English CAIT suggested the cutoff score was 27.5 (Youden index: 0.68, sensitivity: 0.83 and Specificity: 0.75) [14]. Later Wright et al. recalibrated the cutoff score of the English CAIT, and suggested that the cutoff score is 25.5 (Youden index: 0.89, sensitivity: 0.97 and Specificity: 0.87) [146]. The cutoff score of the Japanese CAIT is also 25.5 (Youden index: 0.69, sensitivity: 0.71 and Specificity: 0.98) [138]. The cutoff score of the French and Greek versions of CAIT are 23.5 and 24.5 [142, 143]. The differences in cutoff scores may be caused by different characteristics of the participants. In the English CAIT, the subjects were selected from students in universities and dancers from art schools [14, 146]. In the French version of CAIT the participants were not specifically described and in the Greek version, the participants were students from physiotherapy's school [142, 143]. In the current study, the participants were highly competitive athletes. Although in the Japanese CAIT, the participants were from a soccer club in a university, the study did not provide information of the participants' competitive level [138]. The study of the Korean version of CAIT applied similar subjects as the current study, but they did not evaluate the cutoff score [137]. In addition, the cutoff score of the Dutch version, whose participants were patients in an orthopedic outpatient clinic, was 11.5 (Youden index: 0.72, sensitivity: 0.76 and Specificity: 0.91), which is even lower than the current study [140]. The study population in the French version of CAIT is unknown [142]. This indicates that different populations may need different cutoff points of CAIT to differentiate between a stable and an unstable ankle.

There were some limitations in the current study. First of all, the current study did not categorize the mechanical instability of the CAI group. Mechanical instability also affects the feeling of instability [5, 138]. Secondly, the cutoff point of CAIT-TW was calculated based on an athletic population. Therefore, this cutoff point may not be fit to evaluate the general population. Thirdly, some of the athletes had difficulties in answering item number 9: after a TYPICAL incident of my ankle rolling over, my ankle returns to “normal”, because they have different degrees of rolling over during their daily training, which affects the recovery period. This may affect the precision of scoring. Finally, the sensitivity to change, which is defined as an ability to detect the meaningful clinical change, was not assessed in the current study owing to the limited resources [153].

4.2.6 Conclusion

The Taiwan-Chinese version of the Cumberland Ankle Instability Tool showed satisfactory construct validity, excellent test-retest reliability and good internal consistency. In an athletic population, it can differentiate between a stable ankle and an unstable ankle with a 21.5 cutoff score. This tool can assist experts in sports medicine in Taiwan to conduct research or to apply it to daily practice.

4.3 Study 3

Research article

The prevalence of chronic ankle instability in basketball athletes: a cross-sectional study

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4.3.1 Abstract

Background: Ankle sprain is the most common injury in basketball. Chronic ankle instability develops from an acute ankle sprain may cause negative effects on quality of life, ankle functionality or on increasing risk for further injuries. To facilitate a preventative strategy of chronic ankle instability in the basketball population, gathering epidemiological data is essential. However, the epidemiological data of chronic ankle instability in basketball is limited. Therefore, this study aims to investigate the prevalence of chronic ankle instability in basketball athletes and to determine whether competitive level, gender, and basketball playing position influence this prevalence.

Methods: In a cross-sectional study, in total 391 Taiwanese basketball athletes from universities and sports clubs participated. Besides non-standardized questions about demographics and their history of ankle sprains, participants further filled out the standard Cumberland Ankle Instability Tool applied to determine the degree of ankle instability. Differences in prevalence between competitive level, gender, and playing position were determined using the Chi-square test.

Results: Finally, questionnaires from 255 collegiate and 133 semi-professional basketball athlete (male=243, female=145, 22.3±3.8 years, 23.3±2.2 kg/m^2) were analyzed. In the surveyed cohort, 26% had unilateral chronic ankle instability while 50% of them had bilateral chronic ankle instability. Women had a higher prevalence than men in the whole surveyed cohort ($X^2(1) = 0.515$, $p = 0.003$). This gender disparity also showed from sub-analyses, that the collegiate female athletes had a higher prevalence than collegiate men athletes ($X^2(1) =$

0.203, $p = 0.001$). Prevalence showed no difference between competitive levels ($p>0.05$) and among playing positions ($p>0.05$).

Conclusions: Chronic ankle instability is highly prevalent in the basketball population. Gender affects the prevalence of chronic ankle instability. Regardless of the competitive level and playing position the prevalence of chronic ankle instability is similar. The characteristic of basketball contributes to the high prevalence. Prevention of chronic ankle instability should a focus in basketball. When applying the CAI prevention measures, gender should be taken into consideration.

Keywords: Functional ankle instability, perceived ankle instability, ankle sprain, ankle injury

4.3.2 Introduction

Ankle sprain is one of the most common injuries in active individuals [110]. Residual symptoms after an acute ankle sprain, such as residual pain, swelling, giving way, or weakness, are also prevalent [29]. In a follow-up of 2.4 years after an acute ankle sprain, 74% of patients had residual symptoms [29]. The residual symptoms vary among patients and the terms describing this pathology are also diverse (e.g. chronic ankle instability (CAI), chronic ankle sprain, or recurrent lateral ankle instability) [4]. For research purposes, the International Ankle Consortium characterized Chronic ankle instability as a pathology occurring in individuals who have a history of significant ankle sprains, experience “giving way,” and/or recurrent sprain, and/or “feelings of instability in the injured ankle [4]

CAI is not only related to the residual symptoms after an acute ankle sprain but also leads to different negative consequences, for example, decreased quality of life, recurring ankle sprain, early degenerative joint tissue changes and can potentially increase the load on the anterior cruciate ligament [5]. These negative consequences make the individual prone to further injuries, illness and affect the athletes’ time available for practices and games [76]. To develop an injury prevention strategy for CAI and its negative consequence, injury surveillance is required [19].

CAI is developed from an acute ankle sprain [4]. In basketball, ankle sprain is one of the most common injuries because basketball involves repetitive jumping, cuttings, rapid stops and directional changes [1]. Incidences of ankle sprain in professional basketball athletes (National Basketball Association and the Women’s National Basketball Association) were 3.5 and 4.3 per 1000 athlete exposures (AE), respectively [80]. In an elite Spanish basketball club, the prevalence of ankle sprain was 1.3 per 1000 AE [80]. In college, US student-athletes showed incidences of ankle sprain around 1.2-1.5 and 1.0-1.2 per 1000 AE in men's and women's teams, respectively [1, 80]. In adolescents, the injury rates of ankle sprain were 1.1 and 1.3 per 1000 AE for Finnish boys' and girls' basketball teams [28].

Even if the epidemiology of ankle sprains in basketball is well documented, yet the prevalence of CAI in basketball is documented relatively scarce. Of all injuries, 19-22% attributed to recurrent ankle sprains in the basketball athlete population [1, 28, 84]. In basketball, 60% of the participants experienced recurrent ankle sprain, 28% perceived ankle instability with a history of an ankle sprain, and 30% suffered from persisting symptoms after an ankle sprain [16]. In addition, one study found that 30% (17 out of 57 participants with CAI) student-athletes in the US had CAI [17]. Two studies found that in Japan, 4-64% (1/24, 8/22 and 14/22) of the collegiate basketball athletes had CAI [21, 22]. In other words, the prevalence of CAI in basketball athletes with a history of ankle sprain could range from 4% to 64%. Although the prevalence of CAI in the basketball population has been investigated, the sample sizes of previous studies were small (N=22-57). In addition, previous studies excluded athletes with a history of fractures and injuries in the lower extremities, even though these athletes may also have CAI. Hence, the prevalence of CAI may be underestimated. A survey for basketball athletes should be conducted, and athletes with various other ankle issues should also be included in the surveillance to form an accurate picture of the prevalence of CAI.

Therefore, the purposes of this study were to investigate the prevalence of CAI in elite basketball athletes at different levels (semi-professional and college) and to investigate if the prevalence of CAI is influenced by different competitive levels, genders, and playing positions.

4.3.3 Material and Methods

Study design and procedure

This study presents the cross-sectional data of CAI prevalence during the pre-season of the Super Basketball League and the games of the University Basketball Association in Taiwan. The investigator contacted team staffs from all semi-professional teams and college teams in Taiwan and visited each team. Participants filled out the questionnaire inquiring demographics, history of ankle sprain and the Taiwan-Chinese version of the Cumberland Ankle Instability Tool Questionnaire (CAIT-TW) after a routine practice.

Participants

391 elite Taiwanese basketball athletes of 11 semi-professional and 17 collegiate teams were recruited for this study. 134 athletes at a semi-professional level (99 men and 35 women) from all the teams which attend the Super Basketball League in Taiwan (table 1). 257 athletes from the basketball teams ranked within the top ten in 2017 in the University Basketball Association in Taiwan (table 1). To select the collegiate teams a convenient sampling was applied. Inclusion criteria were: (1) participants were basketball team members and (2) a minimum age of 18 years. Exclusion criteria were acute injuries in the lower extremities and incomplete questionnaires.

Instruments

There were three sections in the questionnaire: demographics, history of significant ankle sprains, and the CAIT-TW. The demographic section included age, gender, height, weight, training hours per week, training experiences, competitive level and playing position. A history of significant ankle sprain was associated with inflammatory symptoms, interrupting at least 1 full day of planned physical activity, resulting in some initial deficits of function, and disability. The CAIT-TW consisting of nine items was applied to determine the presence of perceived ankle instability [154]. CAIT-TW was culturally adapted from the original English Cumberland Ankle Instability Tool Questionnaire (CAIT) and evaluated the psychometric properties in an athletic population. The CAIT-TW showed excellent test-retest reliability ($ICC_{2.1}$ = 0.91), good internal consistency (Cronbach's α: 0.87) and a cutoff score of 21.5 (Youden index: 0.73, sensitivity: 0.87, specificity 0.85) [154].

Data analysis

The International Ankle Consortium suggested the inclusion criteria of CAI are individuals who had a history of significant ankle sprain and either (1) experience of giving way twice or more within the past six months, (2) recurrent ankle sprain, or (3) perceived ankle instability (the score of CAIT-TW is lower than 22) [4]. To reduce the recall bias on the experience of giving way and recurrent ankle sprain, athletes were considered to have CAI if they have a history of significant ankle sprain(s) and the presence of perceived ankle instability evaluated using CAIT-TW.

All data analyses were performed using IBM SPSS 25.0 (Chicago, Illinois, USA).

Descriptive statistics were performed to display the demographic data and prevalence of CAI in the population of basketball athletes (first study purpose). Differences in demographics between participants with CAI and without CAI were examined applying the Mann-Whitney U test or independent T-test depends on the distribution of the data. The Chi-square test was applied to determine the difference in the presence of CAI between genders, two competitive levels, and playing positions (second study purpose). The level of significance was set at p value ≤ 0.05.

4.3.4 Results

In total, 391 basketball athletes filled out the questionnaire, whereby three questionnaires were incomplete. Finally, 388 valid questionnaires were available for analysis. Participants' demographics and the score of CAIT-TW are shown in table 1. In the surveyed cohort, 97% of the participants experienced ankle sprain, 26% of them had unilateral CAI while 50% had bilateral CAI, and 24% of them were without CAI (Table 15). There were no demographical differences between participants with CAI and without CAI (Table 16).

Table 15 Demographic characteristics of participants

	All (N=388)			College (n=255)			Semi-Professional (n=133)			Men (n=243)			Women (n=145)		
	M	±	SD	M	±	SD	M	±	SD	M	±	SD	M	±	SD
Age [year]	22.3	±	3.8	20.1	±	1.5	26.5	±	3.4	22.5	±	3.8	21.9	±	3.9
Height [cm]	179.9	±	10.9	177.6	±	10.8	184.4	±	9.8	186	±	7.5	169.8	±	7.6
Weight [kg]	76.1	±	13.7	72.9	±	13.2	82.3	±	12.4	82.9	±	11.1	64.7	±	9.4
BMI [kg/m^2]	23.3	±	2.2	22.9	±	2.2	24.1	±	2.0	23.9	±	2.0	22.4	±	2.1
Training hours per week [hour]	18.6	±	6.5	16.3	±	5.4	23	±	6.3	19.7	±	6.2	16.8	±	6.7
Training experience [year]	9.2	±	3.8	7.7	±	2.9	12.1	±	3.6	8.9	±	3.7	9.8	±	3.9
Left CAIT-TW score	18.3	±	6.1	18.8	±	6.2	17.5	±	6.1	19.3	±	5.8	16.8	±	6.4
Right CAIT-TW score	18.7	±	6.4	19.3	±	6.5	17.5	±	6.1	19.5	±	6.0	17.3	±	6.8
Unilateral CAI [n (%)]	102 (26)			75 (29)			27 (20)			62 (26)			40 (28)		
Bilateral CAI [n (%)]	195 (50)			116 (46)			79 (59)			112 (46)			83 (57)		
without CAI [n (%)]	91 (24)			64 (25)			27 (20)			69 (28)			22 (15)		

M: mean, SD: standard deviation, CAIT-TW: score of the Taiwan-Chinese version of the Cumberland Ankle Instability Tool. CAI: chronic ankle instability

Table 16 Demographical differences between participants with CAI and without CAI

	CAI (n=297)			Without CAI (n=91)			difference between groups
	M	±	SD	M	±	SD	
Age [year]	22.4	±	3.8	21.9	±	3.8	p>0.05
Height [cm]	179.5	±	11.1	181.5	±	10.3	p>0.05
Weight [kg]	75.7	±	13.6	77.5	±	13.9	p>0.05
BMI [kg/m^2]	23.3	±	2.11	23.4	±	2.5	p>0.05
Training hours [hour/week]	18.5	±	6.6	18.9	±	6.3	p>0.05
Training experience [year]	9.3	±	3.8	8.8	±	3.9	p>0.05
L't CAIT score	16.4	±	5.5	24.8	±	2.8	p<0.001*
R't CAIT score	16.7	±	5.8	25.1	±	3.3	p<0.001*

CAI: chronic ankle instability, M: mean, SD: standard deviation, BMI: body mass index, L't CAIT score: score of the Cumberland Ankle Instability Tool in in left ankle, R't CAIT score: score of the Cumberland Ankle Instability Tool in in right ankle, *: showing a significant difference between groups

The competitive level did not influence the presence of CAI (X^2=0.054, p>0.05) (Table 17). When the data was separated between men and women, there was no difference of prevalence between different competitive levels in both genders (men: X^2=0.054, p>0.05, women: X^2=0.069, p>0.05).

Gender influenced the presence of CAI (table 3). Women had a higher prevalence of CAI than men (X^2=0.151, p<0.05). When data was separated into two levels, at the collegiate level women had a higher prevalence of CAI than men ($X(1)^2$=0.203, p=0.001). No difference based on gender has been found at the semi-professional level ($X(1)^2$=0.203, p=0.467) (Table 17).

In the three playing positions, the prevalence of CAI consisted of 76% in the guard (124/164), 80% in the forward (118/148), and 74% in the center (51/69) position. The prevalence of CAI did not differ among playing positions ($X(2)^2$=0.066, p=0.59) (Table 18).

Table 17 The prevalence of chronic ankle instability in different populations (n, %)

	All	College	Semi-Professional	Differences between competitive level
All	297/388,77%	191/255, 75%	106/133, 80%	$X^2(1)$=0.054, p=0.290
Men	174/243, 72%	99/147, 67%	75/96, 78%	$X^2(1)$=0.117, p=0.069
Women	123/145, 85%	92/108, 85%	31/37, 84%	$X^2(1)$=0.017, p=0.838
Differences between gender	$X^2(1)$=0.151, p=0.003*	$X^2(1)$=0.203, p=0.001*	$X^2(1)$=0.203, p=0.467	

*: the prevalence of chronic ankle instability showed significant difference between men and women

Table 18 The prevalence of chronic ankle instability in different playing positions (n, %)

	All (N=381)	Female (n=143)	Male (n=238)	College (n=248)	Semi-professional
Guard	124/164, 75.6%	53/62, 85.5%	71/102, 69.6%	81/110, 73.6%	43/54, 79.6%
Forward	118/148, 79.7%	38/45, 84.4%	80/103, 77.7%	69/90, 76.7%	49/58, 84.5%
Center	51/69, 73.9%	30/36, 83.3%	21/33, 63.6%	37/48, 77.1%	14/21, 66.7%
Differences of prevalence among playing positions	$x^2(2)=0.55$, $p=0.56$	$x^2(2)=0.02$, $p=0.96$	$x^2(2)=0.21$, $p=0.11$	$x^2(2)=0.04$, $p=0.85$	$x^2(2)=0.15$, $p=0.22$

4.3.5 Discussion

The purposes of this study were (1) to investigate the prevalence of CAI in basketball athletes and (2) to assess if different competitive levels, genders and playing positions influence this prevalence. The prevalence of CAI was high in the studied cohort. Gender affected the prevalence of CAI. Women showed a higher presence of CAI than men. The competitive level and playing position showed no influence on the prevalence of CAI.

The prevalence of CAI

Regarding the first objective, the prevalence of CAI in this study cohort was high and above the prevalence of previous studies [17, 21, 22, 122]. Female basketball athletes in the current study presented an 85% (123/145) prevalence of CAI, yet the previous studies showed 4% (2/26) in Japanese colligate basketball athletes and 64% in Australian netball female athletes (61/96), whose movement patterns are similar to basketball [22, 122]. College basketball athletes in the current study displayed a 75% (79/255) prevalence of CAI, but previous investigations showed 30% (17/57) in the US High school and college basketball athletes and 64% (14/22) and 36% (8/22) in Japanese colligate basketball athletes [17, 21]. Different exclusion criteria applied in the current and previous studies cause discrepancies in results. The previous studies applied the exclusion criteria suggested by the International Ankle Consortium. These criteria exclude participants with a history of previous surgeries, fractures and acute injuries in the lower extremities [17]. However, the current study included the participants who meet the exclusion criteria.

Regarding exclusion criteria, there is a limitation when surveying the prevalence of CAI using the criteria defined by the International Ankle Consortium. If the participants with CAI are excluded because they have the issues mentioned in the exclusion criteria, the prevalence of CAI could be underestimated. Therefore, the previous studies might exclude athletes with both CAI and other issues and showed an underestimated prevalence [17, 21, 22, 122]. On the other hand, if the participants without CAI have any conditions mentioned in the exclusion criteria, they may also perceive ankle instability, yet the perceived ankle instability might be owed to the other conditions instead of CAI. In this case, the prevalence of CAI would be overestimated. Therefore, the prevalence in the current study might be overestimated.

Prevalence is almost double if applying the exclusion criteria than following the exclusion criteria when investigating the prevalence of CAI [21]. Koshino et al. found a prevalence of 36% if excluding the participants who had other (confounding) conditions, but the prevalence was 64% if they were not excluded [21]. Therefore, the real prevalence of CAI in Koshino's and colleagues' study might be in a range of 36% to 64%. In the current study, the prevalence of CAI was 77%. It can be estimated that the prevalence might be 39% if participants were excluded based on the exclusion criteria from the International Ankle Consortium. Therefore, the true prevalence of CAI in the current study might be located between 39% and 77%. A standard method to identify the origin of perceived ankle instability is required to investigate the epidemiology of CAI, and then participants with other conditions can be clearly categorized.

The high prevalence in the current study might be caused by the other factors: preexisting ankle instability, the time period that CAI was measured, and recovery conditions after ankle sprains. Pre-existing ankle instability is a confounder when investigating the prevalence of CAI. In the current study, 30% of the participants without a history of ankle sprain showed perceived ankle instability (left ankle: 14/53 and right ankle 21/69). Therefore, there is a possibility that athletes with pre-exist ankle instability were categorized as CAI even though they recovered well from a significant ankle sprain. The current cross-sectional study cannot clarify if the perceived ankle instability is preexisting or caused by an ankle sprain.

The timing of the investigation might be another explanation for the high prevalence of CAI. The current study surveyed one month prior to the start of the season. Most ankle injuries occurred during the pre-season in college basketball athletes [84]. In the pre-season, the training load intensity and duration are often higher than the in-season phase [155], leading to an increased risk of injury [156]. Recurrent ankle sprain is one of the signs of CAI. Therefore, in the pre-season, a high rate of ankle injury may contribute to the high prevalence of CAI. In addition, data to depict the prevalence of CAI in different seasons is scarce. The optimal method to investigate overuse injury or chronic pain (e.g. the symptoms of low back pain, patellar tendinopathy, or shoulder pain) is to perform a prospective longitudinal study and to measure the symptoms at regular intervals, because the chronic pain may fluctuate among different training seasons [130]. In the case of CAI, the CAI-related symptoms have not been measured continuously in athletic populations, so it is not clear if the presence of perceived ankle instability and frequency of recurrent ankle sprain and giving way fluctuates with time or training seasons as the other overuse injuries.

The inadequate recovery and lacking rehabilitation after an ankle sprain might also contribute to the high prevalence of CAI. Doherty et al. showed that after an acute ankle sprain, 40% of the participants who did not seek the rehabilitation developed CAI, and 60% of them became ankle sprain copers, who sought rehabilitative service from healthcare providers [130]. Nevertheless, the effect of seeking rehabilitation showed no statistical significance [130]. In addition, in the athlete population, only half of the athletes sought a healthcare provider after an ankle sprain [17, 130]. This absence from practices and competitions due to the injury sustained during pre-season may affect participation in the in-season. Koshino et al. found that, in the basketball population, there are no ankle sprain copers, and in the whole surveyed cohort there are only 4.3% to 5.3% of ankle sprain copers [21]. Therefore, athletes might not recover properly after an ankle sprain and/ or keep practicing with CAI. With not properly healed tissue, further secondary injuries could be developed, such as sensori-perceptual and motor-behavioral impairments [5]. CAI affects the motor function of neuromuscular control and biomechanics on lower extremities, which might increase the risk of recurrent ankle sprains, cause posttraumatic osteoarthritis, increase the loading on the anterior cruciate ligament and further development of injuries [5]. Hence, managing CAI in the athletic population to prevent further unwanted injuries are essential.

The prevalence of CAI and different competitive levels

The current study found that the athlete's competitive level did not relate to the prevalence of CAI. The relation between the competitive level and the injury rate of an ankle injury is not clear [79]. Two previous studies showed that athletes competing at a higher competitive level showed a lower prevalence of CAI [17, 122]. This may relate to the more advanced skills and the injury prevention measures applied to higher-level athletes [79, 130]. However, another study found that the rate of ankle sprains is higher in lower-level athletes than those competing at a higher level [30]. Athletes at higher competitive levels of play may create more force when playing and this could result in a higher injury rate. The potential explanation for the inconsistent findings in the current study and the previous studies might be that athletes attend highly specialized training from a young age in Taiwan [157]. Most of the elite Taiwanese athletes attend intense specialized training starting from the age of 14, which is a risk factor for serious overuse injury [157]. Access to healthcare for young athletes was not common 10 years ago in Taiwan, which may lead to the development of CAI. Although nowadays, 60% of the top-ten high school basketball teams employ athletic trainers who can provide injury care. The previously existing overuse injury may last until they are at a higher level and causes the current result: a high prevalence of CAI.

The prevalence of CAI and gender difference

The current study found that gender influences the prevalence of CAI. Female athletes at the collegiate level had a higher prevalence of CAI than men at the same level. This is consistent with one previous work showing that female athletes had a higher prevalence of CAI than male athletes in high school and colleges [17]. In contrast, in a survey of a military cohort, men had a 2.33 times greater incidence of mild CAI than women . The gender difference in the incidence of ankle sprains is also inconsistent. Two studies showed no gender difference between athletes in high school and those between the WNBA and NBA [28, 80]. One study found that male athletes in high school had a higher incidence of ankle injury than female athletes [84].

The factor causing the difference in ankle injury rate between genders could be the different anatomical structural, joint laxity and menstrual cycles [88-91]. Regarding anatomical structure, female college athletes with an increased tibial varum and calcaneal eversion range of motion showed a greater risk of ankle sprain [92, 93]. In the respect of joint laxity, women had a greater ligamentous laxity of the lateral ankle than men [89]. In regards to hormone fluctuation, women in the ovulating phase of menstrual cycles showed less postural stability than in the follicular phase [90-92]. The distinct structure and menstrual cycles between genders might lead to different injury rates.

The prevalence of CAI and the different basketball playing positions

The current study found that the different playing positions showed no difference in the prevalence of CAI. To the best of the authors' knowledge, no study has investigated the prevalence of CAI in different playing positions within basketball athletes. Regarding the relation of ankle injuries and playing positions, the outcome is inconsistent with previous works [84, 105]. Previous studies found that athletes in center and guard positions sustain the most ankle injuries. [84, 98, 105]. The center commonly has a size advantage for this playing position and needs to jump frequently for rebounds causing contact with other players and are therefore prone to suffer more injuries [105]. A guard in basketball sustains high physiological stress due to repetitive direction changes and may cause neuromuscular fatigue increasing the injury rate [84]. However, the current study and a previous study showed no difference between the different playing positions [98]. The current results are inconsistent with the previous studies. This might be due to basic basketball movements and the players' role being shared (e.g. guard position filling in for forward position). Although there are different basketball playing positions, the role of each athlete sometimes is not that distinct in Taiwan. Some athletes may play center and power forward at the same time and some play small forward and shooting guard at the same time. This may make the characteristics of the injury less distinguished. Besides, in all playing positions, athletes have to perform the basic basketball movements including jumping, cuttings, rapid stops, and sudden directional changes, which make an athlete more prone to ankle sprains.

Study limitations

There were some limitations to the study. Firstly, the mechanical instability has not been examined, so the participants with solely ankle pathological laxity may not be shown in the results. In addition, because of limited study resources, there was no physician to differentiate between the CAI and ankle instability caused by other issues. This may lead to an overestimation of the prevalence of CAI in the current study.

4.3.6 Conclusion

An acute ankle sprain can cause the development of CAI, which can impact athletes negatively. In the current study, elite Taiwanese basketball athletes showed a higher prevalence of CAI than in previous studies. Female college athletes have a higher prevalence of CAI than men. Competitive level and playing positions showed no difference in the prevalence of CAI. Prevention of chronic ankle instability should be a focus in basketball. When applying the CAI prevention measures, gender should be taken into consideration.

The recommendations for further studies investigating the prevalence of chronic ankle instability are: (1) prospective longitudinal study is recommended, so the fluctuation of prevalence can be clearly depicted and the pre-exist ankle instability will not confound the prevalence, (2) standard criteria for survey the prevalence of CAI should be developed, that can increase the precision of the prevalence, and (3) implementation of rehabilitation followed by ankle sprains should be reported.

List of abbreviations

CAI: chronic ankle instability

CAIT: the Cumberland Ankle Instability Tool

CAIT-TW: the Taiwan-Chinese version of the Cumberland Ankle Instability Tool

M: mean

SD: standard deviation

p: p-value

Declarations

Ethics approval and consent to participate

All participants read and signed the informed consent document before participating in the study. This study performed in accordance with the Declaration of Helsinki and was approved by the ethical committee at the University of Potsdam (Number: 25/2018). Study was conducted in October of 2018.

Consent for publication

Not applicable

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

CIL conceptualized the research idea, analyzed data, applied for funding, wrote the manuscript, obtained the resources, investigated, and administrated the project. FM reviewed the manuscript and supervised the project. PMW assisted funding acquisition, reviewed the manuscript, and supervised the project.

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5. General Discussion

5.1 Epidemiology of chronic ankle instability and the recommendations for investigating the epidemiology in chronic ankle instability

Epidemiology of chronic ankle instability

Nine studies were included in the current systematic review. The prevalence of CAI is 25% (ranged from 7% to 53%) among high school/ college student-athletes, general students and dancers. The prevalence of CAI within ankle sprained participants was 46% (ranging from 9% to 76%). The prevalence showed a wide range as expected. There are potential explanations for the wide range of prevalence among included studies.

Factors affecting the prevalence of chronic ankle instability

First of all, the different exclusion criteria among studies could cause a wide range of prevalence. In the included studies, seven studies applied the exclusion criteria of IAC and the other two studies applied modified exclusion criteria to conduct the surveillance (see Table 7). Applying the exclusion criteria of the IAC to survey the prevalence of CAI may lead to an underestimation of the prevalence because the participants with both CAI and pre-existing issues (history of injuries and fractures in lower extremities) were excluded. On the contrary, without excluding participants with pre-existing issues, the prevalence of CAI might be overestimated, because the preexisting issue also cause perceived ankle instability. Whether exclusion criteria are applied can account for a doubling of the prevalence percentage [21].

In addition, the surveyed populations are diverse. The levels of physical activity, age and sports disciplines could affect the prevalence of CAI. In the nine included studies, the population consist of high school/ college student-athletes, general students, dancers and patients with a first-time lateral ankle sprain. It seems logical that athletes show a higher prevalence of CAI than the general population (76% vs 51%) [119, 120], because athletes participating in organized practice and competitions are more physically active and therefore have a higher chance to encounter injuries than the general population. Additionally, participants' age ranged from 15 to 32 years. Younger age is one of the risk factors of CAI [123]. In the current review, the prevalence of CAI with a history of ankle sprain presented higher in participants aged younger than 18 years (63%) compared to those aged between 18 and 25 years (36%). Moreover, different sports disciplines showed differing prevalence of CAI [16]. Therefore, the risk factors of ankle sprain or CAI including level of physical activity, age and sports discipline should be clearly reported to depict the surveyed population.

Furthermore, there are some additional potential factors that might affect the prevalence of CAI, for example, body size [75], gender [17], competition level [17] and accessibility of rehabilitation [128] after an ankle sprain. These potential factors should be investigated in the future and be taken into consideration when conducting the surveillance of CAI.

Recommendation ions for the future studies

In order to investigate the epidemiology of chronic injuries, prospective designed studies to investigate the symptoms of CAI at regular intervals and to portray the presence of CAI among whole seasons are recommended [130]. It is not clear if the prevalence of CAI fluctuates in different competitive seasons/measurement time points. The current review cannot answer this question because there is no prospective designed study included in the current review. Eight included studies are cross-sectional studies and one study is a longitudinal study. Studies with a prospective design can give a better insight into the risk factors of CAI and the development of CAI.

Additionally, a method to differentiate between symptoms from pre-existing ankle issues and CAI is required to determine the most accurate prevalence of CAI. Furthermore, the risk factors of ankle sprain or CAI including age and sports discipline should be clearly reported to depict the surveyed population. Finally, certain factors that may affect the rate of ankle sprain and CAI that remain unclear (e.g. gender, body size and history of rehabilitation) should be clarified and described in further epidemiology studies of CAI.

5.2 Validity and reliability of the Cross-cultural translation the Cumberland Ankle Instability Tool

The Cumberland Ankle Instability Tool (CAIT) was culturally adapted and translated to a Taiwan-Chinese version (CAIT-TW) with moderate to strong construct validity, excellent test-retest reliability, good internal consistency and a cutoff score of 21.5.

The CAIT has been culturally adapted and translated to different languages, such as two versions in Spanish [135, 136], Brazilian-Portuguese [134], Dutch [140], French [142], Greek [143], Korean [137], Japanese [138] and Persian [139, 158]. The current study applied the guidelines for cross-cultural adaptation and validation of health status measures from Beaton, Bombardier, Guillemin and Ferraz (2000) to translate the CAIT [144]. Previous studies culturally adapted and translated CAIT based on the guideline from Guillemin (1995) [159], Bullinger (1998) [160] and Beaton et al. (2000) [144] or modified the translation process based on the guidelines mentioned above (see Table 19).

Although previous studies assessed different populations, tools and psychometric properties to evaluate the validity and reliability of the tool, the results are comparable among studies.

This section will discuss the results of psychometric properties between the current study and other studies.

Table 19 Summary of participants and translation procedure from different version of The Cumberland Ankle Instability Tool

Version of CAIT	Participants	Translation procedure
Original English version (2006) [14]	University/general/dancer population (N=92), 23±7 years CAI (n=57), CON (n=35)	NA
Brazilian-Portuguese (2007) [134]	General community and patients from a physiotherapy clinic (N=131) CAI (n=30): 26±10 years, CAIT: 14/30 CON(n=101): 28±6 years, CAIT: 25/14	Beaton et al. (2000)[144]
Spanish (2012) [135]	Volunteers from a sports center (N=108) CAI (n=108): 30±9 years, 171±8cm, 60±11, CAIT: 25/30	Guillemin (1995) [159]
Spanish-2 (2014)[136]	University population (N=171) CAI (n=171): 23±5year. 174±10cm, 70±12kg, CAIT: 25/30	Beaton et al. (2000) [144]
Korean (2015) [137]	National level athletes in Olympic sports (N=168) CAI (n=91): 20±1 year, CAIT: 16/30 CON (n=107): 20±1 year, CAIT: 28/30	Guillemin (1995) [159]
Japanese (2016) [138]	University students from a men’s soccer’s club (N=111) CAI (n= 61): 19 years, 173±66cm, 66±5kg, CAIT: 23/30 CON (n=50): 19 years, 174±5cm. 67±6kg, CAIT: 29/30	Beaton et al. (2000)[144]
Persian (2016) [139]	General population/student (N=135) CAI (n=105): 26±8 year, CAIT: 20/30 CON(n=30)): 23±2 year, CAIT: 27/30	Bullinger et al. (1998) [160]
Dutch (2018) [140]	Patients from a medical center(N=98): 16-74 years (median: 45) CAI (n=55), CON (n=43)	Beaton et al. (2000)[144]
Greek (2019) [143]	Students from a university (N=123) CAI (n=43): 23±5 year, CAIT:20/30 CON (n=80): 24±7 year, CAIT: 27/30	Beaton et al. (2000)[144]
French (2020) [142]	Students from a university (N=102) CAI (n=51): 22 (20-26) year, 23 kg/m^2, CAIT: 16/30 CON (n=51): 22(22-25) year, 23 kg/m^2, CAIT:28/30	Beaton et al. (2000)[144]
Taiwanese (2020) [154]	Collegiate athletes (N=116) CAI (n=58): 20±2 year, 172±10 cm, 69±7 kg, 1 CAIT: 16/30 CON (n=58): 20±1 year, 173±9 cm, 66±14 kg, CAIT: 26/30	Beaton et al. (2000)[144]

NA: not applicable

Construct validity

The results of criterion and construct validity are summarized in Table 20. Criterion validity is the correlation between a particular instrument and a gold standard and construct validity is the correlation between a particular instrument and other instruments that measure a similar concept [145]. There was no other Taiwan-Chinese version of the instrument to measure the degree of ankle instability, so construct validity was applied to evaluate the validity. The correlation between CAIT and the Visual Analog Scale (VAS)/ Numeric Rating Scale (NRS) was 0.73 (strong) in the current study and were between 0.54 and 0.80 (moderate to strong) in the previous studies [14, 139, 140, 143]. Yet, the correlation between CAIT and the Lower Extremity Functional Scale (LEFS) was 0.39 (moderate) in the current study and that were between 0.5 and 0.80 (moderate to strong) in the previous studies [14, 143]. The relatively low correlation between CAIT and LEFS in the current study compared to the other studies may be due to the participants' characteristics. Participants in the current study were highly competitive athletes and participants in previous studies were university students, dancers and general populations. Some questions from LEFS could result in a ceiling effect on an athletic population. For example, item 3, 4 and 5 ask if participants have difficulties of getting into or out of the bath, walking between rooms, and putting on your shoes or socks [147, 148]. For athletes participating in daily training, these questions are not as relevant.

Test-retest reliability

The test-retest reliability in the current study was excellent (ICC2.1 = 0.91, 95%, confidence interval = 0.87-0.94, $p < .001$). $ICC_{2.1}$ of test-retest from previous studies ranged from 0.79 to 0.98 and measurement interval ranged from one week to three weeks. The summary of the results is presented in Table 21.

Table 20 Summary of construct and criterion validity from previous studies

	Version	Participants	Tool	Correlation	P value
Criterion validity	English [14]	N=92 CAI: 57, CON: 35	LEFS VAS	rho=0.50 rho=0.76	<0.01 <0.01
	Spanish-2 [136]	N=54	Original CAIT (2 weeks)	$ICC_{2,1}$=0.91, 95%CI=0.84-0.94	<0.01
	Korean [137]	N=168 CAI: 61, CON: 107	SF36-Physical SF36-Mental component	rho=0.70 rho =-0.06	0.01 0.48
	Japanese [138]	N=111, CAI: 61, CON: 50	Karlsson Score	r=0.604 (moderate)	<0.01
	Persian [139]	N=135 CAI: 105, CON: 30	FAAM-DAL FAAM-Sport VAS (left/right)	rho =0.41 (moderate) rho =0.43 (moderate) rho =0.80/0.64 (strong)	
Construct validity	Korean [137]	N=168 CAI: 61, CON: 107	CAIT-K test/retest	Exploratory factor analysis: Kaiser-Mayer-Olkin score=0.87	P<0.01
	Spanish [135]	N=108	SF36- Physical/ Mental component	rho=0.240 (low) rh0=-0.162	0.01 0.09
	Dutch [140]	N=47/98	Self-report instability FAOS: pain, symptoms, ADL, sport, QoL NRS	-0.65 (moderate) 0.42, 0.37, 0.48, 0.36, 0.43 (moderate) -0.55 (moderate)	<0.01
	French [142]	N=102 CAI: 51, CON: 51	SF36-Physical SF36-Mental component FAAM Sport FAAM ADL VAS	0.595 0.198 0.793 0.763 0.834	<0.01 0.09 <0.001 <0.001 <0.001

	Greek [143]	N=123	LEFS	r = 0.73	<0.01
		CAI: 43, CON: 80	VAS	r = 0.54	<0.01
	Taiwanese [154]	N=118	LEFS	rho =0.39 (moderate)	<0.01
		CAI: 59, CON: 59	NRS	rho =-0.73	<0.01

N: total sample size, CAI: the group of chronic ankle instability, CON: control group, LEFS: The Lower Extremity Functional Scale, VAS: Visual Analogue Scale, CAIT: the Cumberland Ankle Instability Tool, SF-36: The Short Form (36) Health Survey, FAAM-ADL: Foot and Ankle Ability Measure- Activities of Daily Living Subscale, FAAM-SPORT: Foot and Ankle Ability Measure-Sports Subscale, CAIT-K: the Korean version of the Cumberland Ankle Instability Tool, FOAS: Foot and Ankle Outcome Score, ADL: activity of daily life, QoL: Quality of life, NRL: Numeric Rating Scale

Table 21 Summary of test-retest from previous studies

Version	Participants (N, CAI/CON)	Interval between measurements	$ICC_{2.1}$	95%CI	P value
English [14]	N=18	2 weeks	0.96		
Brazilian-Portuguese [134]	N=101	1 week	0.95	0.93-0.97	
Spanish [135]	N=32	1 week	0.98	0.96-0.99	<0.001
Spanish-2 [136]	N=166	1 week	R=0.95 L=0.95	0.94-0.97 0.93-0.96	<0.001 <0.001
Korean [137]	N=168, 61/107	1 week	0.95		SEM = 1.5
Japanese [138]	N=111, 61/50	3 weeks	0.83	0.73-0.89	P<0.001
Persian [139]	N=135, 105/30	1 week	R=0.95, L= 0.91	0.91-0.97 0.80-0.94	<0.001 <0.001
Dutch [140]	N=98,55/43	1 week	0.94		
French [138]	N=102, 51/51	1 week	0.96	0.94-0.97	
Greek [143]	N=123, 43/80	7-10 days	0.79	0.97–0.98	
Taiwanese [154]	N=120,59/59	1 week	0.86	0.80-0.90	0.001

N: total sample size, CAI: group of chronic ankle instability, CON: control group, R: right, L: left, ICC: intraclass correlation, 95%CI: 95% Confidence interval, SEM: Standard Error of Measurement

Internal consistency

CAIT-TW showed good internal consistency (Cronbach's α: 0.87), which is comparable to the results of previous studies (see Table 22). Cronbach's α coefficient from previous studies ranged between 0.70 and 0.90 (see Table 22).

Table 22 Summary of internal consistency from previous studies

Version	(N, CAI/CON)	Cronbach's α coefficient
English [14]	(146)	0.83
Brazilizn-Portugese [134]	(131, 30/101)	R=0.86, l=0.88
Spanish [135]	(108, 108/0)	0.77 (0.70-0.95)
Spanish-2 [136]	(171, 171/0)	R=0.84, L=0.80
Korean [137]	(168, 61/107)	0.92-0.90
Japanese [138]	(111, 61/50)	0.83
Persian [139]	(135, 105/30)	CAI: R=0.81, L=0.79 CON: R=0.77, L=0.73
Dutch [140]	(98,55/43)	0.86
Taiwanese	(120,60/60)	0.87
French [142]	(102, 51/51)	0.89
Greek [143]	(123, 43/80)	0.97

N: total sample size, CAI: group of chronic ankle instability, CON: control group, R: right, L: left

Cutoff score

CAIT-TW is with a 21.5 cutoff score to discriminate between a stable ankle and an unstable ankle in the athletic population. Cutoff scores from different versions of CAIT ranged from 11 to 24 (see Table 23). The wide range of cutoff scores among different versions of CAIT may be caused by the different investigated populations. In general populations or university students, the cutoff scores are between 23 to 25 [138, 142, 143]. In patients, the cutoff score is 11.5 [140]. The current study applied the questionnaire to highly competitive athletes to determine the cutoff score of CAIT. It is highly possible that athletes have greater exposure to training sessions than general populations, so they have more chances than general populations to experience ankle instability during the training session which is highly demanding to maintain ankle stability. For patients, they suffer from injuries which affects their daily activity and further increase the experience of ankle instability.

Table 23 Summary of Cutoff scores from previous studies

Version	N, CAI/CON	Youden index	Cut point	Sensitivity	Specificity
English [14]	151,95/56	0.681	27.5	0.829	0.747
Japanese [138]	111, 61/50	0.685	25	0.705	0.980
Dutch [140]	98,55/43	0.72	11.5	0.76	0.91
Taiwanese [154]	120, 60/60	0.63	21	0.92	0.72
French [142]	102, 51/51	0.922	23.5	1.000	0.922
Greek [143]	123, 43/80	NA	24.5	NA	NA

N: total sample size, CAI: group of chronic ankle instability, CON: control group, NA: not available

Overall, CAIT-TW was culturally adapted and translated to the Taiwan-Chinese version with moderate to strong construct validity, excellent test-retest reliability, good internal consistency and a cutoff score of 21.5. In an athletic population, the questionnaire is able to differentiate between a stable ankle and an unstable ankle with a 21.5 cutoff score. This tool can assist experts in sports medicine in Taiwan to conduct research or to apply it to daily practice.

5.3 Prevalence of chronic ankle instability in basketball population

The third study investigated the prevalence of CAI in basketball athletes and accessed if the prevalence of CAI is different from genders, competitive levels, and play positions. The results showed that the prevalence of CAI was high. In addition, the prevalence of CAI showed gender difference, yet the prevalence showed no difference from competitive level and play positions.

Prevalence of chronic ankle instability

Previous studies that surveyed the prevalence of CAI in athletic populations showed prevalence between 4% and 67% [17, 18, 21, 22, 119, 122]. The current study found a prevalence of 77% in the surveyed population. Causes of the high prevalence of CAI in the current study might be the exclusion criteria applied in the current study. The other potential factors influencing the prevalence might be preexisting ankle instability in participants, the measuring timing, and recovering conditions after sustaining ankle sprains, have been discussed in the third study.

The International Ankle Consortium (IAC) suggested inclusion and exclusion criteria for CAI in controlled research. If applying both inclusion and exclusion criteria suggested from IAC, the prevalence of CAI will be underestimated because it excludes participants with both CAI and issue(s) in the exclusion criteria. On the other hand, the prevalence will be overestimated if investigators apply only inclusion criteria suggested from IAC because participants without CAI but with the issue from exclusion criteria might be considered as CAI patients. Koshino et al. found 10% of collegiate athletes suffer from CAI based on the criteria suggested by the International Ankle Consortium [21]. However, if they did not exclude participants based on the exclusion criteria suggested by IAC the prevalence was 20% [21]. A standard method to identify the cause of the perceived ankle instability can facilitate the precise epidemiological data in CAI.

The association between prevalence of chronic ankle instability and gender

The current thesis found the prevalence of CAI in basketball athletes showed gender differences. It is not clear if the rate of ankle sprain and CAI are associate with gender (Table 2 and Table 24).

The current result is consistent with Tanen's and colleagues' work, which also apply athletic population as participants, but opposite to Hershkovich's and colleagues' work, which investigate 17-year-old citizen [17, 75]. Different results can be explained by different populations and different athletic exposure. Athletes have more athletic exposure than general populations, so the two different populations show different patterns of prevalence. Bescides, women's anatomical structural, joint laxity, and menstrual cycle make them vulnerable prone to injury [82-86]. If men and women have similar athletic exposure, the biological disadvantage might increase the injury rate in women than in men.

Table 24 Association between chronic ankle instability and gender

Authors	Country	Study population	Prevalence of CAI n(%)	Gender difference
Lin et al. [current study]	Taiwan	Basketball athletes (N=388) Semi-pro athletes (n=133) 26.5 ± 3.4 collegiate athletes (n=255) 20.1 ± 1.6	W 123/145 (85) M 174/243 (72)	W > M $X^2(1)$ =0.151, p<0.05
Tanen et al. [17]	USA	Athletes (N=512) Collegiate athletes (n=316) 19.6 ± 1.2 years high school athletes (n=196) 15.9 ± 1.2 years	W 68/213 (32) M 52/299 (17)	high school: W > M $X^2(1)$ = 5.0, p=0.01 college: W > M $X^2(1)$ = 10.1, p=0.01
Hershkovich et al. [75]	Israel	Israeli 17-year-old citizen W 21.8 ± 3.7 kg/m^2, 162.1 ± 6.3 cm M 22.0 ± 3.8 kg/m^2, 174.1 ± 6.8 cm	W 5441/470125(0.7) M 2531/359666 (1.1)	mild chronic ankle instability: M > W (2,33-fold)

N: total sample size, M: men, W: women, CIA: chronic ankle instability

The association between prevalence of chronic ankle instability and competitive level

The current study showed the prevalence of CAI did not differ between competitive levels. However, two studies showed athletes in a lower competitive level have a higher prevalence of CAI [17, 122]. This may relate to that athlete at a higher competitive level have more advanced skills and more resources for preventive measures [30, 79]. On the other hand, another two studies showed that athletes in a lower competitive level suffer a higher rate of CAI than those at a higher level (see Table 25). Athletes in a higher competitive level are with greater body mass [34, 96], higher play intensity [78, 97], more athletic exposure [95], and more prevalence of a history of previous ankle sprain [97, 98] than that in a lower competitive level, that can cause a higher rate of ankle sprain and further develop to CAI.

The inconsistent results among the current study and previous studies may cause by the different characters of and features of the Taiwanese athletic training system (see table 25). Participants in the previous two studies and the current study are heterogeneous. At the competitive level, Attenborough et al. investigated netball athletes at club level which is at the lower competitive with higher average age and inter-district level which represents higher competitive level with younger age [122]. It is not clear which factor (age or competitive level) affects the prevalence. Tanen et al. recruited collegiate (aged 19.6 ± 1.2) and high school athletes (aged 15.9 ± 1.2) [17]. In comparison, the study population in the current study was semi-professional (aged 26.5 ± 3.4) and collegiate athletes (20.1 ± 1.5) [17, 122]. Although the competitive level was controlled, the participants’ ages are different between the two studies. Therefore, it is hard to compare.

In Taiwan, the training system is highly specialized that is conducted when the athletes were young. In this case, athletes develop mature skill in the sport and perform excellently in international tournaments. However, early intensive specialized training and less access to health care resources ten years ago exposed athletes in a vulnerable environment to chronic sports injuries [157]. To date, there are healthcare professionals in the sports teams of schools taking care of sports injuries but the early intensive specialized training still is taken place when athletes are 12 years old or younger.

Table 25 Association between chronic ankle instability and competitive level

Authors	Country	Study population	Prevalence of CAI n(%)	Prevalence between competitive levels
Lin et al. [current study]	Taiwan	Basketball athletes (N=388) Semi-pro athletes (n=133) 26.5 ± 3.4 Collegiate athletes (n=255) 20.1 ± 1.6	Semi-pro (80) Collegiate (75)	No difference X^2=0.054, p>0.05
Tanen et al.[17]	USA	Athletes (N=512) Collegiate athletes (n=316) 19.6 ± 1.2 years High school athletes (n=196) 15.9 ± 1.2 years	High school 61/196 (31) Collegiate 59/316 (19)	High school > college $X^2(1)$ = 10.1, p<0.01
Attenborough et al.[122]	Australia	Female netball players in Sydney(N=96) Club (n=42) 24.1±7.9 years Inter-district (n=54) 19.4±3.5 years,	Moderate-sever instability: - club level 22(52) - inter-district level 22(40) Mild instability: - club level 3(7) - inter-district level 14(26)	Moderate-sever instability: club level > inter-district (p=0.01) Mild instability: no difference

CAI: chronic ankle instability

The association between prevalence of chronic ankle instability and playing positions

The current data display that prevalence of CAI does not associate with play position. However, the relation of the prevalence of CAI and playing position remains unclear due to the lack of investigation. The evidence of the injury rates of ankle sprain and play position is not conclusive (Table 3). Different characteristics of basketball playing positions may cause different injury rates of ankle sprain and further result in the different prevalence of CAI [102-105]. However, basketball athletes on the court can be multirole to assist their teammates, which makes characteristics of different play positions less distinct. Thus, the current data cannot depict different prevalence among play positions.

6 Practical Relevance

The first study systematically reviewed the prevalence of CAI. The study showed the gap in investigating the epidemiology of CAI using the criteria from IAC. Standard criteria to conduct an epidemiological study of CAI should be defined. In addition, the longitudinal study is missing to show seasonal change of the prevalence, Finally, the CAI-related factors should be reported when surveying the prevalence of CAI.

The second study culturally adapted and translated the CAIT to CAIT-TW. The translated tool showed moderate to strong construct validity, excellent test-retest reliability, good internal consistency and a cutoff score of 21.5. The validity and reliability of CAIT-TW allow clinicians to evaluate and manage ankle instability in Taiwanese who speaks Mandarin Chinese.

The third study applied CAIT-TW to investigate the prevalence of CAI in Taiwanese basketball athletes. The prevalence was 76% in 388 Taiwanese basketball athletes and the prevalence was different between genders. Women athletes have a higher prevalence of CAI than men athletes. Yet, play positions and competitive levels do not affect the prevalence of CAI. The current study provides a primary insight into that.

7 Limitations and Perspectives

The main limitation of this Ph.D. project is that the systematic review (2020) could not be conducted before the third study, which investigated the prevalence in Taiwan (2018). More than half of the included studies (5/9) published after the third studies were conducted [21, 22, 118-120]. Therefore, the recommendations from the systematic review could be applied to the third study.

The limitations for the systematic review (first study) are a small sample size, heterogeneous included studies, different exclusion criteria applied in the included studies and the effect of preexisting ankle instability. Firstly, only nine studies were included which may not enough be a strong representative prevalence. In addition, the heterogeneous included studies have discrete surveyed populations, countries, competitive levels and sports [17, 21, 22] which causes a wide range of prevalence. Furthermore, the exclusion criteria were different within the included studies, which may over- or underestimate the real prevalence of CAI. Finally, if the preexisting ankle instability affects the development or the presence of CAI after a significant ankle sprain is not clear. Prospective studies should be conducted to answer this question.

In the second study, mechanical instability, which can also affect the feeling of instability, did not include in the study [5, 138]. The calculation of cutoff point in CAIT-TW targeted at an athletic population, so the cutoff point is not suitable to assess a general population. In addition, item number 9 from CAIT-TW (after a TYPICAL incident of my ankle rolling over, my ankle returns to "normal") was difficult to answer for some athletes, because they experience different degrees of rolling over during their daily training, which affects the recovery period. The unspecific description of the degree of rolling over may affect the precision of scoring. Finally, the sensitivity to change, which is defined as an ability to detect the meaningful clinical change, was not assessed in the current study owing to the limited resources [153].

Limitations to the third study are the surveyed location, mechanical instability and exclusion criteria. Firstly, most of the included collegiate teams (14/16) located in the north of Taiwan, which can cause selection bias. Therefore, the data represents the prevalence of CAI in only the north of Taiwan. Additionally, lack of examining mechanical instability the prevalence of mechanical instability cannot be shown in the results. Finally, the participants with a history of a fractured ankle or surgery were not excluded. There was no physician to differentiate between the CAI and ankle instability caused by other issues. This may overestimate the prevalence of CAI in the current study.

In conclusion, results from previously published studies showed a wide range of the prevalence of CAI and it comes from the different exclusion criteria, age, sports discipline, or other factors among the included studies. To have a better understanding of the prevalence of CAI, standardized criteria to investigate the epidemiology of CAI and prospective studies are needed. In addition, CAIT-TW is a valid and reliable tool to differentiate between stable and unstable ankles in athletes and may further apply in both research and clinical practice in Taiwan. Moreover, CAI is highly prevalent in the Taiwanese basketball population. This might relate to the research method, preexisting ankle instability, and the training-related factors. Finally, gender also plays an important role in prevalence. When applying the preventive measure, gender should be taken into consideration.

8 Reference

1. Roos, K.G., et al., *The Epidemiology of Lateral Ligament Complex Ankle Sprains in National Collegiate Athletic Association Sports.* Am J Sports Med, 2017. **45**(1): p. 201-209.
2. Gribble, P.A., et al., *Evidence review for the 2016 International Ankle Consortium consensus statement on the prevalence, impact and long-term consequences of lateral ankle sprains.* Br J Sports Med, 2016. **50**(24): p. 1496-1505.
3. Bosien, W.R., O.S. Staples, and S.W. Russell, *RESIDUAL DISABILITY FOLLOWING ACUTE ANKLE SPRAINS.* JBJS, 1955. **37**(6).
4. Gribble, P.A., et al., *Selection criteria for patients with chronic ankle instability in controlled research: a position statement of the International Ankle Consortium.* British Journal of Sports Medicine, 2014. **48**(13).
5. Hertel, J. and R.O. Corbett, *An Updated Model of Chronic Ankle Instability.* J Athl Train, 2019. **54**(6): p. 572-588.
6. Marshall, P.W.M., A.D. Mckee, and B.A. Murphy, *Impaired Trunk and Ankle Stability in Subjects with Functional Ankle Instability.* Medicine and Science in Sports and Exercise, 2009. **41**(8): p. 1549-1557.
7. Rios, J.L., A.L. Gorges, and M.J. dos Santos, *Individuals with chronic ankle instability compensate for their ankle deficits using proximal musculature to maintain reduced postural sway while kicking a ball.* Human Movement Science, 2015. **43**: p. 33-44.
8. Lin, C.I., et al., *The effect of chronic ankle instability on muscle activations in lower extremities.* PLoS One, 2021. **16**(2): p. e0247581.
9. Hubbard-Turner, T. and M.J. Turner, *Physical Activity Levels in College Students With Chronic Ankle Instability.* Journal of athletic training, 2015. **50**(7): p. 742-747.
10. Theisen, A. and J. Day, *Chronic Ankle Instability Leads to Lower Extremity Kinematic Changes During Landing Tasks: A Systematic Review.* International journal of exercise science, 2019. **12**(1): p. 24-33.
11. Simon, J.E. and C.L. Docherty, *Health-related quality of life is decreased in middle-aged adults with chronic ankle instability.* Journal of Science and Medicine in Sport, 2018. **21**(12): p. 1206-1209.
12. Thompson, C., et al., *Factors Contributing to Chronic Ankle Instability: A Systematic Review and Meta-Analysis of Systematic Reviews.* Sports Med, 2018. **48**(1): p. 189-205.
13. Docherty, C.L., et al., *Development and reliability of the ankle instability instrument.* J Athl Train, 2006. **41**(2): p. 154-8.
14. Hiller, C.E., et al., *The Cumberland ankle instability tool: a report of validity and reliability testing.* Arch Phys Med Rehabil, 2006. **87**(9): p. 1235-41.
15. Simon, J., M. Donahue, and C. Docherty, *Development of the Identification of Functional Ankle Instability (IdFAI).* Foot Ankle Int, 2012. **33**(9): p. 755-63.
16. Attenborough, A.S., et al., *Chronic ankle instability in sporting populations.* Sports Med, 2014. **44**(11): p. 1545-56.
17. Tanen, L., et al., *Prevalence of chronic ankle instability in high school and division I athletes.* Foot Ankle Spec, 2014. **7**(1): p. 37-44.
18. Simon, J., E. Hall, and C. Docherty, *Prevalence of chronic ankle instability and associated symptoms in university dance majors: an exploratory study.* J Dance Med Sci, 2014. **18**(4): p. 178-84.
19. Palmer-Green, D., et al., *The Injury/Illness Performance Project (IIPP): A Novel Epidemiological Approach for Recording the Consequences of Sports Injuries and Illnesses.* Journal of sports medicine (Hindawi Publishing Corporation), 2013. **2013**: p. 523974-523974.
20. Roos, K.G., et al., *Epidemiology of 3825 injuries sustained in six seasons of National Collegiate Athletic Association men's and women's soccer (2009/2010-2014/2015).* British Journal of Sports Medicine, 2017. **51**(13): p. 1029-U70.

21. Koshino, Y., et al., *Prevalence and characteristics of chronic ankle instability and copers identified by the criteria for research and clinical practice in collegiate athletes.* Physical Therapy in Sport, 2020. **45**: p. 23-29.
22. Kobayashi, T., et al., *The prevalence of chronic ankle instability and its relationship to foot arch characteristics in female collegiate athletes.* Physical Therapy in Sport, 2020. **46**: p. 162-168.
23. Fong, D.T.-P., et al., *A Systematic Review on Ankle Injury and Ankle Sprain in Sports.* Sports Medicine, 2007. **37**(1): p. 73-94.
24. Shah, S., et al., *Incidence and Cost of Ankle Sprains in United States Emergency Departments.* Sports health, 2016. **8**(6): p. 547-552.
25. Whalan, M., et al., *The incidence and burden of time loss injury in Australian men's sub-elite football (soccer): A single season prospective cohort study.* Journal of Science and Medicine in Sport, 2019. **22**(1): p. 42-47.
26. Swenson, D.M., et al., *Epidemiology of US High School Sports-Related Ligamentous Ankle Injuries, 2005/06-2010/11.* Clinical Journal of Sport Medicine, 2013. **23**(3): p. 190-196.
27. McKeon, J.M.M., et al., *Return-to-play probabilities following new versus recurrent ankle sprains in high school athletes.* Journal of Science and Medicine in Sport, 2014. **17**(1): p. 23-28.
28. Pasanen, K., et al., *High ankle injury rate in adolescent basketball: A 3-year prospective follow-up study.* Scand J Med Sci Sports, 2017. **27**(6): p. 643-649.
29. Anandacoomarasamy, A. and L. Barnsley, *Long term outcomes of inversion ankle injuries.* Br J Sports Med, 2005. **39**(3): p. e14; discussion e14.
30. Yeung, M.S., et al., *An epidemiological survey on ankle sprain.* British journal of sports medicine, 1994. **28**(2): p. 112-116.
31. Braun, B.L., *Effects of ankle sprain in a general clinic population 6 to 18 months after medical evaluation.* Arch Fam Med, 1999. **8**(2): p. 143-8.
32. Delahunt, E. and A. Remus, *Risk Factors for Lateral Ankle Sprains and Chronic Ankle Instability.* Journal of athletic training, 2019. **54**(6): p. 611-616.
33. de Noronha, M., et al., *Intrinsic predictive factors for ankle sprain in active university students: A prospective study.* Scandinavian Journal of Medicine & Science in Sports, 2013. **23**(5): p. 541-547.
34. Tyler, T.F., et al., *Risk Factors for Noncontact Ankle Sprains in High School Football Players: The Role of Previous Ankle Sprains and Body Mass Index.* The American Journal of Sports Medicine, 2006. **34**(3): p. 471-475.
35. Freeman, M.A.R., *INSTABILITY OF THE FOOT AFFER INJURIES TO THE LATERAL LIGAMENT OF THE ANKLE.* The Journal of Bone and Joint Surgery. British volume, 1965. **47-B**(4): p. 669-677.
36. Freeman, M.A.R., *TREATMENT OF RUPTURES OF THE LATERAL LIGAMENT OF THE ANKLE.* The Journal of Bone and Joint Surgery. British volume, 1965. **47-B**(4): p. 661-668.
37. Freeman, M.A.R., M.R.E. Dean, and I.W.F. Hanham, *THE ETIOLOGY AND PREVENTION OF FUNCTIONAL INSTABILITY OF THE FOOT.* The Journal of Bone and Joint Surgery. British volume, 1965. **47-B**(4): p. 678-685.
38. Docherty, C.L., B.L. Arnold, and S. Hurwitz, *Contralateral force sense deficits are related to the presence of functional ankle instability.* Journal of Orthopaedic Research, 2006. **24**(7): p. 1412-1419.
39. Peters, J.W., S.G. Trevino, and P.A. Renstrom, *Chronic Lateral Ankle Instability.* Foot & Ankle, 1991. **12**(3): p. 182-191.
40. Karlsson, J., et al., *Surgical treatment of chronic lateral instability of the ankle joint: A new procedure.* The American Journal of Sports Medicine, 1989. **17**(2): p. 268-274.
41. Montella, B.J., et al., *Fibular Osteochondroma Presenting as Chronic Ankle Sprain.* Foot & Ankle International, 1995. **16**(4): p. 207-209.
42. Sugimoto, K., et al., *Chondral Injuries of the Ankle with Recurrent Lateral Instability: An Arthroscopic Study.* JBJS, 2009. **91**(1).

43. Hertel, J., *Functional Anatomy, Pathomechanics, and Pathophysiology of Lateral Ankle Instability.* Journal of athletic training, 2002. **37**(4): p. 364-375.
44. Hiller, C.E., S.L. Kilbreath, and K.M. Refshauge, *Chronic ankle instability: evolution of the model.* J Athl Train, 2011. **46**(2): p. 133-41.
45. Saltzman, C.L., et al., *Impact of Comorbidities on the Measurement of Health in Patients with Ankle Osteoarthritis.* JBJS, 2006. **88**(11).
46. Wikstrom, E.A., et al., *T1ρ MRI of the talar articular cartilage is increased in those with chronic ankle instability.* Osteoarthritis and Cartilage, 2019. **27**(4): p. 646-649.
47. Taga, I., et al., *Articular cartilage lesions in ankles with lateral ligament injury: An arthroscopic study.* The American Journal of Sports Medicine, 1993. **21**(1): p. 120-127.
48. Golditz, T., et al., *Functional ankle instability as a risk factor for osteoarthritis: using T2-mapping to analyze early cartilage degeneration in the ankle joint of young athletes.* Osteoarthritis and Cartilage, 2014. **22**(10): p. 1377-1385.
49. Dejong, A.F., R.M. Koldenhoven, and J.A.Y. Hertel, *Proximal Adaptations in Chronic Ankle Instability: Systematic Review and Meta-analysis.* Medicine & Science in Sports & Exercise, 2020. **52**(7).
50. Moisan, G., M. Descarreaux, and V. Cantin, *Effects of chronic ankle instability on kinetics, kinematics and muscle activity during walking and running: A systematic review.* Gait & Posture, 2017. **52**: p. 381-399.
51. Feger, M.A., et al., *Lower extremity muscle activation in patients with or without chronic ankle instability during walking.* Journal of athletic training, 2015. **50**(4): p. 350-357.
52. McCann, R.S., et al., *Isometric Hip Strength and Dynamic Stability of Individuals With Chronic Ankle Instability.* Journal of athletic training, 2018. **53**(7): p. 672-678.
53. McCann, R.S., et al., *Hip strength and star excursion balance test deficits of patients with chronic ankle instability.* Journal of Science and Medicine in Sport, 2017. **20**(11): p. 992-996.
54. Gribble, P.A. and R.H. Robinson, *Alterations in knee kinematics and dynamic stability associated with chronic ankle instability.* Journal of athletic training, 2009. **44**(4): p. 350-355.
55. Negahban, H., et al., *The eccentric torque production capacity of the ankle, knee, and hip muscle groups in patients with unilateral chronic ankle instability.* Asian journal of sports medicine, 2013. **4**(2): p. 144-152.
56. Terada, M., et al., *Diaphragm Contractility in Individuals with Chronic Ankle Instability.* Medicine & Science in Sports & Exercise, 2016. **48**(10).
57. Vuurberg, G., et al., *Diagnosis, treatment and prevention of ankle sprains: update of an evidence-based clinical guideline.* British Journal of Sports Medicine, 2018. **52**(15): p. 956.
58. Arnold, B.L., C.J. Wright, and S.E. Ross, *Functional ankle instability and health-related quality of life.* Journal of athletic training, 2011. **46**(6): p. 634-641.
59. Kosik, K.B., et al., *Health-Related Quality of Life Among Middle-Aged Adults With Chronic Ankle Instability, Copers, and Uninjured Controls.* Journal of Athletic Training, 2020. **55**(7): p. 733-738.
60. Hubbard-Turner, T., et al., *An Acute Lateral Ankle Sprain Significantly Decreases Physical Activity across the Lifespan.* Journal of sports science & medicine, 2015. **14**(3): p. 556-561.
61. Hubbard-Turner, T.T., Michael J; Burcal, Chris; Song, Kyeongtak; Wikstrom, Erik A *Decreased Self Report Physical Activity One Year after an Acute Ankle Sprain.* Journal of Musculoskeletal Disorders and Treatment, 2018. **4**(4).
62. Booth, F.W., C.K. Roberts, and M.J. Laye, *Lack of exercise is a major cause of chronic diseases.* Comprehensive Physiology, 2012. **2**(2): p. 1143-1211.
63. Mandarakas, M., et al., *Systematic review of chronic ankle instability in children.* Journal of Foot and Ankle Research, 2014. **7**(1): p. 21.
64. Hiller, C.E., et al., *Intrinsic predictors of lateral ankle sprain in adolescent dancers: a prospective cohort study.* Clinical journal of sport medicine : official journal of the Canadian Academy of Sport Medicine, 2008. **18**(1): p. 44-48.

65. Marchi, A.G., et al., *Permanent sequelae in sports injuries: a population based study.* Archives of Disease in Childhood, 1999. **81**(4): p. 324.
66. Steffen, K., et al., *Self-Reported Injury History and Lower Limb Function as Risk Factors for Injuries in Female Youth Soccer.* The American Journal of Sports Medicine, 2008. **36**(4): p. 700-708.
67. Timm, N.L., J. Grupp-Phelan, and M.L. Ho, *Chronic Ankle Morbidity in Obese Children Following an Acute Ankle Injury.* Archives of Pediatrics & Adolescent Medicine, 2005. **159**(1): p. 33-36.
68. Söderman, K., et al., *Injuries in adolescent female players in European football: a prospective study over one outdoor soccer season.* Scandinavian Journal of Medicine & Science in Sports, 2001. **11**(5): p. 299-304.
69. Swenson, D.M., et al., *Patterns of Recurrent Injuries among US High School Athletes, 2005-2008.* The American Journal of Sports Medicine, 2009. **37**(8): p. 1586-1593.
70. Weir, M.A. and A.W.S. Watson, *A twelve month study of sports injuries in one Irish School.* Irish Journal of Medical Science, 1996. **165**(3): p. 165.
71. Hopper, D. and B. Elliott, *Lower Limb and Back Injury Patterns of Elite Netball Players.* Sports Medicine, 1993. **16**(2): p. 148-162.
72. Edouard, P., et al., *Invertor and evertor strength in track and field athletes with functional ankle instability.* Isokinetics and Exercise Science, 2011. **19**: p. 91-96.
73. Wadley, G.H. and J.P. Albright, *Women's intercollegiate gymnastics: Injury patterns and "permanent" medical disability.* The American Journal of Sports Medicine, 1993. **21**(2): p. 314-320.
74. Smith, R.W. and S.F. Reischl, *Treatment of ankle sprains in young athletes.* The American Journal of Sports Medicine, 1986. **14**(6): p. 465-471.
75. Hershkovich, O., et al., *A Large-Scale Study on Epidemiology and Risk Factors for Chronic Ankle Instability in Young Adults.* The Journal of Foot and Ankle Surgery, 2015. **54**(2): p. 183-187.
76. Zuckerman, S.L., et al., *Injuries sustained in National Collegiate Athletic Association men's and women's basketball, 2009/2010–2014/2015.* British Journal of Sports Medicine, 2018. **52**(4): p. 261.
77. Starkey, C., *Injuries and illnesses in the national basketball association: a 10-year perspective.* Journal of athletic training, 2000. **35**(2): p. 161-167.
78. Clifton, D.R., et al., *The First Decade of Web-Based Sports Injury Surveillance: Descriptive Epidemiology of Injuries in US High School Girls' Basketball (2005-2006 Through 2013-2014) and National Collegiate Athletic Association Women's Basketball (2004-2005 Through 2013-2014).* Journal of athletic training, 2018. **53**(11): p. 1037-1048.
79. Clifton, D.R., et al., *The First Decade of Web-Based Sports Injury Surveillance: Descriptive Epidemiology of Injuries in US High School Boys' Basketball (2005-2006 Through 2013-2014) and National Collegiate Athletic Association Men's Basketball (2004-2005 Through 2013-2014).* Journal of Athletic Training, 2018. **53**(11): p. 1025-1036.
80. Deitch, J.R., et al., *Injury Risk in Professional Basketball Players: A Comparison of Women's National Basketball Association and National Basketball Association Athletes.* The American Journal of Sports Medicine, 2006. **34**(7): p. 1077-1083.
81. Rodas, G., et al., *Ankle Sprain Versus Muscle Strain Injury in Professional Men's Basketball: A 9-Year Prospective Follow-up Study.* Orthopaedic journal of sports medicine, 2019. **7**(6): p. 2325967119849035-2325967119849035.
82. Herzog, M.M., et al., *Ankle Sprains in the National Basketball Association, 2013-2014 Through 2016-2017.* The American Journal of Sports Medicine, 2019. **47**(11): p. 2651-2658.
83. Borowski, L.A., et al., *The Epidemiology of US High School Basketball Injuries, 2005–2007.* The American Journal of Sports Medicine, 2008. **36**(12): p. 2328-2335.

84. Tummala, S.V., et al., *10-Year Epidemiology of Ankle Injuries in Men's and Women's Collegiate Basketball.* Orthopaedic journal of sports medicine, 2018. **6**(11): p. 2325967118805400-2325967118805400.
85. Drakos, M.C., et al., *Injury in the national basketball association: a 17-year overview.* Sports health, 2010. **2**(4): p. 284-290.
86. Baker, H., A. Rizzi, and A. Athiviraham, *Injury in the Women's National Basketball Association (WNBA) From 2015 to 2019.* Arthroscopy, Sports Medicine, and Rehabilitation, 2020. **2**(3): p. e213-e217.
87. Hosea, T.M., C.C. Carey, and M.F. Harrer, *The Gender Issue: Epidemiology of Ankle Injuries in Athletes Who Participate in Basketball.* Clinical Orthopaedics and Related Research®, 2000. **372**.
88. Beynnon, B.D., et al., *First-Time Inversion Ankle Ligament Trauma: The Effects of Sex, Level of Competition, and Sport on the Incidence of Injury.* The American Journal of Sports Medicine, 2005. **33**(10): p. 1485-1491.
89. Wilkerson, R.D. and M.A. Mason, *Differences in men's and women's mean ankle ligamentous laxity.* The Iowa orthopaedic journal, 2000. **20**: p. 46-48.
90. Lee, H. and J. Yim, *Increased Postural Sway and Changes in the Neuromuscular Activities of the Ankle Stabilizing Muscles at Ovulation in Healthy Young Women.* The Tohoku Journal of Experimental Medicine, 2016. **240**(4): p. 287-294.
91. Yim, J., J. Petrofsky, and H. Lee, *Correlation between Mechanical Properties of the Ankle Muscles and Postural Sway during the Menstrual Cycle.* The Tohoku Journal of Experimental Medicine, 2018. **244**(3): p. 201-207.
92. Khowailed, I.A. and H. Lee, *Neuromuscular Control of Ankle-stabilizing Muscles-specific Effects of Sex and Menstrual Cycle.* Int J Sports Med, 2021. **42**(03): p. 270-276.
93. Beynnon, B.D., et al., *Ankle ligament injury risk factors: a prospective study of college athletes.* J Orthop Res, 2001. **19**(2): p. 213-20.
94. Chomiak, J., et al., *Severe Injuries in Football Players.* The American Journal of Sports Medicine, 2000. **28**(5_suppl): p. 58-68.
95. Clifton, D.R., et al., *Epidemiological Patterns of Ankle Sprains in Youth, High School, and College Football.* The American Journal of Sports Medicine, 2016. **45**(2): p. 417-425.
96. Fousekis, K., E. Tsepis, and G. Vagenas, *Intrinsic Risk Factors of Noncontact Ankle Sprains in Soccer: A Prospective Study on 100 Professional Players.* The American Journal of Sports Medicine, 2012. **40**(8): p. 1842-1850.
97. Hopper, D.M., J.L. Hopper, and B.C. Elliott, *Do selected kinanthropometric and performance variables predict injuries in female netball players?* Journal of Sports Sciences, 1995. **13**(3): p. 213-222.
98. McKay, G.D., et al., *Ankle injuries in basketball: injury rate and risk factors.* British journal of sports medicine, 2001. **35**(2): p. 103-108.
99. Bisson, E.J., et al., *Effects of ankle and hip muscle fatigue on postural sway and attentional demands during unipedal stance.* Gait & Posture, 2011. **33**(1): p. 83-87.
100. Gribble, P.A. and J. Hertel, *Effect of lower-extremity muscle fatigue on postural control11No commercial party having a direct financial interest in the results of the research supporting this article has or will confer a benefit upon the author(s) or upon any organization with which the author(s) is/are associated.* Archives of Physical Medicine and Rehabilitation, 2004. **85**(4): p. 589-592.
101. Milgrom, C., et al., *Risk Factors for Lateral Ankle Sprain: A Prospective Study Among Military Recruits.* Foot & Ankle, 1991. **12**(1): p. 26-30.
102. Ben Abdelkrim, N., et al., *Positional Role and Competitive-Level Differences in Elite-Level Men's Basketball Players.* The Journal of Strength & Conditioning Research, 2010. **24**(5).
103. Ben Abdelkrim, N., S. El Fazaa, and J. El Ati, *Time-motion analysis and physiological data of elite under-19-year-old basketball players during competition.* British journal of sports medicine, 2007. **41**(2): p. 69-75.

104. Pojskić, H., et al., *Positional Role Differences in the Aerobic and Anaerobic Power of Elite Basketball Players.* Journal of human kinetics, 2015. **49**: p. 219-227.
105. Vanderlei, F.M., et al., *Sports injuries among adolescent basketball players according to position on the court.* International archives of medicine, 2013. **6**(1): p. 5-5.
106. Meeuwisse, W.H., R. Sellmer, and B.E. Hagel, *Rates and Risks of Injury during Intercollegiate Basketball.* The American Journal of Sports Medicine, 2003. **31**(3): p. 379-385.
107. Kofotolis, N. and E. Kellis, *Ankle sprain injuries: a 2-year prospective cohort study in female Greek professional basketball players.* Journal of athletic training, 2007. **42**(3): p. 388-394.
108. Sitler, M., et al., *The Efficacy of a Semirigid Ankle Stabilizer to Reduce Acute Ankle Injuries in Basketball: A Randomized Clinical Study at West Point.* The American Journal of Sports Medicine, 1994. **22**(4): p. 454-461.
109. Cumps, E., E. Verhagen, and R. Meeusen, *Prospective epidemiological study of basketball injuries during one competitive season: ankle sprains and overuse knee injuries.* Journal of sports science & medicine, 2007. **6**(2): p. 204-211.
110. Doherty, C., et al., *The Incidence and Prevalence of Ankle Sprain Injury: A Systematic Review and Meta-Analysis of Prospective Epidemiological Studies.* Sports Medicine, 2014. **44**(1): p. 123-140.
111. Knowles, S.B., et al., *Cost of injuries from a prospective cohort study of North Carolina high school athletes.* Injury prevention : journal of the International Society for Child and Adolescent Injury Prevention, 2007. **13**(6): p. 416-421.
112. Owoeye, O.B.A., L.M. Palacios-Derflingher, and C.A. Emery, *Prevention of Ankle Sprain Injuries in Youth Soccer and Basketball: Effectiveness of a Neuromuscular Training Program and Examining Risk Factors.* Clinical Journal of Sport Medicine, 2018. **28**(4): p. 325-331.
113. Terada, M., B. Pietrosimone, and P.A. Gribble, *Individuals with chronic ankle instability exhibit altered landing knee kinematics: Potential link with the mechanism of loading for the anterior cruciate ligament.* Clinical Biomechanics, 2014. **29**(10): p. 1125-1130.
114. Bahr, R. and T. Krosshaug, *Understanding injury mechanisms: a key component of preventing injuries in sport.* Br J Sports Med, 2005. **39**(6): p. 324-9.
115. Lopes, A.D., et al., *What are the main running-related musculoskeletal injuries? A Systematic Review.* Sports medicine (Auckland, N.Z.), 2012. **42**(10): p. 891-905.
116. Keogh, J.W.L. and P.W. Winwood, *The Epidemiology of Injuries Across the Weight-Training Sports.* Sports Medicine, 2017. **47**(3): p. 479-501.
117. Nauta, J., et al., *Injury Risk During Different Physical Activity Behaviours in Children: A Systematic Review with Bias Assessment.* Sports Medicine, 2015. **45**(3): p. 327-336.
118. Schmitt, M., et al., *Prevalence of Chronic Ankle Instability in French Paratroopers.* Military Medicine, 2020. **185**(3-4): p. 477-485.
119. Donovan, L., et al., *Prevalence and Impact of Chronic Ankle Instability in Adolescent Athletes.* Orthopaedic Journal of Sports Medicine, 2020. **8**(2).
120. Holland, B., et al., *Physical activity levels among rural adolescents with a history of ankle sprain and chronic ankle instability.* PloS one, 2019. **14**(4): p. e0216243-e0216243.
121. Doherty, C., et al., *Clinical Tests Have Limited Predictive Value for Chronic Ankle Instability When Conducted in the Acute Phase of a First-Time Lateral Ankle Sprain Injury.* Archives of Physical Medicine and Rehabilitation, 2018. **99**(4): p. 720-725.
122. Attenborough, A.S., et al., *A snapshot of chronic ankle instability in a cohort of netball players.* Journal of Science and Medicine in Sport, 2016. **19**(5): p. 379-383.
123. Pourkazemi, F., et al., *Predictors of recurrent sprains after an index lateral ankle sprain: a longitudinal study.* Physiotherapy, 2018. **104**(4): p. 430-437.
124. Doherty, C., et al., *Treatment and prevention of acute and recurrent ankle sprain: an overview of systematic reviews with meta-analysis.* Br J Sports Med, 2017. **51**(2): p. 113-125.
125. Rivera, M.J., et al., *Proprioceptive Training for the Prevention of Ankle Sprains: An Evidence-Based Review.* J Athl Train, 2017. **52**(11): p. 1065-1067.

126. Rozzi, S.L., et al., *Balance training for persons with functionally unstable ankles.* J Orthop Sports Phys Ther, 1999. **29**(8): p. 478-86.
127. Hubbard-Turner, T., *Lack of Medical Treatment From a Medical Professional After an Ankle Sprain.* J Athl Train, 2019. **54**(6): p. 671-675.
128. Doherty, C., et al., *Recovery From a First-Time Lateral Ankle Sprain and the Predictors of Chronic Ankle Instability: A Prospective Cohort Analysis.* The American Journal of Sports Medicine, 2016. **44**(4): p. 995-1003.
129. Bielska, I.A., et al., *Is recovery from ankle sprains negatively affected by obesity?* Annals of Physical and Rehabilitation Medicine, 2019. **62**(1): p. 8-13.
130. Bahr, R., *No injuries, but plenty of pain? On the methodology for recording overuse symptoms in sports.* British Journal of Sports Medicine, 2009. **43**(13): p. 966-972.
131. Hubbard, T.J., et al., *Contributing factors to chronic ankle instability.* Foot Ankle Int, 2007. **28**(3): p. 343-54.
132. Witchalls, J.B., et al., *Functional performance deficits associated with ligamentous instability at the ankle.* Journal of Science and Medicine in Sport, 2013. **16**(2): p. 89-93.
133. Valderrabano, V., et al., *Ligamentous posttraumatic ankle osteoarthritis.* Am J Sports Med, 2006. **34**(4): p. 612-20.
134. De Noronha, M., et al., *Cross-cultural adaptation of the Brazilian-Portuguese version of the Cumberland Ankle Instability Tool (CAIT).* Disabil Rehabil, 2008. **30**(26): p. 1959-65.
135. Cruz-Diaz, D., et al., *Cross-cultural adaptation and validation of the Spanish version of the Cumberland Ankle Instability Tool (CAIT): an instrument to assess unilateral chronic ankle instability.* Clin Rheumatol, 2013. **32**(1): p. 91-8.
136. Rodriguez-Fernandez, A.L., et al., *Psychometric properties of the Spanish version of the Cumberland Ankle Instability Tool.* Disabil Rehabil, 2015. **37**(20): p. 1888-94.
137. Ko, J., A.B. Rosen, and C.N. Brown, *Cross-Cultural Adaptation and Validation of the Korean Version of the Cumberland Ankle Instability Tool.* Int J Sports Phys Ther, 2015. **10**(7): p. 1007-14.
138. Kunugi, S., et al., *Cross-cultural adaptation, reliability, and validity of the Japanese version of the Cumberland ankle instability tool.* Disability and Rehabilitation, 2017. **39**(1): p. 50-58.
139. Hadadi, M., et al., *Cross-cultural adaptation, reliability, and validity of the Persian version of the Cumberland Ankle Instability Tool.* Disabil Rehabil, 2017. **39**(16): p. 1644-1649.
140. Vuurberg, G., L. Kluit, and C.N. van Dijk, *The Cumberland Ankle Instability Tool (CAIT) in the Dutch population with and without complaints of ankle instability.* Knee Surg Sports Traumatol Arthrosc, 2016.
141. Cruz-Diaz, D., et al., *Effects of 6 Weeks of Balance Training on Chronic Ankle Instability in Athletes: A Randomized Controlled Trial.* Int J Sports Med, 2015. **36**(9): p. 754-60.
142. Geerinck, A., et al., *French translation and validation of the Cumberland Ankle Instability Tool, an instrument for measuring functional ankle instability.* Foot and Ankle Surgery, 2019.
143. Tsekoura, M., et al., *Cross cultural adaptation, reliability, and validity of the Greek version of the Cumberland Ankle Instability Tool.* Physiother Theory Pract, 2019: p. 1-9.
144. Beaton, D.E., et al., *Guidelines for the process of cross-cultural adaptation of self-report measures.* Spine, 2000. **25**(24): p. 3186-3191.
145. Terwee, C.B., et al., *Quality criteria were proposed for measurement properties of health status questionnaires.* Journal of Clinical Epidemiology, 2007. **60**(1): p. 34-42.
146. Wright, C.J., et al., *Recalibration and validation of the Cumberland Ankle Instability Tool cutoff score for individuals with chronic ankle instability.* Arch Phys Med Rehabil, 2014. **95**(10): p. 1853-9.
147. Binkley, J.M., et al., *The Lower Extremity Functional Scale (LEFS): scale development, measurement properties, and clinical application. North American Orthopaedic Rehabilitation Research Network.* Phys Ther, 1999. **79**(4): p. 371-83.
148. Hou, W.H., T.S. Yeh, and H.W. Liang, *Reliability and validity of the Taiwan Chinese version of the Lower Extremity Functional Scale.* J Formos Med Assoc, 2014. **113**(5): p. 313-20.

149. Lampropoulou, S. and A.V. Nowicky, *Evaluation of the Numeric Rating Scale for perception of effort during isometric elbow flexion exercise.* European Journal of Applied Physiology, 2012. **112**(3): p. 1167-1175.
150. Koo, T.K. and M.Y. Li, *A Guideline of Selecting and Reporting Intraclass Correlation Coefficients for Reliability Research.* J Chiropr Med, 2016. **15**(2): p. 155-63.
151. Deyo, R.A. and R.M. Centor, *Assessing the responsiveness of functional scales to clinical change: an analogy to diagnostic test performance.* J Chronic Dis, 1986. **39**(11): p. 897-906.
152. Steib, S., et al., *Fatigue-induced alterations of static and dynamic postural control in athletes with a history of ankle sprain.* J Athl Train, 2013. **48**(2): p. 203-8.
153. Liang, M.H., et al., *Measuring clinically important changes with patient-oriented questionnaires.* Med Care, 2002. **40**(4 Suppl): p. II45-51.
154. Lin, C.-I., F. Mayer, and P.-M. Wippert, *Cross-cultural adaptation, reliability, and validation of the Taiwan-Chinese version of Cumberland Ankle Instability Tool.* Disability and Rehabilitation, 2020: p. 1-7.
155. Aoki, M.S., et al., *Monitoring Training Loads in Professional Basketball Players Engaged in a Periodized Training Program.* The Journal of Strength & Conditioning Research, 2017. **31**(2).
156. Gabbett, T.J., *Influence of training and match intensity on injuries in rugby league.* Journal of Sports Sciences, 2004. **22**(5): p. 409-417.
157. Jayanthi, N.A., et al., *Sports-specialized intensive training and the risk of injury in young athletes: a clinical case-control study.* Am J Sports Med, 2015. **43**(4): p. 794-801.
158. Mirshahi, M., et al., *Reliability and Recalibration of the Persian Version of Cumberland Ankle Instability Tool Cut-off Score in Athletes with Functional Ankle Instability.* Advanced journal of emergency medicine, 2019. **3**(3): p. e26-e26.
159. Guillemin, F., *Cross-cultural Adaptation and Validation of Heatth Status Measures.* Scandinavian Journal of Rheumatology, 1995. **24**(2): p. 61-63.
160. Bullinger, M., et al., *Translating Health Status Questionnaires and Evaluating Their Quality: The IQOLA Project Approach.* Journal of Clinical Epidemiology, 1998. **51**(11): p. 913-923.

Authors' Contribution

The present thesis is designed as a cumulative dissertation. In this regard, three scientific articles have been prepared, submitted to peer-reviewed journals, and accepted for publication. According to the local doctoral degree regulations (§ 7 (4), sentence No. 2), significant contributions to the articles from the respective co-authors were acknowledged and finally confirmed by each co-author:

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Study	Design	Data collection	Data analysis	Interpretation	Manuscript
Chap 4.1	**CIL**, FM, PMW	CIL	CIL, SH, YHL	CIL, SH, YHL	CIL, SH, YHL, FM, PMW
Chap 4.2	**CIL**, FM, PMW	CIL	CIL	CIL	CIL, FM, PMW
Chap 4.3	**CIL**, FM, PMW	CIL	CIL	CIL	CIL, FM, PMW

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