

## The correlation between chronic ankle instability and strength deficit of the hip and knee musculature: a review of the literature

### La correlación entre la inestabilidad crónica del tobillo y el déficit de fuerza de la musculatura de la cadera y la rodilla: una revisión de la literatura

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**Abstract.** Introduction: The aim of the present study is to analyze the correlation between people that suffer from chronic ankle instability and muscle strength deficits of the proximal joints of the lower limb, which are the hip and knee.

Methods: The narrative review was conducted on MEDLINE using the selected keywords to build the search string. After inclusion and exclusion criteria were applied, the articles were independently screened by two authors reading the titles and abstracts or full articles. The quality assessment was conducted using the NIH quality assessment tool for observational cohort and cross-sectional studies, the methodological index for non-randomized studies scale, the risk-of-bias tool for non-randomized trials, and the Critical Appraisal Skills Programme checklist. Result: From 506 papers originally identified through database search, six studies were finally selected. The quality score was medium to low in all studies according to selected tool. Major of the included studies underlined that the lower limb strength deficits represent a key factor in the rehabilitation path in patients with chronic ankle instability (CAI) and, in addition to predictable ankle's muscle impairments, hip strength was a significant weakness in performance evaluation in this type of patients. Conclusion: It's not possible to confirm to our knowledge a strictly significant correlation between strength deficit of hip and knee, when appreciated. These results, however, might suggest another time that the difference between people who suffer from CAI and coper is the rehabilitation program that patients follow after an injury.

**Keywords:** Strength, Lower Extremity, Ankle Injury, Joint Instability

**Resumen.** Introducción: El objetivo del presente estudio es analizar la correlación entre personas que padecen inestabilidad crónica del tobillo y déficits de fuerza muscular de las articulaciones proximales del miembro inferior, que son la cadera y la rodilla. Métodos: La revisión narrativa se realizó en MEDLINE utilizando las palabras clave seleccionadas para construir la cadena de búsqueda. Después de aplicar los criterios de inclusión y exclusión, dos autores examinaron los artículos de forma independiente y leyeron los títulos y resúmenes o los artículos completos. La evaluación de la calidad se realizó utilizando la herramienta de evaluación de la calidad de los NIH para estudios observacionales de cohortes y transversales, el índice metodológico para la escala de estudios no aleatorios, la herramienta de riesgo de sesgo para ensayos no aleatorios y la Critical Appraisal Skills. Lista de verificación del programa. Resultado: De 506 artículos identificados originalmente mediante búsqueda en bases de datos, finalmente se seleccionaron seis estudios. La puntuación de calidad fue de media a baja en todos los estudios según la herramienta seleccionada. La mayoría de los estudios incluidos subrayaron que los déficits de fuerza de las extremidades inferiores representan un factor clave en el camino de rehabilitación en pacientes con inestabilidad crónica del tobillo (ICA) y, además de las deficiencias musculares predecibles del tobillo, la fuerza de la cadera fue una debilidad significativa en la evaluación del rendimiento. en este tipo de pacientes. Conclusión: No es posible confirmar, hasta donde sabemos, una correlación estrictamente significativa entre el déficit de fuerza de la cadera y la rodilla, cuando se aprecia. Estos resultados, sin embargo, podrían sugerir en otra ocasión que la diferencia entre las personas que sufren CAI y las que padecen coper es el programa de rehabilitación que siguen los pacientes después de una lesión.

**Palabras clave:** Fuerza, Extremidad Inferior, Lesión de Tobillo, Inestabilidad Articular

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### Introduction

Chronic musculoskeletal pain affects between 13.5-47% of the general population, causing pain and disability in 11.4-24% of those affected (Negrini, Imperio, Villafane, Negrini, & Zaina, 2013; San Martín Barra, Rojas Cabezas, & Troc Gajardo, 2021; Villafane, 2021; Villafane, Valdes, Pedersini, & Berjano, 2019). Up to 70% of patients suffer chronic ankle instability (CAI) following an ankle sprain, causing feelings of instability and recurrent ankle sprain injuries, leading to reduced quality of life and early onset of ankle osteoarthritis (Chui, Tudini, Corkery, & Yen, 2021; Valderrabano, Hintermann, & Dick, 2004; Vásquez-Orellana, López-Vásquez, Méndez-Rebolledo, & Guzman Muñoz, 2022; Villafane et al., 2019). CAI has deficits in

neuromuscular control and altered movement patterns (Apaza-Ramos, Zevallos-Ramos, & Bravo-Cucci, 2023).

Several factors contribute to chronic ankle instability, such as impaired dynamic balance, increased peroneal reaction time, and decrease eversion strength, compared with controls (de-la-Morena et al., 2015; Thompson et al., 2018; Barra et al., 2021).

A recent systematic review (Dejong, Koldenhoven, & Hertel, 2020) on CAI and proximal alterations and adaptations of the trunk, hip, thigh, and knee, concludes that there is currently no synthesized information for neuromuscular and biomechanical outcomes during strength, balance, jumping, and running (Bezerra, Vale, Brandão, Pernambuco, & Dantas, 2022; Flores-Leon, Leyton Quezada, Martínez Hernández, Salazar Reinoso, & Berral

de la Rosa, 2022). However, they found triplanar hip strength deficits and altered knee flexion angles during jumping evaluations.

Khalaj et al. found strength deficits in ankle inversion and eversion, as well as differences in hip and knee strength between individuals with CAI and controls (Khalaj, Vicenzino, Heales, & Smith, 2020). These authors point out that strength deficits measured statically are important, as weakness can negatively affect performance in tasks with increasing demand and contribute to functional impairments during dynamic movement.

Donovan et al. developed a clinical trial through which they wanted to determine whether a 4-week rehabilitation program that included destabilization devices obtained greater effects on self-reported function, range of motion, strength, and balance than rehabilitation without devices in patients with CAI (Donovan et al., 2016). As in other research conducted to improve injuries in other joints (Cuenca-Zaldívar, Acevedo, Caballero-Nahúm, & Fernández-Carnero, 2021). There are few published studies examining the trunk and aiming to identify differences between CAI and healthy groups (Orellana et al., 2022).

Accordingly, this review aim to analyze the correlation between people that suffer from chronic ankle instability and muscle strength deficits of the proximal joints of the lower limb, which are the hip and knee.

## Methods

This is a systematic literature review of studies investigating or reporting an association between lower limb joint strength and overall stability in patients with chronic ankle instability. PRISMA guidelines were followed during the design, search and reporting stages of this systematic review. The protocol for this systematic review was registered on PROSPERO.

### Search strategy

Electronic literature search were conducted in the following databases from their inception until August 2022: MEDLINE, CINAHL and EMBASE. The search string was: (((((((("chronic ankle instability"[All Fields]) OR ("lateral ankle sprain"[All Fields])) OR (ankle instability)) OR ("recurrent ankle sprains"[All Fields])) OR ("functional ankle instability"[All Fields])) OR ("lateral instability"[All Fields])) OR ("chronic lateral ankle instability"[All Fields])) OR ("ankle injury"[All Fields])) AND (((((((("strength"[All Fields]) OR ("muscle strength"[All Fields])) OR ("muscle function"[All Fields])) OR ("muscle strengthening"[All Fields])) OR ("muscle training"[All Fields])) OR ("muscle activity"[All Fields])) OR ("muscle mass"[All Fields])) OR ("muscle activation"[All Fields])) OR ("muscle torque"[All Fields])) OR ("torque"[All Fields])) OR ("musculature"[All Fields])).

Additional records were searched through other sources to complement the database findings (manual search of reference lists). Two authors (A.B and J.B.) performed the

search and evaluated the abstracts independently for potential eligibility and subsequently full-text publications for eligibility. A third author (J.H.V.) resolved discrepancies (Villafane, 2022). Each researcher reviewed the title and abstract of all the articles, selecting the relevant ones according to inclusion and exclusion criteria.

### Eligibility criteria

The types of studies included were: cross-sectional studies, quasi-experimental studies, and case-control studies, with restrictions regarding the English language and not regarding the date of publication. We excluded all repeated articles, case reports, letters to the editor, pilot studies, editorials, technical notes, review articles from analysis, and articles written in any other language than English.

The eligibility criteria were prepared following the Population/Problem/Patient; Intervention/Issue; Outcome (PIO) model (Lentell et al., 1995).

- *Population:* The participants in the selected studies had to be adults ( $\geq 18$  years old age) with a diagnosis of chronic ankle instability (Hertel & Corbett, 2019).
- *Intervention:* Hip and knee strength assessment
- *Outcome:* Muscle strength, stability

### Selection of studies

The search was performed independently by two authors (J.B. and A.B.). The titles were evaluated blindly for potential eligibility, and then the abstracts of articles were retained following skimming by title to select full-text publications for eligibility according to the inclusion/exclusion criteria. The reference list of each article was screened in order to find additional original articles.

### Data Extraction

Two authors (A.B and J.B.) conducted the data extraction independently. A third author (J.H.V.) resolved discrepancies. Reviewers were not blinded to information regarding the authors, the journal, or the outcomes for each article reviewed. A standardized form was used to extract data concerning study design, number and mean age of participants, year and country of publication, setting, expectation association with outcome, clinical outcome measures, and reported findings. The form was developed according to the directions of the Cochrane Handbook for Systematic Reviews of Interventions.

### Quality assessment

RCTs' methodological quality was evaluated using the PEDro scale. The PEDro scale is an 11-item scale designed for rating the methodological quality of RCTs. Each item that is satisfied on the scale contributes one point to the total possible score of 10 points.

The Methodological index for non-randomized studies (MINORS) has been used to assess methodological quality and risk of bias. The tool is comprised of 16 and 24 items for non-randomized studies and comparative studies, respectively, and each item is scored from 0 to 2 (Slim et al., 2003).

**Data analysis plan**

We planned to perform a systematic review by descriptively presenting the results of the retrieved studies.

**Results**

**Selection of studies**

Originally 506 papers were identified through the database search. Once duplicates were removed and the titles and abstracts of all remaining unique articles were analyzed, 12 full-text articles were analyzed to verify their eligibility for inclusion in the present study. Five of these articles were excluded. Seven studies were finally selected for this review and 1 study was included from secondary research (Gribble & Robinson, 2009; Kosik et al., 2020; McCann et al., 2018; McCann et al., 2017; Mulligan & DeVahl, 2020; Negahban et al., 2013). The flow of studies through the review process can be found in Figure 1.

**Quality assessment**

The NIH quality assessment tool for observational cohort and cross-sectional studies was used to assess the quality of the article realized by Kosik et al. in 2020 e by Webster et al. in 2016 (Kosik et al., 2020; Webster et al., 2016), that result respectively “fair” and “poor”. The results of the NIH quality assessment tool can be found in Table 1.

The MINORS scale was used to assess the quality of the study realized by Mulligan et al in 2020 and the study realized by Fatima et al. in 2016, and results of the analysis was respectively 18/24 and 19/24. The results of the MINORS scale can be found in Table 1. The risk of bias analysis of the study realized by Mulligan et al. in 2020 (Mulligan & DeVahl, 2020) was realized using the risk-of-bias tool for non-randomized trials (ROBINS-I). Results from ROBINS-

I are reported in Table n.4. The CASP tool was used to assess the quality of the four case-control included in the review: McCann et al 2017, McCann et al 2018, Negahban et al 2013, Gribble et al. 2009 (Gribble & Robinson, 2009; McCann et al., 2018; McCann et al., 2017; Negahban et al., 2013). The results of the CASP tool can be found in Table 1 and Table 2.

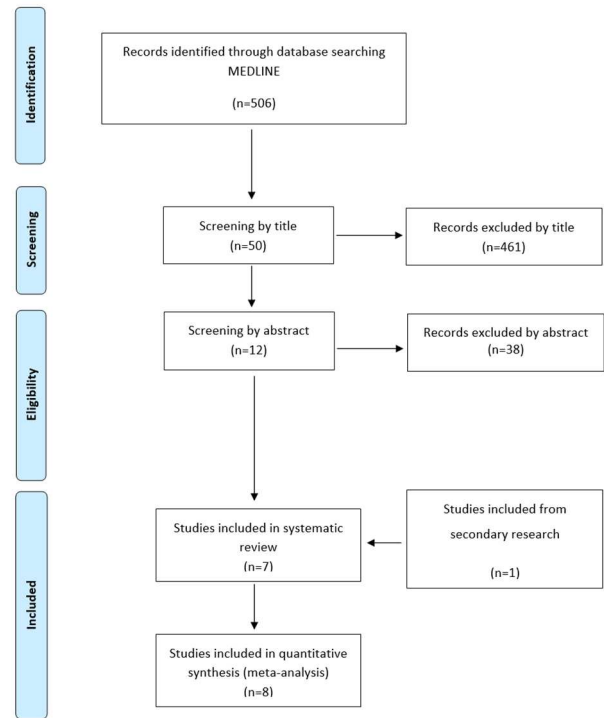


Figure 1. Flow diagram of studies through the different phases of the review

Table 1. Characteristics of included studies.

Author, yrs.	Design of the study	Aim of study	Participants	Interventions	Outcome measures	Results	Authors' conclusion	Quality score
Kosik et al. (2020)	Descriptive cross-sectional study	To compare multi-joint isometric strength of ankle, knee and hip among young and middle-aged adults with CAI, lateral ankle sprain and un-injured controls.	156 subjects	Isometric hip extension, hip abduction and knee extension force assessments were performed on the involved limb only. Participants were instructed to provide resistance for 5-s by slowly increasing force during the first 2-s and then providing maximal effort for the final 3-s. Each participant completed a practice trial and three test trials were recorded.	Strength A BTE™ Evaluator with a portable load cell with attachments designed for handheld dynamometer.	The results of this study showed that, regardless of age, participants with CAI had decreased isometric hip extension compared to the control group, but not LAS group. There were no differences between groups in isometric knee extension strength and isometric hip abduction strength.	The results from the current study provide evidence that highlight the need for clinicians to assess potential strength throughout the lower extremity when identifying specific impairments in patients with CAI.	NIH OC&CS 7
			CAI group 51 subjects					
			LAS group 43 subjects					
Mulligan et al. (2020)	Quasiexperimental experimental ex post facto design	To determine if deficits of hip strength can differentiate subjects as individuals with CAI, LAS and un-injured controls.	60 subjects	Subjects were tested for peak isometric force production of their hip extensors, hip abductors, and a composite of hip extension and external rotation while in a standing position. Subjects completed two practice trial and then performed three best effort repetitions with a 30 second rest interval between trials.	Strength Handheld dynamometer micro-FET®2.	The results of the current study didn't show any significant difference in static hip strength between subjects with CAI, LAS and un-injured control.	The hypothesis that hip strength may assist in screening for potential ankle stability issues was not supported by the results of this study.	MINORS 18
			CAI group 16 subjects					
			LAS group 23 subjects					
McCann et al. (2018)	Case-control study	To compare isometric hip strength among	60 subjects	Isometric strength during hip extension, abduction and external rotation was measured.	Strength Portable load cell	The results of this study showed that there were statistically significant	Participants with CAI displayed reduced isometric hip strength compared with	CASP 8
			CAI group					

		individuals with CAI, LAS and healthy controls..	20 subjects LAS group 20 subjects Ctrl group 20 subjects Age-> 23.7 ± 4.6 Gender-> 47 F, 13 M	Participants were instructed to provide resistance for 5-s by slowly increasing force during the first 2-s and then providing maximal effort for the final 3-s. The participant completed one practice trial and three test trials with 30 second rest intervals between trials.	with attachment s designed for handheld dynamometer.	differences among groups during extension and external rotation. The CAI group had lower extension and external rotation scores than the LAS group and the control group. No differences were identified during hip abduction.	the LAS group and control group. Therefore hip muscle strengthening may be a valuable rehabilitation component for patients with CAI.	
McCann et al. (2017)	Case-control study	To examine isometric hip strength among individuals with CAI, LAS and un-injured control.	84 subjects CAI group 30 subjects LAS group 29 subjects Ctrl group 25 subjects Age-> 23.75 ± 4.49 Gender-> 61 F, 23 M	Isometric strength was measured for hip extension, abduction and external rotation. Participants completed one practice trial and three test trials with 30 second rest intervals between trials. Participants were instructed to provide resistance for 5-s by slowly increasing force during the first 2-s and then providing maximal effort for the final 3-s.	Strength A BTE™ Evaluator with a portable load cell and attachment s designed for handheld dynamometer.	The results of this study showed that there were statistically significant differences among groups for hip abduction and hip external rotation while there weren't significant differences during hip extension.	Rehabilitation exercises that target hip strength are likely necessary for patients with CAI, and may have an added positive effect on dynamic postural control. Future studies should determine the best method for incorporating muscular strengthening in the treatment plan.	CASP 8
Neghaban et al. (2013)	Case-control study	To investigate eccentric torque production capacity of ankle, knee and hip muscle groups in patients with CAI as compared to healthy controls.	40 subjects CAI group 20 subjects Ctrl group 20 subjects Age-> 18-35 years	All subjects participated in two separate sessions with a rest interval of 48 to 72 hours. In each testing session, the torque production capacity of knee, and hip muscle groups was assessed. Three practice repetitions of sub-maximal and three practice trials of maximal contractions were performed, after a two minute rest, three repetitions of maximal eccentric contraction with no rest were performed. All practice and testing trials were performed at the angular velocity of 60 °.s. <sup>-1</sup>	Strength Biodex isokinetic dynamometer.	The results of this study showed that there were statistically significant differences only for eccentric torque production capacity of hip flexor muscle group.	The results of this study showed that CAI is associated with eccentric strength deficit hip flexors, this strength deficit appeared to exist in both the injured and non-injured limbs of the patients. Therefore it's important that the clinicians and researchers focus not only on the strength evaluation of the injured joint but also on other joints of the kinetic chain when faced with CAI.	CASP 7
Gribble and Robinson (2009)	Case-control study	To compare the force production capabilities of the ankle, knee, and hip in the sagittal plane among those with and without unilateral CAI.	30 subjects CAI group 15 subjects Age-> 20,3 ± 2,9 Ctrl group 15 subjects Age-> 23,1 ± 3,9 Gender->16 F, 14 M	Knee flexion and extension and hip flexion and extension were investigated. A few practice trials were performed, and then the subjects performed five continuous maximal effort trials. After the procedures for the first designated test joint were completed for both limbs, a 10-minute rest period was provided, then the procedures were repeated for the second designated joint.	Strength Isokinetic dynamometer.	The results of this study showed that there were statistically significant differences for average peak torque during knee flexion and extension. There were no statistically significant relationship during hip movements.	The results of this study may lead to new approaches to rehabilitation for patient with CAI. Future investigations should continue to examine deficits in strength and other factors that will dictate successful progression to the return of functional status in those with CAI.	CASP 6
Fatima et al. (2020)	Clinical controlled trial	To investigate the EMG activity of the hip muscles during difference functional exercises in CAI subjects vs age-matched healthy controls.	34 subjects CAI group 17 subjects Age: 24.4 ± 2.03 Ctrl group 17 subjects Age: 24.6 ± 2.57 Gender: 22 F, 12 M	Functional exercises (YBT in anterior, posteromedial and posterolateral; single-leg squat with and without Swiss ball). After MVIC recording, participants were made to perform the functional exercise one by one, and simultaneous recordings of EMG.	Muscles Activity Surface EMG of Gmed and Gmax	EMG activity of the Gmed muscle was significantly different between CAI patients and healthy controls. However, statistically significant differences were not observed for the EMG activity of the 2 muscles during different functional exercises within the groups.	EMG activation patterns of hip musculature (Gmed and Gmax) are significantly different between subjects with CAI and healthy controls. The activity of these muscles is diminished in subjects with CAI during all functional task sas compared with healthy individuals without any ankle instability.	MINOR S 19
Webster et al. (2016)	Cross sectional study	To examine the prefatigue and postfatigue EMG activity of TA, PL, Gmed and Gmax in individual with or without CAI before and during the landing of a lateral hop	32 subjects CAI group 16 subjects Age: 20.50 ± 2.00 years Ctrl group 16 subjects Age: 22.00 ± 3.30 years	At prefatigue, the subjects perform 5 lateral hops onto and off of the force platform a distance equal to the length of their fibula (previously measured) and over a barrier that was 5 cm high. Postfatigue the subjects repeat the measurements.	Muscles Activity Surface EMG of TA, PL, Gmed and Gmax	During prelanding postfatigue, the activity level of Gmax were higher in the CAI group than in the control group. No differences were demonstrated in group or fatigue for the Gmed. After functional fatigue, differences with moderate to strong effect sizes in the postfatigue resuts for the PL and Gmax were observed.	During the prelanding phase of a lateral hop, higher activation values were observed in both the PL and Gmax muscles of participants with CAI than in control participants	NIH OC&CS 4

CAI-chronic ankle instability, LAS-lateral ankle sprain, CTRL-control, M-male, F- female, NIH OC&CS- NIH tool for Observational Cohort and Cross-Sectional studies, CASP- Critical Appraisal Skills Programme, MINORS- Methodological Index for Non-Randomized Studies, YBT- Y balance test, MVIC – maximum voluntary isometric contraction, EMG – electromyography, Gmed – gluteus medius, Gmax – gluteus maximus, TA – tibialis anterior, PL – Peroneus longus,

Table 2.  
"CASP tool for case control" scale.

	CASP question										
	1. Did the study address a clearly focused issue?	2. Did the authors use an appropriate method to answer the question?	3. Were the cases recruited in an acceptable way?	4. Were the controls selected in an acceptable way?	5. Was the exposure accurately measured to minimise bias?	6(a) Aside from the experimental intervention, were the groups treated equally? (b) Have the authors taken account of the potential confounding factors in the design and/or in their analysis?	7. How large was the treatment effect?	8. How precise was the estimate of the treatment effect?	9. Do you believe the results?	10. Can the results be applied to the local population?	11. Do the results of this study fit with other available evidence?
McCann et al. (2018)	Yes	Yes	Yes	Yes	Yes	a. / b. Yes	/	/	Yes	ND	Yes
McCann et al. (2017)	Yes	Yes	Yes	Yes	Yes	a. / b. Yes	/	/	Yes	ND	Yes
Negahban et al. (2013)	Yes	Yes	Yes	Yes	No	a. / b. Yes	/	/	Yes	ND	Yes
Gribble et al. (2009)	Yes	Yes	Yes	Yes	No	a. / b. Yes	/	/	Yes	ND	No

### Data from studies

Below are reported the results of the eighth studies included in this review.

1. The aim of the study realized by Gribble et al in 2009 (Gribble & Robinson, 2009), was to determine whether chronic ankle instability (CAI) is associated with deficits in the ankle, knee, and hip torque. The subjects with CAI demonstrated significantly less average peak torque (APT) production for knee flexion ( $F_{1,28} = 5.40$ ;  $p = 0.03$ ) and extension ( $F_{1,28} = 5.34$ ;  $p = 0.03$ ). Subjects with CAI showed significantly less APT for ankle plantar flexion in the injured limb compared with their noninjured limb ( $F_{1,28} = 6.51$ ;  $p = 0.02$ ). No significant difference in ankle dorsiflexion or hip flexion/extension APT production existed between the 2 groups. Individuals with CAI, in addition to deficits in ankle plantar flexion torque, had deficits in knee flexor and extensor torque, suggesting that distal joint instability may lead to knee joint neuromuscular adaptations. There were no similar deficits at the hip.

2. The purpose of the study realized by Kosik et al in 2020 (Kosik et al., 2020), was to compare ankle, knee, and hip isometric peak torque between people with CAI, copers, and un-injured controls. The results indicated a significant interaction between age and injury specifically in dorsiflexion. It was observed that middle-aged un-injured controls ( $p < 0.001$ ) and copers ( $p < 0.001$ ) exhibited lower isometric peak torque compared to their young adult counterparts. However, no differences were found between young and middle-aged adults with CAI ( $p > 0.05$ ). The results indicated a significant interaction between age and injury specifically in dorsiflexion. It was observed that middle-aged un-injured controls ( $p < 0.001$ ) and copers ( $p < 0.001$ ) exhibited lower isometric peak torque compared to their young adult counterparts. However, no differences were found between young and middle-aged adults with CAI ( $p > 0.05$ ). In conclusion, results showed that regardless of age, isometric ankle and hip peak torque

was lower in participants with CAI compared to un-injured controls, but not copers.

3. The article realized by McCann et al in 2017 (McCann et al., 2017), was a single-blinded, cross-sectional, case-control study. The objective of this paper was to examine isometric hip strength in those with and without CAI and determine the degree of Star Excursion Balance Test (SEBT) variance explained by isometric hip strength. The CAI group had lower SEBT-ANT scores compared to LAS copers ( $P = 0.03$ ) and controls ( $P = 0.03$ ). The CAI group had lower ABD compared to LAS copers ( $P = 0.03$ ) and controls ( $P = 0.02$ ). The CAI group had lower ER compared to LAS copers ( $P = 0.01$ ) and controls ( $P = 0.01$ ). ER ( $R^2 = 0.25$ ,  $P = 0.01$ ) and ABD ( $R^2 = 0.25$ ,  $P = 0.01$ ) explained 25% of the CAI group's SEBT-PM and SEBT-PL variances, respectively. In conclusion, the CAI group had deficient dynamic postural control and isometric hip strength compared to LAS copers and controls. Additionally, the CAI group's isometric hip strength significantly influenced dynamic postural control performance.

4. In the case-control study realized by McCann et al in 2018 (McCann et al., 2018), authors compared isometric hip strength and dynamic stability in individuals with or without CAI and examined the degree of dynamic-stability variance explained by isometric hip strength. Results showed that CAI group had less isometric hip-extension strength than LAS copers ( $P = .02$ ,  $d = 0.72$  [0.06, 1.34]) and controls ( $P = .01$ ,  $d = 1.19$  [0.50, 1.84]) and less external-rotation strength than LAS copers ( $P = .03$ ,  $d = 0.78$  [0.13, 1.41]) and controls ( $P = .01$ ,  $d = 1.02$  [0.34, 1.65]). No group differences existed for RVTTS ( $F_{2,57} = 1.16$ ,  $P = .32$ ) or abduction strength ( $F_{2,57} = 2.84$ ,  $P = 0.07$ ). Resultant vector time to stabilization was explained by isometric hip strength for LAS copers ( $R^2 = 0.21$ ,  $f^2 = 0.27$  [0.22, 0.32],  $P = .04$ ) but not for the CAI ( $R^2 = 0.12$ ,  $f^2 = 0.14$  [0.06, 0.22],  $P = 0.22$ ) or control ( $R^2 = 0.10$ ,  $f^2 = 0.11$  [0.03, 0.19],  $P = .18$ ) groups. In conclusion,

results showed that participants with CAI had decreased isometric hip strength, but that did not equate to dynamic-stability deficits. Authors concluded that clinicians should include hip-muscle strengthening in rehabilitation protocols for patients with CAI, yet these gains may not enhance dynamic stability when landing from a jump.

5. The aim of the study realized by Mulligan et al in 2020 (Mulligan & DeVahl, 2020), was to determine if deficits in weight-bearing and non-weight-bearing assessment of hip strength or dynamic balance in lower extremity reaching tasks from flat and inclined surfaces can differentiate subjects classified as controls, ankle sprain copers, or those with chronic, recurrent ankle sprains. There were no significant differences between groups in self-report of Foot and Ankle Ability Measures or Tegner activity levels. Mean hip strength was not significantly different between ankle sprain classification groups ( $p = 0.66 - 0.82$ ). The mean limb symmetry index for hip strength comparing injured and uninjured ankles was nearly symmetrical in all ankle stability groups ( $p = 0.34 - 0.97$ ). The same symmetry was present when comparing injured and uninjured abilities for all dynamic balance reach tasks from both flat and inclined surfaces. ( $p = 0.16 - 0.62$ ). There was a fair relationship between hip extension and weight-bearing hip extension/external rotation strength and the posteromedial and posterolateral reach tasks with correlation coefficients in the range of  $0.33 - 0.43$ . In conclusion, performance measures of tri-planar, static, isometric hip strength, and lower extremity reach in dynamic balance tasks could not differentiate subjects without a history of injury from those subjects with one or more lateral ligamentous ankle sprains.

6. The purpose of the case-control study realized by Negahban et al in 2013 (Negahban et al., 2013) was to investigate the eccentric torque production capacity of the ankle, knee, and hip muscle groups in patients with unilateral chronic ankle instability (CAI) as compared to healthy matched controls. Results showed that there was no significant interaction of group (CAI and healthy controls) by limb (injured and non-injured) for any muscle groups. The main effect of the limb was not significant. The main effect of the group was only significant for an eccentric torque production capacity of ankle dorsi flexor and hip flexor muscle groups. The APT/BW ratio of these muscles was significantly lower in the CAI group than in the healthy controls ( $P < 0.05$ ). In conclusion, CAI is associated with eccentric strength deficit of ankle dorsi flexor and hip flexor muscles as indicated by a reduction in torque production capacity of these muscles compared to healthy controls. This strength deficit appeared to exist in both the injured and non-injured limbs of the patients.

7. The objective of the clinical controlled trial realized by Fatima et al. (Fatima, Bhati, Singla, Choudhary, & Hussain, 2020) was to investigate the EMG activity via maximum voluntary isometric contraction (MVIC) of the hip muscles (Gmed and Gmax muscle) during different functional exercises (Y balance and single-leg squat with

and without swiss ball) in CAI subjects vs age-matched healthy controls. Results showed that EMG activity of the Gmed and Gmax muscles was significantly different between CAI (lower percent MVIC) and healthy controls but it did not differ significantly across the functional exercises (significant main effect of group  $F [1.32] = Gmax 86.24 / Gmed 40.40 \rightarrow P < .001$ ; insignificant main effect for task  $F [2.335, 32] = 0.181 \rightarrow P = .866$ ). In conclusion, although EMG activation patterns of hip musculature (Gmed and Gmax) are significantly different between subjects with CAI and healthy controls, both tested muscles activity do not vary during functional task within each group.

8. The aim of the study realized by Webster et al. (Webster, Pietrosimone, & Gribble, 2016) was to examine the pre-fatigued and post-fatigue EMG activity of Tibialis anterior (TA), Peroneus longus (PL), Gmed and Gmax in individuals with or without CAI before and during the landing of a lateral hop. The authors introduced a fatigue protocol consisted of 5 X 5-m cone drills involving combination of forward sprints, lateral shuffles, pivoting, and backward running. Next, participants completed 30 2-footed lateral hops over a 10-cm barrier, followed by 3 successive step-ups onto and 2-footed hop-downs from boxes measuring 30, 38, and 46 cm high. The participants had to repeat the protocol until *fatigue*, defined as (1) 50% increase in their fastest time to complete the course, (2) inability to repeatedly clear the 10-cm barrier on the lateral jumps, (3) inability to step onto the plyometric box, or (4) unwillingness to continue. The results showed that the activation higher of the PL and Gmax was higher in the CAI than in the control group during the pre-landing phase of a lateral hop. After introduction of functional fatigue, the authors observed differences with moderate to strong effect sizes in the post-fatigue results for the PL and Gmax, demonstrating clinical importance.

## Discussion

The purpose of this study was to determine the correlation between people that suffer from chronic ankle instability and muscle strength deficits in the proximal joints of the lower limb.

Consistent with the different types of intervention investigated, strength was considered as an outcome measure selected by the studies included in this systematic review. In particular, force production of the hip and knee was analyzed in participants with CAI. Four of the studies (McCann et al., 2018; McCann et al., 2017; Mulligan & DeVahl, 2020) analyzed included lateral ankle sprain (LAS) coper group and uninjured controls, while the four others studies (Fatima et al., 2020; Gribble & Robinson, 2009; Negahban et al., 2013; Webster et al., 2016) included an uninjured control group only. Early studies considered frontal plane ankle strength mainly relates to CAI (Lentell et al., 1995; Wilkerson, Pinerola, & Caturano, 1997; Willems, Witvrouw, Verstuyft, Vaes, & De Clercq, 2002),

but inconsistent findings led to the interpretation that inversion and eversion muscles are not highly correlated with CAI (Kaminski & Hartsell, 2002). For this reason, more recent research focused their finding to investigate a possible correlation between CAI and sagittal muscle strength deficits.

Muscle strength continues to decline with age and is a prominent contributor to physical performance later in life (Tieland, Trouwborst, & Clark, 2018; Enríquez Reyna, et al., 2019) that can significantly impact a person's health-related quality of life (Houston, Hoch, & Hoch, 2015) and the ability to remain physically active (Houston et al., 2015; Villafane et al., 2016). Despite this, divergent results are identified. Regardless of age, it appears that participants with CAI had decreased sagittal plane strength, in particular isometric hip extension, compared to the control group, but not the LAS group when included. In support of that, Hubbard et al. (Hubbard, Kramer, Denegar, & Hertel, 2007) found differences in isometric hip extension and abduction strength between the involved side of the CAI group compared to the involved side of the control group. However, these results seem to be in contrast with 60% of the studies included in this review. Not strictly differences between CAI group, LAS coper, and control group were identified during hip extension.

Another research (Friel, McLean, Myers, & Caceres, 2006) observed hip abductor muscle strength and plantar flexion were significantly less on the involved side than on the uninvolved side ( $P < .001$  in each case). The strength of the involved hip abductor and hip extensor muscles was also significantly correlated ( $r = 0.539$ ,  $P < 0.01$ ). In this specific case, it's important to consider that the uninvolved limb had served as the control because uninjured controls were not involved. However, the studies analyzed in this review disagree in supporting the correlation between hip abduction strength deficit and CAI.

To our knowledge, a low side of previous studies investigated knee muscle strength in individuals with CAI, LAS coper, and uninjured controls. Gribble and Robinson (Gribble & Robinson, 2009) identified statistically significant differences in knee flexion and extension which were not observed in the most recent article identified by research (Kosik et al., 2020). Interestingly, comparing these two papers no statistically significant relationship during hip movements were observed (Gribble & Robinson, 2009). The different methodologies used between these two studies, particularly isometric (Gribble & Robinson, 2009) vs. concentric (Kosik et al., 2020) contraction, might explain the varying results.

An interesting result betrays that a significant difference between CAI and controls has been observed only for eccentric torque production of the hip flexor muscle group. This specific result, unfortunately, was not investigated or formerly declared in precedent research.

## Limits

The main limitation that we noticed in this review is represented by a number of included studies that was relatively small. Also, the different selection criteria, scales and questionnaire adopted, and the numerousness of the population strictly limit the ability to generalize potential evidence to the target patients. Finally, despite our effort to search for three databases, some articles may not have been intercepted by our search string, determining possible selection bias. However, we have ensured the quality standard in reporting this systemic revision by adopting the PRISMA guidelines.

## Conclusion

Correlations between chronic ankle instability and muscle strength deficits of the proximal joints of the lower limb seem to be noticed in clinical practice, regardless of age, in most of the studies included. However, the authors did not concur on which joints and muscles group were involved. For this reason, it's not possible to confirm to our knowledge a strictly significant correlation between strength deficit of hip and knee, when appreciated. These results, however, might suggest another time that the difference between people who suffer from CAI and coper is the rehabilitation program that patients follow after an injury. In this perspective, clinicians might focus their attention on the impairments identified and include strength conditioning when needed.

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