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Rehabilitation strategies for lateral ankle sprain do not reflect established mechanisms of re-injury: A systematic review

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ABSTRACT

Objectives: 1) determine the primary impairment addressed by each exercise included in exercise-based rehabilitation programs for patients with an acute ankle sprain; 2) Determine whether prescribed exercises incorporate complex tasks associated with ankle sprain injury mechanisms?
Methods: We searched databases CINAHL, Web of Science, SPORTDiscus, Cochrane Register of Controlled Trials, PEDro, Google Scholar for RCT's including patients with acute ankle sprains, managed through exercise-based rehabilitation. Risk of bias was assessed by the Risk of Bias 2 tool. Exercises were analysed based on: the primary impairment(s) addressed; direction of movement; base of support; weightbearing status; flight phase. (PROSPERO: CRD42020210858)
Results: We included fourteen RCT's comprising 177 exercises. Neuromuscular function was addressed in 44% of exercises, followed by performance tasks (23%), and muscle strengthening (20%). Exercises were limited to movements across the sagittal plane (48%), with 31% incorporating multiplanar movements. Weight bearing exercises were almost divided equally between single-limb (59/122) and double leg stance exercises (61/122). Eighteen percent of all exercises incorporated a flight phase.
Conclusions: Rehabilitation after LAS comprises simple exercises in the sagittal plane that do not reflect mechanisms of re-injury. Future interventions should incorporate more open chain joint position sense training, multiplanar single limb challenges, and jumping and landing exercises.

1. Introduction

Lateral ankle sprains (LAS) are one of the most frequently occurring injuries among athletes (Gribble et al., 2016; Herzog et al., 2019a). There is a high risk of LAS in volleyball, basketball and football with prevalence ranging from 26 to 41% (Herzog et al., 2019a, 2019b; Verhagen et al., 2004). Athletes with a history of LAS have higher future injury prevalence (Wikstrom et al., 2020), with recurrence rates of 28–61% recorded in (Association) football (Attenborough et al., 2014), American football, basketball, and volleyball (Herzog et al., 2019a). Around 40% of patients with a history of LAS have additional long-term problems, such as persisting pain, giving-way episodes, and perceived instability, termed chronic ankle instability (CAI) (Doherty et al., 2017; Hertel & Corbett, 2019; McKeon & Donovan, 2019).

A 2022 systematic review with meta-analysis concluded that exercise-based rehabilitation reduces the risk of recurrent ankle sprain, compared to usual care (Wagemans et al., 2022). The authors also reported some inconsistencies in exercise content and dosage prescribed for LAS rehabilitation, and an optimal program remains unclear (Bleakley et al., 2019; Wagemans et al., 2022). Researchers often simplify the exercise content within an experimental study to facilitate replication and increase participant adherence. However, if exercises are too basic, they lack context and specificity, particularly for athletic populations. Recent scoping

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reviews conclude that most rehabilitation exercises prescribed for common musculoskeletal injuries at the hip (Femero acetabulair Impingement) (Wright et al., 2021) and knee (Anterior cruciale ligmant, Patellofemoral Pain Syndrome) (Dischiavi et al., 2021a, 2021b), are too simplistic and lack complexity, specificity and progression.

A key clinical goal after an index LAS is to prevent recurrence (Vuurberg et al., 2018). The ROAST consensus highlights the importance of addressing mechanical and sensorimotor insufficiencies after LAS (Delahunt et al., 2018); which often present clinically as reduced mobility, strength, and postural control. Understanding the etiology, mechanisms and inciting events that lead to recurrent LAS are also crucial to effectively design rehabilitation exercises (Delahunt et al., 2018). Injury surveillance data suggest that most non-contact LAS occur during multidirectional, reactive phases of play, or during high-speed jumping and landing (Herzog et al., 2019a). Biomechanical studies show that recurrent LAS often involve excessive inversion and internal rotation at initial contact, and a delay in peroneus muscle activation (Fong et al., 2009; Gehring et al., 2013; Li et al., 2019; Lysdal et al., 2022). To date, no research has comprehensively analysed the nature of individual exercises that comprise popular LAS rehabilitation programs.

In a recent systematic review with meta-analysis, we reported about training volume after a comprehensive analysis of the included exercise programs. However, all extracted data regarding the included exercises was too extensive to fall withing the scope of that systematic review. Hence, we decided to perform a secondary exploratory literature review. No new RCT's have emerged since the previous systematic review with meta-analysis was published. This exploratory literature review audited the content of exercise-based rehabilitation programs used in randomized controlled trials (RCT's), with following objectives:

- Determine the primary impairment addressed by each exercise.
- Establish if prescribed exercises incorporate complex tasks associated with common LAS injury mechanisms (multiplanar movements, single limb stance, a flight phase) (phase of gait when both feet are off the ground at the same time).

2. Methods

We performed a systematic literature search according to the 2020 Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) (Supplementary file 1 and 2) (Page et al., 2021). The current literature review is a secondary analysis of the primary systematic review with meta-analysis (Wagemans et al., 2022). The protocol of the systematic review was a priori registered with the International Prospective Registration Register of Systematic Reviews (PROSPERO; CRD42020210858).

Databases PubMed, CINAHL, Web of Science, SPORTDiscus, Cochrane Central Register of Controlled Trials, Physiotherapy Evidence Database (PEDro) and Google Scholar were systematically searched to obtain relevant articles from inception throughout June 2022. Box 1 shows the Medline search, which was modified as required and used across all databases. Additionally, reference lists of screened articles were reviewed to find more relevant articles. Randomized controlled trials (RCT's) which included acute ankle sprain patients who received an exercise-based rehabilitation intervention were eligible for inclusion.

Box 2 depicts a detailed description of the eligibility criteria. Eligibility screening was done firstly based on titles and abstracts, then by reading full texts by two independent reviewers (JW & AS. Rayyan was used to collect articles and to perform both screening phases (Ouzzani et al., 2016). In case of disagreement a third reviewer (CB) was invited to reach consensus.

Box 1
Medline search string

1. Lateral ankle sprain
2. Ankle injuries
3. Ankle sprain
4. "Ankle AND sprain"
5. "lateral ligament, ankle"
6. "Chronic ankle instability"
7. Rehabilitation
8. Exercise therapy
9. Exercise
10. Neuromuscular
11. Physical therapy
12. Physiotherapy
13. Resistance training
14. Active therapy
15. OR/1-5
16. NOT/6
17. OR/7-14
18.15 AND 16
19. Limit 15 to (randomized controlled trials and humans)

Box 2
Eligibility criteria

Study design	Randomized controlled trials
Participants	Patients with acute ankle sprain
Intervention	Exercise-based rehabilitation strategies, in isolation or as an adjunct to usual care
Outcome measures	Re-injury Pain Patient-reported outcome measures Clinical outcomes
Comparison	Exercise-based rehabilitation compared to usual care Usual care plus exercise-based rehabilitation compared to usual care Different types of exercise-based rehabilitation compared to each other

Two reviewers (JW & AS) independently assessed risk of bias by utilizing the Risk of Bias in randomized controlled trials (ROB II) tool (Sterne et al., 2019). This screening tool assessed five categories: 1) randomization process; 2) deviation from the intended intervention; 3) missing outcome data; 4) measurement of the outcome; 5) selection of the reported results. An algorithm considers the answers of the relevant questions of each domain to suggest a final judgement. In case of any disparities, we consulted a third reviewer (CB) to reach consensus.

Two reviewers (JW & AS) independently extracted the following data from the included articles: methodological data (authors, year of publication, language, study design, participants demographics, inclusion/exclusion criteria, recruitment site and time, time since injury at recruitment, diagnosis, ankle injury history, time of follow-up). All individual rehabilitation exercises used across each of the included studies were extracted and analysed independently by two reviewers (JW & CB). Analysis was based on the author's description of the exercise in the article text, figures and/or corresponding appendices or supplementary data. When illustrations or written details were not provided, or in the event of disagreement about allocation in the predetermined categories, a meeting was held to reach consensus between reviewers. Exercises were categorised to determine 1) the primary impairment addressed by each exercise, and 2) the extent to which prescribed exercises incorporated complex tasks associated with common LAS injury mechanisms. Exercises incorporating components of multiplanar movement, single limb weight-bearing, and a flight phase, were most reflective of injury etiology, and therefore presented the highest level of challenge to the patient. A priori definitions, developed from recent scoping reviews by Dischiavi et al. (Dischiavi et al., 2021a, 2021b; Wright et al., 2021) were used to categorize each exercise element.

2.1. Clinical impairments

Each exercise was categorised according to the clinical impairment that they primarily addressed. We acknowledge that exercises can target multiple clinical outcomes, but our objective was to ascertain the primary intent of the prescribing author in their exercise selection. The following clinical outcomes were considered: range of motion, strength, postural control and performance tasks. If applicable, subcategories were used to describe the direction of movement (plantar flexion, Dorsiflexion, Inversion, Eversion).

22. Pathomechanics

Each exercise was analysed to determine (a) primary plane of movement, (b) weightbearing status, and (c) the presence of absence of a flight phase.

2.2.1. Planes of movement

Initially, exercises were categorised as uniplanar (exercise occurred in uniquely in one plane of motion) or multiplanar (exercise occurred in two or three of the cardinal planes of motion). Uniplanar exercises were then categorised into sagittal, frontal, or transverse planes. Exercises such as heel raises, and toe raises are an example of isolated movements considered to occur primarily in the sagittal plane. A side jump is an example of a functional exercise considered to occur primarily in the frontal plane. Exercises such as inversion and eversion muscle strength training are an example of isolated movements considered to occur primarily in the transverse plane. If an exercise was identified as multiplanar, the multiplanar box was checked, and then the 2 or 3 planes were also identified in the analysis.

2.2.2. Weightbearing status

Single limb stance exercises involve bearing full weight on one extremity and contacting the ground. We considered an exercise with a sequential movement, whereby one foot moved in a step-by-step fashion, as having both phases of stance. Similarly, variations of lunges were classified as bilateral weight bearing exercises, because both feet were on the ground during the intentional phase of the exercise. An example of a single limb stance exercise is a single leg heel raise or single leg squat. In a non-weightbearing exercise, neither lower extremity is functionally upright (hip over knee over foot) with the foot/feet on the ground. Quadruped exercises, bridging, open chain ankle strengthening, were not considered weightbearing since the method and position of delivery was not reflective of the upright position identified in the injury mechanism.

2.2.3. Flight phase

For a flight phase to be present, the exercise must include a phase where both lower extremities are simultaneously off the ground during the exercise. This would include any running, jumping, or hopping variations.

3. Results

The systematic literature search yielded 14 RCT's after duplication and screening for eligibility. Fig. 1 shows the Prisma Flow diagram.

Table 1 summarises the study characteristics. We included 14 randomized controlled trials, and a total of 177 exercises were extracted from the articles. The number of exercises prescribed within individual RCTs varied from three to 41. Time since injury at recruitment ranged from the day of injury to 11 weeks. Grade II ankle sprain were mostly represented. Five studies (Hultman et al., 2010; Hupperets et al., 2009; Lazarou et al., 2017, 2018; Mohammadi, 2007) failed to mention injury severity. Five studies (Holme et al., 1999; Hupperets et al., 2009; Janssen et al., 2014; Mohammadi, 2007; Van Reijen et al., 2017) included only athletes, and the population of two other studies (Bleakley et al., 2010; Punt et al., 2016) mostly comprised athletes.

Six studies (Holme et al., 1999; Hultman et al., 2010; JUJespersen et al., 1996; Kachanathu et al., 2016; Mohammadi, 2007; Van Reijen et al., 2017) were determined as “high risk” in the first category “randomization process. Also six studies (Holme et al., 1999; Hultman et al., 2010; JUJespersen et al., 1996; Kachanathu et al., 2016; Mohammadi, 2007; Punt et al., 2016) were judged as “some concern” in the category of selection of the reported results because they neglected to pre-register their protocol or publish their methods. One study (Hultman et al., 2010) was deemed some concern in the category of deviations from the intended interventions, and one other study (Kachanathu et al., 2016) was also judged as some concern in the category of measurement of outcomes (Table 2)

4. Exercise analysis

4.1. Clinical impairments

Fig. 2 summarises the clinical impairments addressed. About 44% (78/177) of all exercises primarily addressed postural control. Forty-one exercises addressed performance tasks. These exercises generally comprised plyometrics (49%, 20/41), jumping and landing (24%, 10/41), and running (27%, 11/41). Muscle strength was addressed in 20% of all exercises, with the majority focused on isolated strength training with resistance bands. ROM was addressed in 13 plantar flexion exercises and 12 dorsiflexion exercises. Exercises specifically addressing joint position sense (JPS) were underrepresented (3/177).

4.2. Planes of motion

Table 3 depicts details regarding planes of motion. Most exercises were of uniplanar nature (68.9%, with the sagittal plane most often represented (47.6%). Most multiplanar exercises were biplanar by nature (27.1%), and all multiplanar exercises comprised the sagittal plane.

4.3. Weightbearing status

Exercises performed while standing were divided in single limb stance (59 exercises) and double leg stance exercises (61 exercises). The most common exercise performed standing involved closed kinetic chain strengthening (27 exercises). Exercises that were not undertaken whilst bearing weight involved mostly exercises whilst

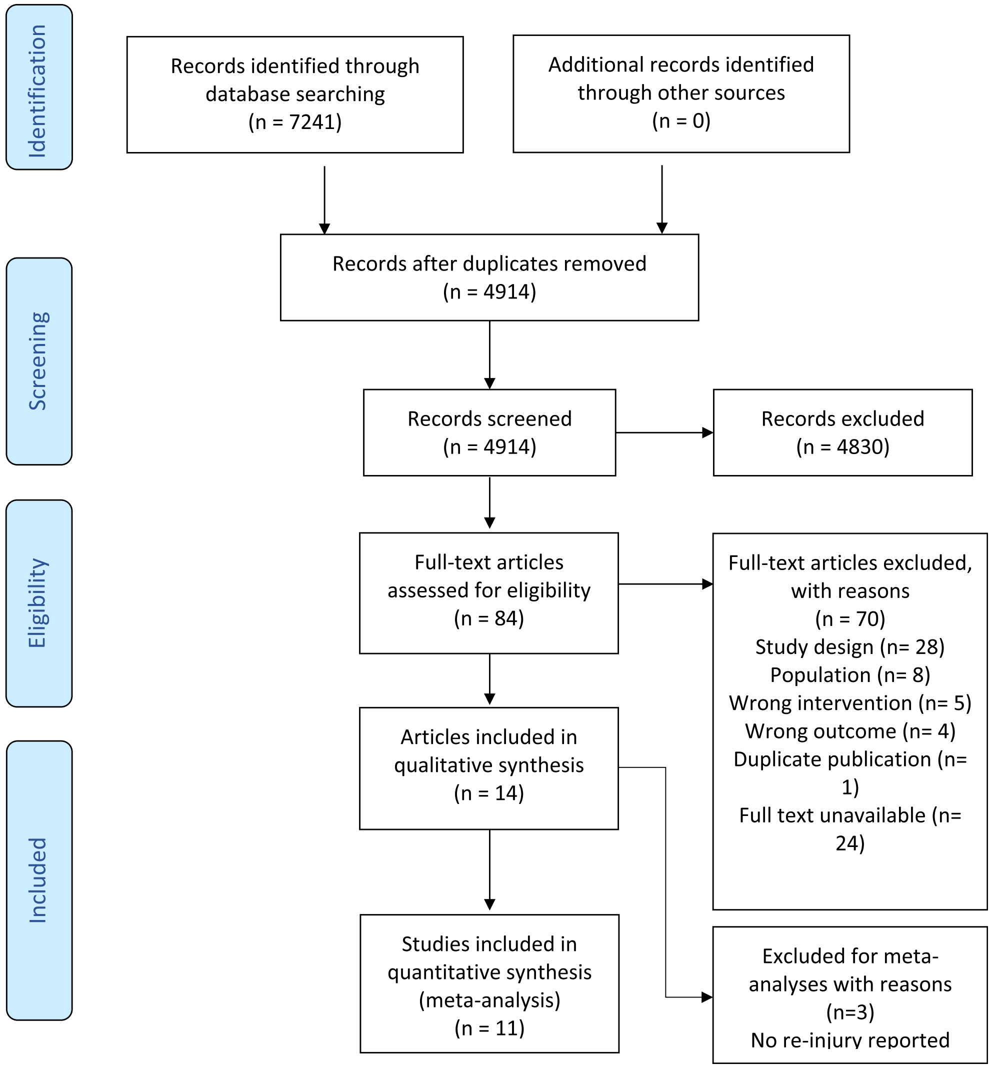

Fig. 1. PRISMA flow diagram of the review process.

seated, open kinetic chain exercises or exercises with a flight phase.

4.4. Flight phase

Of the 34 out of 177 exercises including a flight phase, most were various types of jumping exercises (59%), such as high jumps, long jumps or skate jumps. Agility (9%) and hop & balance (12%) exercises were the least reported (Fig. 3).

5. Discussion

In this exploratory systematic review we audited the content of exercise-based rehabilitation programs in randomized controlled trials (RCT's) that included patients with LAS. Previous reviews and guidelines (Vuurberg et al., 2018; Martin et al., 2021; D'Hooghe et al., 2020; Caldemeyer et al., 2020) conclude that exercise-based rehabilitation is effective after LAS, but because exercise content can vary, there is no consensus on an optimal rehabilitation program (Bleakley et al., 2019; Wagemans et al., 2022). In this study, we reviewed individual rehabilitation exercises for LAS, categorizing them by the impairment addressed, and the extent to which each exercise reflects common mechanisms of re-injury. We included 14 RCT's and categorised an aggregate of 177 exercises. A key finding was that most rehabilitation exercises prescribed within the literature are basic, consequently, some common impairments are not adequately addressed, and few exercises reflect established mechanisms of re-injury.

Ligament injuries such as LAS alter mechanoreceptor function, diminishing proprioception, balance, muscle strength and prolonging muscle reaction time (Zech et al., 2009). Our review found that almost half of exercises prescribed after LAS involve single leg balancing, which were often varied by standing on different surfaces and/or adding implicit motor challenges eg. catching a ball. This type of training integrates sensory information from visual, vestibular and proprioceptive fields (Han et al., 2015; Röijezon et al., 2015), and provides a safe medium for addressing neuromuscular deficits after LAS. Optimal rehabilitation should also involve a series of progressions, whereby exercises eventually recreate more vulnerable conditions and environments. A common inciting event for LAS is excessive ankle supination angle at initial foot contact (Herzog et al., 2019a). These errors are underpinned by aberrations in biomechanical position and (pre)activation of the muscles prior to ground contact; these can be addressed initially through explicit joint repositioning (JPS) tasks in the open kinetic chain. This approach has been used successfully during sensorimotor training at the shoulder joint (Rogol et al., 1998; SELin HK et al., 2016) but

Table 1
Study characteristics.

Study	Participants[a]	Exercises (n)	Time since injury at recruitment	Injury severity (n)	Athletic vs non athletic
Bleakley (Bleakley et al., 2010)	n = 101; 69-32 (68-32%) 26y, ± 8y	8	<7 days	Grade 1 (29) Grade 2 (73)	62–39
Brison (Brison et al., 2016)	n = 503; 223–280 (44–56%) 30y, ±13y	30	<72 h	Grade 1 (149) Grade 2 (354)	215–288
Holme (Holme et al., 1999)	n = 71; 44-27 (62-38%) 26y, ± 4y	7	Day of injury	Grade 1 (21) Grade 2 (38) Grade 3 (12)	71–0
Hultman (Hultman et al., 2010)	n = 65; 35-30 (54-46%) 35y, ±14y	23	Day of injury	Not stated	Not stated
Hupperets (Hupperets et al., 2009)	n = 522; 274-248 (52-48%) 28 y, ±12 y	7	<2 months	Not stated	522–0
Janssen (Janssen et al., 2014)*	n = 340; 157–183 (46–54%) 34 y, ±13 y	7	<2 months	Grade 1 (68) Grade 2/3 (272)	384–0
Kachanathu (Kachanathu et al., 2016)	n = 40; 24-16 (60-40%) 21.8 y, ±2.9 y	8	Not stated	Grade 2 LAS	Not stated
Lazarou (Lazarou et al., 2017, 2018)	n = 20; 6–14 (30–70%) 22 y, ±3 y	10	≥11 weeks	Not stated	10–10
Mohammadi (Mohammadi, 2007)*	n = 60; 60-0 (100-0%) 24.6 y, ±2.63 y	3	Not stated	Not stated	60–0
Punt (Punt et al., 2016)*	n = 90; 51-39 (64-36%) 32.7 y, ±11 y	22	4 weeks	Grade 1 (55) Grade 2 (35)	72–18
Van Reijen (Van Reijen et al., 2017)	n = 220; 110-110 (50-50%) 37.9 y, ±13.4 y	7	<2 months	Grade 1 (91) Grade 2 (64) Grade 3 (18)	220–0
Van Rijn (van Rijn et al., 2007)	n = 102; 59-43 (58-42%) 37 y, ±11.9 y	41	<1 week	Grade 1 (43) Grade 2 (42) Grade 3 (4)	Not stated
Wester (JUJespersen et al., 1996)	n = 48; 29-19 (60-40%) 25 y, ±7 y	4	Day of injury	Primary LAS; grade 2	Not stated

Abbreviations: n = amount; SD: Standard deviation.
[a] Participants: total amount; male-female (%); mean age, ±SD.

surprisingly, we found that only 1.5% of exercises specifically involved open chain training at the ankle complex.

It was also surprising that just over 18% of all exercises included a flight phase. These consisted primarily of various jump exercises (20/34), such as single-leg jumps, forward jumps, stationary jumps and side jumps. Seven of 34 exercises that included a flight phase were running based, of which most involved straight line running, with agility exercises the least represented (3/34). These findings

Table 2
Risk of bias – ROB II Cochrane tool.

Study	1	2	3	4	5
Bleakley[32]	Low risk	Low risk	Low risk	Low risk	Low risk
Brison[63]	Low risk	Low risk	Low risk	Low risk	Low risk
Holme[29]	High risk	Low risk	Low risk	Low risk	Some concerns
Hultman[24]	High risk	Some concerns	Low risk	Low risk	Some concerns
Hupperets[25]	Low risk	Low risk	Low risk	Low risk	Low risk
Janssen[30]	Low risk	Low risk	Low risk	Low risk	Low risk
Kachanathu[35]	High risk	Low risk	Low risk	Some concerns	Some concerns
Lazarou[26, 27]	Low risk	Low risk	Low risk	Low risk	Low risk
Mohammadi[28]	High risk	Low risk	Low risk	Low risk	Some concerns
Punt[33]	Low risk	Low risk	Low risk	Low risk	Some concerns
Van Reijen[31]	High risk	Low risk	Low risk	Low risk	Low risk
Van Rijn[64]	Low risk	Low risk	Low risk	Low risk	Low risk
Wester[34]	High risk	Low risk	Low risk	Low risk	Some concerns

1. Randomisation process; 2. Deviations from the intended interventions; 3. Missing outcome data; 4. Measurement of the outcome; 5. Selection of the reported results
● Low risk ● Some concerns ● High risk

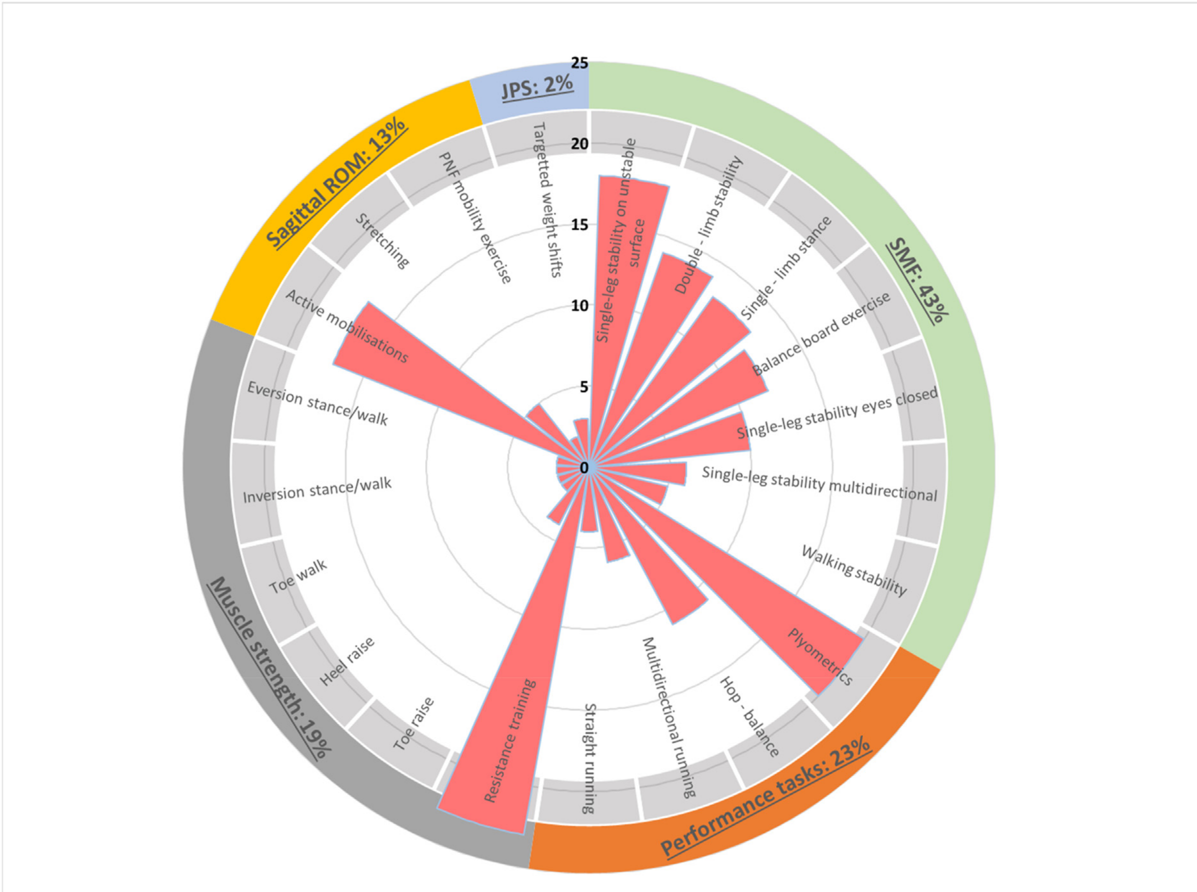

Fig. 2. Clinical impairments with corresponding exercises (N = 177)
Legend: The donut chart (outer circle) depicts the proportion of impairments addressed by the included exercises; the wind rose bar chart (pink bars initiating from the centre) shows the different exercises that reflect each impairment and their number of occurrence.
Abbreviations: SMF= Sensory motor function; ROM = Range of Motion; JPS = Joint position sense. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

Table 3
Planes of motion.

Total exercises: 177	N (%)
Multiplanar	55 (31.1%)
Triplanar	7 (4.0%)
Biplanar	48 (27.1%)
Sagittal-frontal	40 (22.6%)
Sagittal-transverse	8 (4.5%)
Uniplanar	**122 (68.9%)**
Sagittal	84 (47.55%)
Frontal	15 (8.5%)
Transverse	23 (13.0%)

are also disproportionate to the (re)injury mechanism, as most non-contact LAS usually occur during jump landings, multidirectional running and sudden changes of direction (Li et al., 2019). To adequately prepare the patient for these challenges, it is important that rehabilitation exercises move beyond closed chain postural control training, to include more reactive or "perturbation" training and stretch-shortening activities. Again, this should be done in a controlled and progressive fashion to ensure that neuromuscular adaptations occur without placing the patient at risk of re-injury.

A related limitation in the current literature, is that most exercises comprised uniplanar, sagittal dominant movements (47.6%). Common examples are dorsiflexion or plantarflexion exercises, calf stretching and heel or toe raises. Re-establishing sagittal plane mobility and strength is important for balance and functional performance tasks, such as running jumping and landing (Basnett et al., 2013; Drewes et al., 2009). However, exercises must also address impairments across other planes of movement. Non-contact LAS mechanisms are multidirectional, but only 31.1% of all exercises challenged more than one plane of motion, with the majority using sagittal-frontal plane combination. Non-contact LAS occur by an inversion-internal rotation, around the frontal and the transversal plane, with plantarflexion, around the sagittal plane (Hertel & Corbett, 2019; D'Hooghe et al., 2020). Yet, only 4% of exercises challenged the three planes of motion. Restricting exercises to the sagittal plane also limits ligament recruitment and physiological adaptation (Noyes et al., 1974; Rein et al., 2013; Yu et al., 2016). Incorporating multiplanar movements aligns more with the unique anatomy, morphology and biomechanical properties of the lateral ligaments. As connective tissues are mechanoresponsive, inducing progressive and multidirectional loading through exercise also provide a medium to stimulate healing and alter tissue composition (Rein et al., 2013).

Patients with an ankle sprain exhibit decreased eversion peak power (Pourkazemi et al., 2016), and reduced concentric and eccentric eversion peak torque are risk factors for the development of CAI (Thompson et al., 2018). One-fifth of exercises targeted ankle muscle strength, but the majority were undertaken in the sagittal

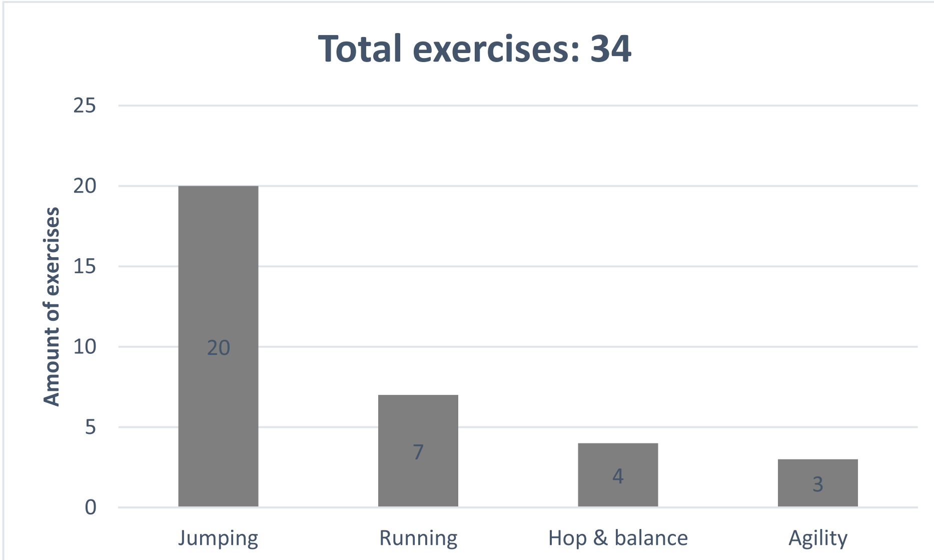

Fig. 3. Exercises including a flight phase.

plane, with only 12/177 exercises (6.8%) primarily addressed eversion muscle strength. Peroneal reaction time can also be an influencing factor. Patients with a history of LAS exhibit a delayed peroneal reaction time, failing to protect the ankle from a sudden inversion perturbation (HOCH & MCKEON, 2014). Exercises that addressed eversion muscle strength primarily involved concentric loading, using an elastic resistance band. Previous studies suggest that a 4-week elastic-resistance exercise-program failed to improve evertor muscle strength or peroneal latency, in patients with a history of LAS (Han & Ricard, 2011). The multiple degrees of freedom of movement, at the ankle complex can make it more difficult to isolate certain muscle groups, and optimal strength training may require additional patient supervision, to ensure optimal training technique.

Our main findings concur with similar scoping reviews undertaken in this field. Dischiavi et al. (Dischiavi et al., 2021b) examined over 1000 exercises used for preventing ACL/knee injuries; they reported that most prescribed exercises did not address the task specific elements identified within ACL injury mechanisms (Dischiavi et al., 2021b), such as single leg landing, trunk hip dissociation, and multiplanar movements. Dischiavi and colleagues noted a reductionist approach to exercise prescription across other musculoskeletal conditions (Dischiavi et al., 2021a; Wright et al., 2021). Their scoping reviews of the patellofemoral pain (PFPS) (Dischiavi et al., 2021a) and femoroacetabular impingement (FAI) literature (Wright et al., 2021), each concluded that the prescribed rehabilitation exercises were too simplistic, lacked progression, and often failed to reflect the etiology of the respective conditions. It seems that there are consistent limitations in rehabilitation content across the current musculoskeletal literature; this could be addressed increasing the specificity, complexity and progression of the exercise content. The current approach limits the effect size of the intervention, particularly in athletes, where exercise progression is paramount for optimal rehabilitation (Blanchard & Glasgow, 2019). Exercise programs must be developed to incorporate more chaotic, sport-specific movements (Taberner et al., 2019), which eventually replicate key features of injury mechanism (Blanchard & Glasgow, 2019; Otte et al., 2019).

6. Limitations

Our key finding was that exercises prescribed after LAS do not incorporate complex tasks associated with common LAS injury mechanisms. Exercise elements were classified based on the impairment addressed, direction of movement, use of flight, and weight-bearing status. This classification could have been subjective; but to minimise this, we aligned our methods and definitions to three previous reviews (Dischiavi et al., 2021a, 2021b; Wright et al., 2021). We must also acknowledge that our classification criteria is informed primarily by mechanical constructs relevant to the injury inciting event. This reductionist approach of discussing only biomechanical effects of rehabilitation exercises deviates from the original biopsychosocial model (Cormack et al., 2022). Our criteria were not exhaustive and the etiology of re-injury involves a complex interaction of several internal and external risk factors (Bahr & Holme, 2003; Verhagen et al., 2018; Vuurberg et al., 2018) These often include psychosocial impairments such as kinesiophobia, fear-avoidance, decreased quality of life, perceived instability and self-reported function (Hertel & Corbett, 2019; Houston et al., 2014, 2018). Current consensus guidelines such as ROAST and PAAS also highlight the importance of using patient-reported outcome measures in the rehabilitation process and return-to-sports decision making (Delahunt et al., 2018; Smith et al., 2021). Future research should consider which psychosocial impairments are addressed by the prescribed exercises in rehabilitation programs. We included exercise-based programs from experimental studies but this may not always reflect the nature of ankle sprain rehabilitation in clinical practice. There is some evidence to suggest that only a small number (6.4%) of patients in the United States of America are treated with therapeutic exercises after an ankle sprain, and that rehabilitation focuses primarily on strength or ROM exercises (Feger et al., 2017).

7. Conclusion

This review highlights that most rehabilitation exercises prescribed in current RCT's are generic, simplistic, and do not fully reflect the pathomechanics of non-contact lateral ankle sprains.

This could introduce a ceiling effect for LAS rehabilitation. Developing exercise interventions that better incorporate JPS training, multi-directional movements, flight phases and single limb landings, would present a more progressive task-specific approach to rehabilitation, cumulating in a greater reduction in re-injury risk. High quality prospective studies can determine the feasibility and clinical effectiveness of using more complex exercise-based training after acute LAS.

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Ethical approval

None declared.

Confirmation of ethical compliance

None to declare as this manuscript is a systematic review.

Declaration of competing interest

None declared.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ptsp.2023.01.008.

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