

Research Progress on Risk Factors and Exercise Rehabilitation Strategies for Ankle Sprains

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Abstract

An ankle sprain is a frequent musculoskeletal injury in sports and during everyday activities, with some individuals suffering repeated sprains and chronic ankle instability. Injury occurrence and recovery are influenced by age, body weight and body mass index (BMI), prior injury history and sensorimotor function, whereas exercise rehabilitation is the next important modifiable phase after injury. The review is mostly based on publicly available medical literature available in PubMed and other similar resources, which summarizes epidemiological reports, prospective cohorts, randomized controlled trials, systematic reviews and meta-analyses. The article will focus on the major risk factors of ankle sprain and on how structured exercise rehabilitation influences pain, function, balance, and recurrence. Evidence on the risk factors and the evidence on post-injury rehabilitation are presented in a sequential manner, highlighting the concept of stratification of risks and a deficit-based approach to rehabilitation. The adolescent group has the highest incidence of ankle sprain; increased BMI has been linked to injury and certain long-term consequences; past injury and sensorimotor performance must also be considered in assessing risk. Balance, proprioception, strength and neuromuscular training have been shown to enhance functionality and less recurrence can be achieved through more or less stable evidence and rehabilitation intensity needs to be personalized based on injury severity and functional impairment.

Keywords

ankle sprain, risk factors, body mass index, chronic ankle instability, exercise rehabilitation

1. Introduction

Ankle sprain is the damage to the ligaments and adjacent soft tissues due to external forces that cause the ankle to go out of its natural range of movement; the most common form of ankle sprain is the lateral ankle sprain (LAS) [1]. The usual form of injury is fast inversion with concomitant plantarflexion when loaded, and the anterior talofibular ligament tends to be the first tissue injured; more serious injuries might involve the calcaneofibular ligament as well [1]. Acute presentations are pain, swelling, tenderness and inability to bear weight but the clinical importance goes further than just the short term symptoms. There are some patients who have limited joint range of motion, muscle weakness, proprioceptive deficits and impaired dynamic postural control even after the healing process of the tissues and can suffer repeated giving way, recurrent sprain and chronic ankle instability (CAI) [1]. Hence, clinical practice guidelines consider first-time LAS and

CAI as interrelated phases of a continuum and focus on restoring sensorimotor function alongside managing the acute symptoms [1].

In epidemiology, ankle sprains are particularly frequent in adolescents, those who engage in sports, and individuals who regularly run, jump, decelerate or alter direction. The systematic reviews have shown that the prevalence of ankle sprain is also higher in children and adolescents compared to adults, and indoor and court sports may also have increased risk [2]. U.S. emergency-department statistics also indicate that the peak age of incidence is adolescence [3,4]. In spite of the fact that the majority of such injuries do not involve hospitalization, the significant number of cases leads to absence during training or competition, limitations of learning and working activities, health care consumption, and the repetition. Competitive athletes can turn a minor injury into a major functional issue by returning to sport too soon [1,5].

Earlier studies indicate that there is no single decisive risk factor involved in LAS. Alongside the history of prior sprain, sport exposures, peroneal strength, proprioception and reaction capacity, age and body mass index (BMI) are often considered as individual factors [1,5,6]. The relationship between age and risk is also likely to change concurrently with sport involvement, sex, and developmental phase; larger body mass could augment the mechanical forces that the ankle needs to control when it lands and changes directions but BMI will not differentiate between muscle and fat and thus cannot alone be used to portray athletic ability or joint stability [6]. Conversely, rehabilitation after injury by exercise has been shown to be actively able to enhance range of motion, strength, balance and neuromuscular control and is a critical intervention to decrease residual dysfunction and likelihood of recurrence [1,9].

The majority of the current LAS studies of risk factors are related to incidence, past injury, physiological features, or sensorimotor function and rehabilitation studies tend to examine each training mode independently; there is not much ongoing information correlating the identification of risk factors to the later rehabilitation process. The review mainly relies on articles listed in PubMed and articles that can be accessed freely in journals like BMJ and Journal of Orthopaedic & Sports Physical Therapy, focusing on epidemiological research, prospective cohorts, randomized controlled trials, systematic reviews, and meta-analyses reporting explicit sample sizes and outcome measures. Age and body weight/BMI are discussed in more detail under the risk-factors part, along with the issue of previous injury, muscle strength, and sensorimotor capacity; the rehabilitation part talks about people with acute LAS or CAI, comparing the structured exercise rehabilitation with the usual care or no special training, and evaluating the results in terms of pain, foot-ankle ability, dynamic balance, and recurrent sprain. It is intended to broaden the discourse on risk identification to the concept of functional recovery and thus offer a literature base to prevent and individualize treatment of ankle sprain.

2. Injury Mechanisms and Risk Factors of Ankle Sprain

2.1 Injury Mechanisms and Functional Consequences of LAS

Following LAS, the injury does not just affect the mechanical integrity of the ligament but also the sensorimotor system. Ligaments, joint capsules, and tendons contain mechanoreceptors that are involved in the sensing of joint position and movement [1]. Patients can have a delay in their peroneal reflex, decreased peri-ankle strength and changes in postural control when they experience acute injury resulting in pain, swelling or neuromuscular inhibition [1,5]. Should the recovery process be limited to addressing if the pain has been relieved and not help recover the range of motion and dynamism at the joint, the patient will continue to be unable to protect themselves sufficiently during the act of jumping, landing or even changing direction once more. CAI is thus not merely the term "ligamentous laxity" but can occur as mechanical instability and sensorimotor dysfunction simultaneously; this also clarifies why contemporary rehabilitation focuses on multi-dimensional training instead of long-term immobilization [1].

2.2 Age

When Waterman et al. examined the U.S. National Electronic Injury Surveillance System data on emergency ankle-sprain cases between 2002 and 2006 they found that there were about 3.14 million such cases over the time of the study, at an average incidence of 2.15 cases per 1,000 person-years; the rate was highest (7.2 cases per 1,000 person-years) among individuals aged 15-19 years, and 49.3 percent of the cases involved sports activity [3]. Doherty et al. in a systematic review and meta-analysis of prospective epidemiological

research identified significant differences by age: about 2.85 cases per 1,000 exposures in children, 1.94 in adolescents, and 0.72 in adults [2]. Though definitions of exposure are not consistent among studies, the general trend indicates increased exposure of younger populations [2,3].

The latest national data support this conclusion. In their analysis of U.S. emergency data between 2010 and 2024, Tyler et al. estimated 7.4 million ankle-sprain visits in the past 15 years, and the total incidence of 1.53 per 1,000 person-years; the peak incidence age group was 1519 (average) at about 2.60 per 1,000 person-years, and more than half of all cases involved people aged 10-24. The sport-related cases comprised 33.2 percent, of which basketball made up 15.8 percent [4]. The general incidence of the emergency has decreased compared to previous studies but the peak of the age has been largely unchanged, which means that adolescents and young adults remain a target of prevention [3,4].

Nevertheless, Youth cannot be seen as a cause of any particular nature. Adolescents and young adults generally have increased participation in sports and more often participate in basketball, football, and similar activities involving jumping, contact, and abrupt changes of direction; sport exposure is then a significant factor in the statistical connection between age and ankle sprain. Lower overall emergency incidence might be observed in older general populations with less sport exposure [2,4]. The current available evidence is best adapted to demonstrate the appropriateness of using age as a means of labeling high-exposure population rather than a linear relationship indicating that younger individuals are at greater risk automatically. In actual prevention, the history of previous sprains, the type of sport, sex, strength and balance capacity should be considered as well [1,5].

2.3 Body Weight and BMI

The role of body weight and BMI is manifested by mechanical loading and functional regulation. A systematic review and meta-analysis of eight studies conducted by Kobayashi et al. showed that LAS risk was associated with BMI, selected peri-ankle strength measures, joint-position sense, and peroneus brevis reaction time [5]. Synthesizing 80 studies, Vuurberg et al. stated that the mean BMI of patients with LAS was higher than that of healthy controls; also, among patients with CAI, there was a higher average body weight and longer time to stabilization after performing jumping tasks [6]. These observations indicate that body-weight factors might have some connection with initial injury as well as future stability, but they cannot be explained separately from the capacity of neuromuscular system [5,6].

Timm et al. have included 199 children, ages 8-18 years with acute ankle injury in a pediatric population and assessed 164 of them who finished six-month follow-up. Children with high BMI were 1.70 times more likely to develop chronic pain, swelling, weakness, pain after exercise, or reinjury at six months when compared to controls based on the fact that age-specific 85 th percentile of BMI was taken as cut-off [7]. The findings indicate that overweight children are likely to be at increased risk of having lasting symptoms following the acute injury and it is important that they receive more careful monitoring over longer periods of time and greater focus on functional recovery [7].

Future adult results are more conservative. In their study, Bielska et al. monitored 504 patients aged 16 years and over with grade I- II ankle sprain over six months, divided into non-overweight, overweight, and obese groups based on BMI, and measured recovery using the Foot and Ankle Outcome Score (FAOS). Recovery differences among groups did not appear significant at one and three months but only about 53-66 per cent of patients achieved the relevant recovery criteria at six months. Unadjusted odds ratio of recovery in the obese group was 0.60 with adjusted odds ratio of recovery of 0.74 with confidence interval limits of 1, which shows that there is no stable relationship between BMI and complete recovery [8]. The differences in pain and activities of daily living dimensions were still worse in the obese group, but the clinical relevance of these differences was small. It is important to consider higher BMI as a possible contributor to increased recovery complexity and not as a justification of the claim that the recovery is inevitably poor [8].

Mechanically, more body weight creates external forces associated with single-leg landing, running, and quick deceleration, which means that peri-ankle muscle must manage more inertia in less time; when the strength is lacking, response time is slow, or balance problems are present, the injury risk can be elevated even more [5,6]. Nonetheless, BMI is just the ratio between height and weight and cannot represent the muscle mass, fat distribution, or training level; the use of BMI only may overestimate the risk among the athletes with high muscle mass [6,8]. One better way to identify risk would be to integrate age, body weight/BMI, history of

sprain, sports exposure, joint range of motion, strength, and balance dynamically instead of predicting injuries with any one demographic variable [1,5,6].

2.4 Other Risk Factors and Interactions

Along with age and BMI, the prior LAS history, the peri-ankle strength, the proprioception, the joint-position sense, and the peroneal reaction capacity are also commonly considered part of the risk assessment process [1,5]. Age and body-weight factors are mainly useful in identifying populations that might require more attention to prevention or follow-up; they can never be used instead of functional assessment. An example is that, in people who have a large percentage of body fat, a strong muscle athlete with excellent single leg control does not have the same true risk as a weak muscled sedentary individual; in teenagers, a high frequency basketball player should not be classified into the same risk category as a low exposure peer. Eccentric inversion strength, plantarflexion strength, joint-position sense, and peroneal reaction time were found by Kobayashi et al. to be related to LAS in addition to BMI [5]. This approach to risk identification should thus move away towards a holistic approach of assessing a combination of exposure level + past injuries + physical factors + sensorimotor capacity [1,5].

3. Research Progress on Exercise Rehabilitation Strategies

The current assessment of exercise rehabilitation is based on only two populations acute LAS and CAI. While the first one emphasizes pain, range of motion, functional recovery, and repeated sprain, the second one focuses more on patient reported function, dynamic balance, joint-position sense and sport performance. A summary of representative studies, their samples, interventions and main findings are shown in Table 1.

Table 1: Representative Studies on Risk Factors and Exercise Rehabilitation for Ankle Sprain

Study	Design / Sample	Main Factor or Intervention	Main Results
Waterman et al. (2010) [3]	National ED epidemiology	Age, sport exposure	Ages 15–19: 7.2/1,000 person-years; 49.3% sport-related
Tyler et al. (2025) [4]	National ED epidemiology	Age, sport exposure	~7.4 million cases 2010–2024; ages 15–19 peak incidence
Bielska et al. (2019) [8]	Prospective cohort, n=504	BMI and recovery	Only ~53%–66% met recovery criteria at 6 months; adjusted BMI differences attenuated
Hupperets et al. (2009) [10]	RCT, n=522	8-week proprioceptive training	1-year recurrence 22% vs 33%, RR=0.63
Wagemans et al. (2022) [9]	Meta-analysis, 14 RCTs, n=2182	Exercise rehabilitation	12-month reinjury OR=0.60 (95% CI 0.36–0.99)
Guo et al. (2024) [11]	Meta-analysis, 9 RCTs, n=341	Balance training	Improved CAIT, FAAM-Sports, and multi-directional dynamic balance
Zhang et al. (2025) [12]	Meta-analysis, 15 RCTs, n=586	Multimodal exercise therapy	FAAM-S mean improvement 7.98; >4 weeks more stable gains
Xu et al. (2026) [13]	Systematic review/meta-analysis, 58 studies, n=2097	Multiple exercise modalities	Balance training broadest effects; supports deficit-based individualization
Brison et al. (2016) [14]	RCT, n=503	Supervised physiotherapy	Excellent recovery at 3 months 43% vs 37%; did not meet pre-specified clinical importance

Note: ED = emergency department; RCT = randomized controlled trial; RR = relative risk; OR = odds ratio; CAIT = Cumberland Ankle Instability Tool; FAAM = Foot and Ankle Ability Measure.

3.1 Early Functional Rehabilitation and Load Management

The main objective of acute LAS rehabilitation is to preserve the injured tissues and return them to tolerable movements and weight-bearing at the earliest opportunity. The clinical practice guideline of 2021 advises that depending on the severity of the injury, bracing or taping should be applied, progressive weight-bearing of the affected limb should be restored, and protective active movement, stretching, neuromuscular, and balance training should be performed; in case of more serious trauma, short-term immobilization could be used, but

long-term fixation is not recommended [1]. The key idea is not the sooner and more intensive the better but a gradual load increase within the limits of symptoms tolerance to avoid the further loss of range of motion, strength, and function due to over protection [1].

As a part of a systematic review of 14 randomized controlled trials of 2,182 patients with acute LAS, Wagemans et al. (2022) observed that exercise rehabilitation had a lower chance of reinjury in 12 months compared to the standard care with a combined odds ratio of 0.60 indicating that the most important benefit of exercise training is reduction of recurrence [9]. The review also observed considerable heterogeneity in training modality, duration and dosage between studies and short term pain and functional results were not consistently uniform; one standardized exercise prescription cannot then be made [9]. Progression should be clinically directed by pain, swelling, weight-bearing ability and functional test outcomes [1,9].

3.2 Range-of-Motion and Strength Training

The restoration of joint range of motion and strength is the basis of advancement to more advanced balance and sport-specific training. Ankle dorsiflexion restriction will influence tibial motion when squatting, descending stairs, running, and landing; compensation by patients can be external rotation of the foot or knee-hip substitution. Initial treatments in the pain range are ankle pumps, active dorsiflexion and plantarflexion, and mild stretching; with recovery of weight-bearing capability, elastic-band resistance, heel raises, closed-chain squats, and single-leg loading can be added gradually [1]. The peroneal musculature is essential in resisting a sudden inversion, whereas the posterior calf assists in propulsion, landing attenuation, and control of ankle stiffness. Strength training in CAI may enhance patient reported function, dynamic balance, and concentric strength, but does not address all sensorimotor deficits and thus it is often accompanied with balance and neuromuscular training [13].

3.3 Balance and Proprioceptive Training

Balance and proprioceptive exercises are the current rehabilitation material with the moderate level of proven effectiveness in preventing recurrence. A randomized controlled trial on 522 athletes who had recently undergone LAS was performed by Hupperets et al.; all patients underwent usual care, but 256 of them also undertook an 8-week home-based proprioceptive training program and 266 acted as controls. In the one-year follow-up, 56 participants in the training group suffered a recurrent sprain (rate of recurrence of 22 per cent) compared to 89 participants in the control group (33 per cent); the relative risk was 0.63 which translates into a 35 per cent decrease in the recurrence risk, or about one fewer recurrent sprain per nine treated [10]. The finding suggests that unsupervised home exercises, as long as the material is understandable, and compliance sufficient, may achieve clinically significant secondary prevention [10].

Also, balance training has been found to be beneficial in patients who have already developed CAI. Guo et al. (2024) in a meta-analysis of nine randomized controlled trials with 341 participants stated that balance training increased the Cumberland Ankle Instability Tool scores by an average difference of about 3.95 points compared to control groups; the Foot and Ankle Ability Measure sports subscale by an average of 17.74 points and scores in various directions of the Star Excursion Balance Test were also improved [11]. Balancing training had some beneficial effects on specific patient-reported functional indices when comparing it with strength training, but dynamic stability was not significantly better than strength training using all the measurements [11]. The results imply that treatment programs ought not to regard balance and strength as interchangeable but incorporate both to suit the patient deficits [11,13].

3.4 Multimodal Training for CAI

The findings of recent studies on CAI also highlight the role of the rehabilitation strategy as a “multimodal and deficit oriented” approach. In a meta-analysis of 15 randomized controlled trials comprising 586 patients with CAI, Zhang et al. (2025) observed that exercise therapy increased the Foot and Ankle Ability Measure (FAAM) sports subscale by an average of 7.98 points; training of longer than four weeks had greater effects on the activities-of-daily-living subscale and dynamic balance [12]. There was a benefit of strength training, range-of-motion-related interventions and proprioceptive training across training subgroups in different directions of dynamic-balance indices [12].

Xu et al. (2026) systematically reviewed and meta-analysed 58 studies with 2,097 participants reporting that balance training had the widest range of effects, namely, enhancing the patient-reported function, dynamic balance, joint-position sense, concentric strength, and functional performance; strength training was more effective in increasing patient-reported function, dynamic balance, and concentric strength; and neuromuscular training was also effective in improving function and dynamic balance [13]. It is emphasized in the paper that diverse training modalities are associated with distinct efficacy profiles and that rehabilitation cannot be offered as a set of fixed packages; rather, an initial training regimen needs to be chosen based on the functional deficits that are most obvious in the patient and added up gradually. This is also why patients with CAI who train using only one form of resistance training or only static balance might not address all the issues [13].

3.5 Supervised Rehabilitation Versus Home Training

The determination on whether supervised rehabilitation is necessary must be based on the severity of the injury and the ability of the patient. A randomized controlled trial of 503 patients with grade I - II acute ankle sprain was done by Brison et al.; one group received customary treatment and the other group received supervised physiotherapy besides that. Three months later, 98 out of 229 patients in the physiotherapy group (43%) had excellent recovery compared to 79 out of 214 (37%) in the usual-care group; the absolute difference was 6% (95% CI: -3% to 15%) and it did not meet the pre-specified level of clinical significance. The primary outcomes after one and six months also did not demonstrate any clear extra benefit [14].

The conclusion cannot be drawn into the fact that exercise rehabilitation is not efficient; instead, it points out that rehabilitation format and treatment resources should be personalized to the needs of patients [10,14]. Structured education, progressive activity, and home exercise have been proven effective to satisfy most of the needs in patients with mild-to-moderate injury who are able to bear normal weights and do exercises properly; however, those who have a recurrent sprain, significant balance impairment, high sports involvement, poor compliance, or lack of progress should receive monitored rehabilitation, which allows adjusting the difficulty level, correcting movements, and tracking the progress based on the performance. Two trials of home-training by Hupperets et al. [10] and supervised-therapy by Brison et al. [14] demonstrate at various viewpoints how the factors determining the efficacy encompass not only the question of whether a person is supervised but also what exactly is taught and to whom, adherence, and assessment of outcomes.

3.6 Return to Sport and Recurrence Prevention

The re-entry into sport is a critical final phase in the rehabilitation process. The choices made purely on the time since the injury occurred or on the basis of walking without pain can fail to take into account functional weaknesses when changing speed, landing a jump, or becoming fatigued. The PAASS model was recommended by Smith et al. based on the international multidisciplinary expert consensus suggesting that the decision-making concerning return to sport should consider five domains including Pain, Ankle impairments, Athlete perception, Sensorimotor control, and Sport/functional performance [15]. Assessment Concrete Concrete assessment could be the combination of joint range of motion, strength and endurance, dynamic balance, single-leg hop, agility, sport-specific movement, and completion of a full training session. It is a paradigm shift in how decisions are made, i.e. moving away from the previous concept of symptom-based to the new one of function-based standard decision making and it has some practical value to prevent recurrent sprain due to early reintroduction [15].

4. Discussion and Outlook

4.1 Clinical Implications of Existing Evidence

The synthesis of the existing evidence indicates that age, body weight, and exercise rehabilitation fall at various points on the risk chain of an ankle sprain. It is mostly employed in determining the high-incidence populations of epidemiology, particularly adolescents and young sportspeople [2-4]. BMI and body weight can be seen as indicators of extra mechanical overload and certain recovery risks, but they should be interpreted with regard to body composition and functional capability [5-8]. Exercise rehabilitation is among the few modifiable factors following any injury and structured training, specifically, can enhance balance and functioning as well as decrease the likelihood of recurring sprain [9,11-13]. Unsupervised treatment of

uncomplicated grade I-II ankle sprain has an additional advantage of modesty and the absence of obvious short term discrepancies between full recovery rates does not undermine the usefulness of specific training to prevent recurrence and CAI [10,14].

Risk identification in clinical or sport practice may also be coupled with a functional assessment. Adolescents and high sport exposure individuals should focus on preventive balance and neuromuscular training as well as landing and direction change techniques and training-load management [1,9,11]. In people who have increased BMI post-ankle sprain, it could also be suggested that weight-bearing tolerance, lower-limb strength and recovery trajectory should be considered, not just weight loss or postponing regular rehabilitation due to being overweight [8]. The treatment after injury should start with the range of motion and basic strength, move on to the single-leg stability, dynamic balance, perturbation control, and sports-related activities, and make the achievement of functional goals the foundation of advancement [1,15]. It must be noted that there is no direct proof that any given age or BMI group needs a certain training dosage; personalized recommendations ought to hence focus on a real functional test [13].

4.2 Research Limitations and Future Directions

However, there are a number of limitations in existing research. One is that other epidemiological studies use emergency visits, sport exposures, or athlete-hours as the denominator, which means that incidence rates cannot be compared across studies; mild cases may also be underreported in U.S. emergency databases since they do not seek medical care or receive care in other settings [2-4]. Secondly, BMI does not distinguish between fat and muscle and age is strongly associated with sport participation and both could be affected by confounding variables [6,8]. Thirdly, exercise-rehabilitation studies are highly heterogeneous in training content, frequency, duration, and outcome measures, and a few have short follow-ups, which restricts conclusions regarding long-term recurrence and return-to-sport quality [9,13]. Finally, there are few studies with a prospective design that can directly assess interaction of the factors of age, BMI, and rehabilitation effects, therefore, sound stratified prescription models cannot be developed yet. Future studies need to increase the length of the follow-up in the age and body-composition groups, apply standardized injury definitions, exposure measures, and functional measurements, and examine the personalized dosage of training depending on the objective measurement of functional deficits.

5. Conclusion

To sum up, ankle sprain demonstrates a distinct age distribution whereby adolescents and young adults are the main populations at a higher incidence; higher BMI and body weight have been linked to LAS and to some long term symptoms but cannot be explained independently of sport exposure and body composition and past injuries and neuromuscular functioning. The value of exercise rehabilitation is fairly evident in enhancing the functionality and reducing the relapse rate; the rehabilitation program must include balance, proprioceptive, strength, and neuromuscular exercises depending on the deficits in the patient and controlled rehabilitation does not necessarily apply to all patients with mild to moderate injury. In future, they need to do good-quality prospective research stratified by age, body composition and sporting demands and identify more accurate risk stratification, training dosage, and return-to-sport criteria.

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