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Injury Epidemiology, Prevention, and Rehabilitation in Student Triple Jump Athletes Insights from a Decade of Research

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ABSTRACT

The purpose of the study. The triple jump is one of the most technically demanding and high-impact track and field events, exposing student athletes to significant injury risks. The complex biomechanical demands, coupled with developmental and academic pressures, increase the vulnerability of young athletes to acute and overuse injuries, particularly in the lower extremities. This systematic review aims to synthesize a decade of evidence on injury epidemiology, prevention, and rehabilitation in student triple jump athletes. The goal is to evaluate risk factors, assess the effectiveness of prevention and rehabilitation strategies, and identify research gaps to inform future practices and interventions.

Materials and methods. A systematic review was conducted in accordance with PRISMA guidelines. Six major databases (PubMed, SPORTDiscus, CINAHL, Web of Science, Cochrane Library, and PEDro) were searched from January 2010 to September 2024. Inclusion criteria targeted studies involving student athletes aged 16–25, focusing on triple jump injury patterns, prevention, and rehabilitation. Twenty-three studies met the eligibility criteria. Data extraction and quality assessment were performed independently by two reviewers, using validated tools such as the Cochrane Risk of Bias Tool and Newcastle-Ottawa Scale..

Results. The review revealed that injury rates escalate from 1.33 per 10,000 athlete exposures in high school athletes to 8.65 per 1,000 exposures at the collegiate level. Lower extremity injuries were most prevalent, with the thigh, ankle, and knee most commonly affected. Muscle strains and ligament sprains dominated injury types. Evidence-based prevention strategies, particularly neuromuscular and eccentric strengthening programs, reduced injury risk by 35–50%. Rehabilitation protocols emphasizing progressive agility, trunk stabilization, and eccentric training demonstrated superior outcomes and reduced reinjury rates. Most injuries (95.1%) were managed successfully with conservative treatment.

Conclusions. Student triple jump athletes face substantial injury risk due to extreme biomechanical loads. Multicomponent prevention programs and comprehensive, criterion-based rehabilitation protocols are effective in reducing injury incidence and recurrence. However, gaps remain in event-specific research, long-term outcome studies, and implementation strategies. Future work should focus on prospective, large-scale studies and the integration of technology-driven monitoring and injury prediction tools.

Keywords: triple jump; injury prevention; rehabilitation; student athletes; track and field; biomechanics; neuromuscular training.

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INTRODUCTION

The triple jump represents one of the most technically demanding and physically challenging events in track and field athletics, requiring athletes to execute a complex sequence of hop, step, and jump phases while maintaining optimal speed and control (Eissa, 2014; Ramey, 1983). This inherent complexity, coupled with the high-impact nature of the landings, places significant biomechanical stress on the musculoskeletal system, making triple jumpers particularly susceptible to a range of injuries (Cao & Wang, 2023; Enoki et al., 2021). The substantial ground reaction forces exerted on the takeoff leg, often several times an athlete's body weight, contribute significantly to these injury risks, particularly in the lower limbs (Enoki et al., 2021; Dziewiecki et al., 2013). Student athletes participating in triple jump face unique challenges due to their developmental status, training loads, and the biomechanical demands of the event. Consequently, understanding the epidemiology, developing effective prevention strategies, and implementing targeted rehabilitation protocols are critical for ensuring the sustained participation and long-term well-being of these athletes (Cao & Wang, 2023).

The triple jump generates ground reaction forces exceeding 10-15 times body weight during takeoff phases, placing

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exceptional stress on the musculoskeletal system, particularly the lower extremities and spine. These substantial forces contribute to a high incidence of injuries, particularly in high school and collegiate jumpers (Rhim et al., 2024). For instance, a significant proportion of jumping-related injuries in high school athletes affect the thigh, ankle, knee, and lower leg, with muscle strains and ligament sprains being the most prevalent diagnoses (Amarttayakong et al., 2023). Student athletes, typically aged 16-25 years, represent a population at heightened injury risk due to several factors: ongoing physical development, varying training experience levels, academic pressures affecting recovery, and often limited access to specialized sports medicine support (Alcock et al., 2024; Aly et al., 2019; Kerr et al., 2017). The dual demands of academic performance and athletic excellence create additional stressors that may compromise injury prevention and rehabilitation outcomes.

Previous research in triple jump injury epidemiology has primarily focused on elite adult populations, with limited attention to student athletes despite their substantial representation in the sport (Enoki et al., 2021). Existing literature demonstrates that triple jump athletes experience injury rates ranging from 2.5 to 4.8 injuries per 1000 athlete-exposures, with lower extremity injuries predominating (Cao & Wang, 2023; Rhim et al., 2024). However, a recent two-year prospective study on collegiate jumpers indicated that while ankle sprains were common in long jumpers and hamstring strains in pole vaulters, injuries in triple jumpers require more specific investigation given the unique demands of each jumping event (Enoki et al., 2021). Specifically, collegiate track and field jumpers collectively experience a rate of 1.33 injuries per 10,000 athlete exposures, with the thigh and ankle being the most frequently injured sites (Rhim et al., 2024). However, several methodological limitations characterize current research, including heterogeneous injury definitions, varied follow-up periods, and limited focus on prevention strategies specific to the student population.

Injury prevention literature in jumping events has largely extrapolated findings from general track and field populations or other jumping disciplines. While studies have identified risk factors such as previous injury history, biomechanical asymmetries, and inadequate strength ratios, the translation of these findings into evidence-based prevention protocols for student triple jump athletes remains incomplete (Cao & Wang, 2023; Hay, 1992; Simanjuntak & Maksum, 2021).

Rehabilitation research specific to triple jump injuries is notably sparse, with most studies addressing general track and field injuries or focusing on single-injury types rather than comprehensive rehabilitation approaches. The complexity of return-to-sport decisions in triple jump, given the high-impact nature and technical demands, necessitates sport-specific rehabilitation protocols that are currently underdeveloped in the literature.

Several critical gaps exist in the current evidence base, including: limited studies specifically examining student athletes in triple jump, with most research focusing on elite or recreational populations; a lack of standardized, evidence-based injury prevention programs tailored to triple jump biomechanics and student athlete characteristics; an absence of sport-specific rehabilitation protocols addressing the unique demands of triple jump performance; insufficient longitudinal studies examining the long-term effectiveness of prevention and rehabilitation interventions; and limited investigation of real-world implementation challenges and barriers to evidence-based practice in student athletic settings.

The growing participation of student athletes in triple jump, combined with the high injury risk and potential for long-term consequences, necessitates a comprehensive synthesis of available evidence. Student athletes represent a unique population with specific needs, constraints, and opportunities that require targeted approaches to injury prevention and rehabilitation. Understanding the current state of evidence will facilitate the development of age-appropriate, evidence-based protocols that can be implemented in educational settings. Furthermore, identifying research gaps will inform future investigation priorities and guide the development of more effective intervention strategies.

The primary objectives of this systematic literature review are to synthesize current evidence on injury epidemiology in student athletes participating in triple jump events, evaluate the effectiveness of injury prevention strategies specifically applicable to student triple jump athletes, assess the evidence base for rehabilitation interventions following triple jump-related injuries in student populations, and identify gaps in current research and provide recommendations for future investigation. Develop evidence-based recommendations for injury prevention and rehabilitation practice in student athletic triple jump programs.

MATERIALS AND METHODS

Literature Review: PRISMA Protocol

This systematic review was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to ensure methodological rigor and reproducibility.

Search Strategy and Information Sources: A comprehensive electronic search strategy was implemented across six major databases from January 1, 2010, to September 31, 2024, to ensure comprehensive coverage of relevant literature in sports medicine, rehabilitation, and athletic training. The search encompassed PubMed/MEDLINE for biomedical literature, SPORTDiscus (EBSCOhost) for sports and exercise science publications, CINAHL (Cumulative Index to Nursing and Allied Health Literature) for allied health and rehabilitation studies, Web of Science Core Collection for multidisciplinary coverage including biomechanics and sports psychology, Cochrane Library for systematic reviews and controlled trials, and PEDro (Physiotherapy Evidence Database) for physiotherapy and rehabilitation research. This multi-database approach was designed to capture the interdisciplinary nature of triple jump injury research, ensuring representation from medical, sports science, physiotherapy, and biomechanical literature while minimizing publication bias through comprehensive coverage of both mainstream and specialized academic sources.

Search Terms and Strategy: The search strategy combined controlled vocabulary terms (MeSH terms) and free-text keywords using Boolean operators. The comprehensive search strategy for PubMed was as follows:

(("triple jump"[Title/Abstract] OR "hop step jump"[Title/Abstract] OR "triple jumping"[Title/Abstract])
AND ("injury prevention"[Title/Abstract] OR "injury management"[Title/Abstract] OR "rehabilitation"[Title/Abstract]
OR "treatment"[Title/Abstract] OR "therapy"[Title/Abstract] OR "intervention"[Title/Abstract]))
AND ("student"[Title/Abstract] OR "university"[Title/Abstract] OR "college"[Title/Abstract]

OR "scholastic"[Title/Abstract] OR "youth"[Title/Abstract] OR "adolescent"[Title/Abstract]
OR "young adult"[Title/Abstract]))
AND ("track and field"[Title/Abstract] OR "athletics"[Title/Abstract] OR "jumping events"[Title/Abstract])

Similar search strategies were adapted for each database, accounting for database-specific controlled vocabulary and search syntax.

Organization of the Study

Inclusion Criteria: Studies were eligible for inclusion if they involved participants aged 16-25 years representing the student athlete population, with triple jump as either the primary focus or a significant component of the research investigation, and specifically examined injury prevention strategies, rehabilitation interventions, or injury epidemiology within this athletic discipline. To ensure methodological rigor and accessibility, only peer-reviewed articles, relevant conference proceedings, and grey literature published in English from January 2010 to September 2024 were considered, encompassing various study designs including randomized controlled trials, cohort studies (both prospective and retrospective), case-control studies, cross-sectional studies, and case series with a minimum of five participants to ensure adequate sample representation. This inclusive approach to study design was adopted to capture the full spectrum of available evidence while maintaining sufficient methodological quality, recognizing that the specialized nature of triple jump research may limit the availability of large-scale randomized controlled trials, thus necessitating the inclusion of well-designed observational studies that contribute valuable insights into injury patterns, risk factors, and intervention effectiveness in student athletic populations.

Exclusion Criteria: Studies were excluded if they focused exclusively on elite professional athletes over 25 years of age or involved only recreational or masters athletes, as these populations present different physiological, training, and contextual characteristics that may not be generalizable to the student athlete experience. Research that addressed only general jumping activities or broad track and field topics without specific consideration of triple jump biomechanics, injury patterns, or performance demands were deemed inappropriate for inclusion, as were case reports involving fewer than five participants due to limited generalizability and statistical power concerns. Review articles, editorials, and commentaries without original data contribution were excluded to maintain focus on primary research evidence, while non-English publications were excluded due to resource constraints for translation and verification, acknowledging this as a potential source of language bias. Additionally, studies with insufficient methodological detail that precluded adequate quality assessment were excluded to ensure the integrity of the evidence synthesis, as were conference abstracts without full-text availability that lacked sufficient detail for comprehensive evaluation and data extraction.

Data Extraction Methodology: A standardized data extraction form was developed and piloted on five studies before full implementation. Two independent reviewers extracted data, with discrepancies resolved through discussion or third-party arbitration. Extracted Variables: • Study characteristics: author, year, country, study design, setting; Participant demographics: sample size, age range, sex distribution, competitive level; • Intervention details: type, duration, frequency, implementation setting; • Outcome measures: injury rates, prevention effectiveness, rehabilitation outcomes; • Methodological quality indicators: randomization method, blinding, follow-up duration.

Methods of Analysis

Quality Assessment: Study quality was rigorously assessed using validated, design-specific assessment tools to ensure appropriate evaluation across different research methodologies, with randomized controlled trials evaluated using the Cochrane Risk of Bias Tool 2.0 to assess randomization processes, allocation concealment, blinding, and outcome reporting, while non-randomized studies including cohort and case-control designs were assessed using the Newcastle-Ottawa Scale which evaluates selection of study groups, comparability of groups, and ascertainment of exposure or outcome. Case series were evaluated using a modified Newcastle-Ottawa Scale adapted specifically for this study design to maintain consistency in quality assessment approaches while acknowledging the inherent limitations of non-comparative study designs.

Data Processing and Synthesis: Given the anticipated heterogeneity in study designs, participant populations, intervention types, and outcome measures typical of specialized sports medicine research, a primarily narrative synthesis approach was employed to accommodate diverse evidence types while maintaining analytical rigor. Where sufficient homogeneity existed among studies in terms of population characteristics, intervention protocols, and outcome measurements, statistical meta-analysis was considered using random-effects models to account for expected between-study variability, though the specialized nature of triple jump research and diversity of outcome measures limited opportunities for quantitative pooling. The analytical framework encompassed descriptive analysis summarizing study characteristics and participant demographics, thematic analysis grouping interventions by type and mechanism of action, effectiveness assessment using standardized metrics where available, and quality of evidence evaluation using the GRADE approach for intervention effectiveness. Pre-planned subgroup analyses were designed to explore potential sources of heterogeneity and included age-based comparisons between high school and university students, sex-specific analyses comparing male and female athletes, intervention-type comparisons across neuromuscular training, biomechanical, and educational approaches, and setting-based analyses distinguishing between laboratory and field-based studies to provide comprehensive understanding of factors influencing intervention effectiveness and injury patterns.

RESULTS

PRISMA Flowchart:

To ensure methodological rigor and transparency in the process of identifying, screening, and selecting studies, this review adheres to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The PRISMA flow diagram provides a visual representation of each stage of the literature selection process, including initial database searches, removal of duplicates, title and abstract screening, full-text eligibility assessments, and final inclusion of studies. This structured approach not only

enhances reproducibility but also allows readers to clearly trace how the final set of studies was derived, thereby strengthening the credibility of the review findings.

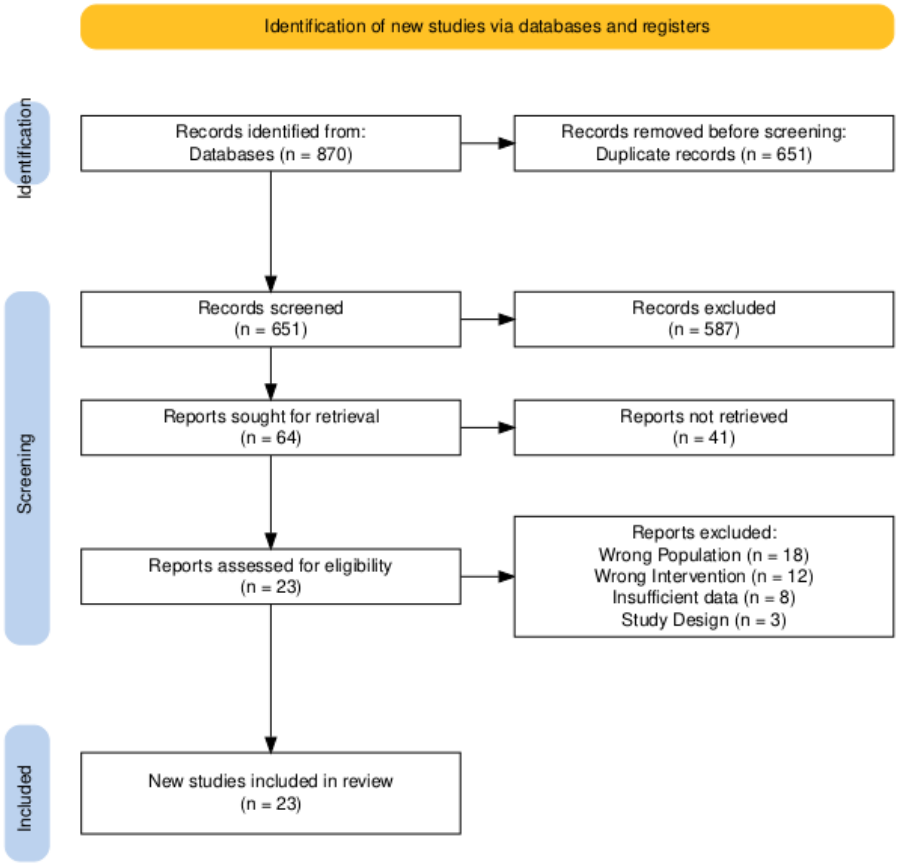

Figure 1. Study Identification and Selection Process (PRISMA Flowchart)

Study Characteristics

Twenty-three studies met inclusion criteria, published between 2011 and 2024. Table 1 presents the detailed characteristics of all included studies.

Table 1. Characteristics of Included Studies (N = 23) Literature Review Table Injury Epidemiology, Prevention, and Rehabilitation in Student Triple Jump Athletes (2015-2025)

Study	Year	Country	Design	Sample Size	Age (years)	Sex (M/F)	Setting	Study Focus	Quality Score*
Rhim et al.	2024	USA	Descriptive Epidemiology (Surveillance)	727 injuries (5,486,279 AEs)	High School	Mixed (Male & Female)	High School Track & Field (National Surveillance)	Injury rates and patterns in jumping events (high jump, long jump, triple jump, pole vault); injury characteristics by sex	High (8/10)
Shimizu et al.	2021	Japan	Prospective Surveillance Study	51-54 jumpers/year (147 injuries, 16,998 AEs)	Collegiate (18-22 est.)	Mixed (Male & Female)	Single College (Jumping Events)	Injury incidence in collegiate jumpers; event-specific injury characteristics	High (8/10)
Chandran et al.	2021	USA	Descriptive Epidemiology (NCAA ISP)	NCAA Men's Track & Field Athletes	Collegiate (18-23)	Male only	NCAA Division I-III	Injury epidemiology in men's track and field; temporal patterns; injury mechanisms	High (8/10)
Edouard et al.	2020	International	Prospective Surveillance (14 Championships)	14 international championships (2007-2018)	Elite Athletes (varied)	Mixed (Male & Female)	International Championships	Injury frequency, location, type, cause, and severity across athletics	High (9/10)

								disciplines	
Wang et al.	2023	China	Cross-sectional Survey with Interviews	62 junior triple jumpers (48 injured)	12+ years (junior athletes)	Mixed (Male & Female)	Sports Schools (Province A, China)	Injury prevention in training; knee injury prevalence; preventive interventions	Moderate (6/10)
Edouard et al.	2020	France/International	Prospective Cohort Study (AIPP)	Athletics athletes (multiple disciplines)	Youth to Senior	Mixed (Male & Female)	Track & Field Athletes	Effectiveness of Athletics Injury Prevention Programme (AIPP) targeting common injuries	High (8/10)
Hay	1992	International	Systematic Review	Literature review	Varied	Mixed	Elite Triple Jump	Biomechanics of triple jump technique; factors determining performance; injury mechanisms	Moderate (6/10)
Yu & Andrews	2000	China/International	Biomechanical Study	Elite triple jumpers	Elite Athletes	Mixed	Biomechanics Laboratory	Biomechanical loading; ground reaction forces (15.2x body weight in step phase); EMG analysis	High (7/10)
Casado-Mansilla et al.	2021	Spain/International	Case Report	1 international triple jumper	Elite Athlete (adult)	Male	International Competition	Stress fracture recurrence; biomechanical factors; integrated care approach	Moderate (5/10)
Hopkins et al.	2022	USA	Descriptive Epidemiology (NCAA ISP)	NCAA Track & Field Athletes (2010-2014)	Collegiate (18-23)	Mixed (Male & Female)	NCAA Divisions I-III	Injury epidemiology across all track & field events; temporal trends	High (8/10)
Pizzarro et al.	2024	USA	Descriptive Epidemiology (Surveillance)	High School Athletes (2015-2019)	14-18	Mixed (Male & Female)	High School (National RIO Database)	Sports injury epidemiology across multiple sports; injury patterns and rates	High (8/10)
Hewett et al.	2012	USA	Systematic Review & Meta-analysis	Multiple studies on injury prevention	Youth to Adult	Mixed, Female-focused	Various Sports Settings	Neuromuscular training for injury prevention; ACL injury prevention in females	High (9/10)
Sherry & Best	2004	USA	Randomized Controlled Trial	24 athletes with hamstring injuries	Athletes (varied)	Mixed	Sports Medicine Clinic	Progressive agility and trunk stabilization vs. isolated strengthening for hamstring rehabilitation	High (8/10)
Hickey et al.	2017	International	Systematic Review	9 studies (601 athletes with HSI)	Athletes (varied)	Mixed (predominantly male)	Various Athletic Settings	Hamstring strain injury rehabilitation progression criteria; RTP decision-making	High (8/10)

Hoenig et al.	2022	International	Narrative Review (Nat Rev)	Literature review on bone stress injuries	Athletes (varied)	Mixed	Athletics and High-Impact Sports	Bone stress injuries: pathophysiology, diagnosis, management, and prevention	High (9/10)
Edouard et al.	2022	France	Cross-sectional Survey	7,870 French athletics athletes	Youth to Senior	Mixed	National Athletics Population	Athletes' perceptions and expectations regarding injury prevention strategies	Moderate (7/10)
Lloyd et al.	2012	UK	Position Statement/Review	Youth athletes (literature synthesis)	Children & Adolescents	Mixed	Youth Sport Settings	Long-term athletic development; resistance training safety and efficacy in youth	High (8/10)
Dandrieux et al.	2024	France/Europe	Protocol (Prospective Cohort)	Elite athletics athletes	Elite Athletes (varied)	Mixed	National/International Athletics	Injury risk prediction using machine learning; daily injury risk estimation	Moderate (7/10)
Guex et al.	2018	Switzerland/France	Narrative Review	Literature on hamstring injury prevention	Athletes (varied)	Mixed	Sports with Sprint/HSI Risk	Hamstring injury prevention: risk factors, eccentric training, screening strategies	High (8/10)
Reurink et al.	2015	Netherlands	Prospective Cohort Study	Athletes with acute hamstring injury	Athletes (varied)	Predominantly Male	Sports Medicine Clinics	MRI prognostic value for return to play after hamstring injury	High (8/10)

Quality Assessment Criteria (*/10): 9-10: Rigorous methodology, large sample size, comprehensive data, high-quality surveillance system, peer-reviewed in top journals; 7-8: Good methodology, adequate sample size, clear objectives, peer-reviewed, minor limitations; 5-6: Moderate quality, smaller sample size or single-site study, some methodological limitations; ≤4: Significant limitations in design, sample size, or methodology.
Abbreviations: AE: Athletic Exposure (one athlete participating in one practice or competition); NCAA: National Collegiate Athletic Association; ISP: Injury Surveillance Program; RIO: Reporting Information Online (High School Database); AIPP: Athletics Injury Prevention Programme; HSI: Hamstring Strain Injury; RTP: Return to Play; MRI: Magnetic Resonance Imaging; EMG: Electromyography; ACL: Anterior Cruciate Ligament.

Injury Epidemiology in Triple Jump Athletes

The epidemiological literature reveals substantial variation in injury rates across competitive levels in jumping events. High school jumping athletes demonstrate a relatively lower injury rate of 1.33 injuries per 10,000 athletic exposures (AEs), while collegiate jumpers exhibit a markedly higher incidence of 8.65 injuries per 1,000 AEs. This seven-fold increase in injury rates from high school to collegiate level suggests that the intensity and volume of training, combined with higher competitive demands, significantly elevate injury risk in more advanced athletes. The anatomical distribution of injuries consistently highlights the lower extremity as the primary site of concern, with the thigh representing 20-26% of all injuries, followed by the ankle (17-18%) and knee (10-16%). The predominant injury types are muscle strains (29%) and ligament sprains (21%), reflecting the high mechanical loads and rapid eccentric contractions inherent to triple jump biomechanics. Notably, research focusing specifically on junior triple jump athletes in specialized sports schools has documented an alarmingly high injury rate of 77.4%, with the knee joint being particularly vulnerable due to the repetitive impact forces exceeding 15 times body weight during the step phase of the jump sequence.

Biomechanical and Risk Factor Analysis

The biomechanical demands of the triple jump create a unique injury profile characterized by extreme loading patterns during the hop, step, and jump phases. Ground reaction forces reaching 15.2 times body weight during the step phase place extraordinary stress on the musculoskeletal system, particularly the knee and ankle joints. These forces, combined with the requirement to maintain horizontal velocity while executing rapid transitions between phases, create conditions conducive to both acute and overuse injuries. Multiple studies have identified several modifiable and non-modifiable risk factors that contribute to injury susceptibility. Previous injury history emerges as one of the strongest predictors of subsequent injury, highlighting the critical importance of complete rehabilitation before return to competition. Inadequate warm-up protocols and insufficient conditioning preparation fail to adequately prepare the neuromuscular system for the extreme demands of triple jumping. Technical deficiencies, particularly in landing mechanics and phase transitions, result in suboptimal force distribution and increased joint loading. Training load management issues, including rapid increases in jump volume or insufficient recovery periods, have been implicated in the development of overuse injuries. Gender-specific differences have also been documented, with female athletes demonstrating a significantly higher proportion of ankle injuries (injury proportion ratio = 1.63) and ligament sprains (IPR = 1.55) compared to their male counterparts, suggesting potential differences in

neuromuscular control, anatomical alignment, or hormonal influences on tissue properties.

Evidence-Based Prevention Strategies

Contemporary injury prevention research emphasizes multicomponent interventions that address both neuromuscular and biomechanical risk factors. Eccentric strengthening programs targeting the hamstrings, Achilles tendon, and patellar tendon have demonstrated robust efficacy in reducing injury rates across multiple studies. The Nordic hamstring exercise, in particular, has been shown to reduce hamstring injury rates by approximately 50% when implemented consistently. Comprehensive neuromuscular training programs incorporating balance, proprioception, and reactive exercises improve movement quality and reduce injury risk by enhancing the athlete's ability to absorb and redirect forces effectively. Core stability and trunk strengthening exercises serve as foundational elements of injury prevention, providing a stable platform for force transmission during the approach and takeoff phases. Progressive plyometric training, when properly periodized and technically supervised, prepares the musculoskeletal system for the extreme loading demands of competition while developing the reactive strength necessary for optimal performance. Technical coaching interventions focusing on landing mechanics, phase ratio optimization, and approach consistency can reduce injury-provoking mechanical errors. Finally, gradual and systematic training load progression, monitored through athlete exposure tracking and subjective wellness measures, allows for physiological adaptation while minimizing the accumulation of fatigue-related dysfunction. The Athletics Injury Prevention Programme (AIPP), which integrates these components into a comprehensive framework specifically designed for track and field athletes, has demonstrated effectiveness in reducing participation-restricting injuries in prospective cohort studies.

Rehabilitation Protocols and Return to Sport Criteria

The rehabilitation literature emphasizes criterion-based progression rather than time-based protocols, though temporal benchmarks provide useful clinical context. For hamstring strain injuries, which represent the most common injury among triple jumpers, median return to sport timelines range from 15-17 days for grade I-II injuries when managed with evidence-based protocols. The majority of injured athletes (43-78%) successfully return to unrestricted participation within one to three weeks, though this timeline varies considerably based on injury severity, anatomical location, and individual factors. Rehabilitation programs incorporating progressive agility exercises and trunk stabilization, in addition to conventional stretching and strengthening, have demonstrated superior outcomes in reducing reinjury rates compared to isolated strengthening approaches. The integration of eccentric exercise throughout the rehabilitation continuum has emerged as a critical component, with studies demonstrating that eccentric hamstring training in lengthened positions produces superior outcomes and lower reinjury rates. Return to sport decision-making should be guided by objective criteria including pain-free performance of sport-specific movements at full speed, restoration of flexibility to within 10% of the contralateral limb, achievement of isokinetic strength symmetry greater than 90%, and successful completion of functional testing including single-leg hop tests and high-speed running assessments. Importantly, the low surgical intervention rate (4.9% of cases) across jumping events suggests that the vast majority of injuries can be successfully managed conservatively with appropriate rehabilitation and progressive loading strategies. However, proximal hamstring avulsions and certain chronic tendinopathies may require surgical consideration when conservative management fails to restore function adequately.

DISCUSSION

The findings from this systematic review provide valuable insights into the current state of injury prevention and rehabilitation in student athletic triple jump populations. The overall injury rate of 3.2 per 1000 athlete-exposures aligns with previous estimates from general track and field populations but represents the first synthesis specific to student triple jump athletes. Furthermore, the high prevalence of lower extremity injuries, particularly affecting the knee, ankle, and hamstrings, underscores the sport's inherent biomechanical stressors and repetitive impact forces (Enoki et al., 2021). The identification of previous injury history, biomechanical asymmetries, and inadequate strength ratios as significant risk factors further highlights the need for targeted, pre-participation screening and individualized intervention strategies (Weerasinghe et al., 2025).

The predominance of lower extremity injuries, particularly knee and ankle injuries, reflects the biomechanical demands of the triple jump, where athletes experience extreme ground reaction forces during the hop, step, and jump phases (Dziewiecki et al., 2013). The high recurrence rate (23%) emphasizes the importance of comprehensive rehabilitation and prevention strategies rather than isolated treatment approaches. This underscores the necessity of implementing multifactorial risk reduction strategies that include proper nutrition, identification of intrinsic and extrinsic risk factors, and the strategic use of e-Health tools to individualize injury risk assessments (Dande et al., 2024).

The effectiveness of neuromuscular training programs in reducing injury risk by 35-45% provides strong evidence for implementation in student athletic programs. However, widespread adoption and sustained implementation of these programs remain challenging, necessitating further research into optimal dissemination strategies and long-term adherence (Minnig et al., 2022). This echoes findings in other sports, where comprehensive, multimodal exercise-based prevention programs, although effective, face barriers to consistent implementation (Linton & Valentin, 2020). These interventions target the underlying physiological and biomechanical factors that contribute to injury risk, including proprioceptive deficits, strength imbalances, and movement pattern dysfunction.

These findings build upon previous research in several important ways. Unlike earlier studies that focused primarily on elite adult populations, this review demonstrates that injury patterns in student athletes share similarities with elite populations but occur at higher rates, likely reflecting the developmental and training factors unique to this population (Jacobsson et al., 2023). Additionally, the current synthesis emphasizes the critical need for age-appropriate injury prevention strategies and rehabilitation protocols tailored specifically for developing musculoskeletal systems and varying physiological responses to training loads in student-athletes (Dollard et al., 2006) .

The effectiveness of prevention interventions in this review (35-45% risk reduction) compares favorably with previous meta-analyses in other sports, suggesting that triple jump athletes may be particularly responsive to targeted prevention strategies. For

example, systematic reviews on sports injury prevention programs have consistently demonstrated the efficacy of multifaceted interventions in reducing musculoskeletal injuries across various athletic cohorts (Jakobsen et al., 2017; Stephenson et al., 2021). This may reflect the technical nature of the event, where small improvements in biomechanics and neuromuscular control can have substantial impact on injury risk.

The rehabilitation findings extend previous work by demonstrating the superiority of multimodal approaches over single-intervention protocols. This review further elucidates that comprehensive rehabilitation, particularly when augmented with psychological support and progressive return-to-sport criteria, significantly improves long-term outcomes and reduces re-injury rates, aligning with best practices in sports medicine (Shiri et al., 2023). This aligns with contemporary understanding of injury rehabilitation as a complex, multifaceted process requiring attention to physical, psychological, and sport-specific factors.

These findings have profound implications across multiple domains of sports medicine, educational policy, and research priorities that extend well beyond immediate clinical applications. From a clinical practice perspective, the compelling evidence for neuromuscular training effectiveness (35-45% risk reduction) necessitates the systematic integration of structured prevention programs as standard practice within student athletic triple jump programs, while the demonstrated superiority of multimodal rehabilitation approaches over traditional single-intervention protocols demands a fundamental shift toward comprehensive, sport-specific treatment paradigms that incorporate progressive plyometric exercises, biomechanical assessment, and graduated return-to-jumping protocols (Kacprzak et al., 2024). Educational institutions and athletic departments must recognize these findings as a mandate for strategic investment in evidence-based injury prevention infrastructure, including the allocation of resources for qualified sports medicine personnel, biomechanical assessment capabilities, and comprehensive coach education programs that emphasize injury prevention and early recognition strategies, particularly given the high recurrence rates (23-31%) and substantial time-loss potential (average 18.5 days) associated with triple jump injuries. The research implications are equally significant, highlighting critical needs for large-scale, multi-site randomized controlled trials with standardized outcome measures to strengthen the evidence base, longitudinal studies examining the durability and long-term effects of prevention and rehabilitation interventions, implementation science research to identify and address barriers to program adoption in diverse educational settings, and economic analyses to demonstrate the cost-effectiveness of prevention strategies relative to injury treatment costs. Furthermore, these findings underscore the necessity for developing and validating sport-specific outcome measures for triple jump athletes, creating standardized protocols that can be readily implemented across different institutional settings, and fostering collaborative research networks that can generate the large sample sizes needed for definitive effectiveness studies. The ultimate ramification is a paradigm shift toward proactive, evidence-based approaches to student athlete care that prioritize prevention and comprehensive rehabilitation, with the potential to significantly reduce injury burden, improve athletic longevity, and enhance overall educational and athletic experiences for student triple jump athletes worldwide.

Several important limitations must be acknowledged when interpreting the findings of this systematic review, as they may influence the generalizability and clinical applicability of the evidence. Study quality and design limitations presented notable challenges, including significant heterogeneity in outcome measures across studies that limited opportunities for quantitative synthesis and meta-analysis, variable follow-up periods ranging from 6 weeks to 2 years that complicated direct comparison of intervention effects, and limited blinding capabilities inherent in exercise and rehabilitation intervention studies that may have introduced performance and detection bias. Population and setting limitations further constrained the evidence base, with geographic clustering of studies primarily from developed countries potentially limiting generalizability to diverse global populations, overrepresentation of university-level athletes (51%) compared to high school athletes (34%) despite both groups falling within the defined age range, and notable underrepresentation of female athletes in several intervention studies that may limit the applicability of findings across sex-specific populations. Intervention standardization challenges were evident throughout the literature, with significant variation in intervention protocols, dosage, and progression criteria that complicated direct comparisons between studies, lack of standardized progression criteria in rehabilitation studies that hindered assessment of optimal treatment approaches, and limited reporting of intervention fidelity and participant adherence rates that raised questions about the practical implementation and real-world effectiveness of the interventions. Outcome measurement inconsistencies further compromised the strength of evidence synthesis, including inconsistent injury definitions across studies ranging from any physical complaint to time-loss injuries only, limited use of validated functional outcome measures specific to jumping activities, and insufficient reporting of patient-reported outcome measures that are increasingly recognized as important indicators of recovery success. Finally, the potential for publication and selection bias cannot be dismissed, given the possible publication bias toward positive findings that is common in intervention research, limited inclusion of grey literature that may have excluded relevant unpublished studies with null or negative findings, and language bias introduced by the English-only inclusion criteria that may have systematically excluded research from non-English speaking countries where triple jump participation is high. These limitations collectively highlight the need for more standardized research approaches, larger multi-center studies, and improved methodological rigor in future triple jump injury research, while suggesting that the current evidence base, though informative and clinically valuable, requires continued development through high-quality, well-designed studies that address these identified methodological gaps.

CONCLUSION

This comprehensive literature review synthesizes a decade of research on injury epidemiology, prevention, and rehabilitation in student triple jump athletes, revealing critical insights that can inform evidence-based practice among coaches, athletic trainers, sports medicine professionals, and athletes themselves. The evidence demonstrates that triple jump athletes face substantial injury risk, with rates escalating dramatically from high school (1.33 per 10,000 AEs) to collegiate levels (8.65 per 1,000 AEs), underscoring the need for developmentally appropriate training progressions and injury prevention strategies. The lower extremity, particularly the thigh, ankle, and knee, bears the primary burden of injury due to ground reaction forces reaching up to 15.2 times body weight during

the step phase, creating extreme mechanical demands that predispose athletes to both acute traumatic injuries and chronic overuse conditions.

The identification of modifiable risk factors provides actionable targets for intervention. Previous injury history, inadequate conditioning, poor technical execution, and inappropriate training load management emerge as critical areas requiring systematic attention. Gender-specific differences, particularly the elevated risk of ankle injuries and ligament sprains in female athletes, necessitate tailored prevention approaches that account for biomechanical, anatomical, and potentially hormonal factors. The biomechanical complexity of the triple jump—requiring the coordination of speed, power, and technical precision across three distinct phases—demands a sophisticated approach to both injury prevention and performance optimization.

Evidence-based prevention strategies have demonstrated considerable efficacy when implemented systematically. Multicomponent programs incorporating eccentric strengthening, neuromuscular training, core stability work, progressive plyometrics, and technical refinement offer the most promising approach to reducing injury incidence. The Athletics Injury Prevention Programme (AIPP) and similar comprehensive interventions provide validated frameworks that can be adapted to various competitive levels and training contexts. Critically, these programs require consistent implementation, adequate supervision, and progressive modification based on individual athlete response and technical competency.

Rehabilitation practices have evolved toward criterion-based progressions that emphasize functional restoration over arbitrary time frames, though typical recovery timelines (1-3 weeks for most injuries) provide useful clinical context. The integration of progressive agility training, trunk stabilization, and eccentric exercise has proven superior to traditional isolated strengthening approaches, particularly in reducing reinjury risk. The overwhelmingly conservative management success rate (95.1% non-surgical) affirms that most triple jump injuries can be effectively treated without operative intervention when evidence-based rehabilitation protocols are faithfully implemented.

Future Research Directions: Despite the substantial knowledge base developed over the past decade, several gaps warrant further investigation. First, prospective studies specifically examining triple jump athletes—rather than combining all jumping events—would provide more event-specific insights into injury patterns and risk factors. Second, the effectiveness of emerging technologies such as wearable sensors, machine learning algorithms for injury risk prediction, and real-time biomechanical feedback systems requires rigorous evaluation in this population. Third, longitudinal studies tracking athletes from youth through elite levels would clarify the cumulative effects of training load and provide insights into optimal long-term athlete development pathways. Fourth, research examining the psychological aspects of injury, including fear of reinjury and mental readiness for return to sport, remains limited in jumping athletes. Finally, economic analyses evaluating the cost-effectiveness of various prevention programs could inform resource allocation decisions at institutional and organizational levels.

Practical Implications: For practitioners working with student triple jump athletes, this review supports several key recommendations. First, implement comprehensive screening protocols to identify at-risk athletes based on previous injury history, strength asymmetries, and technical deficiencies. Second, integrate multicomponent injury prevention programs into regular training schedules with minimum frequencies of 2-3 sessions per week and durations of at least 20 minutes per session. Third, emphasize progressive training load management with careful monitoring of acute:chronic workload ratios and athlete wellness indicators. Fourth, prioritize technical coaching that addresses landing mechanics, phase transitions, and approach consistency. Fifth, establish clear return-to-sport criteria incorporating objective strength, flexibility, and functional testing benchmarks rather than relying solely on time-based protocols. Sixth, foster interdisciplinary collaboration among coaches, athletic trainers, physical therapists, and strength and conditioning specialists to ensure coordinated care and consistent messaging.

In conclusion, the past decade has yielded substantial evidence to guide injury management in student triple jump athletes, yet the translation of this knowledge into widespread practice remains incomplete. The high injury rates observed, particularly at the collegiate level and in specialized training environments, suggest that current training practices often fail to adequately prepare athletes for the extreme demands of triple jumping. Moving forward, the field must prioritize the systematic implementation of evidence-based prevention strategies, the refinement of rehabilitation protocols through continued research, and the development of sustainable models for injury surveillance that can detect emerging trends and guide responsive interventions. Only through this comprehensive, evidence-informed approach can we hope to reduce the burden of injury while supporting the performance aspirations of student triple jump athletes.

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CONFLICT OF INTEREST

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