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Comprehensive Injury Prevention Strategies in Gymnastics: A Systematic Review of Biomechanical and Training-Related Risk Factors

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Hafiz Yazid Lubis[1abcde], Patsy Corwin[2abc], Masoud Kharatzadeh[3cd], Phoebe Kessler[4ad]

[1]Sekolah Tinggi Olahraga dan kesehatan Bina Guna, Indonesia.
[2]Anchorage Gymnastics Association, United States.
[3]Islamic Azad University, Iran.
[4]Goethe University Frankfurt, Germany.

ABSTRACT

The purpose of the study. To comprehensively analyze gymnastics injury prevention research, evaluate existing safety protocols, and identify best practices for reducing injury risks in middle school and competitive gymnastics programs through a systematic review of recent literature.

Materials and methods. A systematic literature review was conducted following the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) methodology. The study examined peer-reviewed articles published between 2012 and 2024, focusing on human participants and injury prevention in gymnastics. A comprehensive electronic search was performed across multiple academic databases, utilizing search terms including "gymnastics injury prevention," "gymnastics safety," and "biomechanical risk factors." The research employed thematic analysis and qualitative comparative techniques to synthesize findings from 19 selected studies.

Results. The review revealed alarming injury statistics, with 91.4% of gymnasts experiencing at least one injury per season and 480.7 musculoskeletal injuries per 100,000 person-years. Key findings highlighted the complex interplay of factors contributing to gymnastics injuries. These included specific biomechanical techniques affecting joint loading, correlation between training load and injury risk, impact of age and physical attributes on injury susceptibility, and significant variations in injury rates between national and non-national team gymnasts.

Conclusions. The systematic review underscores the critical need for comprehensive, holistic approaches to gymnastics safety. Recommendations include developing standardized injury prevention protocols, implementing regular biomechanical assessments, enhancing coach education, and creating individualized training strategies that consider athletes' unique physiological characteristics and technical capabilities.

Keywords: Gymnastics; injury prevention; biomechanical risk factors; sports safety; training load; athlete protection.

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EDITED BY
Dr. Herli Pardilla, M.Pd
Sekolah Tinggi Olahraga & Kesehatan Bina Guna, Indonesia.

Prof. Mohammed Zerf, Ph.D
Université de Mostaganem Abdelhamid ibn Badis, Algeria

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INTRODUCTION

Gymnastics is an inherently risky sport due to its complex movements, substantial landing impact forces, and intensive training regimens that gymnasts must undertake (Griffiths et al., 2006; Kalkhoven, 2024). The sport's dynamic and acrobatic nature, coupled with the significant physical stresses placed on the body, contribute to an elevated susceptibility to various musculoskeletal injuries, including sprains, strains, fractures, and overuse conditions (Griffiths et al., 2006). Recognising and mitigating these inherent risks is essential for cultivating a safe and sustainable training environment for gymnasts of all skill levels.

Implementing comprehensive injury prevention strategies is crucial for cultivating a safe, sustainable, and high-performing training environment that supports the well-being and long-term success of gymnasts at all levels of the sport (Williams et al., 2023). These strategies should adopt a holistic approach, addressing the multifaceted biomechanical, training-related, and intrinsic risk factors that contribute to the high incidence of injuries observed in gymnastics (Westermann et al., 2023; Chandra et al., 2021). By proactively mitigating these risks through evidence-based interventions, coaches, medical staff, and sports governing bodies can foster a training

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Corresponding Author: Hafiz Yazid Lubis, e-mail: yazid.fiz@gmail.com

culture that prioritises athlete safety and enables gymnasts to thrive physically and emotionally throughout their careers.

This systematic review provides a comprehensive examination of the biomechanical and training-related risk factors associated with gymnastics injuries, offering a thorough overview of the current state of knowledge in this field. It investigates the complex interplay of factors contributing to the high incidence of injuries observed in gymnastics, including the unique physical demands, dynamic movements, and repetitive training regimens that characterise the sport (Tisano et al., 2022). By analysing the existing research evidence, this review aims to identify consistent patterns and trends that can inform the development of effective, evidence-based injury prevention strategies tailored to the specific needs and challenges faced by gymnasts.

The current research has identified several key factors that contribute to the high prevalence of injuries in gymnastics. These include inadequate physical conditioning, such as poor muscle strength, flexibility, and proprioception (Emery, 2024; Azari & Zulkifli, 2020), improper landing techniques leading to excessive impact forces transmitted through the musculoskeletal system (Caine & Nassar, 2005) overuse injuries resulting from repetitive, high-intensity training regimens that gymnasts must undertake (Campbell et al., 2019), and insufficient warm-up protocols that may fail to properly prepare the body for the sport's rigorous physical demands (Serafim et al., 2023). Comprehending and addressing these multifaceted biomechanical and training-related risk factors is essential for developing comprehensive injury prevention strategies in gymnastics.

Nonetheless, a comprehensive synthesis of research is essential to identify consistent patterns that can guide evidence-based injury prevention programmes. This review seeks to fill this gap by systematically analyzing studies to determine significant biomechanical and training-related risk factors contributing to gymnastics injuries. Through this analysis, the review aims to establish a solid foundation for effective injury mitigation strategies tailored to the sport's unique demands and risks. The primary goal of this review is to provide an extensive overview of current knowledge regarding injury prevention in gymnastics. It aims to identify prevalent biomechanical risk factors, assess the influence of training-related factors on injury risk, and synthesize evidence for effective injury prevention interventions. By achieving these goals, this review aspires to aid in the creation of evidence-based guidelines and practical strategies for reducing injury risk and enhancing athlete well-being in gymnastics.

MATERIALS AND METHODS

Materials for analysis

The systematic literature review was conducted following Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) a rigorous and transparent methodology to comprehensively analyze gymnastics injury prevention research. Inclusion criteria were carefully established to ensure the selection of high-quality, relevant studies, encompassing peer-reviewed articles published between 2012 and 2025, focusing on human participants and injury prevention in gymnastics, with full-text articles available in English. Conversely, exclusion criteria eliminated case reports, studies without clear methodology, non-peer-reviewed publications, and articles not directly related to injury prevention. A comprehensive electronic search was executed across multiple academic including Scopus. The search strategy employed a sophisticated combination of terms such as "gymnastics injury prevention," "gymnastics safety," "biomechanical risk factors," "training load management," and "gymnast injury mechanisms." This exhaustive search was conducted from June 2024 to August 2024.

Organization of the study

A rigorously standardized data extraction instrument was systematically formulated with the express purpose of obtaining an extensive and comprehensive array of information derived from the meticulously selected studies that were pertinent to the research inquiry. This particular form was designed to meticulously gather detailed and nuanced data across a multitude of dimensions, which encompassed critical aspects such as the characteristics of the studies themselves, the demographic and contextual information regarding the participants involved, the intricate methodological details employed, the salient findings of the research, and the recommendations that emerged from the analyses. The range of variables that were meticulously tracked included a diverse array of elements, spanning from the identities of the authors and the years in which the studies were published to the demographic profiles of the participants, the various research methodologies implemented, the specific techniques utilized for injury assessment, as well as the prevention strategies that were proposed based on the findings of the studies.

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Methods of Analysis

The data synthesis approach employed a comprehensive narrative synthesis complemented by qualitative analysis techniques. Thematic analysis was used to identify recurring themes, categorize injury prevention strategies, and compare methodological approaches across studies. A comparative analysis examined variations in injury rates, evaluated different prevention interventions, and assessed the consistency of findings. While a traditional meta-analysis was not feasible due to the heterogeneity of study designs, descriptive statistical techniques were utilized to calculate aggregate injury rates and identify consistent statistical trends.

Ethical considerations remained paramount throughout the review process. The methodology adhered to established ethical guidelines for research synthesis, ensuring transparent reporting, unbiased interpretation of findings, and proper attribution of original research. By employing this comprehensive and systematic approach, the review aimed to provide a robust and nuanced understanding of injury prevention strategies in gymnastics, synthesizing critical insights from multiple research perspectives.

The methodological rigor employed in the review was meticulously crafted with the intention of comprehensively addressing the intricate and multifarious landscape associated with gymnastics injury prevention, thereby acknowledging the inherently complex and multifaceted nature of ensuring athletic safety, which necessitates the implementation of integrated, evidence-based strategies

that are specifically designed to not only minimize the risk of injuries but also to optimize both the performance levels and overall well-being of athletes engaged in this demanding sport. The stages of the prism protocol can be seen in the image below:

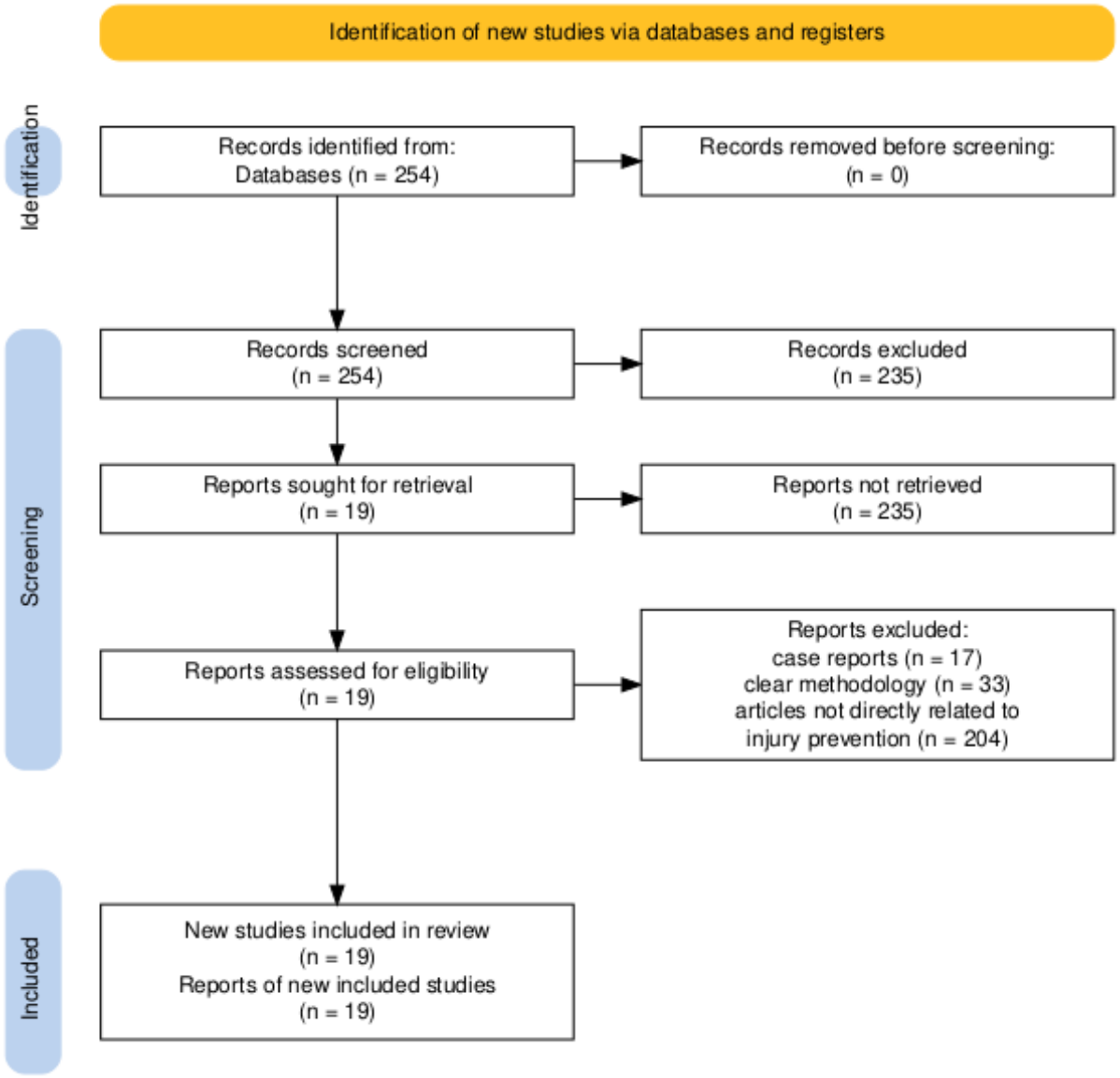

Figure 1. PRISMA flowchart of the article selection process

Interpretation:
The PRISMA flowchart illustrates the systematic process of selecting articles for review. Initially, 254 records were identified from databases, with none removed before screening. All 254 records underwent screening, during which 235 were excluded for not meeting the inclusion criteria. As a result, 19 reports were sought for retrieval, though the flowchart indicates that 235 reports were not retrieved, which seems inconsistent with the screening process.
Next, the 19 retrieved reports were assessed for eligibility. Several articles were excluded for specific reasons, including 17 case reports, 33 studies with clear methodology but not aligning with the research objectives, and 204 articles unrelated to injury prevention. Ultimately, 19 studies met all the criteria and were included in the final review.
In conclusion, this selection process demonstrates a structured and rigorous approach to identifying relevant studies. From the initial 254 records, only 19 were deemed suitable after thorough screening and eligibility assessment, ensuring that only the most relevant research on injury prevention was included.

RESULTS

	Authors	Methods-used	Dynamic-results	Recommendations reported
1	Pascal Édouard, Kathrin Steffen, Astrid Junge et al. 2017	The methods used for gymnastics injury prevention include: - Long-term injury surveillance monitoring during major championships and the competitive season. - Optimal medical follow-up with musculoskeletal screening and pre-participation physical examinations. - Optimized physical conditioning and mastery of techniques. - Improved preparation for competition addressing intensity skill difficulty performance anxiety and competitive stress. - Monitoring growth and the immature musculoskeletal system. - Strategies to prevent initial injuries and enhance healing and rehabilitation. - Focus on recovery nutritional aspects mental preparation education equipment and adherence to rules and the Code of Points .	The findings from [1] emphasize the need for ongoing injury surveillance optimal medical follow-up and comprehensive conditioning strategies to prevent injuries in artistic gymnastics.	- Continued injury surveillance during major championships and competitive seasons. - Long-term monitoring of injuries and optimal medical follow-up. - Implementation of musculoskeletal screening and pre-participation physical examinations. - Enhanced physical conditioning and mastery of techniques. - Improved preparation for competition regarding intensity, skill difficulty, and performance anxiety. - Awareness of the biomechanical stresses of gymnastics. - Monitoring growth and addressing the immature musculoskeletal system. - Strategies for preventing initial injuries and improving rehabilitation processes. - Focus on recovery, nutrition, mental preparation, education, and equipment standards.
2	Séréna Charpy, Pierre Billard, Pierre-Eddy Dandrieux et al. 2023	The reference [2] outlines the methods used in the study as follows: - Conducted a retrospective analysis of injury data over six seasons from 2014. - Collected injury data prospectively from gymnasts at the France Gymnastics National Centre. - Performed descriptive analyses including calculating 1-year injury prevalence.	The results from the study indicate that approximately 91.4% of gymnasts experienced at least one injury per season with an average of 2.6 injuries per gymnast highlighting the urgent need for enhanced injury prevention strategies in Women's Artistic Gymnastics [2].	- Implementing injury prevention strategies targeting growth-related injuries and specific joint pathologies. - Utilizing evidence from previous studies and expert insights to inform prevention measures. - Adapting training practices to accommodate the unique maturation needs of young athletes.
3	James A. Albright, Ozair Meghani, Nicholas J. Lemme et al. 2022	The reference [3] outlines the following methods used in the study: - Querying the National Electronic Injury Surveillance System (NEISS) for gymnastics-related injuries from 2013 to 2020. - Calculating incidence rates per 100000 person-years using NEISS data and national participation statistics. - Employing chi-square and column proportion z-testing for statistical analysis where applicable.	The results from the article [3] indicate that: - The incidence of gymnastics-related musculoskeletal injuries was 480.7 per 100000 person-years predominantly affecting children aged 6 to 15 years.	- Implementing age-appropriate training programs to reduce injury risk in younger gymnasts. - Encouraging gradual progression in skill difficulty to prevent acute injuries. - Utilizing effective injury prevention strategies from other sports to enhance gymnast safety during training and competition.

4	Daphne Ling, Mark D. Sleeper, Ellen Casey 2019	The reference [5] outlines methods used in injury prevention through the Gymnastics Functional Measurement Tool (GFMT) which includes: - Conducting a prospective cohort study with 100 female collegiate gymnasts. - Utilizing a series of 10 sport-specific tests to evaluate physical fitness. - Recording injuries by certified athletic trainers throughout the season. - Applying logistic regression modeling to analyze the relationship between test scores and injury development.	The results from the article [5] indicate that a higher vertical jump score is linked to a significant reduction in trunk injuries among collegiate female gymnasts.	- Implementing the Gymnastics Functional Measurement Tool (GFMT) to assess physical fitness and identify potential injury risks in female gymnasts. - Focusing on improving vertical jump performance to potentially reduce the incidence of trunk injuries.
5	Klaus Greier, Clemens Drenowatz, Johannes Mairoser 2022	The reference [6] outlines the methods used in a study on gymnastics injury prevention as follows: - Conducted an online survey among 30 national team gymnasts and 25 non-national team gymnasts over three years to gather injury data. - Calculated injury rates per 1000 hours of training and stratified injuries by severity body structure and localization. - Employed Mann Whitney U and Chi-square tests to analyze differences between the two groups of gymnasts.	The results from [6] indicate that: - A total of 64 injuries were reported yielding an injury rate of 0.4 per 1000 training hours with national team gymnasts sustaining significantly more injuries per person than non-national team gymnasts.	- Implementing training modifications to manage volume and intensity. - Enhancing conditioning programs to strengthen tendons and ligaments. - Utilizing safer gymnastics equipment to minimize injury risk.
6	Roman Farana, Timothy Exell, Gerda Strutzenberger et al.	The reference [7] outlines the methods used in the study as follows: - Seventeen young female gymnasts performed 30 trials of cartwheel and round-off skills using three different hand positions. - Kinematic and kinetic data were collected at high frequencies (240 Hz and 1200 Hz respectively). - Statistical analysis was conducted using one-way repeated measures ANOVA and effect size calculations.	The findings from [7] indicate that specific hand positions during cartwheel and round-off techniques significantly affect joint loading with parallel and reverse techniques increasing injury risk for the elbow and wrist compared to the T-shape technique.	Utilize the T-shape hand position during cartwheel and round-off techniques to reduce elbow and wrist joint loading.
7	Tejal Sarika Patel, Alex McGregor, Louise Fawcett et al. 2020	The reference [8] discusses methods used in the study which include: - Conducting focus groups with 44 coaches to explore their awareness and practices regarding growth maturation and training load in young gymnasts.	The findings from [8] highlight that coaches recognize the significance of growth-related injuries and the need for monitoring training loads to mitigate injury risks in young gymnasts.	- Educate coaches on monitoring growth and maturation. - Implement systematic training load assessments. - Collaborate with sports science and medicine practitioners to mitigate injury risks
8	Giacomo Farì, Francesco Fischetti, Alessandra Zonno et al. 2021	The reference [9] details the methods used in a study involving an online survey distributed to 79 professional gymnasts to collect data on demographics training practices and musculoskeletal pain prevalence.	The findings from [9] indicate that 82.3% of surveyed professional gymnasts experienced musculoskeletal pain with significant correlations to training duration age BMI and prolonged sitting highlighting the need for targeted injury prevention strategies.	- Implement training strategies to prevent musculoskeletal pain in gymnasts. - Address risk factors such as age, BMI, and prolonged sitting. - Enhance the overall quality of life for gymnasts by reducing pain-related limitations

9	Ally Ferber, David R. Howell, Corrine N. Seehusen et al. 2021	The reference [10] discusses methods used in a cross-sectional survey to assess pain interference among former female collegiate gymnasts focusing on their injury history and its impact on current pain levels. - Online questionnaire distributed via social media to 447 former female collegiate gymnasts. - Grouping of participants based on injury history requiring surgery during gymnastics career. - Utilization of the Patient-Reported Outcomes Measurement Information System (PROMIS) scale to measure pain interference.	The results from the article [10] indicate that: - Most retired female collegiate gymnasts reported having sustained a surgery-requiring injury with an earlier start in gymnastics linked to a higher likelihood of such injuries but no significant differences in current pain interference were found between those who had surgery and those who did not.	- Incorporating weightlifting into training regimens to enhance injury prevention. - Recognizing the increased injury risk associated with starting gymnastics at a younger age.
10	Paul Saluan, Joseph F. Styron, J. Freeland Ackley et al. 2015	The methods used in the study by Saluan et al. [11] include: - Retrospective evaluation of injuries in precollegiate female gymnasts over a 21-year period. - Stratification of gymnasts into four competition levels based on training hours. - Collection of data on age body part injured injury laterality and diagnosis for each gymnast.	The results from the study by Saluan et al. [11] indicate that over a 21-year period 3681 injuries were documented with an overall injury incidence of 2.155 per 1000 exposure hours and a significant prevalence of lower extremity injuries (60.9%) compared to upper extremities (22.6%).	- Counsel gymnasts and their parents about injury risks before participation. - Monitor training hours to manage injury incidence effectively. - Focus on lower extremity injury prevention strategies, given their higher occurrence.
11	Paloma Trucharte Martínez, Ignacio Grande 2021	The methods used in the study by MartÃnez and Grande [12] include: - Assessment of internal training load through subjective perception of effort (PSE) using the sRPE variable. - Daily recording of PSE for ten female gymnasts over four weeks categorized into High Level Gymnasts (HLG) and Medium Level Gymnasts (MLG). - Statistical analysis of RPE and sRPE values across different training contents to evaluate injury risk.	The results from the study in [12] indicate that: - High Level Gymnasts (HLG) exhibited significantly higher ratings of perceived exertion (RPE) and session RPE (sRPE) compared to Medium Level Gymnasts (MLG) suggesting a greater training load and associated injury risk.	- Monitor training load using subjective perception of effort (sRPE) to assess injury risk. - Adjust training volume and intensity based on gymnast's competitive level to mitigate injury risk. - Implement strategies to manage workload, training monotony, and stress to reduce injury occurrences.
12	Dartagnan Guedes 2023	The methods used in the study [13] included: - A retrospective survey of 236 young rhythmic gymnastics athletes aged 9 to 17 years. - Administration of a structured questionnaire to gather data on training history and injuries over the past 12 months.	The results from the article [13] indicate that: - The prevalence of self-reported injuries among young rhythmic gymnasts was 62.3% with lower extremities most affected primarily by tendinitis and sprains.	- Implement targeted injury-risk mitigation strategies for young rhythmic gymnastics athletes. - Monitor training volume and experience to reduce injury incidence. - Maintain awareness of symptoms related to low back pain and hyperextension to prevent spondylolysis.
13	Roman Farana, Daniel Jandačka, Jaroslav Uchytil et al. 2016	The reference [14] outlines the following methods used in the study: - Seven international-level female gymnasts performed 10 trials of round-off skills with different hand positions. - A 3D motion analysis system and force plates were utilized to collect kinematic and kinetic data. - A two-way repeated measure ANOVA was employed to assess differences in parameters between the techniques.	The findings from [14] indicate that the T-shape hand position during round-off techniques may reduce mechanical loads on the wrist joint thereby potentially lowering the risk of injury.	- Utilize the T-shape hand position during round-off techniques to reduce axial compression loads on the wrist joint. - Focus on technique selection to minimize biomechanical injury risk factors associated with peak impact forces at the wrist.
14	Boštjan Jakše, Barbara Jakše, Ivan Čuk et al. 2021	The reference [16] outlines the following methods used in the study: - Assessment of body composition via dual-energy X-ray absorptiometry. - Evaluation of training volume and pattern through an author-developed questionnaire. - Analysis of injury status using a modified questionnaire on overuse injuries.	The findings from [16] indicate that high-performance female gymnasts experience significant injury rates particularly in the ankles and low back necessitating targeted injury prevention strategies integrated into training and dietary practices.	- Implementing yearly screening for injury status to inform training adjustments. - Incorporating injury prevention measures into overall physical preparedness and training strategies.

15	Ross Armstrong, Nicola Relph 2021	The reference [17] outlines the following methods used in the systematic literature review: - Conducted an electronic search across seven databases from inception until March 2021. - Employed specific search terms related to gymnastics and injury screening. - Assessed studies using a 20-point scoring tool for methodological quality.	The results from the article [17] indicate that while some screening tools show potential in predicting injuries in gymnasts methodological inconsistencies and a lack of comprehensive injury definitions limit their clinical applicability.	- Implement screening tools to assess height, mass, and other physical attributes to identify gymnasts at risk of injury.
16	Natália Batista Albuquerque Goulart, Morgana Lunardi, Jennifer Faraon WALTRICK et al. 2016	The reference [19] outlines methods used for injury prevention in gymnastics as follows: - Utilized a morbidity questionnaire to gather data on injury characteristics and circumstances. - Analyzed injury circumstances related to gymnastic apparatus and training overload. - Evaluated anatomical sites affected and biological tissues involved in injuries. - Employed descriptive statistics to assess injury frequency and return-to-training conditions.	The findings from [19] indicate that training overload and specific apparatus usage are significant contributors to injury prevalence in elite male artistic gymnasts with ankle hands/fingers and shoulder injuries being most common.	- Emphasizing controlled landing techniques to manage ground reaction forces. - Incorporating exercises targeting lower limb strength and stability. - Educating gymnasts on proper movement mechanics to reduce injury risk.
17	X. Grapton, Alexis Lion, Gérome C. Gauchard et al.	The reference [20] discusses methods for injury prevention in gymnastics by emphasizing the importance of respecting recovery periods prioritizing health and safety over performance and assessing the gymnast's capabilities to avoid unreasonable attempts.	The findings from [20] emphasize that neglecting recovery periods heightens injury risk and trainers must prioritize gymnast safety over competitive success while assessing their capabilities to prevent injuries.	The recommendations reported in Grapton et al. (2012) emphasize the importance of respecting recovery periods, prioritizing gymnast health over success, and trainers assessing gymnast capabilities to prevent unreasonable attempts.
18	Chen Jun 2023	The reference [21] outlines the following methods used for analyzing gymnastics injury prevention: - Selected male athletes from the National Gymnastics Team for research. - Completed three-dimensional motion trajectory analysis of the backflip landing. - Collected vertical ground reaction force (VGRF) and lower limb muscle electromyography (EMG) data post-landing. - Utilized system simulation software to model the human multi-body system and landing platform.	The reference [21] indicates that gymnasts perform over 200 landings per week significantly increasing their risk of lower limb injuries during backflips.	- Implementing targeted guidance based on biomechanical analysis to reduce lower limb joint load during landings. - Enhancing movement control to minimize injury risk associated with high-frequency landings in training. - Focusing on improving landing stability to support athletes in executing more complex movements safely.
19	Elizabeth Bradshaw, Patria A. Hume 2012	The methods used in the study [23] include: - Conducting a systematic review of 123 articles through electronic database searches using specific keywords related to gymnastics and biomechanics.	The findings from [23] indicate that targeted injury prevention strategies informed by biomechanical analyses can significantly reduce gymnastics injuries by identifying injury mechanisms and quantifying risk factors.	- Implement targeted injury prevention strategies informed by biomechanical analyses. - Identify mechanisms of injury specific to women's artistic gymnastics. - Quantify the effects of various injury risk factors to enhance safety measures.

DISCUSSION

The systematic review underscored the pivotal role of biomechanical analysis in elucidating the underlying mechanisms driving the high incidence of injuries in gymnastics. By examining factors such as joint loading, ground reaction forces, and movement patterns, researchers were able to identify the key contributors to the elevated injury rates observed in this sport ("Annals of the Rheumatic Diseases," 2024). This biomechanical insight was then leveraged to inform the development of targeted prevention strategies, which addressed specific risk factors through interventions like technique modifications, strength and stability training, and equipment adjustments (Emery & Pasanen, 2019). The emphasis on biomechanics reflects the importance of grounding injury prevention efforts in a robust understanding of the physical stresses and demands placed on gymnasts' bodies during their high-intensity, complex movements (Williams et al., 2023). This holistic, evidence-based approach is crucial for designing effective programmes to mitigate the substantial injury burden faced by these athletes (Serafim et al., 2023).

The reviewed literature consistently emphasized the critical role of training load management, encompassing volume, intensity, and recovery periods, as a key factor in mitigating injury risk in gymnastics (Claussen et al., 2024). Multiple studies underscored the importance of closely monitoring and optimising the training load imposed on gymnasts to address the heightened injury risk associated with high-frequency, high-intensity training regimens (Williams et al., 2023). Specifically, the findings indicated that neglecting adequate recovery time and prioritising performance over gymnast safety can significantly increase the likelihood of injury occurrence (Caine et al., 1989). Similarly, the data highlighted the necessity for coaches to assess gymnasts' capabilities and avoid imposing unreasonable training demands that exceed their physical capacity (The Physiological Demands of Youth Artistic Gymnastics, 2024). By integrating a holistic, evidence-based approach to training load management, injury prevention strategies can be tailored to support gymnasts in executing complex movements safely, thereby minimising the substantial injury burden faced by these athletes (Howe et al., 2024). The potential of screening tools to identify athletes at-risk was also discussed, though further validation is needed. Additionally, various injury prevention interventions, such as targeted exercises, technique modifications, and educational programmes, were suggested as potential avenues for mitigating injury risk (Camuncoli et al., 2022). However, further research employing standardized outcomes and rigorous designs is needed to strengthen the evidence base for effective injury prevention strategies in gymnastics.

Comprehensive biomechanical analyses are vital for elucidating injury aetiology and devising targeted prevention strategies (Ghezelbash et al., 2024), such as modifying techniques and training regimens based on assessments of movement patterns (Leite et al., 2023), ground reaction forces, and joint loading (Ghezelbash et al., 2024). Additionally, the management of training load, encompassing volume, intensity, and recovery periods, is a critical component (Casis & Martnez, 2012). Prioritising sufficient recovery time appears essential for mitigating injury risk. While screening tools exhibit promise for identifying susceptible athletes, further research is warranted to enhance their reliability and comprehensiveness (Jones et al., 2016). Finally, a range of injury prevention interventions, including tailored exercises, technique refinements, and education on proper movement mechanics, may contribute to reducing injury incidence (Hübscher et al., 2010).

This systematic review acknowledges the need for more robust and detailed evidence to draw definitive conclusions about effective injury prevention strategies in gymnastics. The limited information provided on study populations, outcome measures, and statistical analyses makes it challenging to fully assess the quality and effectiveness of the reported interventions. Additionally, the lack of specific citations hinders the ability to evaluate the methodological rigour of the included research. To address these limitations, future studies should adopt standardized outcome measures, employ rigorous study designs, and provide detailed reporting of their findings. This would facilitate more comprehensive systematic reviews and meta-analyses, ultimately strengthening the evidence base for developing impactful injury prevention programmes in the sport of gymnastics.

CONCLUSION

The systematic review of gymnastics injury prevention research unveils a critical understanding of the multifaceted nature of athlete safety. With an alarming 91.4% of gymnasts experiencing at least one injury per season and 480.7 musculoskeletal injuries per 100,000 person-years, the findings underscore the urgent need for comprehensive prevention strategies. Biomechanical insights from studies like Farana et al. (2018) demonstrate how precise technical interventions, such as specific hand positioning during movements, can significantly reduce injury risks. The research highlights the complex interplay between training load, physiological attributes, and injury susceptibility, emphasizing the importance of individualized, holistic approaches to athlete care. Key recommendations include developing age-specific training protocols, implementing systematic biomechanical assessments, and enhancing coach education on injury prevention. Despite limitations in existing research, particularly the focus on elite athletes and methodological variations, this review provides a crucial framework for understanding and mitigating injury risks. The ultimate goal remains clear: to create safer training environments that allow gymnasts to pursue their athletic potential while minimizing the risk of injury. By synthesizing diverse research perspectives, this systematic review offers evidence-based insights that can transform training approaches, athlete monitoring, and overall sports safety strategies in gymnastics.

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CONFLICT OF INTEREST

The investigators assert that their research and results are devoid of any conceivable conflicts of interest.

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Author information

Information about the authors/Author Biographies:

Author Information	
Hafiz Yazid Lubis (Author 1) Corresponding Authors	https://orcid.org/0009-0000-1177-8094 **Affiliation:** Sekolah Tinggi Olahraga dan Kesehatan Bina Guna, Indonesia **Address:** Alumunium Raya Street No.77, Medan City, North Sumatera, Indonesia **Disciplines:** Physical Education and Gymnastics Science **Skills And Expertise:** Physical Education **Authors' Contribution:** abcde **Contact e-Mail:** yazid.fiz@gmail.com
Patsy Corwin Author 2)	https://orcid.org/0009-0001-7084-1994 **Affiliation:** Anchorage Gymnastics Association **Address:** 525 W Potter Dr, Anchorage, AK 99518, United States. **Disciplines:** Sport Education **Skills And Expertise:** Sport Education **Authors' Contribution:** abc **Contact e-Mail:** patsy9dircorwin@outlook.com
Masoud Kharatzadeh (Author 3)	https://orcid.org/0000-0002-2330-1477 **Affiliation:** Islamic Azad University, Iran **Address:** Fereshtegaan International Branch, No 1, Iran Zamin Blvd, Khovardin St, Sanaat square, Shahrake-e-Gharb, Tehran, Iran. **Disciplines:** Sport Science Analysis **Skills And Expertise:** Small-sided games, High-Intensity interval training, training load, Monitoring, Performance **Authors' Contribution**: cd **Contact e-Mail:** masoud.kharatzadeh@gmail.com
Phoebe Kessler (Author 4)	https://orcid.org/0009-0004-9023-6443 **Affiliation:** Goethe University Frankfurt, Germany. **Address:** Theodor-W.-Adorno-Platz 1, 60629 Frankfurt am Main, Germany. **Disciplines:** Sport Science **Skills And Expertise:** Sport Science **Authors' Contribution**: ad **Contact e-Mail:** phoebevwake@outlook.com