

Risk factors and injury prevention in open-skill sports: A systematic review and bibliometric analysis with data visualization

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Abstract

Background and purpose. Prevention of injuries in athletes - representatives of open-skill sports should take into account the multifactorial nature of injury risks, and, accordingly, its prevention. Purpose: to identify and systematize the main areas of research on the risk of injury and their relationships in open-skill sports based on the results of bibliometric analysis with data visualization and, based on data systematization, to determine the leading factors of injury risks and means of injury prevention. **Material and methods.** The search for sources was carried out according to the recommendations of PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) in the scientific and metric databases Scopus, Web of Science, PubMed. The following keywords were used for the primary search: "Injuries" AND "sport" AND "factor" AND "regression". Bibliometric analysis and visualization (keyword co-occurrence, geographical distribution, co-authorship, and citation networks) were performed using VOSviewer software. **Results.** In studies, along with traditional injury risk factors (overstrain, fatigue, the presence of previous injuries and lack of special coordination abilities), by using nonlinear multivariate regression analysis, the authors determine the high reliability of psychological injury risk factors, as well as anthropometric indicators (length and body weight) and age and gender of athletes. The majority of studies are aimed at identifying risks of the anterior cruciate ligament. Risk factors for the anterior cruciate ligament include previous injury, young age, poor coordination skills, psychological factors (somatic anxiety, mental anxiety, susceptibility to stress and irritability), activity level, functional performance, muscle strength, jumping performance. Hallux valgus as a factor in injury remains a debatable issue. **Conclusion.** A positive effect of neuromuscular training (visualization of muscle work, balance exercises, coordination development, slow-paced exercises, etc.) on reducing the risk of injury, especially in women, was found. It was determined that the nonlinear multifactorial regression method is more effective in determining risk factors for injury compared to the Korch univariate linear regression method.

Keywords: injuries, risk, factors, sport, neuromuscular training

Introduction

Prevention of injuries in open-skill sports is a complex multifactorial process that combines constant monitoring of the athlete's functional state, his psychophysiological functions, analysis of his competitive efficiency, intensity of training and competitive loads, fatigue, consideration of his anthropometric indicators, equipment, gear, training and rest regimen and other factors (Hidayat, 2025, Prayudho, 2024). The features of these sports are the need for athletes to quickly respond to the actions of rivals and partners, instantly switch from attack to defense and vice versa, and to perfectly master the skills of variability of technique in accordance with external and internal circumstances (Kozin, 2026, Prasetyo, 2025). It should be noted that open-skill sports traditionally include dynamic game sports, martial arts, as well as rock climbing, tourism, and mountaineering. Open-skill sports have their own common features.

The features of these sports are the presence of physical contact of opponents (martial arts, sports games), frequent unforeseen changes in the direction of movements, the need to quickly respond to changes in external circumstances. Therefore, injury prevention for athletes - representatives of open-skill sports should take into account the multifactorial nature of injury risks, and, accordingly, its prevention. These factors include the level of functional state, fatigue, level of technical skill, anthropometric data and other factors (Audini, 2023, Khasanah, 2023, Neledva, 2024). One of the main elements of injury prevention by the coach in open-skill sports

is the organization of the training process, which provides the opportunity for the individual realization of the athlete's own potential. Injury often becomes the main factor limiting the realization of the athlete's potential and achieving his maximum results. To do this, the coach must have modern tools for analyzing injury factors, taking into account the characteristics of each athlete (Audini, 2023, Kirichenko, 2024, Kozin, 2026, Petechuk, 2024, Sobko, 2024).

In this regard, there is a need for a detailed analysis of a large amount of information on the problem of trauma. At the present stage, there are tools that help to systematize and visualize literature data. Such tools include built-in artificial intelligence programs in Scopus and Web of Science for analyzing literary sources, EndNote, Zotero, and others. One of such tools is the VOSviewer program (Bukar, et. al, 2023). It helps to systematize and distribute literary sources into clusters according to the leading research topics and create maps for visualizing bibliometric data.

These maps provide an opportunity to identify the main groups of keywords, authors, journal titles, countries, organizations, and the connections between them. This allows you to systematize the obtained data into separate groups (clusters) according to the concepts considered by the authors, as well as by representatives of different scientific schools, countries, and universities. The main problem that needs to be solved is the identification of the main risk factors for injuries in open-skill sports for the prediction and appropriate prevention of injuries.

Hypothesis: it is assumed that the main risk factors for injuries in open-skill sports are muscle overstrain, fatigue, and insufficient coordination specific to a particular sport.

Purpose: to identify and systematize the main areas of research on the risk of injuries and their relationships in open-skill sports based on the results of bibliometric analysis with data visualization and, based on data systematization, to identify the leading risk factors for injuries and means of preventing injuries.

Material and methods

Overall design of the research process

The search for sources was carried out according to the recommendations of PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) in the scientific and metric databases Scopus, Web of Science, and PubMed (Fig. 1). The following keywords were used for the initial search: “Injuries” AND “sport” AND “factor” AND “regression”. The search results were as follows: 1885 sources were found in the Scopus, Web of Science, PubMed databases from 1995 to 2026.

Then the search was limited from 2000 to 2026. At this stage, 751 sources remained. After limiting the years 2016-2026, by the types of publications “Article”, “Review” and by the categories “Sport sciences”, “Orthopedics”, “Rehabilitation”, 458 sources remained. After further restrictions in the search by citations in the category “Sport sciences” and by selecting only English-language articles, 134 publications remained.

At the next stage, duplicates were removed and articles were selected that met the following inclusion criteria in terms of qualitative and quantitative indicators: analysis of injury risks in open-skill sports, application of statistical methods for quantifying injury risks, minimum observation period of one year. The exclusion criteria for at this stage were the following: analysis of injury risks in cyclic sports (except running) and in sports with constant competition conditions, lack of statistical calculation of injury risks, observation for less than one year. After applying these criteria, the number of publications was reduced to 43.

Criteria for selecting publications for analysis

Inclusion criteria

- Keyword match: “Injuries” AND “sport” AND “factor” AND “regression”
- Document language: English
- Publication period: 2022-2026
- Document types: “Article”, “Review”
- Publication categories: “Sport sciences”, “Orthopedics”, “Rehabilitation”
- Citation categories: “Sport sciences”
- Qualitative and quantitative characteristics of the studies:
 - analysis of injury risks in open-skill sports,
 - application of statistical methods for quantifying injury risks,
 - minimum observation period – one year

Exclusion criteria

- analysis of injury risks in cyclic sports and sports with constant competition conditions,
- absence of statistical calculation of injury risks,
- conduction observations less than one year.

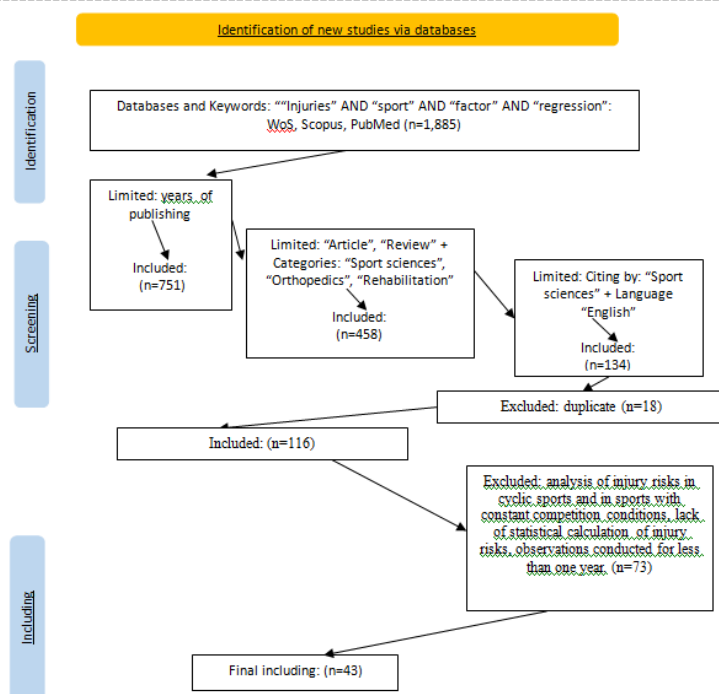


Fig. 1. The process of searching scientific publications on the problem of clinical analysis of risk factors for injury in closed-skill sports based on PRISMA recommendations (Referred Reporting Items for Systematic Reviews and Meta-Analyses)

Visualization of literary data

Visualization and systematization of literary data was carried out using the additional program VOSviewer (Bukar, et. al, 2023) (<https://www.vosviewer.com>), source: Leiden University.

It is a tool specifically designed for bibliometric analysis. It allows you to create relationship maps based on data from databases such as Web of Science, Scopus, and PubMed (which is precisely what is indicated in your figure captions).

VOSviewer Features (Bukar, et. al, 2023)

- Clustering: The program groups authors, countries, or keywords by color. Each color represents a separate scientific field or community.
- Relationship Visualization: Lines indicate co-citations or co-authorship. The thicker the line and the closer the circles are to each other, the stronger the relationship.
- Significance: The size of a circle (node) depends on the number of publications or the frequency of use of a term. For example, in the first figure, the "USA" circle is the largest, indicating that this country is a leader in this topic.

Algorithm of the using program VOSviewer

One of the main features of VOSviewer is the presence of a Java virtual machine: the program is written in native Java and uses a Java installation (JRE).

Documents for analysis, systematization and visualization using VOSviewer were exported and saved in CSV RIS formats with the obligatory headings "Bibliographical information" and "Abstract & Keywords", as well as "Citation". To organize the data, the EndNote program was used.

Then in the VOSviewer program it was found "Create" – "Create a map based on bibliographic data" – "Read data from bibliographic database files" – Selecting a RIS or CSV file – Selecting categories for analysis and visualization (Authors. Countries, Keywords, Citation).

With the help of the VOSviewer program, the literary data were divided into clusters and maps were created to visualize the results of systematization of bibliometric data.

The visualization and systematization of ancient literature was carried out according to the following categories:

- Keyword map (topic structure)
- Country map (geography of science)
- Co-authorship map (who works with whom on scientific research)
- Citation map (authoritative documents).

Results

A bibliometric map of key words on the topic of risks of injury in sports with low conditions

To analyze the conceptual structure of the research area, a gradual visualization of key words from the VOSviewer software was carried out. As a result of the analysis of the publication, 4 clusters were identified, which reflect the main scientific research areas.

The central place in the mesh structure is occupied by the descriptors “epidemiology”, “sport”, “injury”, “risk-factors”, “recovery”, which is confirmed by the largest size of nodes and high thickness of ligaments (Total Link Strength). It is worth noting that most current work is focused on identifying statistical patterns and risk factors for sports injuries (Chandran, 2021a, Chandran, 2021b, Chandran, 2025).

Specialized clusters are clearly visible on the map:

- Preventive cluster (green color): the terms “prevention”, “surveillance” and “physical-activity” dominate, which indicates the applied nature of the research aimed at reducing injuries (Fokkema, 2019) (Fig. 2).
- Sports and clinical-anatomical cluster (red color): the nodes “soccer players”, “hockey” “strength”, “anterior cruciate ligament”, “knee injury” are visible, which reflect a deep interest in scientific research to the most complex types of injuries in sports (Gibson, 2024) (Fig. 2).
- Cluster of specificity of treatment groups (blue color): the children, adult, health, exercises nodes are visible, which indicates a deep interest in the traumatism of representatives of different groups of the population, as well as the influx of traumatism into the health of people of different ages (Fig. 2).
- Rehabilitation cluster (yellow color): the nodes “recovery”, “impact”, “predictors” are visible, which indicates the high importance of the system of renewal after recovery from injuries and prevention of injuries.

The highly intertwined lines between the clusters demonstrate the interdisciplinary nature of the current research, which contributes to the methods of sports medicine, statistics and physical rehabilitation. The term “epidemiology” appears 12 times and has 22 connections with other concepts. The term “prevention” appears 10 times and has 17 connections with other concepts.

The term “sport” appears 11 times and has 20 connections with other concepts. Analysis of the time scale shows that the focus of the remaining studies has shifted from the analysis of government officials to the relationship with the development of prevention methods, differentiating between different types of sports. Care must be taken to increase the frequency of research in order to analyze the influx of indicators of functional activity and the number of injuries, as well as biomechanical factors that risk injury. Injury prevention research tends to look for differentiating methods and injury prevention technologies based on particular characteristics of the athlete's condition, his psychophysiological characteristics, characteristics of the reaction to stress, speed of recovery and movement technique.

Bibliometric map of countries (International Collaboration) of studies on injury risks in open-skill sports

A bibliometric map of countries was constructed to assess the geographical distribution of scientific research and the intensity of international cooperation. The analysis revealed that the global scientific network in the field of injury risk factors in open-skill sports is characterized by a high degree of consolidation around several leading research centers.

Key nodes and leadership. The dominant position is occupied by the United States (USA), which is confirmed by the largest diameter of the node. This indicates the leadership of this country both in terms of the number of publications and the level of their citation in the global scientific community. England, Canada and Australia also make a significant contribution to the development of the topic.

Cluster analysis of cooperation. The clusters highlighted on the map allow us to judge the formed international scientific communities:

- Central cluster (green/red): reflects close interaction between North American and Western European institutions. The high thickness of the connecting lines between the USA, Canada and the Netherlands indicates the conduct of joint multi-center research (Fig. 3).
- Developing nodes: the presence on the map of countries such as China (People's R China), South Korea and Qatar indicates the expansion of the geography of research and the growing interest in the issues in the Asian region (Fig. 3).
- Ukraine is represented in the co-authorship network, having the closest ties with Poland, Bosnia and Herzegovina, Romania (Kirichenko, 2024, Kozin, et. al., 2026, Petechuk, 2024).

Scientific significance: Analysis of ties between countries in injury risk research shows that most of the high-ranking works are created within the framework of international collaboration. This confirms the need to integrate the conducted research into the global scientific context to improve its quality and citation rate.

risk of anterior cruciate ligament injuries (Anterior Cruciate Ligament) injuries in running in athletes from different sports). The school represented by Jauhiainen and Parkkari (Jauhiainen, et. al, 2021) (blue, development of training programs for injury prevention) also stands out (Fig. 4, Table 1).

Cluster analysis of collaboration: The clusters highlighted on the map allow us to judge the most significant scientific schools formed in the world

Central cluster (red) (Fig. 4, Table 1): reflects interactions in determining the risks of lower limb injuries. Based on the publications of representatives of this school, it can be concluded that this school has existed for over 20 years, which indicates the depth of research conducted, which is developing and continuing at the present time. This line of research focuses on testing hypotheses regarding the influence of various factors on injuries (anthropometric indicators, age, past injuries, overstrain, development of physical qualities: strength, endurance, flexibility, agility), etc.

Nodes are developing, represented on the map by the presence of such scientific schools as Emery (2022) on the study of hockey injuries and neuromuscular training to reduce the risk of injury (dark green) (Fig. 4, Table 1).

Important results were obtained by the authors (Fältström, et. al 2016, 2021, 2023) on the reduction of the risk of injury to the anterior cruciate ligament (Anterior Cruciate Ligament), research on the risk of injury to the anterior cruciate ligament during running in athletes from different sports (green) (Fig. 4, Table 1).

Also highlighted is the school on the development of training programs for the prevention of injury, represented by Jauhiainen (Jauhiainen, et. al, 2021) (blue) (Fig. 4, Table 1).

The scientific significance lies in the analysis of the connections between different schools of research on the risk of injury. This analysis shows that most of the high-ranking works are created in the identification of risk factors for injury, in the study of the risk of injury to the lower extremities, especially the anterior cruciate ligament, in the development of injury prevention programs, part of which is neuromuscular training.

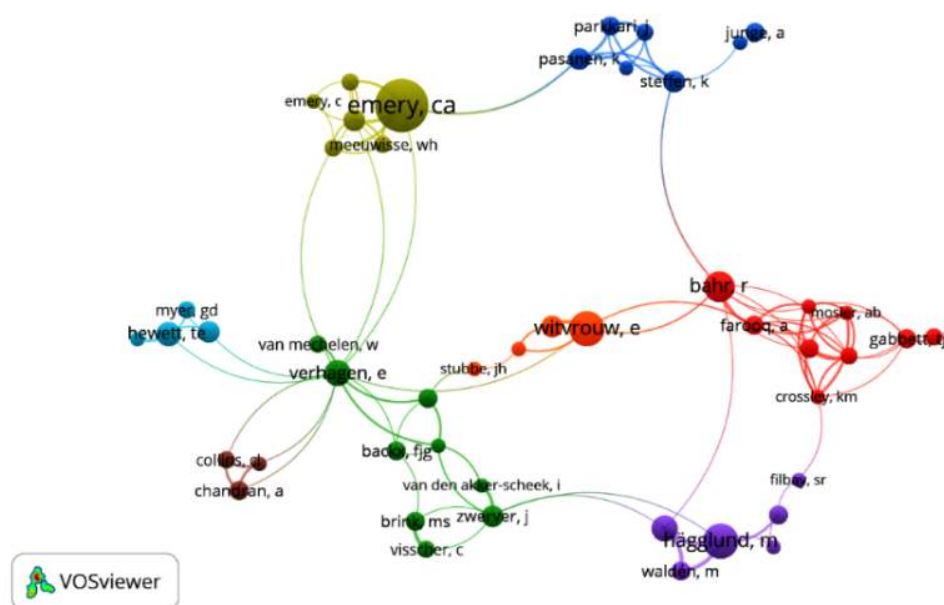


Figure 4. Network visualization of co-authorship of studies on injury risks in open-skill sports (based on Web of Science Core Collection data): *Note. The colors represent different thematic clusters of research, while the size of the circles reflects the relative number of publications associated with each specific term or cluster.*

Description of the citation map of the most influential publications

To identify the theoretical foundation and the most influential concepts in the field under study, an analysis of the citation of documents was conducted. Network visualization demonstrates a hierarchy of scientific works, where the size of the node is directly proportional to the number of citations received.

The core of intellectual influence. The central element of the network is the work of Paterno et al. (2010), which has the greatest weight. This indicates that this study is fundamental for the analyzed topic, the conclusions of which serve as the starting point for most subsequent works. The works of Ekstrand (2016) and Junge also have a significant influence, forming the basis of modern epidemiology of sports injuries.

Table 1. Cluster analysis of author collaboration in studies on injury risks in open-skill sports (based on Scopus and Web of Science data)

Cluster	Color in Figure 4	Main authors / co-authors	Problem	Results
Identification of lower and upper extremity injury risks	Red	Barendrecht (2021), Bukar, et. al, (2023), Rommers et. al (2020), van Dyk, et. al (2018); Verrelst et. al (2018a, 2018b), Zhan (2021)	Testing hypotheses regarding the influence of various factors on injuries (anthropometric indicators, age, past injuries, overexertion, development of physical qualities: strength, endurance, flexibility, agility, coordination), etc.	It was determined that among the risk factors there is a tendency to increase the share of psychological factors (anxiety, functional state of the nervous system, possession of emotions, etc.), as well as the length of the lower extremities, body mass and composition, age of athletes. Also, various studies indicate the different significance of such risk factors for injury as overexertion, fatigue, coordination, technique, and others.
Research on injuries in hard contact sports (hockey, rugby, etc.), effectiveness of neuromuscular training to reduce the risk of injury	dark green	Emery et al. (2020), Emery et al. (2022), Ezzat et. al (2016),	Testing hypotheses regarding the effectiveness of neuromuscular training adapted for a specific sport to reduce the risk of injuries	The positive effect of neuromuscular training (visualization of muscle work, exercises for balance, development of coordination, performing exercises at a slow pace, etc.) has a positive effect on reducing the risk of injury, especially in women.
Risks of Anterior Cruciate Ligament injury	green	Fältström et. al (2016), Fältström et. al. (2023), Fältström et. al (2016), Fältström et. al (2021), Kotsifaki (2025)	Investigating the risk of injuries of the anterior cruciate ligament during running in athletes representing various sports.	It was found that the risk factors for the anterior cruciate ligament are the presence of a previous injury, young age, lack of coordination abilities, psychological factors (somatic anxiety, mental anxiety, susceptibility to stress and irritability), activity level, functional performance, muscle strength, jumping performance. Valgus deformity as a factor of injury remains a debatable issue.
Programs for training in movement technique and physical quality development	Blue	Andersson (2018), Baltich (2015), Chandran (2020), Chandran (2022), Jauhiainen et. al (2021), Resende (2025), Zhang (2024), Zech (2022)	Determining the most effective statistical methods for processing data on the risk of injuries. Developing training programs for the prevention of injuries	It was determined that the non-linear multivariate regression method is more effective in determining the risk factors of injury compared to the Korch univariate linear regression method. The effectiveness of training to reduce the risk of injury was determined based on the results of the analysis of the risk of injury in playing sports using linear and nonlinear methods. It has been shown that the most attention is required by an individual approach, taking into account the following indicators: gender, body mass index, tendon flexibility, ankle plantar flexion, single repetition leg press, and knee valgus.

Structure of connections (clustering). The distribution of documents by clusters reflects the continuity of scientific ideas:

- Cluster of classical research (center): unites works of the 2000s and early 2010s, which laid the methodological foundations of risk analysis.
- Cluster of modern applied works (periphery): includes publications of recent years (for example, Webster, 2018; Webster, 2019), which develop the ideas of the central nodes, adapting them to new sports or rehabilitation methods.

The presence of close connections between the nodes confirms the high level of continuity in the scientific school and justifies the choice of these sources as key for our own critical review of the literature.

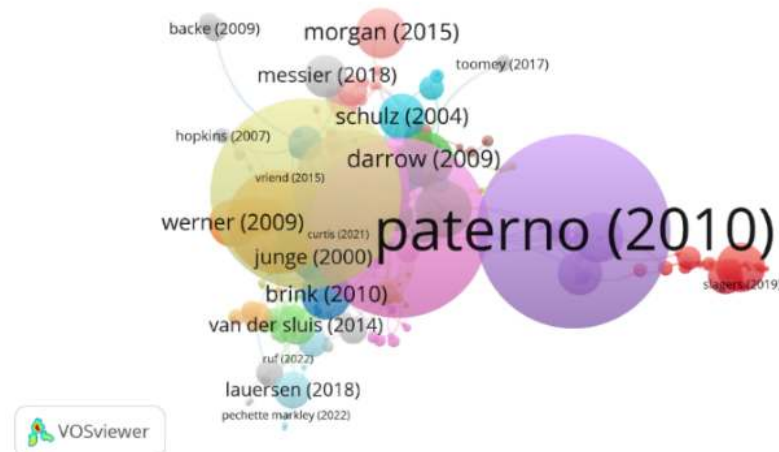


Figure 5. Network visualization of the most cited publications on the topic of the study (based on data from the Web of Science Core Collection, Scopus, PubMed): *Note. The colors represent different thematic clusters of research, while the size of the circles reflects the relative number of publications associated with each specific term or cluster.*

Discussion

The hypothesis regarding the prevalence of such indicators as overexertion, fatigue, previous injuries, and lack of special coordination abilities characteristic of a particular sport among the risk factors for injury in open-skill sports was partially confirmed. Based on the analysis of key works presented by clustering by keywords and scientific schools of co-authors, citations, and geographical regions, it was found that when using the method of statistical analysis of nonlinear logistic multivariate regression (Jauhiainen et. al, 2021), the following risk factors for injury are also identified: psychological (anxiety, functional state of the nervous system, possession of emotions, etc.), as well as anthropometric (length of lower limbs, weight and body composition), age of athletes.

By using nonlinear multivariate regression, the reliability of the influence of psychological factors (somatic anxiety, mental anxiety, susceptibility to stress and irritability) on the risk of injury to the anterior cruciate ligament (Anterior Cruciate Ligament) was revealed in combination with the presence of a previous injury, young age, lack of coordination abilities, activity level, functional performance, muscle strength, jumping indicators (Jauhiainen et. al., 2021, Andersson, 2018, Baltich, 2015, Chandran, 2020). But it was also found that hallux valgus deformity as a factor of injury remains a debatable issue, since there are works that prove the significance of this factor, and there are works that show the unreliability of this indicator as a risk factor of injury. The reliability of the identified injury factors depends on the methods of data analysis, the period of observations and other data. As for the analysis methods, it was determined that the nonlinear multivariate regression method is more effective in determining the risk factors for injury compared to the Korch univariate linear regression method (Fältström et. al., 2023, Jauhiainen et. al., 2021).

In studies on injury prevention, there is a tendency to search for differentiated methods and technologies for injury prevention depending on the characteristics of the athlete's condition, his psychophysiological characteristics, characteristics of the response to load, recovery speed and movement technique (Kirichenko, 2024, Petechuk, 2024). The neuromuscular training method also deserves attention as one of the most effective methods for injury prevention. One type of neuromuscular training is iSPRINT NMT - a specialized warm-up program designed to prevent injuries, especially in young athletes, by combining aerobic exercises, agility, strength and balance training. The main components of iSPRINT NMT include aerobic exercises, balance exercises and strength exercises with your own weight (Emery et al., 2022, Ezzat et. al., 2016, Emery et al., 2020).

Neuromuscular training is a system of exercises aimed at improving the interaction between the brain and muscles. Movement control increases coordination, joint stabilization, and energy efficiency. It includes conscious control of muscle contractions, balance training, and helps to form or restore biomechanically rational movement patterns. The main goals and effects of neuromuscular training are to improve coordination, as the brain sends signals to the muscles more effectively, as well as to stabilize the joints by strengthening the muscle corset and small stabilizing muscles, to form a biomechanically rational technique by consciously engaging the necessary muscles and improving them. The main types of neuromuscular training include rhythmic exercises for the joints and muscle corset (Huber), neuromuscular activation (Exarta) (exercises in a suspended state that relieve the load on the spine and joints), exercises on unstable platforms, and others. Neuromuscular junction is the brain's ability to effectively send signals to and receive signals from muscles. It is the basis of movement control (Kozin, 2026).

Conscious development of this junction allows you to more accurately include the necessary muscles and reduce the risk of injury. The main tools of neuromuscular training include conscious concentration on the target muscle, concentration on sensations, performing isolated movements, performing movements at a slow pace and conscious control of movements, visualization and focusing on the sensations coming from the muscles, as well as isometric exercises. Neuromuscular junction deteriorates from overtraining, as well as from injuries due to the difficulty of performing habitual movements. Rehabilitation after injuries often begins with the restoration of habitual motor patterns, rather than strengthening the muscle itself (Emery et al., 2020, Emery et al., 2022).

The neuromuscular junction also underlies the work of all processes in the body. Most of them occur at a subconscious level, but movements involving skeletal muscles are Andersson (2018), Baltich (2015), Chandran (2020), Chandran (2022), Jauhiainen et. al (2021), Resende (2025), Zhang (2024), Zech (2022).

conscious, and therefore amenable to neuromuscular training. Summing up the application of neuromuscular training, it can be noted that neuromuscular training can be considered any exercises that are accompanied by conscious attention to the work of the muscles, concentration on the sensations that come from the proprioceptors. In fact, neuromuscular training consists in activating level synergy of movement control (Kozin, 2026).

Thus, summarizing the data obtained, we can conclude that there is currently a contradiction in the research on the risks of injury in open-skill sports. However, one of the most effective means in injury prevention is neuromuscular training, which requires adaptation to movements in different sports and to the individual characteristics of athletes.

Conclusions

1. Analysis of the connections between countries in studies of injury risks shows that the majority of high-ranking works are created within the framework of international collaboration, the central link of which is the USA. England, Canada and Australia also make a significant contribution to the development of the topic. Ukraine is represented in the co-authorship network, having the closest ties with Poland, Bosnia and Herzegovina, Romania. This confirms the need to integrate the conducted studies into the global scientific context to improve their quality and citations.

2. Bibliometric mapping of keyword co-occurrence enabled the identification of four distinct research clusters that define the current landscape of the field: 1) the Preventive Cluster, focusing on injury reduction strategies; 2) the Sports and Clinical-Anatomical Cluster, addressing biomechanical and structural aspects; 3) the Population-Specific Cluster, examining characteristics of particular athlete groups; and 4) the Rehabilitation Cluster, dedicated to post-injury recovery protocols.

3. Co-authorship analysis revealed similar clustering, identifying established scientific schools in the field. Beyond traditional risk factors of injuries (overexertion, fatigue, the presence of previous injuries and lack of special coordination abilities), by using nonlinear multivariate regression analysis, the authors determine the high reliability of psychological risk factors for injuries, as well anthropometric indicators (body height and weight) and age and gender of athletes. The overwhelming majority of studies are aimed at identifying risks of the anterior cruciate ligament. The risk factors for the Anterior Cruciate Ligament (ACL) are the presence of a previous injury, young age, lack of coordination abilities, psychological factors (somatic anxiety, mental anxiety, susceptibility to stress and irritability), activity level, functional performance, muscle strength, jumping performance. Valgus deformity as a factor of injury remains a debatable issue.

4. A positive effect of neuromuscular training (visualization of muscle work, balance exercises, coordination development, slow-paced exercises, etc.) on reducing the risk of injury, especially in women, has been found. It was determined that nonlinear multivariate regression models demonstrate higher predictive validity in identifying injury risk factors compared to the Korch univariate linear regression method.

5. The effectiveness of training to reduce the risk of injury was determined based on the results of the analysis of the risk of injury in game sports using linear and nonlinear methods. It was found that different authors determine the reliability of the influence of various factors on the injury of athletes depending on the period of observation, statistical method of data analysis, age, gender, type of sport and other indicators. The greatest attention is required by individual and differentiated approaches to determine the risk of injury in open-skill sports and, accordingly, to form recommendations for the prevention of injuries. In studies on the prevention of injuries, there is a tendency to search for differentiated methods and technologies for the prevention of injuries depending on the characteristics of the athlete's condition, his psychophysiological characteristics, characteristics of the response to stress, speed of recovery and movement technique.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the authors did not use generative AI or AI-assisted technologies to write, edit, or alter the manuscript text.

However, AI-assisted tools and automated software were utilized to optimize literature search, retrieval, and quantitative analysis within the Scopus and Web of Science (WoS) databases. Additionally, VOSviewer

software (version 1.6.20; Centre for Science and Technology Studies, Leiden University, The Netherlands) was employed for the bibliometric visualization and systematic mapping of the literary data, following the methodological framework described by Bukar et al. (2023). After using these tools, the authors reviewed, interpreted, and critically analyzed the results, and accept full responsibility for the content and integrity of the final manuscript.

Limitations

The study refers to open-skill sports, among which mainly sports games related to running were studied. Additional research is needed to extend the conclusions to other open-skill sports (martial arts, sports related to changing natural conditions and unstable competition conditions).

In addition, despite being encouraged, the synthesis of various disciplinary approaches continues to be inconsistent. This highlights a demand for more holistic frameworks capable of systematically tackling the intricate nature of sports injury prevention. Moreover, the recurrent disconnect between empirical research and its practical implementation within training settings requires deeper analysis. Also, while combining different fields of study is supported, it rarely happens in practice. We need broader frameworks to handle the complex challenges of preventing sports injuries. Additionally, the ongoing gap between scientific data and actual training methods should be studied further.

Prospects for further research

Based on the data obtained, future research should focus on:

- expanding the range of studied open-skill sports,
- application of nonlinear multidimensional methods of injury risk analysis,
- differentiated and individual approach to determining injury risks,
- adaptation of neuromuscular training tools to the tasks of specific sports and individual abilities of athletes.

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Conflict of Interest The authors declare no conflict of interest.

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