The effect of neuromuscular training on reducing the risk of sports injuries: A systematic review

Pengaruh Latihan Neuromuskular terhadap Pengurangan Risiko Cedera Olahraga: Tinjauan Sistematis

Review Article

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Abstract.

Background Neuromuscular training is important for improving motor control, balance, and joint stability, making it effective in preventing sports injuries. However, limitations in the number of studies, variations in intervention design, and lack of long-term analysis are barriers to drawing broader conclusions.

Objectives This systematic review aims to analyze the effect of neuromuscular training on reducing the risk of sports injuries.

Methods This study followed the PRISMA guidelines by reviewing articles from Scopus, PubMed, ScienceDirect, and Web of Science. The article search and selection strategy was conducted using several major scientific databases, namely Scopus, ScienceDirect, Web of Science (WOS), and PubMed. The keywords used in the search included "neuromuscular training," "injury prevention," "sports performance," "athletes," and "rehabilitation". Eight studies were selected based on the criteria of relevance to neuromuscular training and injury prevention.

Results Neuromuscular training has been shown to reduce the risk of injury, improve neuromuscular function and improve balance. Effectiveness is influenced by the duration, intensity and consistency of the exercises. This systematic review confirms that neuromuscular training (NMT) is an effective approach in reducing the risk of sports injuries, especially to the lower extremities, through improved neuromuscular control, joint stability, dynamic balance and more efficient biomechanics of motion.

Conclusion Neuromuscular training is an effective strategy for sports injury prevention and is recommended as part of an athlete's training program. Further studies with more uniform methodology and longer follow-up periods are needed.

Keywords: neuromuscular training, injury prevention, sports injuries, athlete performance

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INTRODUCTION

Neuromuscular training has been a widely explored topic in scientific research related to sports injury prevention. Frequent sports injuries are caused by biomechanical factors, insufficient muscle strength, and suboptimal neuromuscular control [1], [2]. In addition, neuromuscular training plays a role in increasing joint stability and improving movement patterns that can reduce the risk of injury [3]. Recent research confirms that neuromuscular-based interventions are effective in reducing the incidence of injury in athletes of various sports [4], [5].

Neuromuscular exercise has various benefits in lowering the risk of injury by improving motor coordination, proprioception, and postural control [6]. A well-designed exercise program can improve the function of the neuromuscular system and accelerate reflex responses in avoiding injury [7], [8]. It also contributes to improved muscle strength, balance, and dynamic stability. All of which play an important role in preventing sports injuries [9]. In addition, neuromuscular programs have been shown to be effective in reducing the risk of ACL injury in young athletes [10], [11].

Environmental factors and training methods also influence the effectiveness of neuromuscular exercises in injury prevention [12]. Implementing these exercises in a fitness center, sports club, or athlete academy requires a systematic approach to ensure the exercises are performed in a consistent and sustainable manner. In addition, the involvement of trainers and medical personnel in designing and supervising exercise programs is an important factor in achieving optimal results [13]. The

combination of neuromuscular training with other training methods, such as plyometric and resistance training, has also been shown to increase effectiveness in reducing injuries [14], [15].

Neuromuscular training not only contributes to injury prevention but also has a positive impact on overall athletic performance. Athletes who undergo this exercise program experience improvements in speed, agility and muscle explosiveness [16]. In addition, these exercises help correct muscle imbalances that are often a risk factor for injury in athletes. Other studies have shown that neuromuscular programs also contribute to increasing aerobic capacity as well as improving movement efficiency in various sports [17].

At a young age, neuromuscular training plays an important role in forming the basis of physical abilities that will be influential into adulthood [18]. The application of these exercises in children and adolescents can improve neuromotor development and fundamental movement skills. Neuromuscular-based exercise programs can be applied in a variety of contexts to support optimal physical development in children and adolescents, both in organized sports activities and in everyday life [19]. Studies show that children who regularly perform neuromuscular exercises have a lower risk of injury than those who do not engage in these exercises [20].

A major challenge in the implementation of neuromuscular exercises is the lack of understanding from coaches and athletes regarding their importance in injury prevention. In addition, limited training time and resources are often an obstacle in implementing an effective exercise program [21]. Many fitness centers and sports clubs have not implemented this exercise program systematically, so the results have not been optimal in reducing injury rates [22]. Therefore, there is a need for better education and implementation strategies so that neuromuscular training can be widely applied in the context of sports and rehabilitation.

This systematic review aims to review the scientific literature on the effect of neuromuscular training on reducing the risk of sports injuries. Although many previous studies have addressed the effectiveness of these exercises, there is still a need for a systematic update of current studies that cover a wider range of sports and athlete populations, so that these studies can hopefully serve as a reference for the development of more effective neuromuscular exercise programs

METHOD

Research Design

This study followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to ensure transparency and repeatability in the systematic review process. The approach used in this study was also in line with previous studies that examined various topics in the field of sport and injury. To identify relevant articles, this study applied the PICO (Population, Intervention, Comparison, Outcome) method, which is an evidence-based research strategy utilizing various academic sources such as books and scientific journals. The main focus of this review was academic literature addressing neuromuscular training in the context of sports injury prevention in various population groups.

Search and Selection Strategy

The article search and selection strategy was conducted using several major scientific databases, namely Scopus, ScienceDirect, Web of Science (WOS), and PubMed. The keywords used in the search included "neuromuscular training," "injury prevention," "sports performance," "athletes," and "rehabilitation." The article selection process followed a systematic approach by using reference management software (Mendeley) to organize citations, screen titles and abstracts, and fully evaluate articles based on predefined selection criteria. From the initial search results, a number of articles were collected and then selected based on their suitability to the topic of this study.

Inclusion and Exclusion Criteria

Inclusion criteria for this study included articles that addressed the effect of neuromuscular training on preventing sports injuries and improving athlete performance, articles that used methods other than systematic reviews, and articles published in peer-reviewed scientific journals between 2021 and 2025. In addition, only articles available in full-text format and published in English were included in the analysis. Conversely, articles were excluded if they were only available in abstract form without access to the full text, were not published in a recognized scientific journal, were not review articles, or

did not meet any of the predefined inclusion criteria. The article selection process was detailed to ensure only relevant studies were included in this review. A PRISMA diagram illustrating the stages of article selection and screening can be seen in Figure 1.

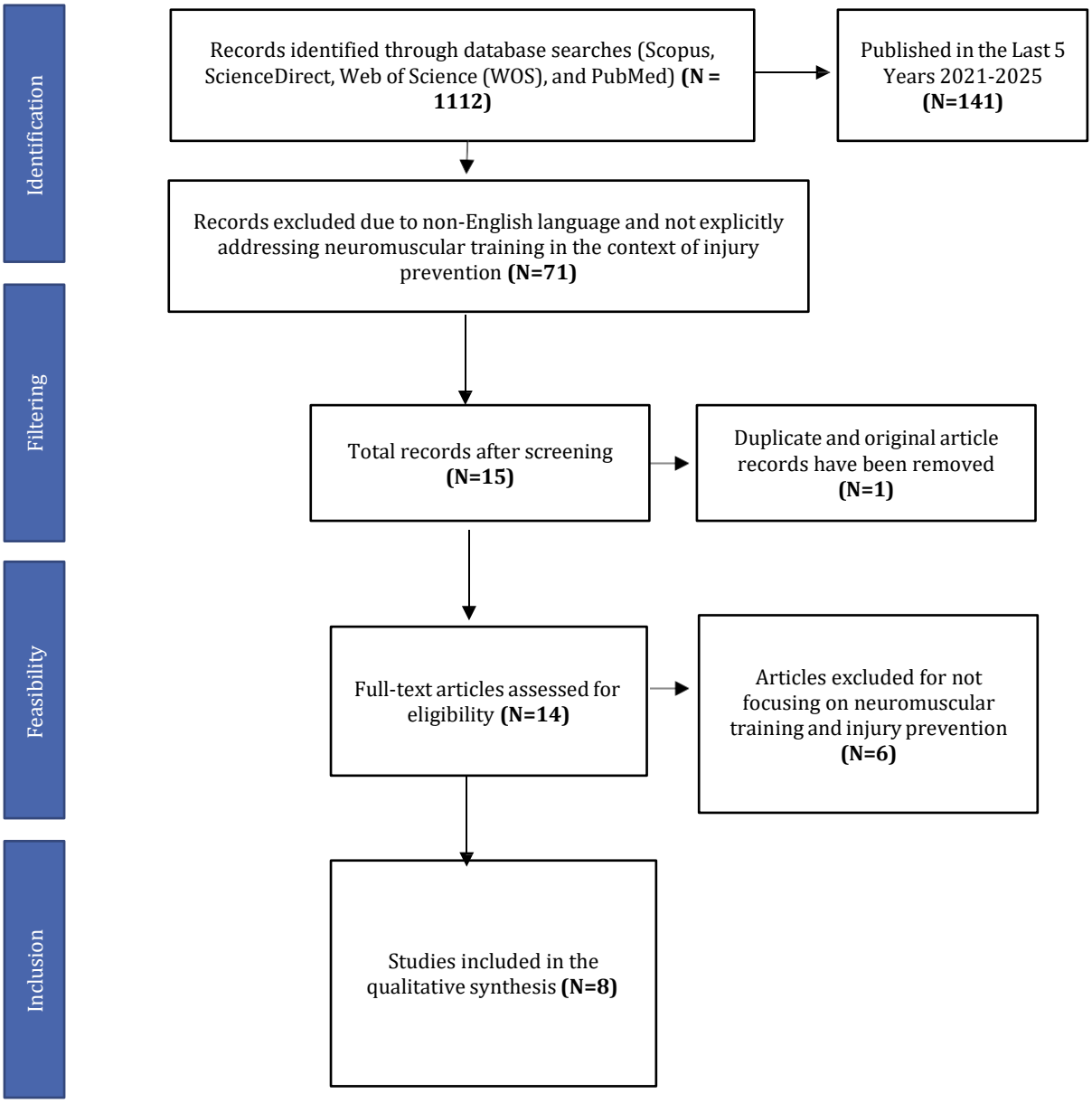

Figure 1. PRISMA Research Flowchart

RESULTS AND DISCUSSION

Results

Table 1 presents a summary of the methodological aspects of studies conducted between 2018 and 2024 related to neuromuscular exercises in sports injury prevention. The results show that neuromuscular exercises can significantly reduce the risk of injury by improving neuromuscular control, balance and joint stability [23], [24]. Recent studies confirm that these exercise programs are effective in reducing injuries across a range of sports, including football, basketball and athletics [6].

In addition, research suggests that neuromuscular exercises can correct faulty movement patterns, thereby decreasing excess stress on joints and soft tissues that are prone to injury [24]. Other findings indicate that the application of these exercises is more effective when combined with other methods, such as proprioceptive and pliometric exercises, than when performed separately [25]. Furthermore, programs implemented over a longer period of time (≥ 12 weeks) showed a more significant impact in reducing injury risk than short-term interventions [26].

However, several studies have reported challenges in the implementation of neuromuscular training, such as the lack of athlete compliance in carrying out the program consistently as well as the coaches' lack of understanding of the importance of this exercise [26]. Other factors such as limited time and resources in the training environment are also obstacles to the optimal implementation of neuromuscular exercises [12].

Table 1. Summary of the Effect of Neuromuscular Training on Sports Injury Risk Reduction

Author	Characteristics of the sample	Method	Conclusion
(Zhao, Wang, Bi, Chen, 2021)[1]	38 female badminton players (high risk: 22, low risk: 16)	8-week integrated neuromuscular training (INT) program (4×90 minutes/week), assessing movement asymmetry, fitness, and ability.	INT improves limb asymmetry, performance, and injury prevention, with effects that vary by risk group.
(Hamoongard, Hadadnezhad, Abbasi, 2022) [27]	30 male futsal players (mean age: 21.86 years) with a predominance of ACL injuries.	8-week dual-task (DT) neuromuscular training (3×60 min/week) vs. control group (daily activities); landing mechanics assessed via 2D kinematics.	DT training significantly improved knee valgus, knee flexion, ankle dorsiflexion and trunk flexion on landing, reducing the risk of ACL injury
(Stojanović, Terrence Scanlan, Radovanović, Jakovljević, Faude, 2023) [28]	112 regional basketball players (57 intervention, 55 control).	Experimental study by comparing the incidence of injury between neuromuscular warm-up and regular warm-up over a season.	Neuromuscular warm-ups significantly reduce the risk of ankle and lower extremity injuries.
(Nixon, Franz, Birchmeier, Knous, Berry, 2023)[29]	14 recreational runners	An 8-week Neuromuscular Training (NMT) program (two sessions/week, 22 minutes/session) measured balance, strength, and plyometric ability.	NMT improves leg balance, plyometric performance and lower limb strength without disrupting running routines or increasing the risk of injury.
(Ding, Mackey, Li, 2023) [26]	421 primary school students (9-14 years old)	A 13-week randomized controlled trial; the intervention group underwent the Neuromuscular Warm-Up Program (NWP) 8 minutes before exercise, while the control group underwent a standard warm-up.	NWP is effective in reducing sports injuries in school children, especially for participants with high compliance.
(Faisal, Mahnoor, Khan, 2023) [24]	Two groups of female cricketers	The study used a randomized controlled trial (RCT) design, by comparing differences before and after the intervention in both groups.	The group that underwent neuromuscular training showed greater improvement in functional movement quality

(Paravlic, Bakalár, Puš, Pišot, Kalc, Teraž, Šlosar, Peskar, Marušič, Šimunič, 2024)[30]	275 Slovenian youth basketball players (15 ± 1.7 years), divided into intervention (NMT) and control groups.	RCT for three months, the intervention group underwent NMT-based warm-up, the control group had regular warm-up.	NMT effectively reduced the risk of injury (10.9% vs. 23.3% in controls) and improved neuromuscular function without significant differences in balance.
(Bayram, Sahin, Tarakci, Aydos, Celik, Sertogullarindan, 2024)[31]	30 university amateur futsal players (18-25 years old), divided into intervention (NMT) and control groups.	An 8-week RCT, the intervention group underwent additional NMT training, while the control group only did regular futsal training.	NMT improves balance, performance and reduces the risk of injury.

Discussion

Neuromuscular training (NMT) has become one of the main approaches in sports injury prevention. Studies have shown that it improves neuromuscular control and joint stability through improved balance and proprioceptive function. In the context of athletes, especially students and novice athletes, this improved neuromuscular control is important as they often have immature movement patterns, making them susceptible to injury [26]. The findings in this systematic review generally suggest that structured and consistently performed neuromuscular exercises can significantly reduce the risk of injury, both to the lower limbs and overall injury.

One notable study by [27] showed that six weeks of NMT practice provided significant improvements in postural and neuromuscular control in young athletes. This improvement had a direct impact on reducing joint stress during explosive activities such as jumping and landing, which are common causes of knee and ankle injuries. This study provides a theoretical basis that injury prevention can start from improving movement control and muscle recruitment patterns through an appropriate training stimulus.

In addition to young athletes, the application of neuromuscular training has also proven effective in the recreational runner population. Nixon et al. demonstrated that runners who followed an NMT program on a foam surface for eight weeks showed improvements in limb dynamic balance, lower limb strength, as well as plyometric performance [29]. Interestingly, none of the participants sustained injuries during the intervention period even though they kept up with their running routine. This indicates that NMT exercises can be integrated with the main training program without causing excessive fatigue, and even contribute to injury prevention.

In primary school-aged children, the implementation of neuromuscular training as part of the warm-up was shown to significantly reduce the incidence of injuries. A study by [26] showed that an NMT-based warm-up program conducted for 13 weeks was able to lower the injury rate from 7.60 to 1.80 per 1000 hours of activity, especially if done more than twice per week. The fact that even the low-compliance group still showed a reduction in injuries suggests that this exercise is quite effective even at a limited intensity.

The effectiveness of NMT exercises was also seen in female athletes in the context of the sport of cricket. The study by [24] reported that the group undergoing neuromuscular exercises alongside the basic program showed significantly improved functional movement scores compared to the control group. This supports that minor modifications in exercise routines through the addition of neuromuscular components are enough to improve biomechanical efficiency and lower the risk of injury, even at the level of competitive sports.

In the context of youth basketball, research by [30] strengthens the evidence that neuromuscular training during warm-ups is effective in reducing injury incidence. The intervention group showed an injury prevalence of 10.9%, significantly lower than the control group. In addition, results showed improvements in neuromuscular function through faster muscle contraction times. Although balance improved in both groups, this suggests that NMT exerts additional effects on neuromotor variables that play an important role in dynamic stability.

Interestingly, most of the studies in this review not only measured injury incidence, but also quantitatively assessed biomechanical and neuromuscular indicators such as muscle contraction time, dynamic balance and jumping performance. This shows that the benefits of NMT are multidimensional,

not only preventing injuries but also improving athletes' functional performance. This approach is very important in the context of modern sports that demand athletes to perform optimally while minimizing the risk of injury.

However, there are some limitations to be noted from the reviewed studies. Some studies had small sample sizes and relatively short intervention periods, which may limit the generalizability of the results. On the other hand, adherence to the exercise program is also a challenge. The study [26], showed that the effectiveness of the program is highly dependent on the frequency of implementation. Therefore, educating coaches, sports teachers, and athletes on the importance of NMT exercise adherence is a crucial aspect in long-term implementation.

Overall, the findings from this systematic review strengthen the argument that neuromuscular exercises are an effective, practical and low-cost intervention in the prevention of sports injuries. They improve motion control, strength and balance, all of which are important components of joint stability. Systematic and structured implementation of these exercises, both at the school and sports club level, can provide protection against injury while supporting optimal athletic performance. Therefore, this approach should be standardized in the training programs of both young and adult athletes

CONCLUSION

This systematic review confirms that neuromuscular training (NMT) is an effective approach in reducing the risk of sports injuries, especially to the lower extremities, through improved neuromuscular control, joint stability, dynamic balance and more efficient biomechanics of motion. Evidence from various studies shows that a structured NMT program, performed at a frequency of two to three times per week for a duration of six to twelve weeks, can significantly reduce the incidence of injury compared to a control group. In addition to the preventive benefits, it contributes to improved functional performance such as speed, muscle strength and motor control. However, the reviewed studies still have limitations, such as small sample sizes, variations in intervention protocols, lack of long-term reporting, and limited generalizability across different age groups, genders, and sport skill levels. Therefore, future studies need to use experimental designs with tighter controls, involve more diverse populations, as well as evaluate the long-term impact of NMT exercises on recurrent injuries, movement efficiency, and quality of life of athletes. It is also desirable to explore the integration of neuromuscular training in technology-based sports training programs as well as multidisciplinary approaches involving coaches, physiotherapists, and sports medical personnel to support more holistic and sustainable injury prevention.

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AUTHOR CONTRIBUTION STATEMENT

The writing of this article involved roles in devising the research concept and design, reviewing and analyzing relevant literature, and drafting the overall manuscript.

CONFLICT OF INTEREST AND FUNDING

There is no conflict of interest

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