

Does neuromuscular exercise training improve proprioception in ankle lateral ligament injury among athletes? Systematic review and meta-analysis

O treinamento neuromuscular melhora a propriocepção em lesão ligamentar lateral do tornozelo entre atletas? Revisão sistemática e metanálise

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ABSTRACT

Aims: The prevalence rate of ankle complexities is increasing at a constant rate among athletes. This study aimed to systematically describe the facts and findings related to the effectiveness of training programs on proprioception among athletes suffering from ankle ligament injury.

Methods: A literature search in online libraries (Google Scholar, PubMed, EBSCOhost, and ProQuest) using different search engines was conducted for the systematic review and meta-analysis. The common keywords included NEUROMUSCULAR, EXERCISE, TRAINING, PROPRIOCEPTION, and ATHLETES. Studies related to the topic, having relevant resources, and published within the past 10 years were used as inclusion criteria. Methodological quality was assessed through PEDro scale. A meta-analysis of the selected trials was conducted to assess the effectiveness of intervention.

Results: Two hundred research articles were initially selected. After close scrutiny, 15 articles were included. Five moderate to excellent quality trials were selected, which involved 2,459 participants. It has been mainly identified that ankle sprain and its complications can be easily prevented with the help of training programs (five trials, relative risk: 0.69, 96%CI: 0.65-0.87). A statistically significant relationship was identified among athletes regarding the preventive impacts of training on proprioception.

Conclusions: Preventive training programs were helpful for athletes in terms of proprioception, thus reducing the risk of ankle sprains.

KEY WORDS: ankle; athletes; athletic injuries; ligament injury; proprioception; physical education and training.

RESUMO

Objetivos: A taxa de prevalência de lesões no complexo ligamentar lateral vem aumentando entre os atletas a uma velocidade constante. Este estudo teve por objetivo descrever sistematicamente os achados relacionados à eficácia dos programas de treinamento na propriocepção entre atletas com lesão ligamentar do tornozelo.

Métodos: Foi realizada uma busca em bases de dados online (Google Scholar, PubMed, EBSCOhost e ProQuest) com o uso de diferentes mecanismos de busca, para revisão sistemática e metanálise. Os descritores comuns foram NEUROMUSCULAR, EXERCISE, TRAINING, PROPRIOCEPTION, and ATHLETES. Os estudos relacionados ao assunto, os que continham recursos relevantes e aqueles publicados nos últimos 10 anos foram usados como critério de inclusão. A qualidade metodológica foi avaliada pela escala PEDro. Foi feita uma metanálise dos estudos selecionados a fim de avaliar a eficácia da intervenção.

Resultados: Inicialmente, foram selecionados 200 artigos de pesquisa. Após uma avaliação detalhada, restaram 15 artigos. Cinco estudos de qualidade moderada a excelente foram selecionados, totalizando 2.459 participantes. Verificou-se, principalmente, que o entorse de tornozelo e suas complicações podem ser evitados facilmente com o auxílio de programas de treinamento (cinco estudos, risco relativo: 0,69, IC 96%: 0,65-0,87). Observou-se uma relação estatisticamente significativa em termos dos efeitos preventivos do treinamento na propriocepção entre atletas.

Conclusões: Os programas de treinamento preventivos foram úteis aos atletas em termos de propriocepção, reduzindo o risco de entorses de tornozelo.

DESCRITORES: tornozelo; atletas; traumatismos em atletas; lesão ligamentar; propriocepção; educação física e treinamento.

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Abbreviations: RR, relative risk; NNT number needed to treat.

INTRODUCTION

The prevalence of ankle injuries is extremely common in a wide variety of sports and athletics. Athletes who suffer ankle sprains are prone to reinjure the same ankle, which usually results in disability and chronic instability. Among all sports, volleyball has a relatively higher incidence of ankle injuries [1]. Several balance exercises and other neuromuscular training have been arranged in order to reduce the clinical manifestations of ankle injuries. Exercise-related training programs are aimed to increase neuromuscular strength, which is required for resistance against the destabilizing load on the knee [2]. It is well documented that female athletes are comparatively at higher risk of acquiring knee injuries as compared to male athletes [3]. Therefore, most of the training programs are designed to reduce the risk of injuries and their complications among female individuals. Future complications of knee injuries have a direct impact on athletes' quality of life [4]. Similarly, knee ligament injuries are widely associated with chronic pain which, in turn, results in long-term disability. Tendons and ligaments are systematic parts of the neuromuscular system that require certain dietary supplements and training programs for enhancement of energy levels. Therefore, athletes are always recommended to enhance their energy levels by means of exercise training programs.

Osteoarthritis has now been considered the second most common morbidity among older adults. Moreover, this diagnosis has been identified as a major contributing factor to the increase in the risk of disability in senior individuals [5]. Along with the older population, athletes have been also identified as individuals at risk for acquiring such complications [6]. For patients with knee disability, total knee replacement is considered a major surgical approach to effectively addressing the complications [7]. According to the most recent meta-analysis, preoperative exercises play a vital role in functional recovery. Some of the common exercises identified as the best intervention against the complications of osteopathy include mainly aerobics, proprioceptive exercises, and strength exercises [8,9]. An appropriate exercise program is an important way to assess and address deficiencies in the human body [10,11]. Therefore, exercises have been identified

as an effective therapeutic intervention for the morbid complications of osteoarthritis or ankle injuries.

Proprioception and its clarification have different meanings in diverse regions. In early years, proprioception was defined as the ability to receive input from tendons, joints, and muscles through proper functioning of the central nervous system. This definition of proprioception, however, was not acceptable across different countries. Therefore, controversies continued to prevail over universally accepted definitions of proprioception. Since 1906, many definitions of proprioception have been formulated on the basis of different facts. Currently, neurophysiologists have defined proprioception as the input that occurs due to stimuli in three locations, which include peripheral mechanoreceptors, the visual system, and the vestibular system [12]. Shifting et al. [13] have suggested the significant functional capabilities of proprioceptive training exercises for reducing the risk of ankle sprains in the sporting population. There are reports that ankle sprains are extremely common consequences of sports-related injuries, being frequently associated with ankle replacement or disability [14,15].

High prevalence of ankle sprains is associated with directional changes, jumping activities, and pivoting [16,17]. Ankle tendon dysfunction, disability and pain, and economic burden have been commonly seen when assessing such complications. Chronic instability and impairment have been also diagnosed in athletes with ankle sprains [18]. For that purpose, proprioception has been identified as a complex neuromuscular process, which is concerned with kinesthetic awareness of body movement and body positioning. Efferent signaling and afferent responses play a significant role in injury prevention and joint stability [19]. Proprioceptive training exercises have been targeted to detect and improve joint position. Systematic reviews have explored proprioceptive exercises for the prevention and management of ankle sprains among athletes [20,22]. Strengthening, proprioceptive training, plyometric training, agility, and the combination of such neuromuscular interventions have been identified as rehabilitation measures. A systematic review also found effectiveness of functional rehabilitation interventions, evaluated by functional assessment tools, in improving athlete strains in accordance with their symptoms and complications [23].

Verhagen et al. [24] have demonstrated that proprioceptive balance training is a valuable effective approach for the prevention of ankle sprains in volleyball players. This approach is widely used in

rehabilitation centers, in order to restore damaged structures and ligaments around the ankle. Such training programs are also considered an effective alternative to bracing or taping for the prevention of sprains. Holm et al. [3] mention that side-to-side differences between limbs are usually expressed by the limb symmetry index. This approach is useful in training programs for assessing the value and frequency of functional deficit. Neuromuscular training programs were also introduced for handball teams because a study showed the risk of anterior cruciate ligament rupture among handball players [3].

Therefore, it can be said that neuromuscular training programs are widely used in the athletic domain in order to reduce the risk of severe complications of ankle-related injuries. Based on such facts, this systematic review aimed to analyze the effects of neuromuscular training programs on proprioception among athletes.

METHODS

A mixed research design was implemented for data collection and interpretation. The rationale behind the selection of this design was to gather authentic and relevant data for a systematic review and meta-analysis. Moreover, the mixed research design is also an authentic and widely recognized format in innovative research. Similarly, the mixed research design has also been effective for collecting a wider range of data for identification of the best outcome. Therefore, it is said that the mixed research design helps explore proprioception in neuromuscular training programs [37].

An appropriate search in the published literature using online libraries (Google Scholar, PubMed, EBSCOhost, and ProQuest) and different search engines was carried out. Keywords included NEUROMUSCULAR, EXERCISE, TRAINING, PROPRIOCEPTION, and ATHLETES. The inclusion criteria consisted mainly of studies related to the topic, having relevant resources, and published in the past 10 years.

The articles were scrutinized on the basis of relevance to the topic, abstract quality, knowledge level, quality of information, and authentication of resources. The initially selected 15 articles were further scrutinized by associated experts, resulting in the selection of the five best research articles for the systematic review and meta-analysis. Relevance and updated resources were two major aspects of the selection criteria. This process helped investigators enhance the quality of research articles in an effective way.

The collected data were analyzed by means of a systematic review and meta-analysis. After data collection, the research articles were evaluated on the basis of research questions. Relevant and necessary information was obtained from the selected articles in order to answer the research questions. The statistical analysis was conducted using IBM SPSS, version 20.

RESULTS

Initially, 200 research articles were selected for analysis, but this number dropped to 15 after the scrutiny process. The electronic search in the database yielded 200 research studies after removal of duplicate articles. Out of such extensive database collection, 15 research articles underwent full-text review. Ten of these were excluded from the research process for different reasons. The first one was that the studies were not randomized controlled trials. Another reason was that the control groups were also receiving neuromuscular training similar to the training groups. The remaining five research studies were included for the final analysis (**Figure 1**).

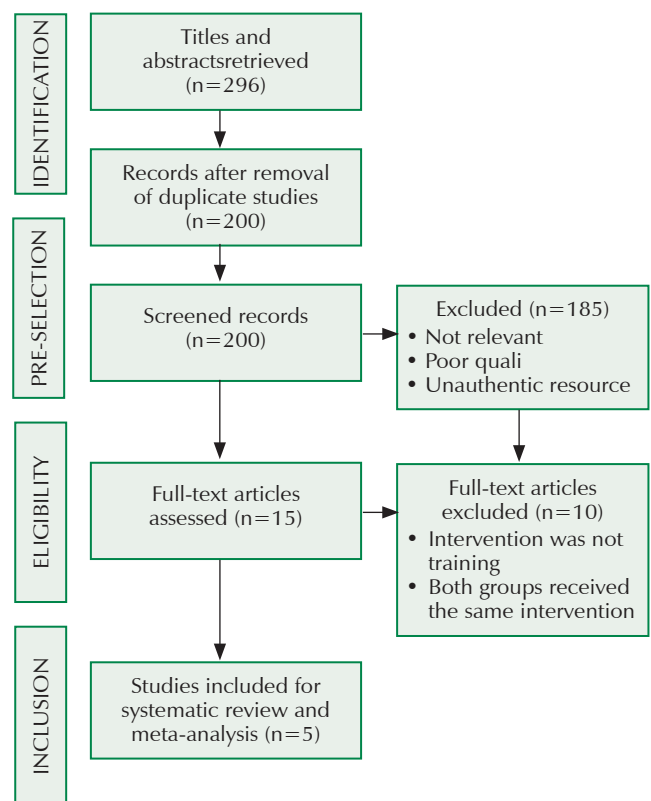


Figure 1. Selection of studies on the effectiveness of proprioceptive training programs among athletes suffering from ankle ligament injury.

These five research studies comprised 2,459 participants. **Table 1** shows the complete details about the included studies. PEDro scores of the selected studies ranged from 3 to 6 with an average score of 4.4/10. Using a grading system for PEDro scores, two of the selected five articles were identified as having “excellent quality” (score around 5 or 6), two were considered to be of “good quality” (score 3 or 4), and one study was of “moderate quality” (score 2). The five selected trials were identified to be homogenous from a statistical point of view. A meta-analysis of the five selected trials was performed, which revealed a statistically significant reduction in the extent of ankle injuries during proprioceptive training programs (5 trials, relative risk [RR]=0.69, 96%CI: 0.65-0.87). Such findings represented the number needed to

treat (NNT) of 17 (96%CI: 0.65-0.87), indicating that around 17 athletes would require proprioceptive training in order to prevent ankle injuries or its complications.

Comparison interventions included warm-up routines, usual care, and strength training. When such results were subdivided for analyzing the secondary effects of proprioceptive training programs, the outcomes were mainly related to the intervention (four trials, RR=0.54, 94%CI: 0.56-0.85; NNT=12, 93%CI: 99-6). While assessing the effect of proprioceptive training among athletes without any related history of ankle injuries, the pooled outcomes were statistically significant (RR=0.56, 94%CI:0.38-0.95; NNT=35, 93%CI:1000-13). The confidence interval was also analyzed, showing larger differences (**Figure 2**).

Table 1. Details of the interventions, outcomes, participants, and quality score of the studies that assessed effectiveness of proprioceptive training programs among athletes suffering from ankle ligament injury.

Study Details		Participants		Intervention			Outcomes	
Study	Quality	Characteristics	n	Intervention	Frequency	Duration	Control	Follow-up
Hupperets et al. (2009) [25]	Excellent (PEDro = 6)	Male and female athletes with percentile of 52% and 48%, respectively, were selected, with ankle sprain for around 2 months.	522	Usual care was given immediately after the injury. In addition, proprioceptive training programs were also arranged.	30-minutes session, 3 times a week.	8 weeks	Usual care after injury	One complete year
Emery et al. (2007) [26]	Excellent (PEDro = 5)	50% of male and female athletes, specifically basketball players, with ankle lateral ligament injury, were selected.	920	Specific sport balance training programs were arranged along with home-based training programs through wobble board.	Around 5 minutes for each practice session. 20 minutes for home training.	18 weeks	Warm-up programs as per the standards	18 weeks.
Mohammadi (2007) [27]	Good (PEDro = 4)	Professional soccer players with mean age of 25 years and past history of ankle sprain were selected.	80	Home-based proprioceptive training programs were arranged.	Around 30 minutes every day	120 sessions	Ankle evertor strength training	Conclusion of the entire season.
McGuine & Keene (2006) [28]	Good (PEDro = 3)	68% of female and 32% of male basketball and soccer players were selected. 76% of participants did not have any history of ankle sprain; however, 24% did.	765	5-phase balance training programs were developed by using single leg stance exercises.	5x5 training session for 4 weeks	4 weeks	Conditioning exercises under training programs	Exact duration was not mentioned
Eils et al. (2010) [2]	Moderate (PEDro = 2)	Professional basketball players, with past medical history of ankle sprain were selected.	172	Multistation proprioceptive training programs were arranged.	Once a week for around 20 minutes.	One specific season (duration undefined)	Standard workout only	Unspecific duration.

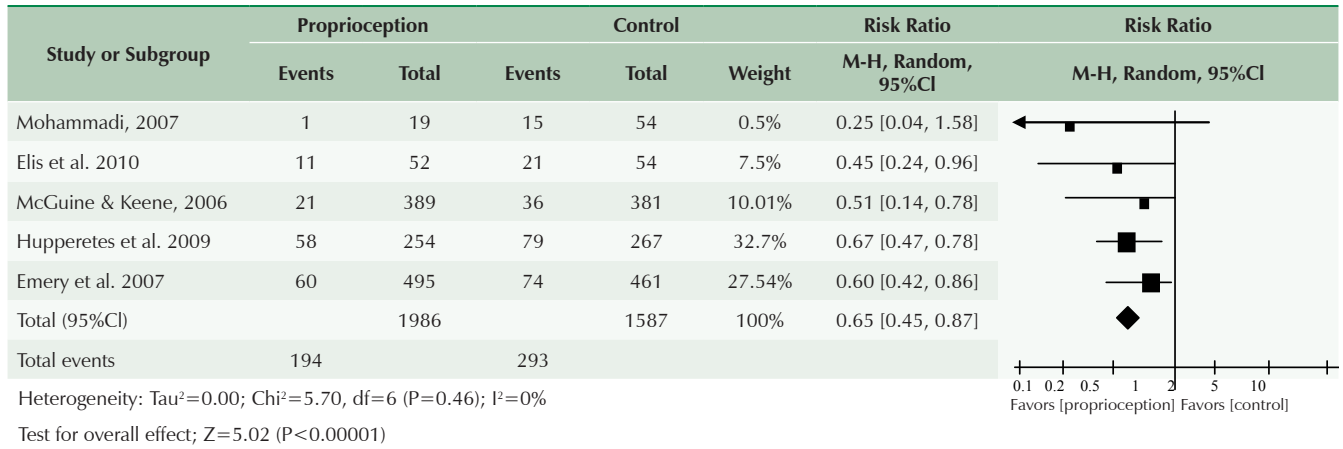


Figure 2. Meta-analysis of the studies on the effectiveness of proprioceptive training programs among athletes suffering from ankle ligament injury.

DISCUSSION

The overall findings of the meta-analysis and systematic review indicated that there was a direct impact of neuromuscular training programs on proprioception, preventing and reducing the risk of chronic complications. The findings also indicated that ankle injury and sport were two independent variables as there was not a major impact of these variables on health or training programs. As suggested by the systematic review and the meta-analysis, all of the five studies supported the implementation of proprioceptive neuromuscular training programs [2,25-28]. In order to develop a supportive argument for the implication of neuromuscular training programs, the study utilized a wider range of qualitative and quantitative studies. The rationale behind this approach was to specify the attained outcomes with the previous literature on the basis of authenticity and review.

Bazzucchi et al. [29] focused on the significance of training exercises concerning neuromuscular complications among diabetes *mellitus* patients. Diabetes *mellitus* is directly associated with the development of severe disability; therefore, the trends and significance related to neuromuscular training exercises can be easily witnessed. The study mentioned that deleterious changes usually occur in muscle contractile properties and motor nerves, often reducing muscle strength and power. Therefore, regular neuromuscular exercises are beneficial as they reduce the risk of morbidities. Similarly, Ageberg and Roos [30] identified that neuromuscular exercise training can be easily used as significant treatment for degenerative diseases. Degenerative diseases usually

affect the muscular system, specifically among women. The outcomes specifically depict that knee problems resolve after neuromuscular exercise training for a specified time frame. A randomized controlled trial was conducted by Villadsen et al. [31], demonstrating beneficial results of neuromuscular exercises after hip and knee arthroplasty. The trial also mentions that neuromuscular exercises are beneficial for tendons and muscles during strains. Although the three selected studies have no relationship with athletics and sports, they strongly support the importance of neuromuscular exercises for morbidities related to the muscular system. Therefore, it can be said that neuromuscular exercise training programs help patients avoid pain and other complications associated with the muscular system.

Proprioceptive training programs for prevention of pain and strains is another valuable aspect. Many outcomes have been identified through systematic reviews and meta-analyses. However, the previously published literature also supports the statistical relationship between prevention and proprioception. A randomized controlled trial was conducted [28], which focused on participants with no history of ankle sprains. This trial did not show any impact of training programs on proprioception as regards prevention. However, the meta-analysis showed a statistically significant pooled impact after comparison with those participants with a history of ankle sprains [28]. A research study selected those individuals or athletes with a prior history of ankle sprains. The results show a positive impact of training programs on proprioception [2]. Similarly, compliance levels are directly associated with the impact of training programs on proprioception

regarding the prevention of ankle injuries. There was variability among different research studies; however, the level of compliance plays a major role in experimental settings in so that the best outcomes can be achieved [17]. At the same time, the effectiveness of proprioceptive training to treat ankle injury among athletes suggests that rehabilitative effects have been analyzed because of a proper mechanism. It has been ideally proposed that such training programs help patients address their impairments and fight the complications of ankle injury. A past research study supported that neuromuscular training programs help athletes effectively reduce the risk of acquiring severe chronic complications [32].

Because of the remarkable similarities between the clinical perspective and the selected research studies, it can be said that the findings of this research study can be also applied in the clinical environment. The selected research studies utilized the best possible clinical approaches, which may help clinicians improve their practices in an effective way. Therefore, it can be said that the clinical application of all these outcomes is possible due to the appropriate level of impact on preventive approaches [2,25-28].

As clinical approaches are effective, proprioceptive training programs significantly help athletes assure their well-being and wellness regarding ankle strains and disability. In addition, athletes are also exposed to disability risk, which is mostly reduced through trainings. Moreover, proprioceptive training exercises are mostly broken into different sessions, which are necessary for organization and promotion of wellness in accordance with the human body [2,28]. Therefore, it can be said that training programs and exercises must be arranged through effective strategies to avoid any potential risk of ankle injuries.

The study also demonstrates that training programs that include vigorous exercises are not as effective as functional exercises in reducing the risks and complications of ankle strains. Proprioceptive and neuromuscular exercises substantially help athletes to prevent the risk of such complications for their normal osteopathic and physiological functioning [17]. Similar outcomes were retrieved by the current study in order to assess the compliance level. Therefore, it is said that proprioceptive training programs greatly help prevent the risks of ankle strains in the sporting population.

Sugimoto et al. [33] carried out a meta-analysis that revealed a significant relationship between training programs and proprioception for the prevention of injuries. The statistical analysis showed

that proprioceptive training programs helped prevent ankle strains among athletes. In a similar context, Myer et al. [34] focused on the implication of proprioceptive exercises among athletes. The relative outcomes indicated that ankle strains among athletes are extremely common and can be easily prevented through proprioceptive programs. A critical review carried out by Sugimoto et al. [35] also supported the usage of proprioceptive training programs for reducing muscular diseases. Brandon et al. [36] utilized different techniques for assessing the role of proprioceptive exercises. Their study indicated that proprioceptive training programs help reduce strain-related outcomes among athletes.

A limitation of the selected research studies concerns insufficient information about training parameters and substantial variability. For instance, all of the selected research articles indicated that the training programs were divided into different sessions with pre and post techniques. However, the studies failed to provide knowledge about the parameters utilized for measuring ankle problems and their complications. At the same time, the selected research studies also failed to provide relevant information about exercise duration. None of the research studies indicated the specific length of time and number of sessions for the training programs [2,25-28]. Despite this perspective of variability, a proper impact was also detected in this review.

The optimal ratio between dose and response for the prophylactic impact of proprioceptive training programs remains unclear. A cumulative impact may exist; however, longer programs have a direct preventive impact [1]. It is extremely difficult to assess training programs and their effectiveness as far as preventive parameters are concerned. Future studies can develop different training parameters in order to increase safety and quality of life. However, this systematic review has its own strengths. To begin with, this review completely focused on the effectiveness of proprioceptive training programs among athletes. This review did not deviate from the topic or relative variables at any point of the research process. This review selected only five controlled trials for analysis among a diversified range of research articles. Thus, it can be said that the outcomes of this review are reliable comparatively to other research studies.

CONCLUSIONS

Ankle-related injuries have been identified as a severe muscular condition, which is usually

characterized by pain and strains. The prevalence rate of ankle-related injuries has increased at a constant rate among athletes across the globe. Therefore, proprioceptive exercises have been analyzed through meta-analyses and systematic reviews. A wide range of previously published literature has indicated that proprioceptive exercises relatively help athletes prevent ankle strains. Moreover, a comparison between the studies selected for the systematic review and previously published literature has identified that proprioceptive exercises are necessary to enhance the quality of life of athletes. Therefore, it can be concluded from the meta-analysis that ankle strains and other injuries can be easily minimized and prevented

among athletes through neuromuscular proprioceptive exercise training. However, a larger sample size can be utilized in future studies to identify more comprehensive outcomes related to ankle injuries.

NOTES

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Conflicts of interest disclosure

The authors declare no competing interests relevant to the content of this study; they state to have full access to all available data and to take complete responsibility for the integrity of the results.

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