REVIEW ARTICLE

The efficiency of proprioceptive training in preventing injuries to team athletes: A systematic review

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Abstract

The aim of this systematic review was to evaluate the effectiveness of proprioceptive training in the prevention of lower extremity injuries, especially the ankle and knee joint, in team athletes. PRISMA recommendations were applied for this research. PubMed, ScienceDirect, and BioMed Central were used to identify relevant studies. The methodological quality of studies was assessed using the Physiotherapy Evidence Database-PEDro scale. Only 7 research met the eligibility criteria, and their outcomes were presented. Proprioceptive training has been shown to be very effective in preventing ankle injuries, especially in recurrent ankle sprains. However, in 3 of 4 studies lacked the effects of proprioceptive training in the prevention of knee and ACL injuries. Based on the results of the analyzed research, I can conclude that proprioceptive training is a very effective training tool in the prevention of ankle sprains in the population of team athletes, but proprioceptive training is not sufficient as the only training component in preventing knee injuries.

Keywords proprioceptive training • prevention • ankle injuries • knee injuries • team athletes.

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Introduction

In modern sport, there is a great emphasis on the physical fitness of athletes, which causes a large number of injuries. For this reason, many studies are focused on detecting the most common injuries, as well as those that have the most serious consequences on the quality of sports performance, but also on the health of the athletes. The lower extremities are the most often affected by injuries when we look at professional-level football players (Stubbe et al., 2015; Giza et al., 2005) and elite young players (Le Gall, Carling, & Reilly, 2008). An ankle sprain is the most frequent injury in sports such as volleyball (Bahr & Bahr, 2008; Bere et al., 2015; Verhagen et al., 2004) and basketball (Darkos et al., 2010; Baker, Rizi, & Athiviraham, 2020). The knee joint is a big problem for handball players, 18 of 49 lower extremity injuries are localized to the knee, while ACL is a leader in injuries of the mentioned joint (Seil et al., 1998), but Giroto et al. (2015) showed that the ankle joint (19,4%) is the most commonly injured body segment in elite Brazilian handball players. A longitudinal study conducted on NBA basketball players showed that injuries such as patellofemoral inflammation (7569, 11.5%), knee sprains (5712, 8.6%), ankle sprains (5122, 7.7%), and lumbal strains (3365, 5.1 %) were responsible for a large number of days missed (Starkey, 2000). Also, knee injuries had the greatest consequences on the length of absence from football fields (on average 45 days) (Stubbe et al., 2015).

Proprioception is the ability of an organism to perceive the position and movements of joints. Proprioception requires the coordinated action of different types of receptors. Mechanoreceptors,

more precisely proprioceptors, are located in tendons, muscles, ligaments, and joint capsules and they transmit proprioceptive information to the central nervous system, which is very important for better control of movement (Ferlinic et al., 2019). Also, proprioception is a wide concept that include balance and postural control with visual and vestibular contribution, joint kinestesia, position sense, and muscle reaction time (Ergen & Ulkar, 2008). Injuries to joints connective tissues can damage afferent mechanoreceptors, causing disruption of the proprioceptive mechanism (Hoffman & Payne 1995). Proprioceptive training is effective in preventing ankle sprain injuries in athletes, especially recurrent injuries (Huppertes, Verhagen, & Van Mechelen, 2009). Also, the same training method can prevent the recurrence of ankle sprains in volleyball players who have experienced first or second-degree sprains (Paul, 2016), and increase ankle dorsoflexion range of motion (ROM) in individuals with ankle sprain (Lazarou et al., 2018). Eils and Rosenbaum (2002) have shown that multi-station proprioceptive training improves joint position sense, postural sway as well as significant changes in muscle reaction times (peroneal muscles complex) in patients with chronic ankle instability. The subjective feeling of instability improved after six weeks of balance training in patients with chronic ankle instability (CIA) as assessed by CAIT (Cruz-Diaz et al., 2015).

Proprioception was a component of neuromuscular training (which also included strength exercise, plyometrics as well as jump and landing module) and which proved to be very effective in preventing severe knee injuries in adolescent handball players (Achenbach et al., 2017). Young football players who realized neuromuscular training, with a component of balance, and after those 15 minutes additional exercise on a wobble board, reduced the risk of injury to the ankle and knee joint (Emery & Meeuwisse, 2010). Addition, proprioceptive exercise as a segment of neuromuscular warm-up can contribute to the protective effect against lower extremity (LaBella et al. 2011; Benis, Bonato, & La Torre, 2016) and ankle injuries (Owoeye et al., 2018). There is not a large number of review papers that focused exclusively on proprioceptive training and the prevention of athletes' injuries. Some of them says that proprioceptive training is efficient in preventing ankle sprain in the athlete's population (Schiftan, Ross, & Hahne, 2015; Souza de Vasconcelos et al., 2018). However, Owen et al. (2006) do not recommend the implementation of proprioceptive training as the only training component in the prevention of ACL injuries. Of course, multicomponent training, which includes elements of strength, stretching, plyometrics, running, and proprioception, is the best way to prevent ACL injuries (Acevado et al., 2014).

To the author's knowledge, this is the first review study that examines the effectiveness of exclusively proprioceptive training in the prevention of lower extremity injuries, with an emphasis on ankle sprains and knee injuries (especially ACL injuries), when athletes only competing in team sports.

Method

A systematic review was performed using the guidelines of the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) (Moher et al., 2009).

Literature search strategy

Literature electronic search was performed in January 2021, using PubMed, ScienceDirect, and BioMed Central. The following keywords were used in the search: "proprioception training", "balance exercise", "neuromuscular training", "wobble board", "injury prevention", "lower extremity injuries", "ankle injury prevention", "knee injury prevention", "ACL injury prevention", "team athletes", "soccer", "basketball", "volleyball", "handball". These keywords were used separately or in combination with AND. Also, the references of all selected studies and relevant systematic reviews were manually checked for additional researches.

Inclusion and exclusion criteria

The inclusion criteria for the selected articles included the following: (1) the participants in the study were only team athletes, (2) studies must be published after 1996, (3) proprioceptive training is aimed at preventing injuries to the lower extremities, (4) the experimental group performed proprioception exercise exclusively, without the addition of neuromuscular training, (5) studies written on English.

There were several exclusion criteria: (1) without a control group, (2) no injury data, (3) participants must come from only one team sport, without multiple team sports in one study (4) PEDro score is less than 4.

Methodological quality of studies

The Physiotherapy Evidence Database (PEDro) was used to assess the methodological quality of the studies (Maher et al., 2003). The PEDro scale evaluated the included studies from 0-10, based on 10 methodological criteria. The PEDro scale represents a valid measure of the methodological quality of clinical trials (De Morton, 2009). Due to the nature of this review, it was considered unlikely that participants, therapist, or assessor would be blinded to the intervention: therefore, a maximum score of 7 was predicted. Studies scoring 6 or 7 were considered to be a "high" methodological quality, while studies scoring between 4 or 5 were considered to be "moderate" quality, and studies scoring less than 4 were considered to be "poor" quality and were excluded from the review.

Data extraction

The following data were extracted from each study: author of the study and year of publication, journal of publication, methodological quality (PEDro score), sports data, number of participations, age and gender of participants, information and description of proprioceptive training, program details of included studies, outcomes (data on injuries of the lower extremity, ankle or knee joint), results.

Results

A search finding

Initially, 378 studies were identified after searching 3 databases. After duplicates were removed, a total of 257 articles were screened. After reading the title and abstracts, 194 studies were excluded. The remaining 63 full-text articles were read and assessed for eligibility, and 56 studies that did not fulfill eligibility criteria were excluded. Thus, 7 studies were included in this review (Figure 1).

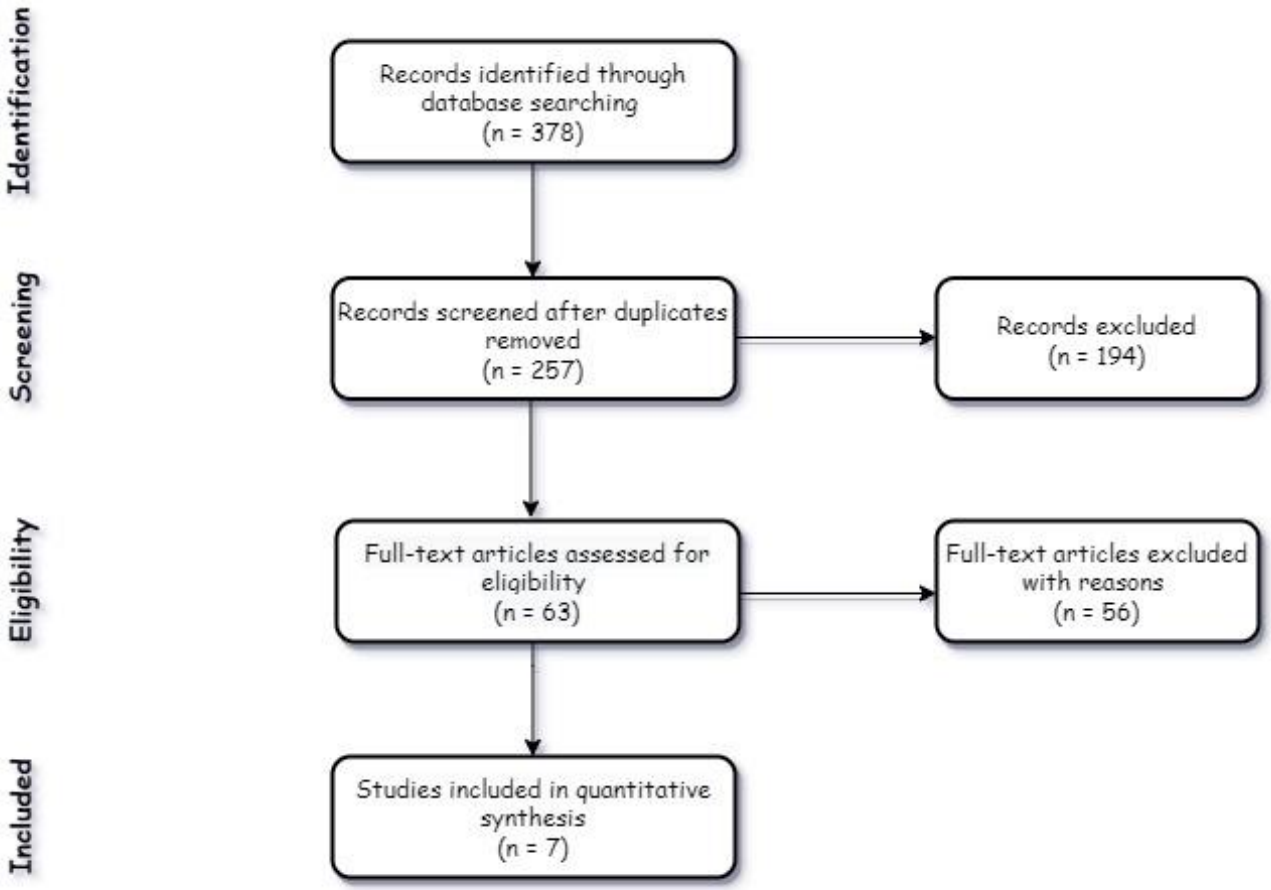

Figure 1. PRISMA flow diagram

The studies were excluded for the following reasons: non-English studies (n=8), participants are not team athletes (n=13), year of publication of the article is before 1996 (n=1), there were more team athletes in the sample (n=1), no control group (n=5), there were no reports of injuries (n=4), the experimental group performed additional exercise in addition to proprioceptive training, or realize neuromuscular training (n=22), PEDro score was less than 4 (n=2).

The PEDro score of the studies included ranged from 4 to 7. Three studies classified as "high" quality (one article had a score 7, and two 6), and the other four studies were classified as "moderate" quality (one study had a score of 5, and three studies had a score of 4). The average PEDro score of the included articles is 5.1, which means that the review could be marked as "moderate" quality. The results of the methodological quality of the included studies are shown in Table 1.

Methodological quality of studies

Table 1. Methodological Quality, PEDro Scale

Study	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	Score
1. Eils et al. (2010)	+	-	-	X	X	X	+	+	+	+	5
2. Cumps et al. (2007)	-	-	+	X	X	X	+	-	+	+	4
3. Emery et al. (2007)	+	+	+	X	X	X	+	+	+	+	7
4. Verhagen et al. (2004)	+	+	+	X	X	X	-	+	+	+	6
5. Mohamadi et al. (2007)	+	-	+	X	X	X	+	+	+	+	6
6. Söderman et al. (2000)	+	-	+	X	X	X	-	-	+	+	4
7. Malliou et al. (2004)	-	-	+	X	X	X	-	+	+	+	4

1. Random allocation, 2. Concealed allocation, 3. Baseline comparability, 4. Blind subjects, 5. Blind therapist, 6. Blind assessors, 7. Adequate follow-up, 8. Intention-to-treat analysis, 9. Between-group comparison, 10. Point estimates & variability

Description of included studies

The main characteristics of included studies are in Table 2. Three articles relate to basketball, one to volleyball, and three to football.

Eils et al. (2010) showed a significantly reduced frequency of ankle injuries. In the control group, 21 injuries occurred, while the experimental group experienced 7 injuries. The risk of ankle injury was significantly reduced in the training group by approximately 35%. Chumps et al. (2007) documented a significantly lower incidence of lateral ankle sprain in the experimental group compared to the control group by calculating Relative Risks (RR= 0.30 [95% CI: 0.11-0.84]). Also, the risk for new or recurrent ankle sprains was slightly lower in the experimental group (new: RR= 0.76 [95% CI: 0.17-3.40]; re-injury: RR= 0.21 [95% CI: 0.03-1.44]). Emery et al. (2007) showed fewer lower extremity injuries in the training group than in the control group (106 vs. 111). Ankle sprain injuries are represented in a smaller percentage in the interventional group (47,7% vs 53,9%). However, acute knee injuries (including all ligament sprains and meniscus tear) are present in a higher percentage in the interventional group (13,8%) compared to the control group (9.2%).

Verhagen et al. (2004) demonstrated significantly fewer ankle sprains in the interventional group than in the control group. A significant reduction in ankle sprain risk was found only for players with a history of ankle sprains. The incidence of overuse knee injuries was increased in the interventional group.

Mohammadi (2007) reported that the incidence of ankle sprains for subjects who suffered ankle sprain was significantly lower in the proprioception training group than in the control group (relative risk of injury, 0.13; 95% confidence interval, 0.003-0.93; P = .02). Söderman et al. (2000) demonstrated a higher number of ACL injuries in the group performing balance board training (4 ACL) compared to the control group (1 ACL). Malliou et al. (2004) reported fewer lower extremity injuries in the intervention group (60 vs. 88). Also, number of ankle sprains was lower in the experimental (22) than in the control group (38) as well as knee ligament strains (14 vs. 28).

Table 2. Characteristics of studies included in the review

Study	Journal	PEDro score	Sport	Participants	Intervention	Program details	Outcomes
1. Eils et al. (2010)	Medicine & Science in Sport and Exercise (2010)	5 Moderate quality	Basketball	n=198, male and female, professional basketball players, age 14-43	Multi-station-(6 exercises) proprioception exercise program	Once a weak- 20 minutes	Ankle injuries
2. Cumps et al. (2007)	Journal of Sports science and Medicine (2007)	4 Moderate quality	Basketball	n=50, male and female, elite young and elite senior, age IG (17.7), CG (18.0)	Basketball specific balance training with balance semi globes	22 weeks – 3x 5-10 minutes a week	Lateral ankle sprain
3. Emery et al. (2007)	Clinical Journal of Sport Medicine (2007)	7 High quality	Basketball	n=920, male and female, adolescent basketball players, age 12-18	Sport-specific balance training program and home-based training program with a wobble board	5x 5 minutes balance training program and 20 minutes with a wobble board	Lower extremity injuries Ankle sprain Knee injuries
4. Verhagen et al. (2004)	The American Journal of Sports Medicine (2004)	6 High quality	Volleyball	n=1127, female and male, second and third Dutch volleyball divisions, age 24.3	Balance board training program performed as a part of warm-up	36 week- 4 prescribe exercise (1 of 4 was used during warm-up), 5 minutes for each of them	Ankle sprain Knee injuries
5. Mohammadi et al. (2007)	The American Journal of Sports Medicine (2007)	6 High quality	Football	n=80, male, professional football players, age 22-26	Proprioception training using ankle disk	30 minutes daily	Ankle sprain
6. Söderman et al. (2000)	Knee Surgery, Sports Traumatology Arthroscopy (2000)	4 Moderate quality	Football	n=140, female, second and third Swedish football division, age 20.5	Balance board training in addition to standard football practice and games	30 days, 10-15 minutes daily, 5 exercise- 3x15s on each leg, and then 3x per week for the rest of the season	ACL injuries

Table 2 (continued). Characteristics of studies included in the review

7. Malliou et al. (2004)	Journal of Back and Musculoskeletal Rehabilitation (2004)	4 Moderate quality	Football	n=100, male, young Greek football players, age 16.8	Balance exercise (1."Biodex stability system", balance device 2.Balance boards, 3.Mini trampoline)	12 month, 2x 20 minutes a week	Lower extremity Ankle sprain Knee ligament strains

Discussion

The review identified 7 relevant articles documenting the effectiveness of proprioceptive training in the prevention of team athletes' injuries. Research results unequivocally show that proprioceptive training is an excellent prophylactic tool for an ankle injury. Six of seven studies demonstrated information on ankle injuries. Three of them (Chumps et al., 2007; Verhagen et al., 2004; Mohammadi et al., 2007) emphasizes the effect of the mentioned training method in preventing recurrent ankle sprains. Also, 2 articles say that proprioceptive training inhibits overall lower extremity injuries (Emery et al., 2007; Malliou et al., 2004). However, as I assumed, this review says that proprioceptive exercise can't prevent knee injuries. Söderman et al. (2000) have shown that proprioceptive training cannot prevent ACL injuries in female football players. In two more studies (Emery et al., 2007; Verhagen et al., 2004), proprioceptive training did not prove to be a valid tool for preventing knee injuries. Only Malliou et al. (2004) have demonstrated the effect of proprioceptive training in the prevention of some knee injuries.

In accordance with the results of this research, some of the previous systematic reviews and meta-analyzes have stated the importance of proprioceptive training in the prevention of ankle injuries (Huerta Ojeda, Casanova Sandoval, & Barahona-Fuentes, 2019; Postle, Pak, & Smith, 2012). Schiftan, Ross and Hahne (2015) also expose the significance of proprioceptive training in preventing recurrent ankles sprains. Certain articles from this review (Eils et al., 2010; Malliou et al., 2004) say that proprioceptive training reduces the frequency of ankle injuries. Also, Stasinopoulos (2004) investigated the effect of various training methods that reduce the incidence of ankle inversion among female volleyball players. Proprioceptive training has proven to be a very effective training method in preventing recurrent of the ankle in those volleyball players who have experienced injury once or twice. After six weeks home-based proprioceptive balance-training program, the risk of ankle sprains is significantly reduced in healthy adolescent (Emery et al., 2005). As already mentioned, the results of this research and a large number of previous ones demonstrate the power of proprioceptive training in the prevention of recurrent ankle sprain. Based on an analysis of incorporated studies, I would recommend 5-20 minutes of proprioceptive training 2-3 times a week to prevent ankle injuries in team athletes, especially recurrent ankle sprains.

On the other hand, this research suggests that proprioceptive training is not a recommended tool in the prevention of knee injuries (ACL). Similarly, Owen et al. (2006) found in their review that proprioceptive training was not sufficient to prevent ACL injuries. Research shows that neuromuscular training is superior in preventing ACL injuries (Waldén et al., 2012; Murray et al., 2017; Myklebust et al., 2003). Plyometric training proved to be the most effective of all segments (including strength, balance) of multicomponent training (Alentron-Geli et al., 2009). Also, Riva et al. (2016), in a six-year longitudinal study, presented a lack of effectiveness of proprioceptive training in the prevention of knee injuries in professional Italian basketball players. Proprioceptive exercise along with plyometric (jump) exercise is appropriate for the prevention of knee injuries among women handball players (Petersen et al., 2005). Also, neuromuscular training (proprioceptive exercises are the most important component) increases the joint position sense in elite female handball players, which contributes to a lower incidence of knee injuries (Pánics et al., 2008).

This review has several strengths. First of all, the study is oriented only to athletes who compete in team sports. Also, the review paper shows injuries of the ankle and knee joint, unlike previous studies that examined the effects of proprioceptive training. The research included only studies of "high" or "moderate" quality, those of "poor" methodological quality were not considered. There are also some limitations. Studies are mainly focused on sports such as football and basketball. There is an obvious lack of articles that show efficiency exclusively proprioceptive training and injury prevention in handball. There was no limit in gender, age, or competitive rank of the athletes. The following research could focus only on professional or elite athletes. The study involved only researches written in English (there are quality articles in Spanish and German).

Conclusion

The results of the presented systematic review emphasize that proprioceptive training is effective in the prevention of ankle injuries, especially by recurrent ankle sprains in team athletes. However, proprioceptive exercises are not sufficient in

preventing knee injuries (ACL). Some of the next research could focus on the prevention of ankle sprains in athletes who have not experienced ankle sprain injury.

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