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Is an Exercise-Based Injury Prevention Programme Effective in Team Handball Players? A Systematic Review and Meta-Analysis

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Abstract

Objective

This systematic review and meta-analysis aimed to assess the effectiveness of exercise-based injury prevention programmes in preventing sports injuries in team handball players.

Data Sources

Two independent researchers performed a systematic search in the electronic databases Scopus, PubMed, Web of Science (WOS), SPORTDiscus, and CINAHL from inception until Aprile 2023.

Study Selection

Studies were included if they were randomized-controlled or prospective cohort trials, contained a population of competitive team handball players, included an intervention designed specifically to prevent or reduce the risk of team handball injury, and reported injury incidence rates specific to team handball players. Two researchers independently assessed trials for inclusion criteria and methodological quality.

Data Extraction

Study design, intervention details, participant characteristics, and the number of injuries in each group were extracted from each study by two independent researchers. The outcome of interest was the incidence rate of injury. Injury data were classified into 5 groups: lower extremity injuries, shoulder injuries, knee injuries, ankle sprains, or ACL injuries. Extracted data were analyzed by Comprehensive Meta-Analysis software, version 3.0 (CMA.V2) using a random-effects model to compute the overall effect estimates of injury prevention programmes in reducing the risk of injuries. Odds ratios (ORs) with 95% CIs were calculated based on the number of injuries in each group.

Data Synthesis

Meta-analyses were conducted independently for each injury classification. Results indicate that prevention programmes significantly reduced the risk of shoulder injuries (OR, 0.56; 95% CI, 0.36-0.87; $P = 0.01$), lower extremity (OR, 0.59; 95% CI, 0.37-0.98; $P = 0.03$), knee (OR, 0.53; 95% CI, 0.35-0.78; $P = 0.002$) and ankle sprains (OR, 0.57; 95% CI, 0.40-0.81; $P = 0.002$), and ACL ruptures (OR, 0.67; 95% CI, 0.45-0.97; $P = 0.03$) in team handball players.

Conclusion

In team handball players, prevention programmes appear effective in reducing the risk of shoulder, lower extremity, knee, ankle, and ACL injuries.

Keywords: shoulder injury; lower extremity injury; knee injury; ankle injury; ACL injury; handball

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Key points

- Given the apparent disparity between studies on the effectiveness of exercise-based injury prevention programmes for team handball, it remains unclear whether such programmes are truly effective in reducing the risk of team handball injuries or not.
- Exercise-based injury prevention programmes can reduce the risk of injuries for the shoulder (from 36% to 87%) and lower extremity (37% to 98%) in team handball players.
- Regarding lower extremities, exercise-based injury prevention programmes may reduce the risk of knee and ankle injuries in team handball players from 35 to 78% and from 40 to 81%, respectively.
- In the case of specific injuries, exercise-based injury prevention programmes may help to reduce the risk of ACL injuries by 45-97% in team handball players.
- Due to the relatively low number and quality of studies on this topic, higher-quality studies may help to improve the strength of the recommendations.

Introduction

Team handball is one of the most popular ball sports played by nearly 20 million people around the world.[1] Handball is played by two teams consisting of seven field players in two periods of 30 min. Each team includes five substitutes players who can be substituted at any time during the game. Each player uses their hands to pass a ball with the aim of throwing it towards the opposing team's goal and the team that scores the most goals is the winner. Previous studies have shown that playing team handball improves several physical and physiological parameters.[2] However, participation in handball is also associated with a high risk of injury,[1] mainly because players are exposed to high physical demands during training sessions and games.[3] Team handball is a high-intensity contact sport, involving repeated acceleration and deceleration movements, fast sidestep cutting and pivoting maneuvers, sudden jumping and landing movements, and frequent throws.[1, 4-6] Additionally, professional players endure busy competition schedules (between 70 and 100 international,

national, and club competitions) and intense training pressures to stay at a competitive level,[4, 7] which probably contributes to the high prevalence of injuries in team handball.[8] At the elite level, the increase in the number of national/international matches and tournaments has resulted in a typical season lasts 9-10 months.[9] During the season, elite players typically play two matches per week compared to one match at lower levels of play, and in different periods elite players often train twice a day.[9]

Compared to other team sports the risk of injury in team handball was in 2008 the third (after soccer and field hockey),[10] in 2012 the second (after soccer),[8] and in 2016 the fourth (after soccer, rugby, and water polo).[11] The overall incidence of injury in team handball is reported to be between 10 to 40 per 1000 player hours, with the majority of injuries occurring during matches.[10, 11] The most frequent injuries in team handball players are located in the lower limbs (thigh, knee, and ankle), the shoulder, and the upper limbs.[3, 12] Nearly half of all team handball injuries involve the knee and ankle[3, 5, 11, 12] of which ankle injuries are the most reported in team handball (8 to 45%), while ACL injuries occur less frequently (7 to 27%), they are more severe.[13] Injuries in hand joints are around 9.9% and those in the shoulder joints amount to 9.3%.[9] Even though the incidence of shoulder injuries is relatively low, shoulder injuries require the third-longest interval of convalescence after trauma, following knee and ankle injuries.[9] Injuries not only affect players' health and performance, but also come at costs to the sports team and the athlete's family,[14, 15] and may in the long term lead to early joint degeneration of especially the knee.[16]

Injury prevention should be a primary goal for handball players of all ages and participation levels (e.g., recreational, semiprofessional, professional) since an injury will not only result in athletic performance deficits, an increased risk of re-injury and chronic sequelae but also loss of playing time, a high financial burden for the professional athlete's employer and the healthcare system.[17] Yet, it is not clear whether such programmes do indeed diminish the incidence of injuries in handball players. Therefore, the aim of this meta-analysis was to assess the effectiveness of exercise-based injury prevention programmes in preventing sports injuries in team handball players. We hypothesized that the literature presents inconsistent results in the prevention of injuries in handball players, ultimately resulting in no evidence for a significant reduction of the lower extremity, ACL, or ankle sprain injury risk in this population by such exercise-based injury prevention programmes.

Methods

Study Design

This systematic review and meta-analysis was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Statement.[18] The protocol was registered in PROSPERO on December 2021 (XXX).

(Figure 1 about here)

Search Strategy

The literature search was independently conducted by two researchers (XXX and XXX). First, relevant studies were identified through an internet-based search in five health-related, biomedical, and psychological databases (Scopus, PubMed, Web of Science (WOS), SPORTDiscus, CINAHL). No filters or limitations were imposed during any of the database searches. The search was carried out from inception until April 2023. Relevant search keywords were combined with Boolean operators (OR/AND) and applied to three search levels (Table 1).

(Table 1 here)

Further, the bibliographic references of identified studies were searched manually for additional relevant studies. Finally, all eligible studies were entered into Google Scholar to identify all of the articles that had cited them.

Retrieved articles from each database were imported into EndNote X7 software (Thomson Reuters, New York, NY, USA) for duplicate removal, screening, and review. After accounting for duplication, the eligibility of returned articles was judged by screened title and abstract. Where study selection was unclear from the reading title or abstract, the article was screened in full text. Studies were screened against the predetermined inclusion and exclusion criteria by two independent reviewers (XXX and XXX). In situations where conflicts arose, the two authors discussed the manuscript and reached a consensus. If consensus was not achieved, a third reviewer (XXX) was involved.

Eligibility Criteria

The inclusion criteria, according to the 'PICOS' model (Population, Interventions, Comparisons, Outcomes, and Study Design)[18], were: (1) Population: competitive handball players of any age (e.g., professional, collegiate, scholastic, intramural); (2) Intervention: intervention programmes was designed specifically to prevent or reduce the risk of team handball injury (overall of regional-specific injury prevention programmes). The exercise-based injury prevention programme has to be multifaceted and include sport-specific skills, strength, balance or plyometric exercises. Sport-specific exercises mimic specific technical skills such as landing and throwing techniques that apply directly to handball. Resistance exercises were defined as activities that improve muscle strength through using resistance like body weight, free weights, elastic bands, or strength machines. Balance exercises refer to activities that require maintaining the line of gravity at the base of support like single-legged or double-legged stance activities that were designed to improve proprioceptive awareness. Activities were characterised as plyometric exercises if they utilised powerful movements, such as jumping or bounding movements. (3) Comparisons: at least one control group that did not receive any intervention (CON); (4) Outcomes: incidence rate of the injury or other outcome data such as injury counts and athlete exposures that made it possible to calculate incidence rate was reported; (5) Study Design: a randomized controlled or prospective cohort study; (6) Full-text article published in English in a peer-reviewed journal.

All types of multicomponent exercise interventions to prevent team handball injuries were selected, but interventions using protective devices (e.g., braces, tapes) or including only one exercise component (e.g., using Nordic eccentric exercise to prevent hamstring injuries) were excluded. Case studies, lectures, commentaries, editorials, review articles, or articles that were not peer-reviewed or not written in English were excluded.

Quality Assessment

The risk of bias (for randomized controlled trials, and prospective cohort trials) was independently assessed by two reviewers (XXX, XXX) using Physiotherapy Evidence Database (PEDro) scale.[19, 20] The PEDro scale is a valid and reliable measure of the methodological quality of randomized controlled trials in systematic reviews.[19, 20] The PEDro scale is an 11-item scale with "yes" and "no" answers. The first item pertains to external validity and is not used to compute the overall quality score. The remaining 10 items (2–11) are summed to obtain a final PEDro score out of 10; a higher score reflects the higher methodological quality. A PEDro score of ≥6 is considered to represent a high-quality study, a score of 4-5 is considered moderate quality, and a score of ≤ 3 is considered to represent a low-quality study.[20] Disagreements regarding PEDro scoring were resolved by a discussion between the reviewers. If consensus was not achieved, a third reviewer (XXX) was involved. All studies were scored and entered into an individual spreadsheet (table 2).

(Table 2 about here)

Data Extraction and analysis

Two authors (XXX, XXX) independently extracted data using a specifically designed standardized form, and afterward, the authors compared the extracted data for consistency. Any discrepancies between the two forms were resolved during a consensus meeting. Study design, country, and competitive level, study population (sex, size, age), size of control and intervention groups, dropout rate, details of the intervention (type, duration, frequency), and the number of injuries per group were extracted. Injuries included all injuries (overuse and traumatic) sustained during the study period in training and match play. Data were classified into 5 groups based on the anatomic location of the injury (lower extremity injuries, shoulder injuries, knee injuries, ankle sprains, ACL injuries). When applicable, data from a single study were included in more than 1 group.

Data Synthesis

Meta-analyses were undertaken with Comprehensive Meta-Analysis version 3.0 using a random-effects model to compute the overall effect estimates of injury prevention programmes in reducing the risk of shoulder injuries, lower extremity injuries, knee injuries, ankle sprains, and ACL injuries. Odds ratios (ORs) with 95% CIs were calculated based on the number of injuries in each group. Statistical heterogeneity was assessed using the I^2 statistic to describe the proportion of the observed variability in effect among studies that is due to true differences in effect. I^2 value of 0% indicates no heterogeneity, 30%-60% meant moderate heterogeneity, and more than 75% shows a considerable heterogeneity.[21, 22] Publication bias was assessed via visual inspection of a standard funnel plot, Orwin fail-safe N, and Egger's regression test. An alpha level of 0.05 was considered for statistical significance.

Results

Search Results

The initial database search using Scopus, PubMed, Web of Science (WOS), SPORTDiscus, and CINAHL databases yielded 562 results. After duplicate removal, 235 articles were screened for relevancy. Screening by title and abstract yielded 24 potentially eligible articles and after a full-text review, 15 were excluded. Thus, a total of ten studies were included in the final analysis. A flowchart of the selection process is displayed in Figure 1.

These articles were categorized into: shoulder injury (n = 5),[23-27] lower extremity injury(n = 5),[23, 25, 28-30] knee injury (n = 5),[23, 25, 28-30] ankle injury (n = 5)[23, 25, 28-30] and ACL injury (n = 5).[23, 25, 28, 31, 32] All analyzed articles are summarized in Table 3.

(Table 3 here)

Study characteristics

Ten studies with 3461 handball players allocated to exercise-based injury prevention programmes and 3516 players to the control group (as usual) were included in this review. The study design in three studies was RCT[24, 25, 27] and in six prospective cohorts.[23, 26, 28-31]

Two studies were conducted in Germany[23, 28] and seven in Norway.[24-27, 29-31] All studies were published between 1999 and 2018. [23, 30] The mean age of players in the reviewed studies ranged from 14.9 to 23.5 years.[24, 29] Except for the study by Petersen et al [28] that included adult players, all other reviewed studies included handball players under the age of 22 years. The included studies comprised 6,977 participants (3461 in control group and 3516 intervention group) with a median sample size of 275 (range 87–1,746) per study. Five studies only included female athletes[27-31] and others comprised mixed male/female cohorts.[23-26] All included studies had a follow-up period of one season with a median intervention duration of 8 months (range from 6 to 9 months) and median of 66 training sessions (range from 45 to 126 sessions).[25, 29, 30] The dropout rate ranged from 2.1% to 34.3% but was not reported in two studies.[24, 25] Table 3 shows the main characteristics of the included studies.

Quality assessment

Interrater agreement for quality analysis between the two reviewers (XXX and XXX) assessing the ten included studies was 95.4%. PEDro scores ranged from 3 to 10 points, with an average score of 5 points (see Table 2 for individual scores). Two studies were considered to be of high methodological quality,[24, 25] five studies were rated as moderate quality,[23, 27, 29-31] and two were of low quality.[26, 28] Some limitations in the poor and moderate-quality studies were the lack of reporting participant eligibility criteria,[23, 25, 27, 29-31] randomization,[28-31] and adequate allocation concealment.[23, 25-31] Some studies have not blinded the subject, therapist, or assessor,[23, 26-28, 31] or did not describe the blinding status.[29, 30] Additionally, the high dropout rate and absence of conducting intent-to-treat analysis were the most common limitations in the reviewed studies.[23-31]

Shoulder injuries

Five studies reported the effects of an exercise-based injury prevention programme for shoulder injuries.[23-27] Among those, three studies reported that exercise-based injury prevention programmes are associated with a lower risk of shoulder injuries,[24, 26, 27] and the other two did not conduct statistical analysis.[23, 25] The meta-analysis showed that using an exercise-based injury prevention programme is associated with a lower risk of shoulder injury in handball players (OR, 0.56; 95% CI, 0.36-0.87; P = 0.01; Figure 2). Heterogeneity was low (I^2 = 17.1%) and not significant (p=0.31) in these analyses.

(Figure 2 here)

Lower extremity injuries

Five studies reported the effects of an exercise-based injury prevention programme for lower extremity injuries.[23, 25, 28-30] A lower extremity injury is any physical complaint (acute or chronic and traumatic or nontraumatic) incurred during competition or training directly related to handball and involves one of the lower parts of the body from the hip to the toes. If this complaint is limited to the knee, it is defined as a knee injury, if it is limited to the ankle, it is defined as an ankle injury, and if it involves the ACL, it is defined as an ACL injury. Among those, two studies reported that exercise-based injury prevention programmes are associated with a lower risk of lower extremity injuries,[25, 30] two studies did not report a significant association between exercise-based injury prevention programmes and risk of lower extremity injury,[28, 29] and one did not conduct statistical analysis.[23] The meta-analysis showed that using an exercise-based injury prevention programme is associated with a lower risk of lower extremity injury in handball players (OR, 0.59; 95% CI, 0.37-0.98; P = 0.03; Figure 3). Heterogeneity was high (I^2 =65.6%) and significant (p=0.02). A classic fail-safe N test revealed that 17 additional studies should be included in the meta-analysis to change the results to nonsignificant.

(Figure 3 here)

Knee injuries

Five studies reported the effects of an exercise-based injury prevention programme for knee injuries.[23, 25, 28-30] Among those, two studies reported that exercise-based injury prevention programmes are associated with a lower risk of knee injuries[25, 30] and three studies did not report a significant association between exercise-based injury prevention programmes and risk of knee injury.[23, 28, 29] The meta-analysis showed that an exercise-based injury prevention programme is associated with a lower risk of knee injury in handball players (OR, 0.53; 95% CI, 0.35-0.78; P = 0.002; Figure 4). Heterogeneity was zero and not significant in these analyses (p=0.89).

(Figure 4 here)

Ankle injuries

Five studies reported the effects of an exercise-based injury prevention programme for ankle injuries.[23, 25, 28-30] Among those, two studies reported that exercise-based injury prevention programmes are associated with a lower risk of ankle injuries[25, 30] and three studies did not report a significant association between exercise-based injury prevention programmes and risk of ankle injury.[23, 28, 29] The meta-analysis showed that an exercise-based injury prevention programme is associated with a lower risk of ankle injury in handball players (OR, 0.57; 95% CI, 0.40-0.81; P = 0.002; Figure 5). Heterogeneity was zero and not significant in these analyses (p=0.42).

(Figure 5 here)

ACL injuries

Five studies reported the effects of exercise-based injury prevention programmes for ACL injuries.[23, 25, 28, 31] Among those, two studies reported that exercise-based injury prevention programmes are associated with a lower risk of ACL injuries[25, 31] and two studies did not report a significant association between exercise-based injury prevention programmes and risk of ACL injury.[23, 28] The meta-analysis showed that an exercise-based injury prevention programme is associated with a lower risk of ACL injury in handball players (OR, 0.67; 95% CI, 0.45-0.97; $P = 0.03$; Figure 6). Heterogeneity was zero and not significant in these analyses ($p=0.44$).

(Figure 6 here)

Discussion

Handball is a team throwing sport characterized by frequent and rapid overhead throwing at high velocity, high tempo, rapid changes of movement, jumping with hard landings, and frequent contact and collisions between opponents that distinguishes it from other multidirectional sports. As a consequence, this sport is characterised by a high injury rate. Yet, up to the present time, no meta-analysis was available that specifically evaluated the effects of exercise-based injury prevention programmes in team handball. This meta-analysis indicates that exercise-based injury prevention programmes are effective in reducing the risk of shoulder, lower extremity, knee, ACL, and ankle injuries in handball players.

In our systematic review, three studies examined the effectiveness of shoulder-specific injury prevention programmes for reducing the risk of shoulder injuries[24, 26, 27] and the other two studies reported shoulder injury risk after total body injury prevention programmes in team handball players.[23, 25] It revealed that team handball-specific injury prevention programmes may reduce the risk of shoulder injuries from 0.13% to 0.64%. Interestingly, even whole-body injury prevention programmes reduced shoulder injury risk, which is in line with kinetic chain theory that predicts that impairments or alterations in lower extremity movement patterns or core stability can contribute to abnormal force dissipation and shoulder injuries in team handball athletes[33-35]. Further support from this comes from a systematic review study that included 15 full-text articles where improved lumbopelvic control related to improved athletic performance and decreased shoulder injury[36] and alterations in lower extremity postural stability and core stability have also been proposed to affect upper extremity function and contribute to upper extremity injury.[37, 38] Therefore, these two studies on whole-body injury prevention included in our study analysis using exercises that restore and enhance lower extremity postural stability and core stability can contribute to the observed shoulder injury prevention. This lower risk of shoulder injury may be related to improved proprioception, coordination, and overall balance, making it possible for the player to prevent collisions and unprovoked falls that ultimately can not only reduce the number of traumatic injuries of the lower extremities, but also the upper extremities.[29] A closer look at the shoulder-specific injury prevention interventions in the reviewed studies[24, 26, 27] highlights that the programmes should be handball-specific; 1) increasing the glenohumeral internal rotation range of motion, 2) increasing both glenohumeral external rotator and scapular muscle strength, 3) improving thoracic mobility and kinetic chain.

The present meta-analysis indicated that exercise-based injury prevention programmes are effective in reducing the risk of the lower extremity from 2% to 67%, knee from 22% to 65%, ACL from 3% to 55%, and ankle injuries from 19% to 60% in handball players. Five studies evaluated the effectiveness of exercise-based injury prevention programmes for injury risk of the lower extremity, knee, ACL, and ankle in team handball players.[23, 25, 28-30] Though the prevention programmes between studies in this review differed in their exercise intensity and duration, almost all focused on education of proper technique (such as planting and cutting maneuvers and landing movements), balance training (such as balancing on a single leg with the eyes closed, balancing on an ankle disk, and balancing on a single leg while completing a task such as catching or throwing a ball), jumping and landing (plyometric) exercises, and strength training.[23, 25, 28-30] As these programmes were multifaceted and addressed many aspects of injury risk (agility, power, strength, balance, joint position sense, muscle recruitment patterns, lower extremity alignment, playing technique) it is difficult to determine precisely which component of these programmes were particularly effective in in reducing injury risk. However, all injury prevention programs were designed based on handball specific skills, the areas of the body are most susceptible to injury, and the risk factors and mechanisms of these injuries. Nevertheless, further studies may shed light on the effects of each component of the injury prevention programmes on injury risk.

Considering that almost all the reviewed studies have focused on the proper technique of planting and cutting and jump-landing maneuvers, this risk reduction of ACL injuries is not unexpected. Because approximately 80% of ACL injuries are non-contact injuries and occur in a cutting maneuver or one-leg landing after a jump shot.[32] Indeed, education on the proper technique used in the included studies aiming at a narrower stance as well as a knee-over-toe position during planting and cutting maneuvers and landing following a jump movement has been successfully applied to decrease knee varus/valgus moments.[39] Regarding ankle injuries, it also appears that understanding how the foot position at landing in the transverse plane can contribute to reducing the ankle inversion moment is important to the prevention of lateral ankle sprains.[40] Several other studies have confirmed that one of the main components of any injury prevention programme for knee and lower extremities should be educated on proper technique.[41, 42] Because planting and cutting and jump-landing maneuvers are common movements of team handball, the use of technical education in the injury prevention programmes of this sport can be of great importance.

The other three components that were used in most of the reviewed studies were balance, plyometric, and strength exercises. Regarding this, Brunner, Friesenbichler, Casartelli, Bizzini, Maffiuletti, Niedermann [41] in a systematic review and meta-analysis study concluded that strength and balance exercises were included in all effective injury prevention programmes for lower extremities, knee, ACL and ankle injuries. Balance exercises in reviewed studies consisted of single-legged or double-legged stance activities that were designed to improve proprioceptive awareness. Balance exercises have been used to good effect to prevent lower extremity, knee, ACL[43] and ankle[44] injuries. The risk of injury, such as ankle sprains, has been attributed to poor control of balance and ankle joint position sense,[45] and balance exercise has been shown to reduce the incidence rates of ankle sprains in the athletic population, irrespective of a history of ankle sprains.[44, 46] In another study,[47] using balance board exercises was associated with a significant reduction in ACL injuries in male soccer players. Balance exercises can enhance the sensorimotor system's ability to adapt to a changing environment and subsequently protect the body from injury. Balance exercises can also promote the neuromuscular mechanisms responsible for agonist and antagonist co-contraction, which enhance active joint stability.[48] This increased joint stiffness results in less joint laxity and thus less strain on joint structures. Altering the kinematics and kinetics of lower extremity joints following the use of balance exercises[49] may be another reason for reducing the risk of sports injuries after these exercises.

Previous studies that incorporated plyometric and specific jumping and landing exercises into exercise-based prevention programmes demonstrated a significant reduction in ground reaction force on landing[50] and knee valgus[51] and improved balance between knee flexor and extensor muscles.[52] As high ground reaction force,[53] knee valgus, and quadriceps dominance[54] were identified as the risk factors for non-contact ACL injury in athletes, implementing a set of plyometric and specific jumping and landing exercises into exercise-based injury prevention programmes in included studies may have contributed to the diminished injury rates of ACL injury. Plyometrics can also help improve athletes' lower extremity power, biomechanical technique, joint stability, and neuromuscular control[55, 56] and has the potential to reduce the risk of ankle injuries. It has been shown that plyometric exercises contributed to a risk reduction of lower extremity injuries that were associated with knee valgus angles and moments.[57] Plyometric exercises by facilitating neural adaptations can enhance lower extremity muscle activation and proprioception that increasing functional stability[58, 59] and reducing the injury incidence of lower extremity joints. Finally, evidence shows that plyometrics not only induce optimal neuromuscular but also bone[60] and musculo-tendinous adaptation,[61] which can be effective in the potential reduction of lower limb sports injuries. Therefore, another advantage can be that the muscles, joints and other structures are prepared to tolerate the quick impacts and rebounds needed in the sport. However, in this regard, movement control (knee-over-toe positioning) during plyometric exercises is very important to avoid endangering movement patterns. Therefore, most of the included studies have used plyometric exercises with verbal feedback to alter the knee abduction landing pattern.

Another component of the exercise-based injury prevention programmes in this review was strength exercises most commonly used for the hamstring and core muscles. A systematic review and meta-analysis show that using strength exercises with balance training enhanced the benefits of an injury prevention programme[62] and even just core muscle exercises in injury prevention programmes elicited a reduction in knee and ACL injuries.[63] The suggested role of strength exercises was to allow the joint to better withstand injurious loads and control lower extremity alignment during specific sports activities. Considering the high loads associated with ankle injuries,[64] it seems that strengthening the ankle stabilizers does not help to prevent the injury of this area and the lower extremity. Hence, most of the reviewed preventive programs emphasize strengthening proximal joints (eg, hip and knee joints) instead of the ankle joint, which may be effective in preventing lower limb injuries. Since the hamstrings, an antagonist of the quadriceps, act as agonists to the ACL during stop-and-jump tasks,[65] stronger hamstring muscles may counterbalance the anterior shear force produced by the quadriceps and thereby prevent ACL injuries. Russian/Nordic hamstring curl is the most commonly incorporated strength exercise in prevention programmes that is an effective exercise for reducing hamstring strain and ACL injury.[66] However, a common defect in most of prevention programmes[23, 25] was failure to follow the principle of progressive overload, which is a common guideline for strength training that can limit the effect of these strength exercises on the risk of injury.[67]

Limitations

This systematic review and meta-analyses are limited by the relatively low quantity of studies and low quality of most of the included studies. Among the ten reviewed clinical trials, 3 had a randomized design,[24, 25, 27] and the remaining 7 used a prospective cohort design.[23, 26, 28-32] Randomisation is an effective method to reduce potential bias; therefore, a lack of randomisation may cause a component of bias that could potentially lead to an overestimation of the intervention effect. However, since all studies included usual routine controls, the bias introduced by non-randomisation is probably minimal. Another common weakness in included studies is the existence of attrition bias due to high drop-out rates and a lack of intention-to-treat analysis.[23, 24, 26-28] In addition, the heterogeneity analysis for lower extremity injuries demonstrated significant differences among studies. This can be explained by a limited number of reviewed studies, where a low number of studies makes an accurate estimation of heterogeneity difficult.[68]

Another limitation of this systematic review and meta-analysis is the possibility of publication bias, as studies published in languages other than English were excluded. However, deleting non-English articles usually does not have a significant effect on the results of systematic reviews.[69]

Compliance should also be considered when evaluating the effectiveness of an exercise-based prevention programme, as this can affect the effectiveness of the intervention. Myklebust, Engebretsen, Brækken, Skjølberg, Olsen, Bahr [31] have shown that despite the close follow-up of the teams by physical therapists, acceptable compliance was achieved in less than half of the players. Low compliance is reported in several other preventative intervention studies.[27, 29]

Although all included studies assessed the occurrence of injury as a clinical outcome, the results of our review should be interpreted in light of the variety of methods used to collect injury data. Although the definition of sports injury and the classification of injury severity were almost the same in all studies, data collection methods were self-reports,[24, 29] physiotherapist reports,[25, 28, 32] and coach reports[23] which may have an impact on injury recording.[70] For example, a previous study showed that compared to medical professionals, athletes underestimated the disruption and short-term effects of the injury, while coaches overestimated these.[71] Because the bias caused by data collection may lead to a biased interpretation of the preventive effect of interventions, future studies should collect accurate data with the help of medical professionals and diagnostic methods to enable the assessment of potential bias in estimating preventive effects.

According to PEDro scores, the overall quality of the included studies was moderate, therefore higher-quality studies may help to improve the strength of the recommendations. In addition, only ten handball studies were included in this review, which is consistent with other studies that highlight the lack of qualitative evidence on basketball injury prevention [72, 73].

One problem inherent in this kind of studies is that this systematic review also included outcomes of the knee, ACl, and ankle injuries as lower extremity injuries and injuries to other areas of the lower extremity (such as hip, groin, hamstring, and lower leg). There are, however, numerous other review studies that have used this reporting pattern [72, 73] and we expect that the lumping of injuries will have a minor impact on the study outcome.

In the present systematic review only multicomponent exercise interventions were selected and interventions including one exercise component were excluded, as we observed in a pilot study that there have been no studies assessing the effectiveness of a specific exercise in preventing injuries in handball players. Future studies can evaluate the effects of such interventions in preventing sports injuries in handball players. Considering that in the current meta-analysis, the confidence interval for the outcomes of lower extremity and ACL injuries is wide, the results of the study should be interpreted with caution. The width of a confidence interval in a meta-analysis depends on the precision of individual study estimates and the number of studies included.[74] As the number of studies included in a meta-analysis increases, the width of the confidence interval usually decreases.

Conclusions

The primary finding of this systematic review was that current exercise-based injury prevention programmes may be effective in preventing lower extremity, knee, ankle, and ACL injuries in team handball players. However, Due to the relatively low number and quality of studies on this topic, higher-quality studies may help to improve the strength of the recommendations.

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Figure 1. PRISMA flow diagram of search and the study selection process.

Study name	Odds ratio	Lower limit	Upper limit	Z-Value	p-Value
Achenbach et al, 2018	1.329	0.239	7.383	0.325	0.745
Olsen et al, 2005	0.331	0.105	1.043	-1.888	0.059
Andersson et al, 2017	0.689	0.449	1.058	-1.703	0.089
Osteras et al, 2014	0.216	0.062	0.755	-2.401	0.016
Sommervold and Osteras, 2017	0.574	0.205	1.606	-1.057	0.291

(Statistics for each study)

Test for heterogeneity: tau^2:0.05, chi^2=4.8, df=4, p<0.31, I^2=17.1

Test for overall effects: z= -2.58, p=0.01.

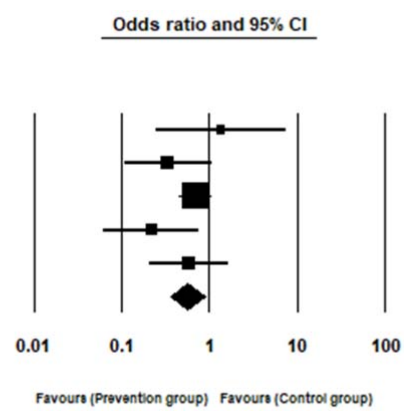
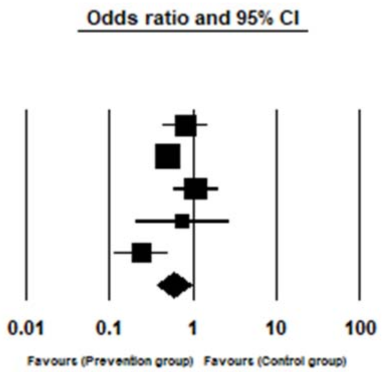


Figure 2. Forest plot of the effect of exercise-based injury prevention programmes on shoulder injuries in handball players. CI: confidence interval.

Study name	Odds ratio	Lower limit	Upper limit	Z-Value	p-Value
	Statistics for each study				
Achenbach et al, 2018	0.809	0.436	1.502	-0.671	0.502
Olsen et al, 2005	0.492	0.358	0.675	-4.381	0.000
Petersen et al, 2005	1.073	0.576	1.999	0.221	0.825
Wedderkopp et al, 2005	0.731	0.198	2.692	-0.472	0.637
Wedderkopp et al, 1999	0.238	0.112	0.506	-3.728	0.000

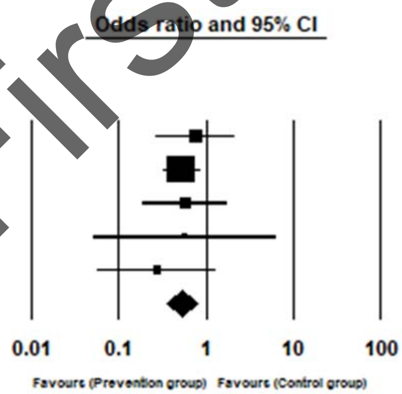


Test for heterogeneity: tau²:0.18, chi²=11.3, df=4, p<0.03, I²=65.6

Test for overall effects: z= -2.19, p=0.03.

Figure 3. Forest plot of the effect of exercise-based injury prevention programmes on lower extremity injuries in handball players. CI: confidence interval.

Study name	Odds ratio	Lower limit	Upper limit	Z-Value	p-Value
	Statistics for each study				
Achenbach et al, 2018	0.743	0.262	2.110	-0.558	0.577
Olsen et al, 2005	0.509	0.309	0.838	-2.653	0.008
Petersen et al, 2005	0.573	0.187	1.755	-0.975	0.329
Wedderkopp et al, 2005	0.553	0.049	6.217	-0.480	0.631
Wedderkopp et al, 1999	0.271	0.056	1.302	-1.630	0.103

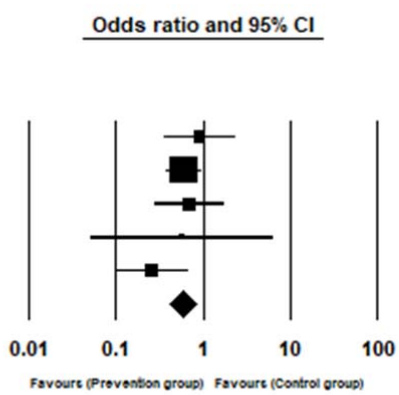


Test for heterogeneity: tau²:0.00, chi²=1.2, df=4, p<0.89, I²=0.00

Test for overall effects: z= -3.17, p=0.002.

Figure 4. Forest plot of the effect of exercise-based injury prevention programmes on knee injuries in handball players. CI: confidence interval.

Study name	Odds ratio	Lower limit	Upper limit	Z-Value	p-Value
	Statistics for each study				
Achenbach et al, 2018	0.902	0.351	2.319	-0.214	0.831
Olsen et al, 2005	0.592	0.373	0.941	-2.219	0.026
Petersen et al, 2005	0.688	0.272	1.739	-0.791	0.429
Wedderkopp et al, 2005	0.553	0.049	6.217	-0.480	0.631
Wedderkopp et al, 1999	0.256	0.100	0.654	-2.846	0.004



Test for heterogeneity: tau²:0.00, chi²=3.9, df=4, p<0.42, I²=0.00

Test for overall effects: z= -3.17, p=0.002.

Figure 5. Forest plot of the effect of exercise-based injury prevention programmes on ankle injuries in handball players. CI: confidence interval.

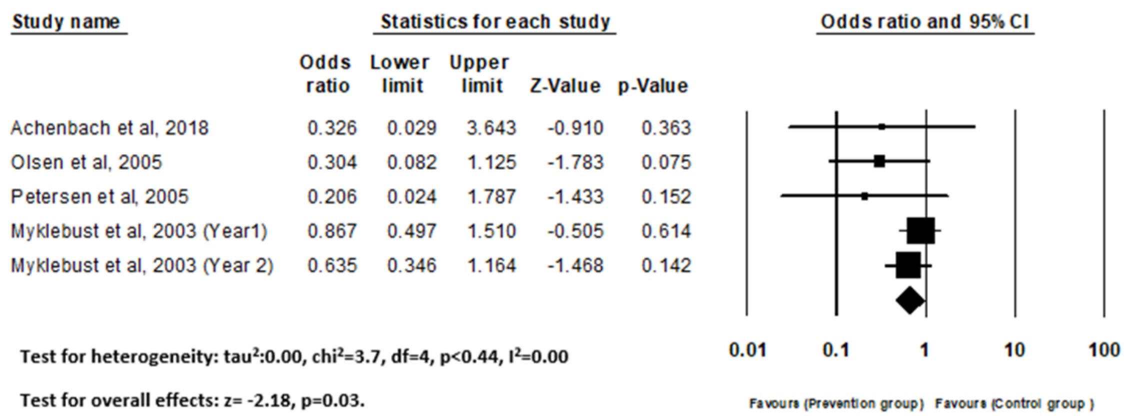


Figure 6. Forest plot of the effect of exercise-based injury prevention programmes on ACL injuries in handball players. CI: confidence interval.

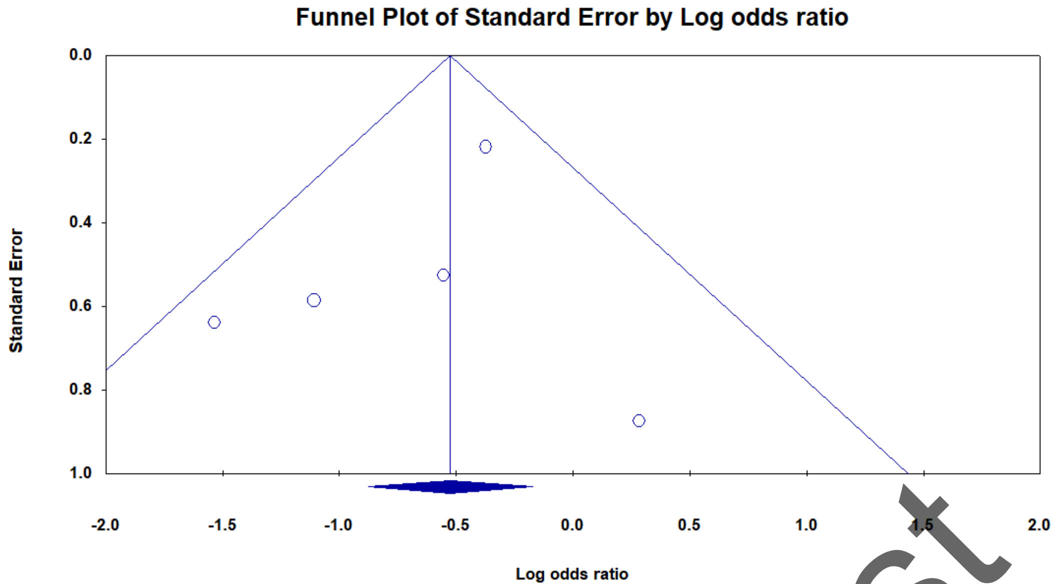


Figure 1 Meta-analysis funnel plot for the assessment of the effects of an exercise-based injury prevention program for shoulder injuries in handball players

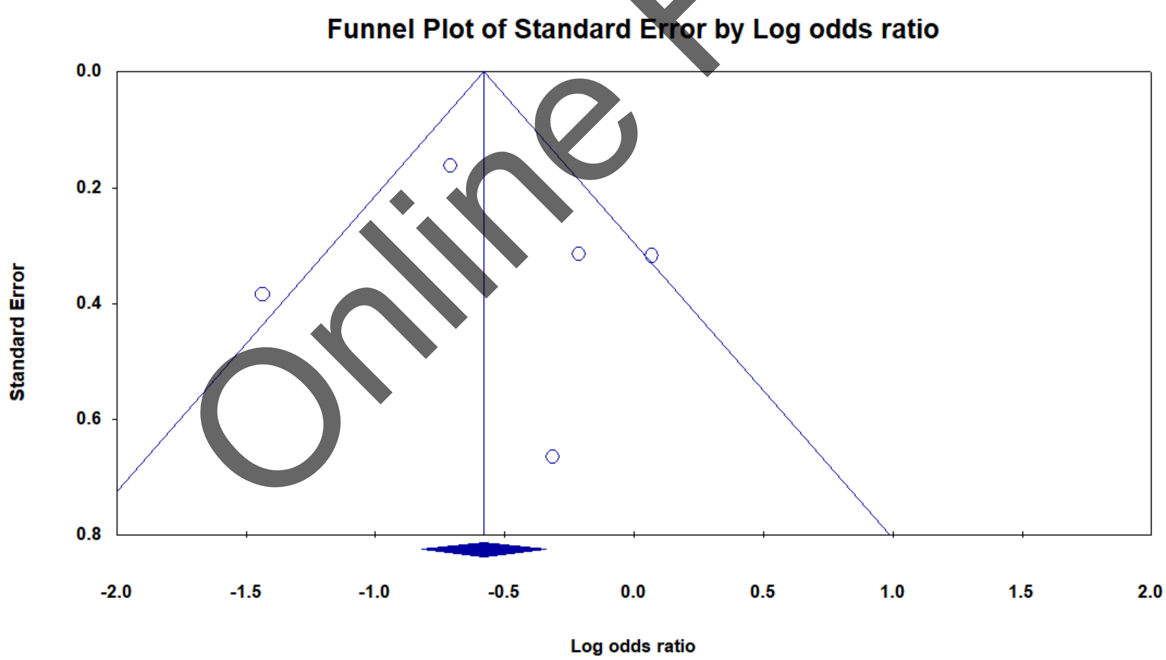


Figure 2 Meta-analysis funnel plot for the assessment of the effects of an exercise-based injury prevention program for lower extremity injuries in handball players

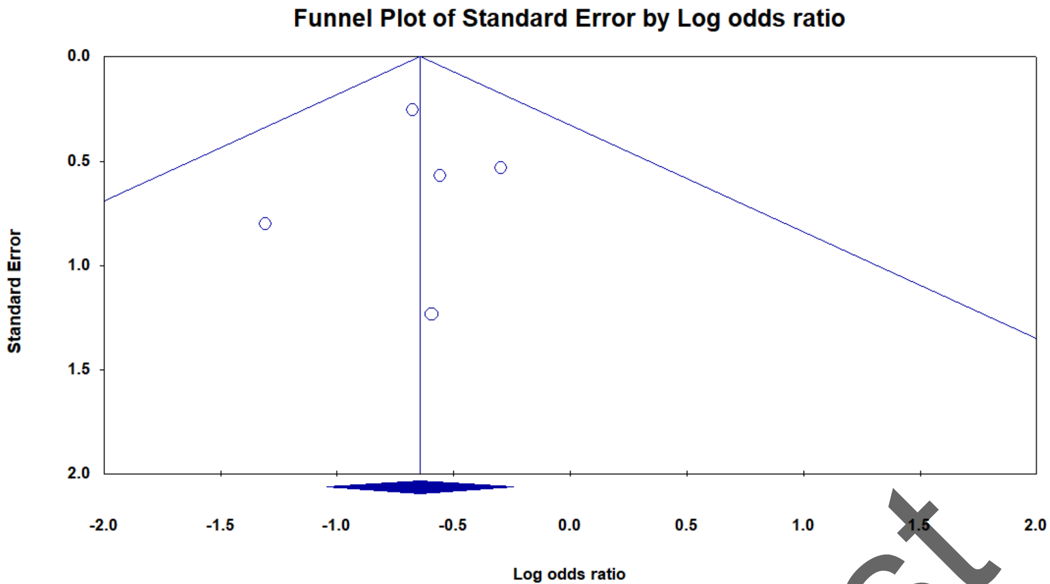


Figure 3 Meta-analysis funnel plot for the assessment of the effects of an exercise-based injury prevention program for knee injuries in handball players

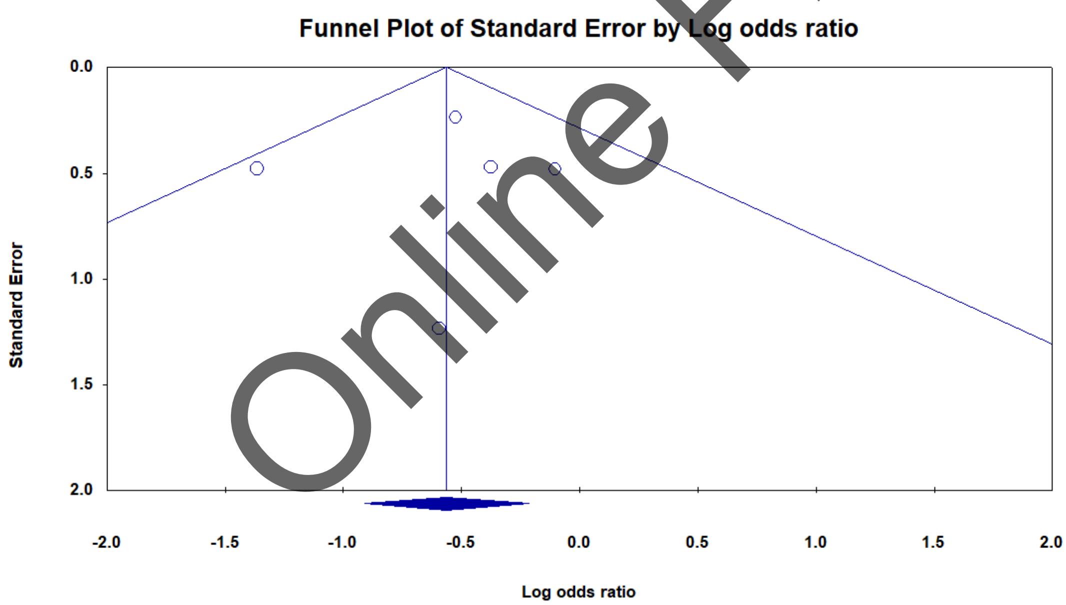


Figure 4 Meta-analysis funnel plot for the assessment of the effects of an exercise-based injury prevention program for ankle injuries in handball players

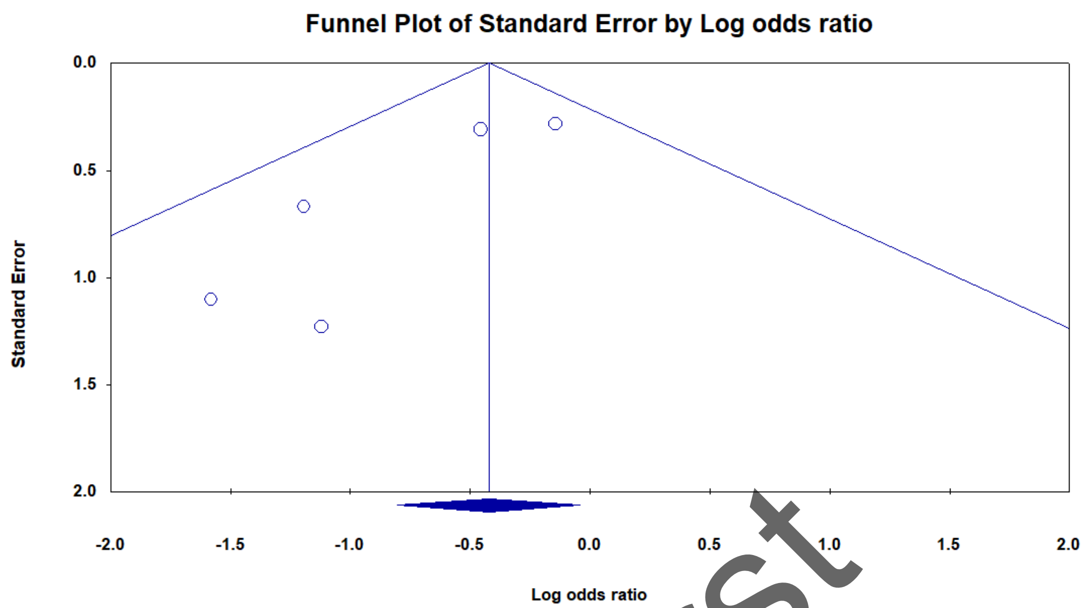


Figure 5 Meta-analysis funnel plot for the assessment of the effects of an exercise-based injury prevention program for ACL injuries in handball players

Table 1 Levels and terms of the literature search process

Search level	*Search terms with Boolean operators*
Search #1	(handball[Title/Abstract])
Search #2	AND (injury[Title/Abstract] OR Injuries[Title/Abstract] OR tear[Title/Abstract] OR dislocate[Title/Abstract] OR break[Title/Abstract] OR sprain[Title/Abstract] OR twist[Title/Abstract] OR strain[Title/Abstract] OR tearing[Title/Abstract])
Search #3	AND (prevention[Title/Abstract] OR exercise[Title/Abstract] OR training [Title/Abstract] OR conditioning[Title/Abstract] OR preparation[Title/Abstract] OR warm-up[Title/Abstract] OR intervention [Title/Abstract])

Table 2. Methodological Quality Assessment for Eligible Studies

Study	RA	CA	BS	SB	TB	AB	DR	ITA	BC	PM	CSQ
Achenbach (2018)	No	No	Yes	No	No	No	Yes	No	Yes	Yes	4/10
Andersson (2017)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	9/10
Myklebust (2003)	No	No	Yes	No	No	No	Yes	No	Yes	Yes	4/10
Myklebust (2003)	No	No	Yes	No	No	No	Yes	No	Yes	Yes	4/10
Olsen (2005)	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	9/10
Østerås (2014)	No	No	Yes	No	No	No	Yes	No	No	Yes	3/10
Petersen (2005)	No	No	No	No	No	No	Yes	No	Yes	Yes	3/10
Sommervold (2017)	Yes	No	Yes	No	No	No	Yes	No	No	Yes	4/10
Wedderkopp (2003)	No	No	Yes	No	No	Yes	No	No	Yes	Yes	4/10
Wedderkopp (1999)	No	No	Yes	No	No	Yes	No	No	Yes	Yes	4/10

PEDro scoring components. RA, random allocation; CA, concealed allocation; BS, Baseline similarity; SB, subject blinded; TB, therapist blinded; AB, assessor-blinded; DR, dropout rate; ITA, intention-to-treat analysis; BC, between-group comparison; PM, points measures; OSQ, overall study quality. PEDro scores of 6 or greater are considered high methodological quality

Table 3. Characteristics of the exercise-based prevention programs attempting to reduce sport injuries in handball players

Study	Study Design	Country/ competition level	Sex, number (age)	Dropout rate	Intervention	Control	Duration	Frequency (no. per week)	Total Player Seasons	Total Training Sessions	Total Training Time, h	PEDro score
Achenbach (2018)	Prospective cohort	Germany/ under 16 and 18	Male = 105 Female = 174 (13–18 y)	Both group=~31%	The multi-intervention training program included jump and landing exercises, proprioceptive exercises, plyometric exercises, and strength exercises for the quadriceps, hamstring, and core muscles.	As usual	Pre- and In-season for 9 months	Pre-season (2-3x/wk) In-season (1x/wk)	I=168 C=111	56	13.9	4
Andersson (2017)	RCT	Norway/ two top divisions	Male = 339 Female = 321 (21.6-23.5 y)	I=34.3% C=29.4%	The prevention program consisted of five exercises aiming at increasing the glenohumeral internal range of motion and external rotation strength and improving scapula control, kinetic chain, and thoracic mobility.	As usual	In-season for 6 months	In-season (3x/wk)	I=264 C=270	75	12.5	9
Myklebust (2003)	Prospective cohort	Norway/ Division I–III	Female = 1745 (21-22 y)	I=2.6% C=3.1%	A five-phase multi-intervention training program: Wobble board balance exercises and planting/landing skills	As usual	Pre- and In-season 6-7 months	Pre-season (3x/wk) In-season (1x/wk)	I=832 C=913	55	13.8	4
Myklebust (2003)	Prospective cohort	Norway/ Division I–III	Female = 1746 (21-22 y)	I=2.6% C=3.1%	A five-phase multi-intervention training program: balance exercises and planting/landing skill	As usual	Pre- and In-season 6-7 months	Pre-season (3x/wk) In-season (1x/wk)	I=833 C=913	55	13.8	4
Olsen (2005)	RCT	Norway/ 16- to 17-y divisions	Male = 235 Female = 1483 (15–17 y)	I=3% C=2.1%	The multi-intervention training program included running exercises, cutting and landing technique training, balance training, and strength and power training.	As usual	In-season for 8 months	Every training and competition	I=958 C=879	45	13.5	9
Østerås (2014)	Prospective cohort	Norway/ 15- to -16 y divisions	Male = 15 Female = 94 (15 - 20 y)	I= 28% C= 27%	The prevention program consisted of push-ups plus standing glenohumeral internal and external rotation with an elastic band as resistance.	As usual	Pre- and In-season for 8 months	In-season (3x/wk)	I=38 C=34	96	16	3
Petersen (2005)	Prospective cohort	Germany/ semiprofessional and amateur	Female = 270 (>19 y)	I=9.7% C=12.6%	Information about injury mechanisms, balance-board exercises, and jumping and landing training.	As usual	Pre- and In-season for 8 months	Pre-season (3x/wk) In-season (1x/wk)	I=134 C=143	55	9.8	3
Sommervold (2017)	RCT	Norway/ 16-y divisions	Female = 87 (>17 y)	I=13.2% C=22.6%	The prevention program consisted of two exercises for strengthening the shoulder complex.	As usual	In-season for 7 months	In-season (3x/wk)	I=46 C=41	79	13.2	4
Wedderkopp (2003)	Prospective cohort	Norway/ recreational to elite	Female = 163 (14-16 y)	NR	Wobble board exercise and 1 functional exercise for all major muscle groups including both upper and lower extremities.	As usual	In-season for 9 months	Pre and in-season (2-5x/wk)	I=77 C=86	126	21	4
Wedderkopp (1999)	Prospective cohort	Norway/ recreational to elite	Female = 237 (16-18 y)	NR	Wobble board exercise and 1 functional exercise for all major muscle groups including both upper and lower extremities	As usual	In-season for 9 months	Pre and in-season (2-5x/wk)	I=111 C=126	126	21	4

Abbreviations: C, control group; I, intervention group; RCT, randomized controlled trial; PEDro, Physiotherapy Evidence Database.