International Journal of Human Movement and Sports Sciences 12(4): 606-624, 2024 http://www.hrpub.org
DOI: 10.13189/saj.2024.120402

The Effects of Prevention Exercise Programmes for the Prevention of Shoulder Injuries in Overhead Athletes

Paraskevopoulos Eleftherios*, Zacharis Alexandros

Department of Physiotherapy, Aegean College, Greece

Received February 23, 2024; Revised April 17, 2024; Accepted June 17, 2024

Cite This Paper in the Following Citation Styles

(a): *[1] Paraskevopoulos Eleftherios, Zacharis Alexandros , "The Effects of Prevention Exercise Programmes for the Prevention of Shoulder Injuries in Overhead Athletes," International Journal of Human Movement and Sports Sciences, Vol. 12, No. 4, pp. 606 - 624, 2024. DOI: 10.13189/saj.2024.120402.*

(b): *Paraskevopoulos Eleftherios, Zacharis Alexandros (2024). The Effects of Prevention Exercise Programmes for the Prevention of Shoulder Injuries in Overhead Athletes. International Journal of Human Movement and Sports Sciences, 12(4), 606 - 624. DOI: 10.13189/saj.2024.120402.*

Abstract Shoulder injuries impose a burden on overhead athletes, affecting participation and performance. Studies show that shoulder injury rates of overhead athletes have increased overtime. Repetitive overhead motions can alter biomechanics, creating risk factors such as glenohumeral internal rotation deficit (GIRD), rotator cuff muscle imbalance and decreased shoulder stability, predisposing athletes to shoulder injuries. Several prevention programmes have been created to counter these effects and protect overhead athletes. The aim of this review was to assess the effectiveness of prevention exercise programmes in the prevention and risk factors of shoulder injuries in overhead athletes. The PubMed, PEDro, LILACS and SciELO databases, and the search engine Google Scholar were searched, and eleven randomised control trials (RCTs) were identified for further analysis. The search was based on the PICOS framework and PEDro scale rating, with pre-set inclusion and exclusion criteria to ensure quality and reduce bias amongst the chosen studies. The prevention programmes and the results of the eleven studies are discussed thoroughly. The analysis performed for the study's findings, demonstrates promising results, with decreased injury rates, risk, prevalence or incidence or improvement of at least one risk factor observed in ten out of the eleven included RCTs. The limitations of the studies and recommendations are also discussed. The conclusion of this study is that shoulder prevention programmes are effective in ensuring prevention and improving risk factors in overhead athletes.

Keywords Injury Prevention, Prevention Programmes, Risk Factors, Overhead Athletes, Shoulder

1. Introduction

Shoulder injuries provide significant problems in the overhead athlete's population [1]. Sports such as volleyball, handball, baseball, and football goalkeeping can be classified as overhead sports [2]. The aforementioned sports require repetitive ball throwing, serving, or smashing overhead actions at high velocity, which impose heavy loads on the glenohumeral joint [3]. To achieve such motions, overhead athletes generate maximum force in short times, imposing the shoulder musculotendinous and capsuloligamentous structures to high stress [4]. These motions demand dynamic stabilisation for the shoulders integrity to be preserved [5].

Shoulder injury rates in overhead athletes vary between 18% and 61%, depending on different factors such as athletes age, sex, sport category and performance level [1]. Overhead sports present a shoulder injury incidence of 0.2-1.8/1000 hours of sport [2]. The National Collegiate Athletics Association has demonstrated that overuse shoulder injuries represent 12% and 13.1% of all injuries at high school and college levels, respectively [6]. In football, there has been an increase in shoulder injury rates throughout the years [7, 8]. Goalkeepers are more vulnerable to shoulder injuries than outfield payers, due to

the nature of the position, which requires extensive use of the upper body and of overhead movements [9]. Additionally, goalkeepers miss more trainings and games than the rest of their teammates because of shoulder injuries, having a 4.6 times higher injury risk than outfield players [9, 10]]. A study of twelve goalkeepers in the Norwegian male first league, derived that upper limb injuries consist of 36% of all goalkeeper injuries, with the shoulder being the most common overuse injury location [11].

Handball is a sport that requires ball passing and throwing of high volume and a lot of physical contact, therefore often leading to acute or overuse shoulder injuries [12-14]. Shoulder problems constitute the injury type that affects handball participation and performance the most, representing 4-27% of all handball injuries [12, 15]. Shoulder issues in handball have a prevalence of 17%-41%, with reported 19-36% preseason prevalence and 28% weekly season prevalence with 12% of adult elite male players having to limit or completely avoid handball trainings weekly [2, 16]. The risk of injury during training for professional adult players is 0.6-2.4 per 1000 hours, with the youth players presenting a higher reported risk up to 4.3 injuries/1000 training hours and 8.3-40.7 injuries/1000 game hours [5].

In professional baseball, the shoulder is the most endangered joint in terms of injury, with 17% of all injuries occurring being shoulder related [17]. In Major League Baseball (MLB), shoulder injuries represent 31% of all injures faced by pitchers, making it the most frequent source of pathology in the MLB, but also at lower levels of competition [18]. Moreover, only 53% of pitchers that suffered a shoulder injury in preseason performed during the season, with 31% of them facing a re-injury, while their performance was negatively affected [19]. Volleyball as a sport, however, presents more shoulder injuries than baseball [20]. Shoulder injuries have the third highest prevalence amongst volleyball injuries, and the incidence of both acute and chronic shoulder pathologies reaches up to 16 injuries per 1000 training and match hours [20].

1.1. Research Aim

The evidence provided highlights the burden that shoulder injuries are for the overhead athletes. Research studies show an increase in the injury rates, incidence, prevalence, and risk of glenohumeral joint injuries for both young and adult overhead athletes. Shoulder injuries affect their participation and performance and can be the cause of chronic pain, affecting their overall careers [1]. Overuse injuries can develop into severe shoulder pathologies like SLAP damage and require surgery, with the return to professional sport rates having been demonstrated to be low [21]. It would therefore be beneficial for more research to be performed focusing on the prevention of shoulder injuries, through the creation of effective prevention warmup and strengthening exercise programmes and the assessment of their efficiency in injury prevention and risk factors modification [2, 3, 5, 6, 12]. The most important risk factors that predispose overhead athletes to injuries are glenohumeral internal rotation deficit (GIRD), rotator cuff muscle imbalance and decreased shoulder stability [3]. Injury prevention programmes are based on the pathology identification and injury mechanism and risk factors and once created and implemented to athlete populations, effectiveness of which is examined through different studies [1].

However, while such programmes have been demonstrated to have promising results, there is a lack of studies focusing on the effectiveness of preventative exercise programmes for shoulder injuries of overhead athletes [22]. The aim and outcome measures of this literature review are therefore, to add to the lacking literature by examining the effectiveness of existing exercise programmes in shoulder injury prevention (effect on injury rates, incidence, prevalence, and risk) and on shoulder injury risk factors (rotator cuff imbalance, shoulder dynamic stability, GIRD). The research question that will be tested as the alternative hypothesis through the literature review is therefore: H1= Shoulder prevention exercise programmes are effective in preventing shoulder injuries and modifying sport-specific risk factors in overhead athletes. The null hypothesis is: H0= Shoulder prevention exercise programmes are not effective in preventing shoulder injuries and modifying sport-specific risk factors in overhead athletes.

1.2. Background Information

1.2.1. Mechanism of Injury

Sports such as baseball, handball, and football goalkeeping to a lesser extent, require repetitive overhead throwing motions. The overhead athletes generate maximum force in short time periods to perform the overhead throwing motions, constituting them the fastest motion performed in sports [18]. Handball training and games as well as baseball pitching follow a pattern of recurrent high-speed throwing motions followed by low intensity moments [14]. The throwing motion is a complicated action consisting of six phases that require coordination of the whole kinetic chain: windup, stride, cocking, acceleration, deceleration, and follow through phases (Figure 1).

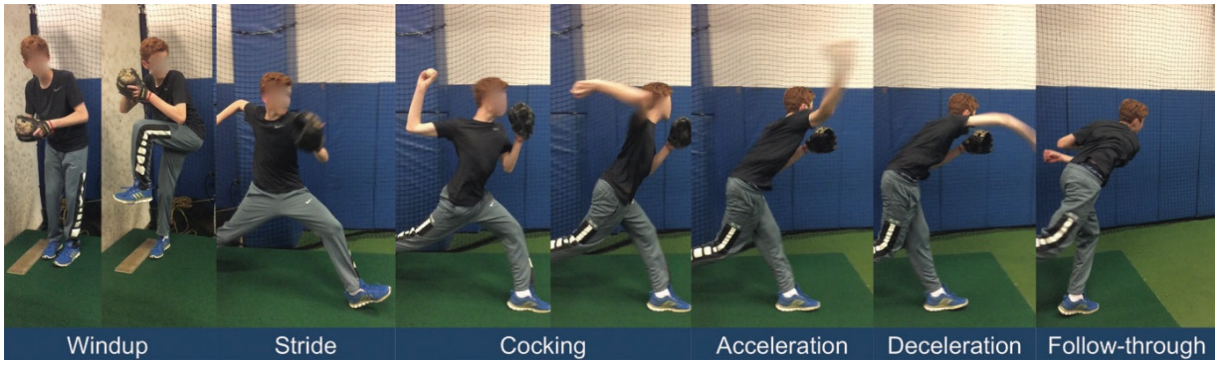

Figure 1. The six phases of the overhead throwing motion (Lin et al., 2018).

According to Lin et al. [18], the most injuries occur from the cocking phase onwards. In the windup phase, a weight adjustment is observed to reach a single leg stance. During the second phase, the stride takes place with the foot landing on the ground and shoulder external rotation (ER) and horizontal abduction are initiated. In the cocking phase, the shoulder adopts a position of 90° abduction and maximum external rotation. From this shoulder position, the acceleration phase begins, which is characterised by the ball release and activation of the subscapularis, latissimus dorsi and pectoralis major as the internal rotation (IR) of the shoulder is initiated. In the transitional moment between the cocking and acceleration phases, the forces experienced by the shoulder are the highest, with peak risk of injury, as shoulder impingement, anterior capsule stretching, peak rotator cuff activation and labrum tension are observed, due to the explosive transition from maximal ER to IR. During the last two phases, deceleration and follow-through, shoulder, and scapula musculature act eccentrically to internally rotate, adduct and control the arm and stabilise the shoulder, creating shear compression forces in the glenohumeral joint [18]. The shoulder reaches 165-175o of external rotation and internal rotation velocity of 7000-7500o/s [1].

The volleyball overhead attack or 'spike', and the volleyball serve, are divided into the same phases as the throwing motion, with the kinetic chain adopting the same positions [23]. These extreme shoulder ranges of motion (ROM), velocities and forces observed during the repetitive high speed overhead motions that require high level of shoulder joint movement and muscle activation lead to musculotendinous and capsuloligamentous stress, muscle imbalances, adaptive changes, and therefore, to repetitive overuse shoulder injuries[4].

1.2.2. Risk Factors

The repetitive nature of the overhead shoulder motions performed by overhead athletes, is correlated with sport-specific biomechanical and functional adaptions (affecting shoulder mobility, shoulder stability, overhead technique) of the dominant thrower shoulder [1]. The available literature has demonstrated differences between overhead athlete's two shoulders with increased ER ROM, glenohumeral internal rotation deficit (GIRD), shoulder rotator cuff muscle imbalance and scapular dyskinesis that predispose to overuse shoulder injuries [3]. Concerning the rotator cuff muscle imbalance, the rotator cuff is the principal glenohumeral joint stabiliser [24]. Isometric and isokinetic IR and ER muscle strength need to be balanced for the humeral head to remain in a central position within the joint (need of a 66% isokinetic and 75-100% isometric ER:IR ratio) [24].

The ER and IR concentric and eccentric strengths are measured through isokinetic testing torque values, and the most functional method of ER:IR ratio calculation is the functional deceleration ratio (FDR) that measures the strength balance ratio of ER eccentric strength: IR concentric strength, to include the eccentric role of the antagonist muscles and examine efficiently the integrity of the dynamic shoulder stability [24]. During overhead motions, the humeral head can move because of the stress that a small FDR value imposes on the shoulder soft tissue passive stabilisers [23]. Overhead athletes experience affected isokinetic IR and ER muscle strength because of repetitive throwing motions, with observed lower ER that IR strength, affecting the shoulder's dynamic stabilisation, with studies agreeing that it constitutes the most notable risk factor for developing dominant shoulder problem [1, 23].

Furthermore, the ER:IR strength ratio and GIRD are two factors that can affect each other and co-exist [23]. GIRD can lead to posterior capsule stress and increased anterior humeral translation which may cause subluxation and consequently, shoulder pain in overhead athletes [4]. The aforementioned internal risk factors can be the source of many shoulder pathologies, such as overuse muscle, tendon or ligament injuries, degenerative joint changes and instability or acute injuries such as dislocation [4]. However, these risk factors can be altered with strength exercise programmes or avoided with prevention exercise programmes [25].

1.2.3. Prevention Exercise Programmes

According to Cools et al. [1], the creation of an injury prevention exercise programme follows a cycle of four steps. The first step is the identification of the injury rates

of a specific injury and profile of athletes from epidemiological data. The second step is the analysis of the injury mechanism and the risk factors that contribute or predispose athletes to shoulder injuries. The identification of risk factors is key for the effectiveness of such programmes [26]. This step is the basis of step three, which is the creation of an exercise programme that focuses on sport-specific motions, on modifying the risk factors and preventing shoulder injury occurrence, and thus, reducing injury rates. The fourth and last steps, are the assessment of the effectiveness of the prevention programme on shoulder injuries, through different types of studies [1]. The main goals of shoulder injury prevention exercise programmes are the modification of risk factors by ameliorating shoulder ROM, ER strength, shoulder dynamic balance and scapular control, and as a result, decreasing shoulder injuries in overhead athletes[12].

2. Methodology

The present literature review was performed through the analysis of randomised controlled trials (RCTs). To identify available RCTs, research was performed on the following scientific databases: PubMed, PEDro, LILACS and SciELO and the search engine Google Scholar. The keywords used for the pathology of interest were: 'shoulder'; 'shoulder joint'; 'glenohumeral joint'; 'shoulder injury'; 'shoulder overuse injury' and 'overhead injury'. The keywords used for the sports of interest were: 'overhead sports'; 'throwing sports'; 'volleyball'; 'handball'; 'baseball'; 'football' and 'goalkeeper'. The keywords used for the intervention of interest were: 'prevention programme'; 'exercise programme'; 'prevention exercise programme'; 'neuromuscular strengthening'; 'FIFA 11+ S'; 'OSTRC programme' and 'resistance band'. Finally, the keywords used for outcome measures of interest were: 'incidence'; 'prevalence'; 'injury rates'; 'dynamic stability'; 'isokinetic strength'; 'ER strength'; 'rotator cuff strength'; 'IR deficit' and 'GIRD'.

The research strategy and choice of selected RCTs of this literature review were based on the PICOS methodology: P (population), I (intervention), C (comparison), O (outcome) and S (study design) according to Wright et al., 2021). The population of interest was football goalkeepers and handball, volleyball, and baseball, male or females, amateur or professional, youth or adult athletes. The intervention of focus was shoulder specific injury prevention warmup or neuromuscular strengthening programmes that were examined for their effect on shoulder injuries of overhead athletes. For the comparison criteria, studies were included that compared a specifically designed prevention programme with a regular warm-up or strengthening programme. Concerning the outcome criteria, this literature review aimed to study the effects of such programmes on shoulder injury prevention indicators (rates, incidence, prevalence, risk) and on the main risk factors that contribute to injury, ER strength (muscle imbalance), dynamic stability (ER:IR ratio) and IR ROM (GIRD). Studies that therefore included at least one of the desired outcomes, were assessed. Finally, only English language RCTs were selected as study design, to ensure randomisation.

2.1. Quality and Bias

To ensure a level of quality and reduced bias amongst the RCTs chosen for this literature review, some inclusion and exclusion criteria were set prior to the search. The inclusion criteria included RCTs only to ensure randomised allocation, a range of a decade for year of study publication (2013-2023) to ensure recent results, a PEDro scale of at least 5/10, at least one outcome measure of interest (injury rate, incidence, prevalence, risk, ER strength, GIRD, FDR), intervention of interest (prevention warmup or strengthening exercise programme), population of interest (overhead athletes) and pathology of interest (shoulder overuse or acute injuries). The exclusion criteria were all types of studies other than RCTs, like systematic reviews or pilot studies, RCTs older than 2013, ratings below 5/10 in the PEDro scale, as well as outcome measures, interventions, populations, and pathologies of no interest.

The PEDro scale calculates the methodological quality of physiotherapy related RCTs [27]. It's a scale with acceptable validity and high reliability (intraclass correlation coefficient ICC = 0.58-0.91), constituting it a dependable tool of RCTs assessment. A final rating between 0 and 10 points is derived from 11 assessment criteria presented on Table 1 below:

Table 1. PEDro scale 11 assessment criteria

PEDro RATING CRITERIA	
1.	Specification of eligibility criteria
2.	Random allocation of subjects in groups
3.	Concealed allocation meaning the person that does the allocation of the subjects, doesn't know in which group they go
4.	Baseline comparability between the condition of the subjects and the groups
5.	Blinded subjects to which group they have been allocated
6.	Blinded therapists who conduct the intervention
7.	Blinded assessors who measure the results
8.	Follow up of outcome measures from over 85% of trial subjects
9.	Intention to treat analysis meaning the subjects receive the planned intervention
10.	Between group analysis of trial results for at least one outcome of interest
11.	Point estimate and variability results for at least one outcome of interest

Once the desired databases, keywords, and PICOS, inclusion, exclusion and quality criteria were set, a combination of keywords with the use of the Boolean operators 'AND' and OR' was created to identify the available literature of interest. Different combinations were tried and examined while using PubMed, however the top 3 combinations that yielded the most results were the 'Shoulder AND (injury OR overuse) AND prevention' with 163 studies, 'programme AND (prevention OR exercise) AND overhead AND (sport OR athletes)' with 73 results, and finally 'Shoulder AND (injury or overuse) AND prevention AND sport' with 57 results. Concerning PEDro, the combination with the most results was 'shoulder AND injury AND prevention' with 27 findings. Search at LILACS and SciELO derived 38 and 6 papers respectively, with only one being of interest. A total of 165 studies were screened based on title and abstract. From the 165 studies, 27 were chosen for careful evaluation by reading the whole text. Sixteen were excluded due to different reasons such as different outcome measures, pathology, sport, intervention, or population of interest, with two ending up not being RCTs despite the appropriate filter.

3. Results

The process of study identification is illustrated in Figure 2.

Finally, 11 studies that satisfied the research criteria were chosen to be reviewed in this study. The detailed PEDro ratings of the studies included in this study are presented in Table 2 .

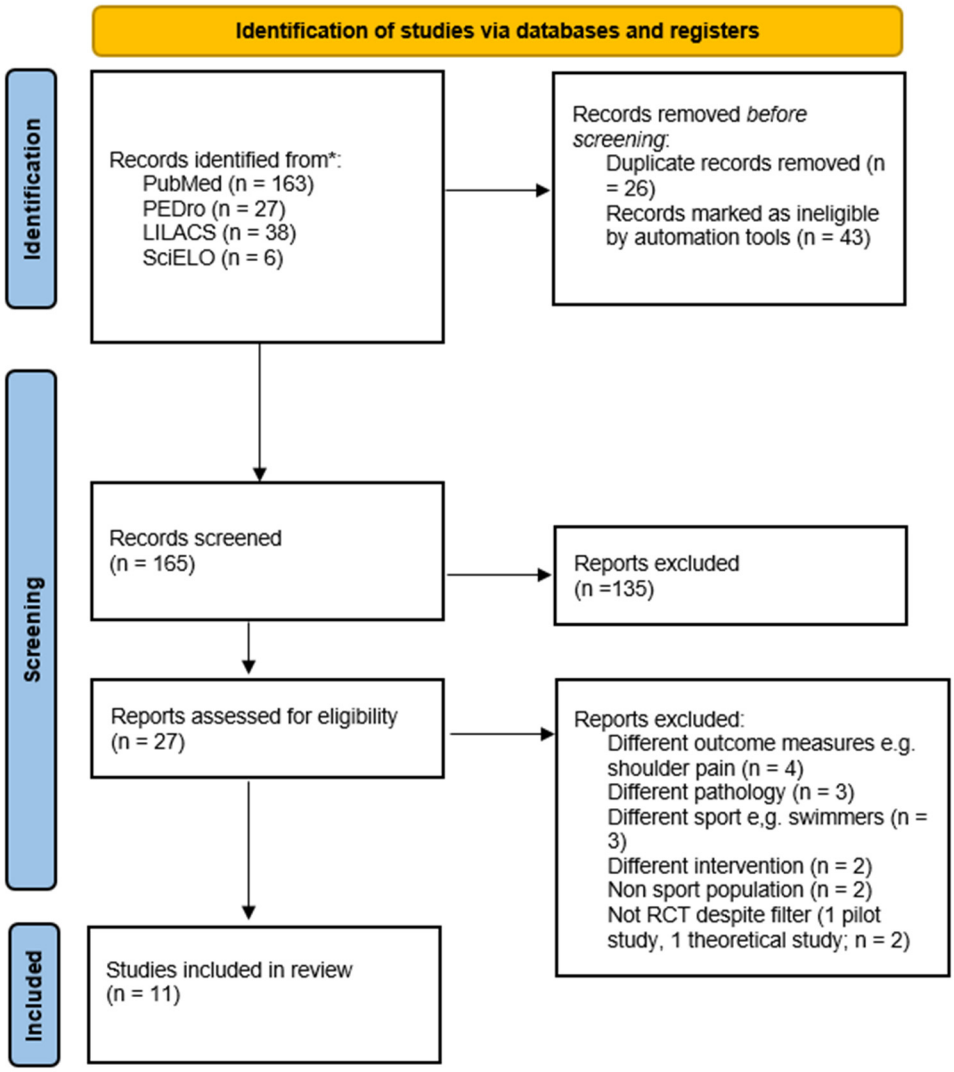

Figure 2. PRISMA flow diagram for the identification process of studies via databases and registers based on the preset criteria

Table 2. The PEDro ratings of the eight out of the eleven RCTs included in this study

RCTs	1	2	3	4	5	6	7	8	9	10	11	Final score
Achenbach et al., 2022	Yes	Yes	Yes	Yes	No	No	No	No	Yes	Yes	Yes	6/10
Andersson et al., 2016	Yes	Yes	Yes	No	No	No	No	Yes	No	Yes	Yes	5/10
Asker et al., 2022	Yes	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes	7/10
Eshgi et al., 2022	Yes	Yes	No	Yes	No	No	No	Yes	No	Yes	Yes	5/10
Fredriksen et al., 2020	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	No	Yes	7/10
Mascarin et al., 2017	Yes	Yes	Yes	Yes	No	No	No	Yes	No	No	Yes	5/10
Moradi et al., 2017	Yes	Yes	No	No	No	No	Yes	Yes	Yes	Yes	Yes	6/10
Sakata et al., 2019	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	8/10
Attar et al., 2021	Yes	Yes	No	No	No	No	Yes	Yes	Yes	Yes	Yes	6/10
Raeder et al., 2015	Yes	Yes	No	No	No	No	Yes	Yes	Yes	Yes	Yes	6/10
Zarei et al., 2021	Yes	Yes	No	No	No	No	Yes	Yes	Yes	Yes	Yes	6/10

A summary of the eleven studies included in this review is presented on Table 3 below:

Table 3. Analysis of selected studies

	Characteristics of the sample			**Characteristics of the intervention**		**Outcome measures**	**Results**
Studies	Sample	Dropout	Final	Interventions	Number of sessions Frequency (times/week) Period (weeks)		
Achenbach et al., 2022	n=825 players from 61 teams Amateur, recreational, and professional handball athletes of both sexes.	n=246	n=579 IG n=284 (161 males, 123 females) from 30 teams CG n=295 (159 males, 136 females) from 31 teams	IG: Achenbach handball prevention programme (stretching and resistance band strengthening exercises) CG: Normal warm-up routine	Pre-season: 15 minutes, 2-3 times/week for 10-12 weeks Competition period: 15 minutes, 2 times/week	Primary outcome: Prevalence and risk factors of overuse and substantial overuse throwing shoulder injuries Secondary outcomes: influence of compliance on the primary endpoint and intensity of shoulder overuse symptoms	No significant difference in the prevalence and symptoms of overuse shoulder injury between IG and CG. No significant reduction of prevalence and symptoms of overuse shoulder injury for the IG → the 10% injury reduction benchmark was not reached.
Andersson et al., 2016	45 elite handball teams (22 female, 23 male) with total N=660 players IG (22 teams): n=331 CG (23 teams): n=329	n=126 EG: n=51 CG: n=39 Insufficient injury entry criteria data: IG: n=16 CG: n=20	n=534 IG: n=264 (139 without shoulder problem, 125 with shoulder problem) CG: n=270 (146 without shoulder problem, 124 with shoulder problem)	For primary outcome: IG: OSTRC Shoulder injury prevention programme on top of normal warm-up routine CG: Team regular warm-up routine For secondary outcome: OSTRC overuse injury questionnaire for secondary outcome	Part of handball warm-up, before throwing exercises → 10 minutes, 3 times/week for 1 competitive season (7 months)	Primary outcome: Prevalence of dominant overuse shoulder problems and substantial shoulder problems Secondary outcome: Severity score of shoulder problems	The average prevalence of substantial shoulder injuries was: IG=5% CG=8% 28% lower risk of shoulder problem reporting in IG than CG, with severity score average of any reported problem being 29 and 35 respectively. Players with shoulder pathology at baseline: the risk of shoulder problem reporting was 35% lower in the intervention group, with no significant difference for substantial shoulder problem reporting between the two groups. Players without shoulder pathology at baseline: No statistical difference in risk of shoulder problem or considerable shoulder problem reporting in IG than CG. OSTRC prevention programme decreases handball shoulder injury prevalence and risk.

Table 3 continued

Asker et al., 2022	18 secondary schools n=709 Swedish handball players (female and male) IG 1 (Shoulder group): n= 222 IG 2 (Knee group): n=244 CG: n==243 Age: 14-19	n=82 IG 1: n=23 IG 2: n=28 CG: n=31	n=627 IG 1: n=199 IG 2: n=216 CG: n=212	IG 1: The Shoulder control warmup programme added to normal handball warm-up routine IG 2: Knee control intervention CG: Usual training and game routine.	Shoulder control programme 10-15 minutes Pre-season: 3 times/week, 3 sets of 30 seconds for each exercise Season: 2 times/week, 3 sets of 30 seconds for each exercise	Primary outcome: Preventive nature of exercise programmes, injury risk (prevalence) Secondary outcomes: shoulder problems, substantial shoulder problems	IG 1: Injury rate of 0.8/1000 handball hours CG: Injury rate of 1.8/1000 handball hours IG 1 had 56% lower injury rate than CG. IG 1 had weekly prevalence of shoulder and substantial shoulder problems 3% and 1% respectively, compared to 8% and 2% respectively for the CG. IG 1 had lower injury risk and prevalence of shoulder injury compared to CG.
Attar et al., 2021	n=765 amateur football goalkeepers 18-35 years old IG: n=379 (mean age=26.8) CG: n=386 (mean age=26.20)	n=39 IG: n=19 CG: n=20	n=726 IG: n=360 CG: n=366	IG: FIFA 11+S warmup programme CG: Usual routine warm-up programme	FIFA 11+S: 20-25 minutes Before all training sessions for the 6 month season	Primary outcomes: Incidence of upper extremity injuries Mechanism of injury Type of injury Severity of injury Secondary outcomes: Intervention group compliance	IG: 50 injuries → Injury rate of 0.62/1000 football hours CG: 122 → Injury rate of 1.94/1000 football hours 68% reduction in upper extremity injury for FIFA 11+S compared to usual warm-up → Significant statistical difference IG: For 2.5 goalkeepers, 1 injury was prevented IG: Statistically significant reduction in shoulder injuries and Reduced injury incidence and risk compared to CG → The risk of initial and recurrent injuries was 3.34 and 4.05 higher in the control group. The incidence of all injury mechanisms (contact, noncontact, initial, recurrent, overuse) decreased because of the FIFA 11+S programme, with no statistically significant observed differences concerning injury severity. FIFA 11+S is an effective prevention warmup programme → 50% less injuries

Table 3 continued

Eshghi et al., 2020	n=32 young volleyball players from Iranian youth Premier League Mean age: 17.5 IG: n=16 CG: n=16	n=4 IG: n=2 CG: n=2	n=28 IG: n=14 CG: n=14	IG: FIFA 11+S warmup programme CG: Normal routine programme	At least 3 times/week For the first 8 weeks of the season 8 sessions of each FIFA 11+S stage	Isokinetic shoulder strength of dominant shoulder	IG: FIFA 11+S didn't increase isokinetic strength IG: Significant increased FDR at 180°/s by 20% IG: ER strength and shoulder muscle balance increased
Fredriksen et al., 2019	3 youth handball teams (3 female, 1 male): n=57 players Mean age: 17.1 IG: n=28 (5 males, 23 females) CG: n=29 (6 males, 23 females)	Tested players at 18 weeks: IG ER dominant: n=21 IG ER non dominant: n=24 IG IR dominant: n=25 IG IR non dominant: n=25 CG ER dominant: n=25 CG ER non dominant: n=26 CG IR dominant: n=28 CG IR non dominant: n=26		IG: OSTRC shoulder injury prevention programme as a part of handball warm-up CG: Normal handball warmup routine	IG: OSTRC programme 15 minutes, 3 times/week for 18 weeks	Primary outcomes: The risk factors of ER strength and IR ROM on dominant shoulder Secondary outcomes: IR strength, ER/IR strength ratio, ER ROM, total ROM, GIRD	Statistically significant increase in ER isometric strength in both groups (IG 10%, CG 6%), with no significant difference between the groups No change in IR ROM was observed in any of the two groups No significant difference for the secondary outcomes between the two groups OSTRC prevention programme didn't influence risk factors.

Table 3 continued

Mascarin et al., 2017	n=25 young female handball athletes with ER weakness Group 1 ER weakness in dominant shoulder: n=15 IG 1: n=8 CG 1: n=7 Group 2 ER weakness in non-dominant shoulder: n=10 IG 2: n=5 CG 2: n=5			CG 1+2: Regular handball and strength training IG 1+2: Regular handball and strength training + TheraBand progressive strengthening programme	6 weeks 3 times/week 18 sessions 3 sets of 10 repetitions 30minutes before handball training	Muscle strength Rotator cuff imbalance Throwing velocity	IG 1: Significant increase in concentric ER peak torque, no change in eccentric ER peak torque, no change in functional strength balance ratio (ER:IR; 93% probability of improvement), significant increase in throwing velocity IG 2: Significant increase in both concentric and eccentric ER peak torque and significant improvement of functional strength balance ratio (ER:IR) IR peak strength torque did not change in EG 1 nor EG 2 TheraBand strengthening programme increased ER strength and muscular balance
Moradi et al., 2020	n=60 male volleyball players with asymptomatic GIRD	NO	n=60 IG: n=30 CG: n=30	IG: TheraBand throwing exercise programme +stretching CG: Active home self-exercise programme	IG: 30-40-minute sessions (including 10-min warmup like running or stretching and 5-mion cool down) 5 stretching and 3 strengthening sessions/week 8-week programme CG: 3 sessions/week 40-minute sessions For 8 weeks	Rotator cuff muscle strength Shoulder joint IR ROM Functional strength ratio ER:IR ratio Proprioception (Shoulder joint position)	Statistically significant improvement in shoulder IR ROM, shoulder concentric and eccentric strength, functional strength ratio ER:IR and shoulder joint position in the IG compared to CG.

Table 3 continued

Raeder et al., 2015	n= 28 competitive amateur female handball players Mean age: 20.8 Mean height: 170.5 Mean weight: 65.2 IG: n=15 CG: n=13			CG: Normal warmup + elastic band shoulder injury prevention programme +normal ball throwing protocol IG: Same as CG + Medicine ball training	IG Medicine ball training: 3 times/week for 6 weeks	Shoulder rotational isokinetic strength Throwing velocity and precision	IR: significant increase of concentric ER and a 15% significant increase of concentric IR at 180º/s IG demonstrated significant amelioration of shoulder rotators isokinetic strength and throwing velocity, with no effect on throwing precision A medicine ball training as part of handball warm-up is recommended
Sakata et al., 2019	n= 237 youth baseball players from 16 teams (boys and girls) Age: 9-11 IG: n=117 CG: n=120	n=18 IG: n=8 CG: n=10	n=219 IG: n=109 (99 boys, 10 girls) CG: n=110 (102 boys, 8 girls)	CG: Usual stretching and training on their own IG: Usual warm-up routine plus Yokohama Baseball-9 prevention programme	10 minutes, 1 set of 10 repetitions, at least once a week during warm-up for 12 months	Injury incidence of shoulder and/or elbow AND shoulder and elbow separately. Baseball pitching performance (ball speed)	Incidence of shoulder and/or elbow in IG was 1.7/1000 sport hours compared to 3.1/1000 sport hours in CG → statistically significant reduction Incidence of just shoulder injuries in IG was 0.6/1000 sport hours compared to 1.2/1000 sport hours in CG → not statistically significant reduction Improved pitching performance → velocity
Zarei et al., 2021	n=32 healthy young elite male volleyball players mean age: 17.5 IG: n=16 CG: n=16	n=4 IG: n=2 CG: n=2	n=28 IG: n=14 CG: n=14	IG: FIFA 11+S warm-up protocol CG: Usual warm-up protocol	3 times/week for 8 weeks	Shoulder dynamic stability Shoulder proprioception (shoulder joint position sense, threshold to detect passive motion)	Shoulder dynamic stability significantly improved only in IG IG demonstrated improved shoulder dynamic stability at the end of 8 weeks compared to baseline. FIFA 11+S improved shoulder dynamic stability, no effect in shoulder proprioception

Abbreviations: IG=Intervention group; CG=Control group; ER=External rotation; IR=Internal rotation; OSTRC= Oslo Sports Trauma Research Center).

This literature review includes studies that use eight different prevention exercise programmes. The programmes and the corresponding RCTs that investigate their effects on shoulder injury prevention and risk factors are analysed below.

3.1. FIFA 11+ S

The FIFA 11 + Shoulder (S) is a prevention warmup exercise programme that was created by sport injury specialists [15]. Its aim is injury reduction in upper extremities by improving core stability, neuromuscular shoulder control and rotator cuff eccentric strength [28]. According to previous research, the FIFA 11+ S programme is divided in three sections, with the first part including three general warm up exercises [7]. The second part consists of strengthening and balance exercises of progressive difficulty for shoulder and other arm joint muscles. The third stage includes advanced exercises such as plyometric or overhead sport specific exercises to improve core stability and muscle control [7].

The RCT by Attar et al. [28], investigated the effect of the FIFA 11+S programme on the incidence of upper extremity injuries and injury mechanism, type, and severity, in 726 amateur football goalkeepers. The intervention group (n=360, mean age 26.8) adopted the FIFA 11+S programme as warmup, before every training session for a whole season (6 months), while the control group (n=366, mean age 26.2) followed their normal warm-up protocol. During the season, the intervention group recorded 50 injuries with an injury rate of 0.62/1000 football hours, and the control group recorded 122 injuries with an injury rate of 1.94/1000 football hours. There was a 68% reduction of injuries in the upper extremities for the FIFA 11+S group compared to the control group, with 1 injury for 2.5 goalkeepers averted. Additionally, a statistically significant reduction in shoulder injuries and a decreased injury incidence and risk were reported for the intervention group. The risk of initial and recurrent injuries was greater in the control group (4.05) than the intervention group (3.34). Finally, the incidence of all injury mechanisms (contact, noncontact, initial, recurrent, overuse) decreased because of the FIFA 11+S programme.

The FIFA 11+S protocol was used in two more studies, examining its effect on risk factors. In the RCT by Eshghi et al. [20], the FIFA 11+S was assessed for its effect on isokinetic dominant shoulder strength on volleyball players, measured by a Biodex System 4 dynamometer. A total of 28 volleyball players for the Iranian youth Premier League were allocated into a FIFA 11+S intervention group (n=14), who performed the protocol at least 3 times per week for the first 8 weeks of the season as warmup, and the control group (n=14) that carried on with their usual warmup programme. The ER-specific exercises of the intervention protocol led to a significantly increased FDR at 180o/s by 20%. However, the shoulder isokinetic strength remained unaffected.

The RCT by Zarei et al. [29], investigated the efficiency of the FIFA 11+S programme in 28 young elite male volleyball players. They evaluated shoulder dynamic stability, measured by the Upper Quarter Y Balance Test, and shoulder proprioception assessed by an isokinetic Biodex System 4 dynamometer. The intervention group (n=14) performed the protocol for 20-25 minutes, 3 times per week for 8 weeks, and the control group kept their usual warm-up programme. At the end of the intervention, shoulder dynamic stability of the intervention group significantly improved from baseline to end of trial.

3.2. OSTRC Program

The Oslo Sports Trauma Research Center (OSTRC) shoulder injury prevention program aims to improve ER, scapular strength and glenohumeral IR [3]. It's a warmup programme of five blocks of exercises, with one exercise per block being chosen for periods of six weeks, with progressive difficulty [3].

The Andersson et al. [3] cluster RCT assessed the effectiveness of the programme on overuse problems and substantial problems prevalence of the dominant shoulder of elite handball players. Specifically, 534 male and female players, from 46 elite handball teams from the Norwegian top two elite divisions, with and without shoulder problem at baseline, were randomly allocated into two groups: the intervention group (n=264, 139 without and 125 with shoulder problem at baseline) and the control group (n=270, 146 without and 124 with shoulder problem at baseline). The control group was instructed to continue its regular warm-up routine, while the intervention group performed in addition, the 10-minute OSTRC programme, 3 times per week for one competitive season (7 months). The players were assessed six times during the season about shoulder condition with the OSTRC Overuse Injury questionnaire (OSTRC-O). The trial findings were that the average prevalence of shoulder overuse injuries and substantial injuries was lower in the intervention group (17% and 5% respectively) compared to the control group (23% and 8% respectively). Additionally, the risk of shoulder problem reporting was 28% lower in the intervention group than the control group. For athletes with a baseline shoulder problem, the risk of additional shoulder problem reporting was 35% lower in the intervention group, with no significant difference for substantial shoulder problem reporting between the two groups.

The RCT by Fredriksen et al. [13] included 57 youth male and female handball players (mean age 17.1) and divided them into the OSTRC intervention programme group (n=28), performed for 15-minutes, 3 times per week for a total of 18 weeks, and the control group that used their normal handball warmup exercises (n=29). Their main aim was to assess the effectiveness of the OSTRC programme on ER isometric strength, measured by a handheld dynamometer, and IR ROM measured by a digital goniometer, in both dominant and non-dominant shoulders.

The players were assessed at baseline, 6 weeks, 12 weeks, and 18 weeks. IR strength, ER:IR strength ration, ER ROM, GIRD, and total ROM were also examined as secondary outcomes. The results demonstrated a statistically significant increase in ER isometric strength (intervention group 10%, control group 6%) and a FDR increase in both groups with no significant difference between the groups. No change in IR ROM was observed.

3.3. Yokohama Baseball-9

According to Sakata et al. [30], the 10-minute Yokohama Baseball-9 (mYKB-9;) warmup prevention programme consists of nine exercises: five stretching exercises to increase shoulder and elbow ROM, two dynamic mobility exercises for scapular mobility, and two balance exercises.

The mYKB-9 programme was investigated in RCT by Sakata et al. [30], which allocated 219 youth male and female baseball players from 16 teams, aged 9-11 to two groups, the control group that followed the usual stretching and training protocol, and the intervention group that added the mYKB-9 prevention programme on their protocol, performed at least once per week, for 12 months with assessment every four months. The primary outcomes examined were the injury of incidence of shoulder and/or elbow, and shoulder separately, with the baseball pitching performance based on ball speed, as secondary outcome. This study demonstrated a statistically significant reduction of shoulder and/or elbow injuries in the intervention group (1.7/1000 sport hours compared to the control groups 3.1/1000 sports hours). A reduction of shoulder injury incidence was also observed; however, it was not significant (0.6 against 1.2/1000 sports hours). Finally, pitching velocity increased in the intervention group and thus performance increased.

3.4. Achenbach Prevention Programme

The Achenbach program, a 15-minute regimen tailored for handball athletes, was developed by identifying key risk factors such as diminished external rotation strength, abnormalities in scapular movement, and deficits in glenohumeral internal rotation. It consists of five exercise blocks of progressive difficulty to improve: scapular position, ER strength, scapular strength, scapular control and glenohumeral IR ROM. The parameters are 2-3 sets of 8-10 repetitions for the exercises and 40-60 seconds for the stretches[21].

The cluster RCT by Achenbach et al. [21], collected 579 recreational, amateur, and professional male and female handball athletes, and randomly assigned them to an intervention group (n=284) that performed the 15-minute Achenbach prevention programme, 2-3 times per week for 10-12 pre-season weeks, and 2 times/week during competition period, and a control group (n=295) that continued with their normal training protocol. The aim of this study was to assess the effect of the intervention programme on prevalence and symptoms of overuse and substantial overuse shoulder injuries. The data was collected from the players through questionnaires. The study showed no statistically significant difference between the two groups nor significant reduction of prevalence and symptoms of overuse and substantial overuse shoulder injuries for the intervention group as the preset 10% injury reduction benchmark was not reached.

3.5. Shoulder Control Programme

According to Asker et al. [2], the 10–15-minute Swedish shoulder control programme is a handball preseason strengthening programme (3 times per week, 3 sets of 30 seconds for each exercise) and a season warm-up exercise programme (2 sets of 30 seconds for each exercise, added to the normal handball warm-up routine). The aim of this programme is shoulder and trunk strengthening and the improvement of trunk mobility and control and of handball performance (velocity and frequency of throwing load). It includes five primary exercises consisting of 4 sub exercises of increasing difficulty, plus a partner exercise, and a pre-season only handball throwing programme. Blocks 1 and 2 consist of exercises focusing on shoulder strength/control. Block 3 focuses on upper body mobility rotations. Block 4 consists of variations of the diver with one arm in overhead positions exercise. The goal of block 5 is trunk rotation strengthening. The pre-season handball programme consists of four levels of progressive throwing difficulty [2].

A handball specific cluster RCT by Asker et al. [2], examined the effect of the shoulder control warmup programme, on shoulder injury prevention in adolescent elite Swedish handball players, between 14-19 years old (mean age 16.5). The sample (n=627) was randomised into three groups: the intervention shoulder group, the intervention knee group (following a knee programme independently of the shoulder study), and the control group. The intervention group was instructed to add the shoulder control programme to their normal handball protocol, while the control group followed their usual training and games warmup routine. The shoulder control programme was implemented three times per week during preseason and twice per week during the season. The OSTRC-O was used for outcome measurement. The results derived from this study were: a 56% lower shoulder injury rate (0.8/1000 handball hours) in the shoulder control group, than in the control group (1.8/1000 handball hours). Additionally, the shoulder group had weekly prevalence of shoulder and substantial shoulder problems 3% and 1% respectively, compared to the 8% and 2% of the control group. The shoulder control group therefore demonstrated lower injury risk and prevalence than the control group.

3.6. Thera-Band Strengthening Programme

According to Mascarin et al. [5], the Thera-Band

programme is a 30-minute preventive strength training programme focusing on ER muscles strengthening with the use of resistance bands. The exercises are ER with 90o abducted shoulder and flexed elbow, and ER with neutral shoulder and 90o flexed elbow, and are progressing in difficulty through increased rubber band colour resistance. A population of 25 young female handball athletes with ER weakness, was divided into four groups. Two intervention groups, with dominant shoulder (n=8) and non-dominant shoulder ER weakness (n=5), were compared with their corresponding control groups (n-7 and n=5 respectively). The control groups followed their regular handball and strength training, while the intervention groups performed TheraBand programme also, for 18 sessions in 6 weeks, 3 times per week. The outcomes of interest were muscle strength, rotator cuff imbalance and throwing velocity. The dominant shoulder TheraBand group demonstrated a significant increase in concentric ER peak torque but no change in eccentric ER peak torque, no change FDR (ER:IR; 93% probability of improvement), while throwing velocity significantly increased. In the non-dominant TheraBand group, both concentric and eccentric ER peak torque increased, with a significant improvement of functional ER:IR strength balance ratio. IR peak strength torque did not change in any group.

3.7. TheraBand Throwing Programme

According to Moradi et al. [31], the TheraBand throwing programme is an 8-week programme of five stretching and three strengthening 30-minute sessions per week. The aim of this programme is improving neuromuscular control, by improving rotator cuff strength and the FDR ratio. The stretching programme consists of six variations of the sleeper stretch. The strengthening sessions focus on ER strengthening with eccentric ER with abducted shoulder, and 90o ER exercises. Finally, an additional catching exercise is performed [31].

Moradi et al. [31] collected 60 male volleyball players with asymptomatic GIRD (assessed with goniometer, greater that 18o IR ROM difference between upper limbs). The intervention group (n=30) followed the TheraBand throwing exercise and programme, three 30-40-minute sessions per week for a total of 8 weeks, plus 5 stretching sessions per week. The control group followed an active home self-exercise protocol. The outcomes of interest in this study were muscle activity measured by surface electromyography, rotator cuff muscle strength and FDR measured by an isokinetic dynamometer, shoulder IR ROM measured by a goniometer and proprioception (shoulder joint position) measured by a Biodex 3 isokinetic device. The results of this RCT were a statistically significant improvement in shoulder IR ROM, shoulder concentric and eccentric strength, and FDR in the TheraBand throwing group compared to the control group.

3.8. Medicine Ball Throwing Training Programme

According to Raeder et al., [14], the medicine ball throwing training programme aims to improve shoulder rotators isokinetic strength and performance (throwing velocity and precision) for handball players. It's a warmup handball-specific movement patterns programme, where six variations of two-arm medicine ball throws are performed with progressive difficulty in terms of sets, repetitions, and loads. It can be performed on top of a resistance band prevention strengthening program and a regular ball throwing programme. Its effectiveness was assessed in a population of 28 female handball players with mean age 20.8 of competitive amateur level. The control group (n=13) followed a warmup, elastic band prevention programme and normal throwing exercises, while the intervention group added the medicine ball throwing programme, for three times per week for 6 weeks. The intervention group demonstrated a significant amelioration of shoulder rotators isokinetic strength, with a significant increase of concentric ER and a 15% significant increase of concentric IR at 180o/s, and throwing velocity, with throwing precision remaining unaffected.

4. Discussion

The results of the RCTs that investigated the FIFA 11+S prevention programme revealed that it can offer significant effectiveness on the prevention and risk factors of shoulder injuries in overhead athletes. It was demonstrated that it can reduce rates, risk, and incidence for all types of shoulder and generally upper extremities injury mechanisms, more than a normal warm-up protocol. Additionally, it was shown to decrease shoulder injuries of football goalkeepers more than 68% in one season [28]. It was also shown by two studies that FIFA 11+S can positively affect overhead athletes' shoulder dynamic stability more than conventional warmup, by increasing the ER muscle strength ensuring an improved FDR (ER:IR). In the first study specifically, the FDR was improved at 180o/s, an angle that represents the overhead motion of overhead sports [20]. However, one of the two studies concluded that the programme didn't increase shoulder isokinetic ER and IR strength [20]. The multifaceted nature of the FIFA 11+S programme, and specifically its diverse combination of plyometric, strengthening and throwing sport-specific exercises, as opposed to a solely strengthening programme, could be the reason for the observed shoulder dynamic balance improvements and the unaffected isokinetic strength.

The results of the RCTs that assessed the OSTRC Shoulder injury prevention programme were mixed. One study demonstrated that the programme should constitute part of elite handball players warmup, because it leads to reduced prevalence of shoulder and substantial shoulder injuries and risk of injury over a seven-month season,

compared to a regular warmup protocol [3]. However, a more recent RCT, derived the conclusion that the programme has no effect on any risk factor of overhead injuries. Specifically, ER isometric strength increased significantly in both intervention and control groups, with no significant difference between them while no change in IR ROM was observed in any of the two groups. Although, it is not known whether the different characteristics between the control groups may have explained that difference. The findings so far suggest that the OSTRC programme didn't offer anything more compared to regular warmup [13]. According to Fredriksen et al. [13], the FDR of the intervention group was already high. Moreover, the intervention period was shorter than in the first study. Therefore, it's possible that the programme could not produce a significant impact on FDR due to time constraint or an already high FDR.

Three more studies included in this review assessed the prevention effects of exercise programmes. The mYKB-9 warmup prevention programme was found to significantly decrease shoulder injuries in youth baseball players, more than a usual strengthening and stretching protocol [30]. Another study added on the evidence that prevention programmes decrease shoulder injury prevalence, by demonstrating that a shoulder control prevention programme that aims to improve shoulder and trunk strength and control can lead to a lower injury rate and prevalence of shoulder injuries in handball players compared to usual training [2]. One study however yielded a different outcome on prevalence, as the Achenbach handball prevention programme that includes exercises to improve scapular mobility, ER strength and IR ROM, found no significant difference and reduction of the prevalence and symptoms of overuse shoulder injuries in handball athletes compared to normal warm-up [21]. Despite that the normal warm up of the control group was not described in the published study, it can be hypothesized that it was a warm-up programme that targeted the whole body. The heterogenic sample of this study, which included amateur, recreational, and professional handball players, could possibly have an effect in the results, as the levels and lifestyles of the participants differed. Additionally, twenty-one feedback questionnaires were planned for this study, with only seventeen being completed due to COVID-19, with the response rate for the 17 questionnaires being only 61%, which could have an impact on the study results as well.

However, three more studies identified a positive correlation between prevention exercise programmes and shoulder risk factor. In the first study, a TheraBand progressive strengthening programme significantly increased concentric ER peak torque with 93% probability of improving the FDR in handball athletes with ER weakness on their dominant shoulder, and significantly increased both concentric and eccentric ER peak and FDR ratio in handball athletes with ER weakness on their non-dominant shoulder [5]. The next two studies assessed throwing protocols. A TheraBand throwing exercise programme led to a statistically significant amelioration of shoulder IR ROM, shoulder concentric and eccentric strength and FDR ratio than an active home self-exercise programme [31]. Additionally, a medicine ball throwing programme in baseball athletes led to a significant amelioration of shoulder rotators isokinetic strength [14]. The ER strengthening-specific exercises of the first two programmes, led to increased ER strength and therefore, to improved shoulder muscular imbalance. Finally, the overhead specific exercises of the last study, managed to increase both ER and IR strength.

The analysis of this literature review shows that five out of six RCTs that investigated the effects of exercise programmes on shoulder injury prevention of overhead athletes demonstrated promising results, with a decreased injury risk, prevalence and incidence observed across the studies. Similarly, all risk factors RCTs showed an improvement of at least one of the main shoulder risk factors (ER strength, dynamic stability, GIRD). These findings enhance the belief that these risk factors affect shoulder injury rates, risk, prevalence, and incidence. The prevention programmes included in this review, were structured by considering these risk factors, with risk-factor specific modifying exercises being incorporated in the protocols. Six studies demonstrated a direct significant positive effect of these protocols on risk factors. Five studies showed increased prevention through decreased shoulder injury rates, risk, prevalence, and incidence. This could be a result of risk factor modification. For example, FIFA 11+S was shown in a study[28] to decrease shoulder injury risk and incidence, while in two other studies it improved shoulder dynamic stability (FDR). There is evidence, therefore, that the outcomes of interest are correlated.

Additionally, this study agrees with Zarei et al. [29], who demonstrated that the goalkeeper FIFA 11+S programme had positive effects on volleyball players too. While some of these programmes were constructed for a specific overhead sport, there's belief that since the overhead mechanism of injury and risk factors are the same, the prevention programmes included in this study could be adopted by any type of overhead athletes. Moreover, a universal programme incorporating different types of exercises could benefit all overhead athletes. The most promising programme according to the evidence looks to be FIFA 11+S, because it's a multicomponent exercise programme, offering a holistic approach of the overhead athlete, incorporating a variety of different types of shoulder but also core strengthening and balance exercises (strengthening, plyometric, shoulder sport-specific), while it has been investigated the most, with promising results on goalkeepers, but also volleyball players having been demonstrated. Another promising multicomponent programme is the shoulder control programme [2].

4.1. Limitations

This literature review is not without limitations. Firstly, due to lack of RCTs investigating shoulder prevention programmes, some low-quality studies were included (PEDro scale: 5/10). Secondly, not solely one intervention programme is investigated, as this review incorporates eight different prevention protocols. Thirdly, given the nature of the interventions, coaches, players, and medical stuff were not blinded to allocation and intervention and were responsible for the implementation and progression of the prevention programme which could have led to the Hawthorne effect, and athletes may have altered their behavior and performance to reach a desired outcome [32]. In addition, in some studies, injuries and compliance were self-reported by the athletes, predisposing the RCTs to recall bias, meaning affected accuracy of information provided [33]. Thirdly, physiotherapists supervised the entirety of the prevention programme to ensure quality of exercise implementation and performance in only three studies [3, 20, 31]. Additionally, information on the control group programmes concerning the exercises performed and level of supervision, was not provided in any of the studies.

Five studies selected a small sample [5, 14, 20, 29, 31], limiting the findings effect, while a few studies included amateur athletes [21, 28], with the results therefore not being representative of the professional elite athlete population. Moreover, the sample in one study was heterogenic, including combination of amateur and professional athletes or female and male athletes which could have affected the results, due to differences in lifestyles, anatomy and biomechanics, physical condition, or susceptibility to injury [21]. The long-term effects of the interventions were not investigated in any of the included studies, something that is however common amongst RCTs [34]. A couple of studies included athletes with a diagnosed risk factor at baseline [5, 14, 20], which could have inflated the results due to higher gain potential. Finally, one study was not completed in its entirety, as it ended prematurely due to Covid-19 [21].

4.2. Interpretation of the Findings

This literature review provides a comprehensive overview of various exercise programs aimed at preventing shoulder injuries in athletes, particularly those engaged in overhead sports like volleyball, handball, and baseball. The findings offer valuable insights into the effectiveness of different prevention protocols and their impact on injury rates, risk factors, and athletic performance. Here are some perspectives and interpretations that could add depth and clarity to the discussion:

Effectiveness of FIFA 11+S Program: The review highlights the FIFA 11+S program as particularly promising due to its multifaceted approach, incorporating warm-up, strengthening, plyometric, and sport-specific exercises. The significant reduction in shoulder injury rates among football goalkeepers and improvements in shoulder dynamic stability in volleyball players underscores the potential of this program. Its comprehensive nature may contribute to its effectiveness by addressing various aspects of shoulder health and function.

Mixed Results of OSTRC Program: While the OSTRC program showed promise in reducing shoulder injury prevalence among elite handball players, the mixed results from different studies suggest that its effectiveness may vary depending on factors such as athlete population, implementation protocol, and duration of intervention. Further research may be needed to clarify the optimal use of this program and identify potential limitations.

Role of Specificity in Prevention Programs: The review highlights the importance of tailoring prevention programs to the specific needs and demands of overhead athletes. Programs like the Achenbach Prevention Program, designed specifically for handball players, may offer targeted benefits but could yield different results when applied to athletes in other sports. Understanding the unique biomechanical and injury risk profiles of different sports can inform the development of more effective prevention strategies [35, 36, 37].

Evidence for Progressive Strength Training: Several studies emphasize the role of progressive strength training, particularly focusing on eccentric and concentric external rotation (ER) strength, in reducing injury risk and improving shoulder function. Programs like the Thera-Band Strengthening Program demonstrate significant improvements in ER strength and functional ratios, suggesting that targeted strength interventions can address key risk factors associated with shoulder injuries.

Considerations for Study Design and Implementation: The review acknowledges various limitations inherent in the study designs, such as small sample sizes, lack of blinding, and reliance on self-reported data. Addressing these limitations in future research through larger-scale, randomized controlled trials with rigorous methodology could enhance the validity and generalizability of findings.

Implications for Injury Prevention Strategies: Overall, the findings suggest that structured exercise programs incorporating a combination of warm-up (that included shoulder mobility exercises), strengthening, and neuromuscular control exercises hold promise for reducing shoulder injury risk in overhead athletes. By targeting specific risk factors and addressing the biomechanical demands of each sport, such programs have the potential to enhance athlete performance and longevity while minimizing the burden of shoulder injuries [35].

5. Recommendations

The available evidence in the existing literature, which was analysed in this review, leads to the belief that shoulder prevention warmup (that included shoulder

mobility exercises) or strengthening exercise programmes are effective. However, because of the limited available RCTs on the topic, this review proposes some recommendations for future research. More high-quality RCTs with bigger sample size are needed to investigate the efficiency of each of the eight programmes presented, especially for the promising multicomponent FIFA 11+S and shoulder control programmes, to solidify this reviews findings. Additionally, future studies should examine the efficiency of such programmes on specific population groups, such as professional athletes, adults, males, or females, to identify potential population-specific differences or different outcomes such as performance. Moreover, the long-term effects of prevention programmes need to be studied. Finally, more RCTs should assess the impact prevention programmes have on prevention and risk factors simultaneously, to establish a link between these two outcomes.

6. Conclusions

This literature review aimed to investigate the effectiveness of prevention warm-up and strengthening exercise programmes on prevention (injury risk, incidence, prevalence) and risk factors (rotator cuff imbalance, dynamic stability, GIRD) of shoulder injuries in overhead athletes. The conclusion of this review, given the available evidence, is that shoulder prevention exercise programmes can indeed be effective on modifying and ameliorating risk factors and preventing shoulder injuries for overhead athletes. More high-quality studies are needed however, due to the scarcity of shoulder prevention RCTs in the literature, to expand on the available knowledge.

Declarations

Funding: This research received no external funding.

Conflict of interest: All authors declare no conflict of interest in this review.

Informed Consent Statement: Not applicable.

Ethics Approval: Not applicable.

REFERENCES

[1] Cools, A.M.; Tongel, A.V.; Berckmans, K.; Spanhove, V.; Plaetevoet, T.; Rosseel, J.; Soen, J.; Levy, O.; Maenhout, A., "Electromyographic analysis of selected shoulder muscles during a series of exercises commonly used in patients with symptomatic degenerative rotator cuff tears". Journal of Shoulder and Elbow Surgery, vol. 29, no. 10, pp. e361-e373, 2020. DOI: 10.1016/j.jse.2020.03.019.

[2] Asker, M.; Brooke, H.L.; Waldén, M.; Tranaeus, U.; Johansson, F.; Skillgate, E.; Holm, L.W., "Risk factors for, and prevention of, shoulder injuries in overhead sports: a systematic review with best-evidence synthesis". British Journal of Sports Medicine, vol. 52, no. 20, pp. 1312-1319, 2018. DOI: 10.1136/bjsports-2017-098254.

[3] Andersson, S.H.; Bahr, R.; Clarsen, B.; Myklebust, G., "Preventing overuse shoulder injuries among throwing athletes: a cluster-randomised controlled trial in 660 elite handball players". British journal of sports medicine, vol. 51, no. 14, pp. 1073-1080, 2017. DOI: 10.1136/bjsports-2016-096226.

[4] Cobanoglu, G.; Aka, H.; Guzel, N.A., "The effect of shoulder injury prevention program on glenohumeral range of motion and upper extremity performance in adolescent throwers: A pilot study". Baltic Journal of Health and Physical Activity, vol. 13, no. 4, pp. 9-15, 2021. DOI: 10.29359/BJHPA.13.4.02.

[5] Mascarin, N.C.; de Lira, C.A.B.; Vancini, R.L.; da Silva, A.C.; Andrade, M.S., "The effects of preventive rubber band training on shoulder joint imbalance and throwing performance in handball players: A randomized and prospective study". Journal of bodywork and movement therapies, vol. 21, no. 4, pp. 1017-1023, 2017. DOI: 10.1016/j.jbmt.2017.01.003.

[6] Wright, A.A.; Ness, B.M.; Donaldson, M.; Hegedus, E.J.; Salamh, P.; Cleland, J.A., "Effectiveness of shoulder injury prevention programs in an overhead athletic population: a systematic review". Physical therapy in sport, vol. 52, no. 14, pp. 189-193, 2021. DOI: 10.1016/j.ptsp.2021.09.004.

[7] Ejnisman, B.; Barbosa, G.; Andreoli, C.V.; de Castro Pochini, A.; Lobo, T.; Zogaib, R.; Cohen, M.; Bizzini, M.; Dvorak, J., "Shoulder injuries in soccer goalkeepers: review and development of a FIFA 11+ shoulder injury prevention program". Open access journal of sports medicine, vol. 7, no. 1, pp. 75-80, 2016. DOI: 10.2147/OAJSM.S97917

[8] Hart, D.; Funk, L., "Serious shoulder injuries in professional soccer: return to participation after surgery". Knee surgery, sports traumatology, arthroscopy: official journal of the ESSKA, vol. 23, no. 7, pp. 2123-2129, 2015. DOI: 10.1007/s00167-013-2796-1.

[9] Castagna, A.; Nordenson, U.; Garofalo, R.; Karlsson, J., "Minor shoulder instability". Arthroscopy: the journal of arthroscopic & related surgery: official publication of the Arthroscopy Association of North America and the International Arthroscopy Association, vol. 23, no. 2, pp. 211-215, 2007. DOI: 10.1016/j.arthro.2006.11.025.

[10] Ekstrand, J.; Hägglund, M.; Waldén, M., "Epidemiology of muscle injuries in professional football (soccer)". The American journal of sports medicine, vol. 39, no. 6, pp. 1226-1232, 2011. DOI: 10.1177/0363546510395879.

[11] Strand, E.; Krosshaug, T.; Andersen, T.E., "Injury risk for goalkeepers in norwegian male professional football". British journal of sports medicine, vol. 45, no. 4, pp. 331-331, 2011. DOI:10.1136/bjsm.2011.084038.59.

[12] Clarsen, B.; Bahr, R.; Andersson, S.H.; Munk, R.; Myklebust, G., "Reduced glenohumeral rotation, external rotation weakness and scapular dyskinesis are risk factors for shoulder injuries among elite male handball players: a prospective cohort study". British journal of sports medicine, vol. 48, no. 17, pp. 1327-1333, 2014. DOI: 10.1136/bjsports-2014-093702.

[13] Fredriksen, H.; Cools, A.; Bahr, R.; Myklebust, G., "Does

an effective shoulder injury prevention program affect risk factors in handball? A randomized controlled study". Scandinavian journal of medicine & science in sports, vol. 30, no. 8, pp. 1423-1433, 2020. DOI: 10.1111/sms.13674.

[14] Raeder, C.; Fernandez-Fernandez, J.; Ferrauti, A., "Effects of Six Weeks of Medicine Ball Training on Throwing Velocity, Throwing Precision, and Isokinetic Strength of Shoulder Rotators in Female Handball Players". Journal of strength and conditioning research, vol. 29, no. 7, pp. 1904-1914, 2015. DOI: 10.1519/jsc.0000000000000847.

[15] Jasim, A., "The Impact of the Use of the Program (FIFA11+S) in the Kinetic Capabilities and the Prevention of Injuries of Elite Handball Players Shoulder Joint". International Journal of Psychosocial Rehabilitation, vol. 24, no. 6, pp. 14317-14321, 2020. DOI: 10.13140/RG.2.2.13467.49444.

[16] Møller, M.; Nielsen, R.O.; Attermann, J.; Wedderkopp, N.; Lind, M.; Sørensen, H.; Myklebust, G., "Handball load and shoulder injury rate: a 31-week cohort study of 679 elite youth handball players". British journal of sports medicine, vol. 51, no. 4, pp. 231-237, 2017. DOI: 10.1136/bjsports-2016-096927.

[17] Makhni, E.C.; Morrow, Z.S.; Luchetti, T.J.; Mishra-Kalyani, P.S.; Gualtieri, A.P.; Lee, R.W.; Ahmad, C.S., "Arm pain in youth baseball players: a survey of healthy players".. The American journal of sports medicine, vol. 43, no. 1, pp. 41-46, 2015. DOI: 10.1177/0363546514555506.

[18] Lin, M.T.; Hsiao, M.Y.; Tu, Y.K.; Wang, T.G., "Comparative Efficacy of Intra-Articular Steroid Injection and Distension in Patients With Frozen Shoulder: A Systematic Review and Network Meta-Analysis". Archives of physical medicine and rehabilitation, vol. 99, no. 7, pp. 1383-1394, 2018. DOI: 10.1016/j.apmr.2017.08.471.

[19] Makhni, E.C.; Lee, R.W.; Nwosu, E.O.; Steinhaus, M.E; Ahmad, C.S. "Return to competition, re-injury, and impact on performance of preseason shoulder injuries in Major League Baseball pitchers". The Physician and sportsmedicine, vol. 43, no. 3, pp. 300-306, 2015. DOI: 10.1080/00913847.2015.1050952

[20] Eshghi, S.; Zarei, M.; Abbasi, H.; Alizadeh, S. "The Effect of Shoulder Injury Prevention Program on Shoulder Isokinetic Strength in Young Male Volleyball Players". Research in sports medicine, vol. 30, no. 2, pp. 203-214, 2022. DOI: 10.1080/15438627.2020.1860050.

[21] Achenbach, L.; Huppertz, G.; Zeman, F.; Weber, J.; Luig, P.; Rudert, M.; Krutsch, W., "Multicomponent stretching and rubber band strengthening exercises do not reduce overuse shoulder injuries: a cluster randomised controlled trial with 579 handball athletes". BMJ open sport & exercise medicine, vol. 8, pp. 1-10, 2022. DOI: 10.1136/bmjsem-2021-001270.

[22] Kilic, O.; Maas, M.; Verhagen, E.; Zwerver, J.; Gouttebarge, V., "Incidence, aetiology and prevention of musculoskeletal injuries in volleyball: A systematic review of the literature". European journal of sport science, vol. 17, no 6, pp. 765-793, 2017. DOI: 10.1080/17461391.2017.1306114.

[23] Challoumas, D.; Stavrou, A.; Dimitrakakis, G., "The volleyball athlete's shoulder: biomechanical adaptations and injury associations". Sports biomechanics, vol. 16, no 2, pp. 220-237, 2017. DOI: 10.1080/14763141.2016.1222629.

[24] Berckmans, K.; Maenhout, A.G.; Matthijs, L.; Pieters, L.; Castelein, B.; Cools, A.M., "The isokinetic rotator cuff strength ratios in overhead athletes: Assessment and exercise effect". Physical therapy in sport: official journal of the Association of Chartered Physiotherapists in Sports Medicine, vol. 27, pp. 65-75, 2017. DOI: 10.1016/j.ptsp.2017.03.001.

[25] Pozzi, F.; Plummer, H.A.; Shanley, E.; Thigpen, C.A.; Bauer, C.; Wilson, M.L.; Michener, L.A., "Preseason shoulder range of motion screening and in-season risk of shoulder and elbow injuries in overhead athletes: systematic review and meta-analysis". British journal of sports medicine, vol. 54, vol. 17, pp. 1019-1027, 2020. DOI: 10.1136/bjsports-2019-100698.

[26] Ness, B.M.; Tao, H.; Javers, D.; Thielsen, A.; Tvedt, H.; Whitcher, J.; Zimney, K., "Development of an upper extremity 'swing count' and performance measures in NCAA division I volleyball players over a competitive season". International Journal of Sports Physical Therapy, vol. 14, no. 4, pp. 582-591, 2019. DOI: 10.26603/ijspt20190582.

[27] Yamato, T.P.; Maher, C.; Koes, B.; Moseley, A., "The PEDro scale had acceptably high convergent validity, construct validity, and interrater reliability in evaluating methodological quality of pharmaceutical trials". Journal of clinical epidemiology, vol. 86, pp. 176-181, 2017. DOI: 10.1016/j.jclinepi.2017.03.002.

[28] Al Attar, W.S.A.; Faude, O.; Bizzini, M.; Alarifi, S.; Alzahrani, H.; Almalki, R.S.; Banjar, R.G.; Sanders, R.H., "The FIFA 11+ Shoulder Injury Prevention Program Was Effective in Reducing Upper Extremity Injuries Among Soccer Goalkeepers: A Randomized Controlled Trial". The American journal of sports medicine, vol. 49, no. 9, pp. 2293-2300, 2021. DOI: 10.1177/03635465211021828.

[29] Zarei, M.; Eshghi, S.; Hosseinzadeh, M., "The effect of a shoulder injury prevention programme on proprioception and dynamic stability of young volleyball players; a randomized controlled trial". BMC Sports Science, Medicine and Rehabilitation, vol. 13, no. 1, pp. 71, 2021. DOI: 10.1186/s13102-021-00300-5.

[30] Sakata, J.; Nakamura, E.; Suzuki, T.; Suzukawa, M.; Akeda, M.; Yamazaki, T.; Ellenbecker, T.S.; Hirose, N., "Throwing Injuries in Youth Baseball Players: Can a Prevention Program Help? A Randomized Controlled Trial". The American journal of sports medicine, vol. 47, no. 11, pp. 2709-2716, 2019. DOI: 10.1177/0363546519861378.

[31] Moradi, M.; Hadadnezhad, M.; Letafatkar, A.; Khosrokiani, Z.; Baker, J.S., "Efficacy of throwing exercise with TheraBand in male volleyball players with shoulder internal rotation deficit: a randomized controlled trial". BMC musculoskeletal disorders, vol. 21, no. 376, pp. 1-13, 2020. DOI: 10.1186/s12891-020-03414-y.

[32] Chen, L.F.; Vander Weg, M.W.; Hofmann, D.A.; Reisinger, H.S., "The Hawthorne Effect in Infection Prevention and Epidemiology". Infection control and hospital epidemiology, vol. 36, no. 12, pp. 1444-1450, 2015. DOI: 10.1017/ice.2015.216.

[33] Colombo, D.; Suso-Ribera, C.; Fernández-Álvarez, J.;

Cipresso, P.; Garcia-Palacios, A.; Riva, G.; Botella, C., "Affect Recall Bias: Being Resilient by Distorting Reality". Cognitive Therapy and Research, vol. 44, no. 5, pp. 906-918, DOI: 10.1007/s10608-020-10122-3.

[34] Davies, G.; Jordan, S.; Brooks, C.J.; Thayer, D.; Storey, M.; Morgan, G.; Allen, S.; Garaiova, I.; Plummer, S.; Gravenor, M., "Long term extension of a randomised controlled trial of probiotics using electronic health records". Scientific Reports, vol. 8, no. 1, pp. 7668. DOI: 10.1038/s41598-018-25954-z.

[35] Paraskevopoulos, E.; Pamboris, G.M.; Papandreou, M., "The Changing Landscape in Upper Limb Sports Rehabilitation and Injury Prevention". Sports, vol. 11, no. 4, pp. 80, 2023. DOI: 10.3390/sports11040080.

[36] Paraskevopoulos, E, Simeonidis, T.; Tsolakis, C.; Koulouvaris, P.; Papandreou, M., "The adjunctive benefits of mirror cross education on kinetic chain exercise approach in volleyball athletes with scapular dyskinesis". The Journal of Sports Medicine and Physical Fitness, vol. 62, no. 1, pp. 98-109, 2021. DOI: 10.23736/S0022-4707.21.12174-7.

[37] Paraskevopoulos, E.; Simeonidis, T.; Tsolakis, C.; Koulouvaris, P.; Papandreou, M., "Mirror Cross-Exercise on a Kinetic Chain Approach Improves Throwing Performance in Professional Volleyball Athletes with Scapular Dyskinesis". Journal of Sports Rehabilitation, vol. 31, no. 2, pp. 131-139, 2021. DOI: 10.1123/jsr.2021-0103.