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Systematic Review/Meta-Analysis

Risk Factors Associated with New Onset of Shoulder Pain and Injury Among the Athletic Population: A Systematic Review of the Literature

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Introduction

There is a high incidence of shoulder injuries among overhead athletes. Identifying and understanding risk factors for these injuries, particularly those that can be modified, is a necessary step towards being able to effectively develop and implement shoulder specific injury prevention programs. Therefore, the purpose of this systematic review was to identify risk factors associated with a new onset of shoulder pain and injury among the athletic population.

Design

Systematic Review.

Methods

A systematic review of the literature was performed within PubMed, Embase, AMED, CINAHL, and EmCare databases. Studies were screened utilizing the following inclusion criteria; (a) athletes currently pain free or no history of pain at baseline, (b) athletes with shoulder and or arm pain originating from a musculoskeletal shoulder problem (c) risk factors captured prospectively (d) pathoanatomy and biomechanics in isolation or in addition to personal characteristics, etc. (e) reporting relative risk, odds ratios, and/or hazard ratios and (f) follow up ⩾ 6 months. Due to data heterogeneity, only a descriptive data synthesis was performed. Data were extracted and underwent risk of bias assessment utilizing the Quality in Prognosis Studies (QUIPS) tool. PRISMA guidelines were utilized throughout.

Results

Nineteen papers were included. A total of four studies investigated baseball, five handball, three swimming, two tennis, two military, one cricket, one American football, and one with multiple sports, totaling 7,802 athletes. The risk of bias among the included studies was rated from moderate to low overall with no single study being identified as high risk of bias. All studies designs were a level of evidence of II except for two studies that were level III. The most significant risk factors included range of motion, reduced strength, history of local/regional musculoskeletal pain, previous injury, and training load. There are inconsistencies in how injury and pain are defined within studies.

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Conclusion

Many risk factors are easily objectifiable and modifiable which may help in developing shoulder injury mitigation strategies. Three of the five significant risk factors for injury can be identified by objective pre-screening measures. While previous pain and injury cannot be mitigated, training loads should be closely monitored and adapted according to other risk factors and the athlete's response.

Level of Evidence

2

INTRODUCTION

The incidence of shoulder pain and injury among overhead athletes varies considerably depending on the sport and level of competition with ranges between 18% and 90%.[1-3] Shoulder pain and injury commonly result in decreased sports performance, time missed from training and competition, increased potential need for rehabilitation or surgical interventions, and athletes with a shoulder injury may no longer be able to participate in sport depending on the severity or chronicity of the condition.[4-6] Certain overhead sports have been highlighted regarding the incidence of shoulder pain and injury as well as associated risk factors; for example, in Major League Baseball (MLB) the shoulder has been reported as the most injured area overall.[7] The injury rate related to the shoulder in MLB (particularly for pitchers) is partly associated with the velocity and force required during the throwing motion, and more notably with the eccentric braking of the arm that must occur once the ball is released.[8,9] The physical demands involved with these forces are most evident in the late cocking phase of throwing.[8] During the late cocking phase of throwing, glenohumeral joint external rotation range of motion can reach ranges from 165-175 degrees with subsequent glenohumeral joint internal rotation velocities peaking at over 7,000 degrees per second.[8,9] Other overhead sports such as handball, volleyball, and tennis demand similar means of force production and deceleration but to a lesser degree. Swimming may demand less force production and velocity than other overhead sports, but the number of revolutions without rest that the shoulder must endure during practice and competition makes it vulnerable to pain and injury.[3] Among tactical athletes (military, law enforcement, and firefighters) glenohumeral joint instability occurs at a higher rate than in the civilian population.[10,11]

Given the incidence of shoulder pain and injury in overhead athletes, there has been considerable interest and effort placed into identifying associated risk factors and subsequently creating and implementing shoulder injury prevention programs.[1,4,6,12] However, there is limited research evaluating the effectiveness of shoulder injury prevention programs in overhead athletes. A recent systematic review of the literature on the topic of shoulder injury prevention programs in overhead athletes found that only three studies were able to demonstrate a favorable outcome when implementing an injury prevention program.[6]

There is a clear need to identify and understand risk factors associated with shoulder pain and injury in athletes who participate in overhead sports to effectively develop and implement shoulder specific injury prevention programs. Additionally, these injury prevention programs should account for the unique demands of each sport and in some instances, individual positions within a given sport. The most recent unregistered systematic review[13] performed on the topic utilized a broad inclusion criterion which did not include a specific follow up time or indicate if studies including athletes currently experiencing pain were excluded. Additionally, the systematic review limited the included sports to those classified as overhead and did not include tactical athletes. Therefore, the purpose of this study of this systematic review was to identify risk factors associated with a new onset of shoulder pain and injury among the athletic population.

METHODS

GUIDELINES

This systematic review utilized the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines for all phases of the review process. The PRISMA statement includes a 27-item checklist designed to improve reporting of systematic reviews and meta-analyses.[14] This study was registered using the international prospective register of systematic reviews PROSPERO with the corresponding reference number CRD42020187086

SEARCH STRATEGY

Searched databases included Medline (PubMed), Embase, AMED, CINAHL, and EmCare utilizing a search strategy developed by one of the authors (HD) with assistance from a medical librarian. No restrictions on date of publication or language were utilized in the search. The search was performed from database inception through October 9, 2022. An example of the search strategy utilized for PubMed can be found in Table 1.

Table 1. PubMed Search Strategy

((first ADJ incidence).ti,ab OR (prognost*).ti,ab OR (risk ADJ factor).ti,ab OR (first ADJ onset).ti,ab OR (first ADJ episode).ti,ab) AND ("SHOULDER PAIN"/ OR "SHOULDER IMPINGEMENT SYNDROME"/ OR "ROTATOR CUFF"/ OR SHOULDER/ OR (shoulder* ADJ1 bursitis).ti,ab OR (shoulder* ADJ1 frozen).ti,ab OR (shoulder* ADJ1 impinge*).ti,ab OR (shoulder* ADJ1 instab*).ti,ab OR (shoulder* ADJ1 tendin*).ti,ab OR (shoulder* ADJ1 tendon*).ti,ab OR (shoulder* ADJ1 sublux*).ti,ab OR (shoulder* ADJ1 pain*).ti,ab OR (adhesive ADJ capsulitis).ti,ab OR (rotator ADJ cuff).ti,ab)

Citations were imported into Rayyan, an online screening tool, for storage, access and management for review.

STUDY SELECTION

Title and abstract screening were performed by two independent reviewers (MD and HRT for the initial round as well as PS and DW for the subsequent round) with discrepancies handled through discussion. The inclusion criteria for studies included in this review consisted of the following: (a) athletes either currently in a pain free state (for any length of time) or with no history of shoulder pain at baseline, (b) athletes presenting with shoulder and or arm pain described by the clinician or researcher as originating from a musculoskeletal shoulder problem (c) study designs in which risk factors were captured in a prospective manner (d) factors such as patho-anatomy and biomechanics in isolation or in addition to personal characteristics, environment, activity, participation, lifestyle, beliefs expectations, past experience, etc. (e) studies including relative risk, odds ratios, and/or hazard ratios and (f) follow up of ⩾ 6 months. Studies were excluded if they were published in a language other than English and if the results were presented using mixed patient populations where data could not be separated.

There are discrepancies in how researchers define pain and injury and in some cases the definition of pain was similar to that of the definition of injury. For comprehension, the authors chose to retain studies that examined risk factors associated with both shoulder pain and injury among the athletic population. Risk factors were defined as an exposure that, when present, may increase the risk of an unfavorable outcome, in this case, shoulder pain or injury.[15] Further boundaries created around risk factors identified within the retained studies included physical (ie. range of motion [ROM]), behavioral (ie. pain experience), environmental (ie. turf vs. grass playing surface) and sport specific demands (ie. training load). Lastly, risk factors were considered modifiable if they could be controlled or changed.

DATA EXTRACTION AND APPRAISAL

Data were extracted by two independent research assistants (EL and KF). Data extracted included first author, population/demographic information as well as physical and or psychological variables reported as relative risk (RR), odds ratios (OR), and/or hazard ratios (HR). Relative risk results are performed through a Poisson model and are the risk of sustaining the outcome compared to the entire sample. Odds ratios were performed through a logistic regression and are the odds of sustaining the outcome by dividing the total number with the outcome by the number of participants in the sample who do not sustain the outcome. Hazard ratios were performed through survival (i.e., time to event) analyses. Hazard ratios incorporate time within the denominator. Given that no one tool for measuring risk of bias fit the varied study designs represented, the authors chose the Quality in Prognosis Studies (QUIPS) tool. This tool has been shown to be reliable with a median inter-rater reliability of 0.75. This tool consists of six elements (study participation, study attrition, prognostic [risk] factor measurement, outcome measurement, study confounding, and statistical analysis and reporting). Each element contains subheadings that examine particular features of the six larger elements. The six elements are then given a score of low, moderate or high risk of bias based on clearly outlined criteria for each subheading within the tools supplementary file.[16]

Included articles were distributed to members of the review team (CC, HD, RC, JL, PS, and DW) with all articles being reviewed independently for risk of bias (ROB) by two reviewers and consensus scoring agreed upon for each element of all retained articles. The use of summated scoring for overall risk of bias is discouraged and instead selecting criteria *a priori* for determining overall quality is encouraged. Prior to scoring, two of the reviewers with research experience in this area (PS and CC) agreed that if four or more of the six elements were given a particular score, the majority score would be given as the overall score. If the scores were split three of one and three of another, the score of moderate would be given and if there were three of one score and the others did not all agree, it would be given an overall score of moderate.

STATISTICAL ANALYSIS

Due to the heterogeneity in the data, a descriptive data synthesis was performed. Aggregated data were reported as median (range). Individual data points were reported as reported in the individual study. All analyses were performed with R 4.21. (R Core Team (2022). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.) . The *dplyr* package was used for all cleaning, coding, and descriptive analyses.

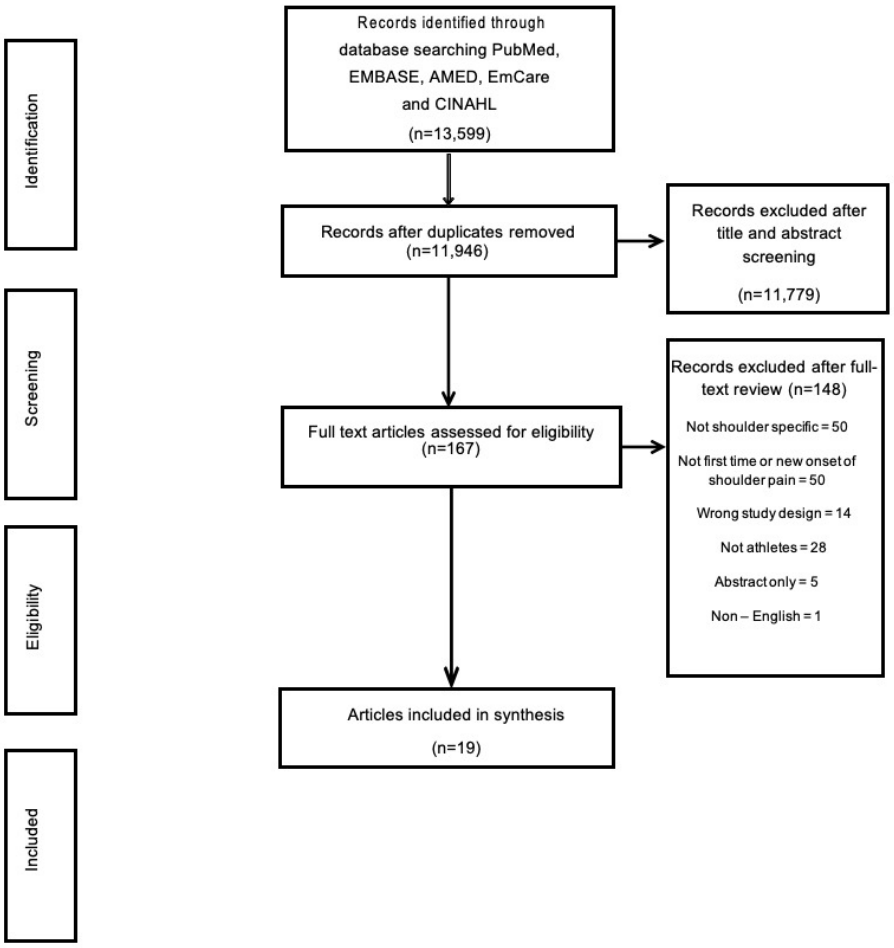

Figure 1. PRISMA Flow Diagram

RESULTS

The search yielded a total of 13,599 citations, 1,653 duplicates were detected and removed to allow for 11,946 unique citations for screening of which after screening, a total of 19 studies were included in this systematic review (Figure 1). Four studies investigated baseball,[5,17-19] five handball,[20-24] three swimming,[25-27] two tennis,[28,29] two military,[30,31] one cricket,[32] one American football,[33] and one examined multiple overhead sports.[34] Overall, 7,802 athletes were studied (Table 2).

METHODOLOGICAL DESIGN AND RISK OF BIAS

One study was a randomized controlled trial[21] and eighteen studies were prospective cohort studies.[5,17-20,22-34] Thirteen studies received an overall rating of low risk of bias,[5,17,19,21-23,26,28-32,34] six received an overall rating of moderate risk of bias[18,20,24,25,27,33] with no studies rated as having high risk of bias overall. Element 2, study attrition, was what led to most articles receiving a score other than low, with three studies receiving a score of high risk of bias[18,20,24] and ten receiving a score of moderate risk of bias.[19,21,25-29,32-34] Element 4, outcome measurement, contributed to most articles rated as low risk of bias with only three rated as moderate[20,24,27] and none rated as high. Seventeen of the included studies were considered Level 2 evidence and the remaining two case control studies considered Level 3.

PHYSICAL FACTORS

ANATOMY

Increased glenoid retroversion as associated with an increased risk of posterior shoulder instability for those in the military service. Every one degree increase in glenoid retroversion there was an increased hazard of 1.17 (HR 1.17 [1.03-1.34]) is.[30] In this population, decreased glenoid height to width ratio also demonstrated increased anterior instability hazard (HR 8.12 [1.07-61.72]).[31]

Among 46 adolescent swimmers (Female: 30; Male: 16) increased body mass index (BMI) (OR 1.48 [1.00-2.19]) demonstrated increased risk of developing shoulder pain. Additionally, humeral head position which included a smaller inferior Kibler distance in abduction (OR 0.90 [0.83 -0.97]), a smaller horizontal distance between the anterior humeral head and the anterior acromion (OR 0.76 [0.59-0.98]), and BMI (OR:1.48 [1.00-2.19]).[26]

An investigation of 113 recreational overhead athletes (Female: 59; Male: 54) found that less scapular upward rotation at 45° (OR: 1.038) and 90° (OR: 0.986) of humeral ad-

Table 2. Relevant Data Extracted from Retained Studies (risk factors reported are those identified as significant unless otherwise noted)

Study	Subjects	Risk Factors	Pain/Injury Definition	Incidence of Shoulder Injury
Achenbach et al. 2019	**N = 138** • Males = 70 • Females = 68 **Age (years):** • Males = 14.7 ± 0.4 • Females = 13.5 ± 0.6 • Total = 14.1 ± 0.8 **Height (cm):** • Males = 181.2 ± 5.9 • Females = 169.8 ± 5.9 • Total = 175.2 ± 8.2 **Weight (kg):** • Males = 70.4 ± 8.5 • Females = 58.5 ± 6.7 • Total = 64.0 ± 9.6 **BMI (kg/m2):** • Males = 21.7 ± 2.1 • Females = 20.5 ± 2.0 • Total = 21.1 ± 2.0 **Team handball experience (years):** • Males = 8.7 ± 2.3 • Females = 7.9 ± 2.1 • Total = 8.2 ± 2.2	**Absolute Shoulder strength:** • Isometric ER (Newtons) • OR = 10.70 (1.2-95.6) per 10 N **Normalized muscle strength:** • Isometric ER (N/kg) • OR = 1.2 (1.0-1.4) per 0.1 N/kg • Eccentric ER <2.9 N/kg: • Both sexes ◦ OR = 3.5 (1.1-11.8) • Men ◦ OR = 5.89 (1.2-27.9) **Ratio ER:IR strength:** • Isometric ER:Iso IR ◦ OR = 1.2 (1.1-1.5) • Isometric ER:Iso IR <0.75 ◦ OR = 4.29 (1.3-14.5) • Eccentric ER:Iso IR <1.30 ◦ OR = 3.20 (1.0-10.1) **GH PROM:** • ER gain >7.5° both sexes ◦ OR = 4.1 (1.1-15.4) • ER gain >7.5° Women ◦ OR = 15.20 (1.1-185.3) • GIRD >7.5° Men ◦ OR = 0.61 (0.5-0.8) • GIRD >7.5° Women ◦ OR = 12.50 (1.4-114.6)	Injury – self reported through online questionnaire with no specific criteria provided	N = 36 (26%)
Asker et al. 2020	**Handball players** 344 uninjured players (50% female) 452 player-seasons **Age (years):** • Female = 16.5±0.9 • Males = 16.6±0.8 **Height (cm):** • Female = 169.6±9.3 • Male = 183.9±6.8 **Weight (kg):** • Female = 69.3±8.9 • Male = 80.1±10.6 **Time playing handball (years):** • Female = 9.4±2.1 • Male = 9.3±2.3 **Playing level:** • Female: • Regional = 169 (75) • National = 57 (25) • Male: • Regional = 175 (77) • National = 51 (23)	*Per Each Exposure Analysis (hazard rate ratio reported only, significance not examined)* Strength Normalized to body weight **Isometric ER:** • Female: 1.45 • Male: 1.57 **Isometric IR:** • Female: 1.87 • Male: 2.27 **Eccentric ER:** • Female: 1.72 • Male: 1.87 **Isometric ABD:** • Female: 1.31 • Male: 1.52 • *Ratio between isometric ER and isometric IR: <0.75* • *Ratio between eccentric ER and isometric IR: <0.75* **Range of Motion** • IR • Female *Pre-Season Clinical Test Analysis* **Female** Strength Normalized to body weight • Isometric ER: ◦ Crude HRR = 2.37 (1.03, 5.45) ◦ Adjusted HRR = 2.37 (1.03, 5.44) • Isometric IR: ◦ Crude HRR = 2.43 (1.06, 5.58) ◦ Adjusted HRR = 2.44 (1.06, 5.61) • Eccentric ER: ◦ Crude HRR = 1.25 (0.58, 2.71) ◦ Adjusted HRR = 1.21 (0.57,2.62) • Isometric ABD: ◦ Crude HRR = 1.14 (0.53, 2.47) ◦ Adjusted HRR = 1.10 (0.50, 2.38) • Ratio between isometric ER and IR: ◦ Crude HRR = 0.87 (0.40, 1.87) ◦ Adjusted HRR = 0.85 (0.39, 1.83) • Ratio between eccentric ER and isometric IR:	Injury – a score of 40 or more on the OSTRC (self-reported) regarding the dominant shoulder	N = 48 (14%)

Study	Subjects	Risk Factors	Pain/Injury Definition	Incidence of Shoulder Injury
		◦ Crude HRR = 0.45 (0.11, 1.88) ◦ Adjusted HRR = 0.41 (0.10, 1.73) • ER ROM: ◦ Crude HRR = 0.71 (0.33,1.55) ◦ Adjusted HRR = 0.74 (0.34, 1.62) • IR ROM: ◦ Crude HRR = 1.56 (0.70, 3.51) ◦ Adjusted HRR = 1.59 (0.70, 3.54) • TROM: ◦ Crude HRR = 0.70 (0.32, 1.53) ◦ Adjusted HRR = 0.70 (0.32, 1.53) • Difference in TROM nondominant vs. dominant: ◦ Crude HRR = 1.21 (0.56, 2.62) ◦ Adjusted HRR = 1.30 (0.59, 2.83) • Scapular dyskinesis (yes/no) flexion: ◦ Crude HRR = 0.50 (0.17, 1.45) ◦ Adjusted HRR = 0.49 (0.17, 1.44) • Scapular dyskinesis (yes/no) abduction: ◦ Crude HRR = 1.65 (0.39, 6.98) ◦ Adjusted HRR = 1.53 (0.36, 6.52) • Joint position sense: ◦ Crude HRR = 1.06 (0.49, 2.29) ◦ Adjusted HRR = 1.06 (0.49, 2.29) **Male** Strength Normalized to body weight • Isometric ER: ◦ Crude HRR = 0.99 (0.43, 2.28) ◦ Adjusted HRR = 1.02 (0.44, 2.36) • Isometric IR: ◦ Crude HRR = 0.66 (0.28, 1.55) ◦ Adjusted HRR = 0.74 (0.31, 1.75) • Eccentric ER: ◦ Crude HRR = 0.64 (0.27, 1.50) ◦ Adjusted HRR = 0.70 (0.29, 1.64) • Isometric ABD: ◦ Crude HRR = 1.13 (0.49, 2.62) ◦ Adjusted HRR = 1.19 (0.51, 2.77) • Ratio between isometric ER and IR: ◦ Crude HRR = 2.04 (0.69, 6.04) ◦ Adjusted HRR = 2.00 (0.68, 5.92) • Ratio between eccentric ER and isometric IR: ◦ Crude HRR = 1.08 (0.44, 2.66) ◦ Adjusted HRR = 1.10 (0.45, 2.69) • ER ROM: ◦ Crude HRR = 0.84 (0.36, 1.95) ◦ Adjusted HRR = 0.74 (0.31, 1.73) • IR ROM: ◦ Crude HRR = 1.06 (0.46, 2.44) ◦ Adjusted HRR = 1.03 (0.45, 2.37) • TROM: ◦ Crude HRR = 0.87 (0.37, 2.00) ◦ Adjusted HRR = 0.77 (0.33, 1.81) • Difference in TROM nondominant vs. dominant: ◦ Crude HRR = 0.56 (0.24, 1.35) ◦ Adjusted HRR = 0.53 (0.22, 1.25) • Scapular dyskinesis (yes/no) flexion: ◦ Crude HRR = 1.44 (0.56, 3.67) ◦ Adjusted HRR = 1.53 (0.60, 3.94) • Scapular dyskinesis (yes/no) abduction: ◦ Crude HRR = 3.45 (1.49, 7.95) ◦ Adjusted HRR = 3.43 (1.49, 7.92) • Joint position sense: ◦ Crude HRR = 1.14 (0.49,2.63) ◦ Adjusted HRR = 1.12 (0.48,2.59)		
Asker et al. 2022	**Handball players** **Shoulder group (n=201):** • Age = 16.5±0.9 • Males = 120	**Shoulder Group vs control for shoulder injury:** • HRR = 0.44 (0.29-0.68) **Shoulder Group vs control for time-loss shoulder injury:** • HRR = 0.44 (0.29-0.65) **Shoulder Group vs group for time-loss shoulder injury**	Injury – a score of 40 or more on the OSTRC-O (self-reported)	N = 100

Study	Subjects	Risk Factors	Pain/Injury Definition	Incidence of Shoulder Injury
	• Years handball experience= 9.5 ± 2.0 • Performing specific shoulder strengthening exercises on a Regular basis previous season= 82 • Hx of shoulder pain= 97 **Knee group (n=218)** • Age = 16.5 ± 0.9 • Males = 111 • Years handball experience = 9.1 ± 2.3 • Performing specific shoulder strengthening exercises on a regular basis previous season = 71 • Hx of shoulder pain = 103 **Control group (n=217):** • Age = 16.5 ± 0.9 • Males = 116 • Years handball experience = 9.3 ± 2.1 • Performing specific shoulder strengthening exercises on a regular basis previous season = 77 • Hx of shoulder pain = 112	• HRR = 0.60 (0.38-0.94) **Shoulder Group vs control for substantial shoulder problem:** • HRR = 0.51 (0.30-0.87) **Shoulder Group vs control for any shoulder problem:** • HRR = 0.49 (0.29-0.83) **Shoulder Grupo vs knee group for any shoulder problem** • HRR = 0.65 (0.42-0.99)		
Bullock et al .2022	**N = 297 pitchers** • Kinematic chain injuries = 5.2 per 10,00 AEs • Age = 23.0 ± 2.2 • BMI = 24.8 ± 2.2 • Previous arm injury hx = 69% • Initial shoulder injury = 62% of 84 initial arm injuries	**Kinematic Chain Injury:** • Adjusted HR = 2.6 (1.2-5.6) arm injury **Initial Shoulder Injury:** • Adjusted HR = 9.3 (1.1-83) subsequent shoulder injury	Injury - an injury to a tendon, ligament, nerve, muscle or bone occurring team activity or event with at least one day of missed practice or game, requiring medical attention	N = 7.9 shoulder injuries/ athletic exposure
Edouard et al. 2013	**Shoulder Group (n=16)** **Youth female handball players:** • Age = 18 ± 1 years • Height = 174 ± 6 cm • BMI = 23 ± kg/m^2 • Right-handed = 11 Trained 10 hours/week Played 28 matches per year 2 goalkeepers, 5 wingers, 5 backcourts, 3 centres, and 1 pivot. **Control Group (n=14)** **Healthy youth female non-athletes:** • Age =20 ± 2 years • Height = 168 ± 7 cm • BMI = 21 ± 2 kg/m^2 • Right-handed = 13	**Conventional ratios:** • ER concentric/IR concentric at 240°/sec: ◦ RR = 2.57* (1.60-3.54) **Functional ratios:** • IR eccentric/ER concentric at 60°/sec: ◦ RR = 2.08* (1.18-2.98) **Muscular imbalance criteria (at least 2 of the parameters):** • RR = 2.57* (1.60-3.54)	Injury - time loss definition through registry system. Unable to take full in handball activity or match play at least one day beyond the day of injury	N = 19
Feijen et al. 2020	**N = 201** • Injured = 42 • Uninjured = 159 • Age = 13.9 ± 2.2 • Male = 96 • Female = 105 • Height = 164.8 ± 12.4 cm • Weight = 54.42 ± 13.08 kg **Competitive Level:** • *international:* 17 • *national:* 83	*(odds ratio reported only, significance not examined)* **Acute:chronic workload ratio**: • OR = 4.31 (1.001-18.537) **Competitive level (regional vs club)**: • OR = 0.19 (0.058-0.629) **Posterior shoulder muscle endurance**: • OR = 0.96 (0.916-0.998) **Hand entry position error**: • OR = 0.37 (0.155-0.906)	Pain - time-loss injury requiring the athlete to miss part of a single training or competition session	N = 42 (30%)

Study	Subjects	Risk Factors	Pain/Injury Definition	Incidence of Shoulder Injury
	• *regional:* 79 • *club:* 22			
Johansson et al. (a) 2022	**N = 301 Swedish tennis players (N = 270 without pain at baseline):** • Age = 14.5±2 • Males = 58% (N=176) • Height = 169.8 ± 11.2 cm • Weight = 58.3 ± 12.7 kg • Hours/week tennis training in 2017 = 9.5 ± 3.8 • Hours/week fitness training in 2017 = 3.8 ± 2.5	*(hazard risk ratio reported only, significance not examined)* **Each workload spike tennis training/match play:** • Shoulder complaint: ◦ HRR = 1.26 (1.13-1.40) • Shoulder injury: ◦ HRR = 1.26 (1.15-1.39) **Each workload spike Fitness training:** • Shoulder complaint: ◦ HRR = 1.11 (1.02-1.20) • Shoulder injury: ◦ HRR = 1.18 (1.09-1.27) **Accumulated workload spike in fitness training and/or tennis training/match play:** • Shoulder complaint: ◦ HRR = 1.23 (1.12-1.36) • Shoulder injury: ◦ HRR = 1.22 (1.12-1.34) **Workload/age ratio (0.9-1.1)** • Shoulder complaint: • HRR = 1 (-) • Shoulder injury: • HRR = 1 (-) **Workload/age ratio (<0.9)** • Shoulder complaint: • HRR = 1.06 (0.40 – 2.82) • Shoulder injury: • HRR = 0.66 (0.36-1.21) **Workload/age ratio (>1.1)** • Shoulder complaint: • HRR = 1.64 (0.60-4.49) • Shoulder injury: • HRR = 0.77 (0.39-1.54)	Injury – a score of at least 40 on the OSTRC-O (self-reported) Complaint - a score of at least 20 on the OSTRC-O (self-reported)	Injury N = 44 Complaint N = 90
Johansson et al. (b) 2022	**N = 269** • Female = 114 (42%) • Age = 14.5 ± 2 • Years of playing tennis = 8.5 ± 2.6 • Ever experienced shoulder pain while playing tennis = 143 (53%)	**Risk of shoulder overuse injury(for every 10 unit increase on AIMS):** • Adjusted HRR = 0.89 (0.36-2.20) **Playing through pain (for every 10 unit increase on AIMS):** • Adjusted OR = 2.41 (0.74-8.96)	Injury (overuse) - a score of less than or equal to 40 on the OSTRC-O (self-reported)	N = 44
Lawrence 2016	• Team games included = 960 • Total number of injuries = 4133 • Total athletes = 1654 • Games with a shoulder injury = 283 • Total number of shoulder injuries = 357	**Increased risk of shoulder injury for team games played on grass vs turf:** • Incidence rate ratio = 1.36 (1.02-1.81)	Injury - Official National Football League injury report and reserve data	N = 357 (29.5%)
Matsuura et al. 2017	**Youth Baseball Players** • N = 900 • Training hrs per week: ◦ >16 but ≤36 = 284 • History of shoulder pain = 122 • History of elbow pain = 187 • Pitcher = 107 • Catcher = 96	*(multivariate analysis)* **Training hrs per week:** • >16 but ≤36: ◦ OR = 2.00 (1.07–3.92) **History of shoulder pain:** • OR = 3.34 (2.16-5.17) **History of elbow pain:** • OR = 1.53 (1.00-2.31) **Pitcher**: • OR = 2.99(1.65 - 5.43) **Catcher**: • OR = 2.02 (1.07 - 3.76)	Pain - asked if they had experienced shoulder pain that kept them from participation greater than or equal to 1 day (self-reported questionnaire with help from coach and or parent)	N = 165 (18.3%)
McKenna et al. 2012	**Shoulder Group (n=46)** **Adolescent swimmers no pain:**	*(adjusted odds ratios for multivariate logistic regression)* **BMI (kg/m^2):** • OR = 1.48 (1.00-2.19) **Inferior Kibler in abduction (mm):**	Pain – self reported questionnaire one year after initial contact asking yes or no to the question:	N = 11

Study	Subjects	Risk Factors	Pain/Injury Definition	Incidence of Shoulder Injury
	• Female gender = (23 of 35) • Age = 14.5 (1.4) • Time as a swimmer = 3.6 (2.6) years • Height = 1.65 (0.09) m • Weight = 54.7 (10.4) kg • BMI = 19.8 (2.3) kg/m^2 **Adolescent swimmers with pain:** • Female gender = (7 of 11) • Age = 14.9 (1.7) • Time as a swimmer = 4.7 (2.3) years • Height = 1.65 (0.09) m • Weight = 57.9 (9.7) kg • BMI = 21.3 (2.2) kg/m^2 **Control Group (n=39)** **Adolescent non swimmers no pain:** • Female gender = (18 of 27) • Age = 14.2 (1.5) • Time as a swimmer = NA • Height = 1.62 (0.08) m • Weight = 53.0 (9.3) kg • BMI = 20.0 (2.4) kg/m^2 **Adolescent non swimmers with pain:** • Female gender = (6 of 12) • Age = 14.8 (1.0) • Time as a swimmer = NA • Height = 1.66 (0.09) m • Weight = 59.2 (9.9) kg • BMI = 21.4 (2.7) kg/m^2	• OR = 0.90 (0.83-0.97) **Humeral head in neutral (mm):** • OR = 0.76 (0.59-0.98)	"Have you had any pain in your shoulder in the last year?"	
Møller et al. 2017	**Youth Handball Players** • N = 679 (44% female) • Age: 14-18 yrs	**Increase in handball load by >60%:** • HR = 1.91 (1.00-3.70) **Increase in handball load by >60% with reduced ER strength:** • HR = 4.2 (1.4-12.8) **Increase in handball load by 20-60% with reduced ER strength:** • HR = 4.0 (1.1-15.2) **Increase in handball load by 20-60% with scapular dyskinesis:** • HR = 4.8 (1.3-18.3)	Injury - any handball-related shoulder problem irrespective of the need for time loss or medical attention	N = 68
Murphy et al. 2020	**Female Cricket Players** • N = 114 • Age (years) = 26.0 ± 4.4 • Height (cm) = 168.9 ± 6.0 • Weight (kg) = 66.7 ± 6.7	(m*ultivariate analysis)* **Shoulder IR:ER strength ratio dominant:** • OR = 1.79 (1.12 – 2.88)	Injury - unable to throw or function due to shoulder injury even if they are still available to play	N = 14 (12%)
Owens et al. 2013	**N = 714 participants** **Male:** • N = 630 • Age = 18.8 ± 1.0 y • Height = 178.5 ± 7.5 cm • Weight = 76.1 ± 12.9 kg **Female:** • N = 84 • Age = 18.7 ± 0.9 y • Height = 165.4 ± 7.0 cm • Weight = 63.2 ± 9.1 kg **Events:** • Glenohumeral Instability Events = 46 • Posterior Instability Events = 7	**1° increased Glenoid retroversion (controlled for hx of instability):** • HR = 1.17 (1.03-1.34) **Participants in upper quartile for Glenoid retroversion (controlled for hx of instability):** • HR = 5.83 (1.11-30.65) **Increase ER strength in adduction:** • HR = 1.06 (1.01-1.12) **Increased ER strength 45° abduction:** • HR = 1.07 (1.01-1.13) **Increased IR strength in adduction:** • HR = 1.05 (1.00-1.11) **IR to ER strength ratio at 45°:** • HR = 0.97 (0.96-0.99)	Glenohumeral Instability (anterior) - acute anterior dislocations were documented and confirmed with documentation of reduction maneuver by a healthcare provider. Subluxation determined by history, physical exam findings, imaging results and surgical findings if surgery was performed	N = 46 shoulders (39 anterior)
Owens et al. 2014	**N = 714 participants** **Male:**	**Apprehension sign:** • HR = 2.96 (1.48-5.90)	Glenohumeral Instability (posterior) - acute posterior	N = 46 shoulders (7 posterior)

Study	Subjects	Risk Factors	Pain/Injury Definition	Incidence of Shoulder Injury
	• N = 630 • Age = 18.8 ± 1.0 years • Height = 178.5 ± 7.5 cm • Weight = 76.1 ± 12.9 kg **Female:** • N = 84 • Age = 18.7 ± 0.9 years • Height = 165.4± 7.0 cm • Weight = 63.2 ± 9.1 kg **Events:** • Glenohumeral Instability Events = 46 • Anterior Instability Events = 39	**Relocation sign:** • HR = 4.83 (1.75-13.33) **Glenoid Height to width ratio:** • HR = 8.12 (1.07-61.72) **Glenoid height to width ratio >1.58:** • HR = 2.64 (1.28-5.34) **Increased coracohumeral interval size:** • HR = 1.20 (1.08-1.34)	instability events were determined by history, physical exam findings, imaging results and surgical findings if surgery was performed. No posterior dislocations occurred	
Plummer et al. 2022	**Minor League baseball players** • N = 188 total subjects • N = 98 pitchers **Injured (N = 12):** • Age = 21.3±2.6 years • Height = 186.3 ± 7.6 cm • Weight = 86.2 ± 9.2 kg • Years in MiLB = 3.3 ± 1.6 • Prior injury = 33.3% • Hx of sx on throwing arm = 0% • Hip asymmetry ratio = 15.6 ± 14.4% • Lead leg stronger than trail leg = 33.3% **Non-Injured (N = 86):** • Age = 22 ± 2.3 years • Height = 188.3 ± 6.3 cm • Weight = 91.8 ± 11.5 kg • Years in MiLB = 3.7 ± 2 • Prior injury = 25.6% • Hx of sx on throwing arm = 15.1% • Hip asymmetry ratio = 10 ± 9.6% • Lead leg stronger than trail leg = 47.7%	**Pitcher hip abduction asymmetry strength (continuous for every 5% increment):** • RR = 1.24 (1.06-1.46)	Injury - examined and diagnosed by sports medicine staff. Having occurred as a result of baseball, missed at least one day of practice or game and diagnosed with injury to the shoulder of the throwing arm (Upper extremity injuries included both elbow and shoulder but data was reported separate in discussion)	N = 9 (5 pitchers and 4 position players)
Struyf et al. 2013	**Recreational overhead athletes** • N = originally 196 • N = 113 completing 2 year follow up • Men = 54 • Women = 59 • Mean Age = 17-64 (12) years • Left-handed = 12 • Right-handed = 101	**Pain-free versus pain developed:** • Scapular upward rotation at 45° humeral abduction: ◦ OR = 1.038 • Scapular upward rotation at 90° humeral abduction: ◦ OR = 0.986	Pain – any physical complaint during the past month lasting for a day or longer that came about in competition or training. Did not require medical attention or loss of time (self-reported)	N = 25 (22%)
Walker et al. 2012 *Significant interfering shoulder pain (SIP) = pain interfering (causing cessation/ modificatio) with training /competition or progression of training Significant shoulder injury (SSI) = any SIP*	**Competitive Swimmers:** • N =74 **Male:** • N = 37 • Age = 16 ± 3 years • Height = 175 ± 14 cm **Female:** • N = 37 • Age = 15 ± 3 years • Height = 166 ± 6 cm **Shoulder ROMs:** • Left IR(°) = 54 ± 8 • Right IR(°) = 53 ± 8 • Left ER(°) = 96 ± 9 • Right ER(°) = 97 ± 8 • Left laxity(mm) = 29 ± 4 • Right laxity(mm) = 29 ± 4 Reported Significant interfering shoulder pain	**Significant shoulder injury adjusted for swim km:** • Low ER (<93°): ◦ OR = 32.5 (2.7-389.6) • High ER (≥100°): ◦ OR = 35.4 (2.8-441.9) • Past history: ◦ OR = 11.3 (2.6-48.4) **Significant shoulder injury unadjusted for swim km:** • Low ER (<93°): ◦ OR = 24.9 (2.3-262.6) • High ER (≥100°): ◦ OR = 23.0 (2.2-236.8) • Past history: ◦ OR = 10.0 (2.5-39.2) **Significant interfering shoulder pain adjusted for swim km:** • Low ER (<93°):	Pain/Injury - significant interfering shoulder pain defined as pain that interfered with training, competition, or progression in training and caused a modification or cessation of training or racing. significant shoulder injury shoulder pain lasting for at least two weeks was used as well.	N = 28 (Significant interfering shoulder pain) N = 17 (Significant shoulder injury)

Study	Subjects	Risk Factors	Pain/Injury Definition	Incidence of Shoulder Injury
episode lasting at least 2 weeks Past history defined as history of shoulder injury in past 12 months	= 28 Reported Significant shoulder injury = 17	◦ OR = 12.5 (2.5-62.4) • High ER (≥100°): ◦ OR = 8.1 (1.5-42.0) • Past history: ◦ OR = 4.1 (1.3-13.3) **Significant interfering shoulder pain unadjusted for swim km:** • Low ER (<93°): ◦ OR = 11.1 (2.4-51.6) • High ER (≥100°): ◦ OR = 5.9 (1.3-28.05) • Past history: ◦ not reported		
Wilk et al. 2015	**Male major league baseball players:** • N = 296 **Injured group:** • Age = 25.0 (5.1) • Height (meters) = 1.9 (0.1) • Mass (kg) = 91.2 (11.1)	**Shoulder Injury:** • Insufficient ER (<5° greater ER in throwing shoulder): ◦ OR = 2.2 (1.2-4.1) **Shoulder Surgery:** • Insufficient ER (<5° greater ER in throwing shoulder): ◦ OR = 4.0 (1.5-12.6)	Injury – player placed on the disabled list for any throwing shoulder injury	N = 51 (17%) pitchers (total of 75 shoulder injuries)

Abbreviations: cm; centimeters, kg; kilograms, m; meters, ER; external rotation, OR; odds ratio, N; newtons, IR; internal rotation, GIRD; glenohumeral internal rotation deficit, OSTRC; Oslo shoulder trauma research center, ABD; abduction, HRR; hazard risk ratio, TROM; total range of motion, Hx; history, OSTRC-O; Oslo shoulder trauma research center overuse, AEs; athletic exposures, BMI; body mass index, HR; hazard ratio, sec; seconds, RR; risk ratio, AIMS; abnormal involuntary movement scale, hrs; hours, m; meters, mm; millimeters, NA; not available, sx; symptoms, ROM; range of motion

duction during humeral elevation in the frontal plane were significant for developing shoulder pain.[34]

RANGE OF MOTION

Both increased and decreased ROM in certain movements were found to increase the risk of shoulder pain or injury depending on the sport and in some cases sex.

Handball: A difference of >7.5° for external shoulder ROM on the dominant throwing shoulder (OR 4.1 [1.1-15.4]), compared to the non-dominant, demonstrated increased shoulder injury risk in handball players, irrespective of sex. A loss of >7.5° in the dominant throwing shoulder for men (OR 0.61 [0.5-0.8]) demonstrated a protective factor against shoulder injury, while a loss of 7.5° for women (12.50 [1.4-114.6]) demonstrated an increased risk of shoulder injury in handball players. The authors of this handball study surmise that the differing findings are likely due to a difference in exposure, pathomechanics and injury mechanics among male versus female handball players.[20] In another handball study of 344 players (Female: 172; Male: 172) when stratified by sex, females that had decreased total ROM on their dominant shoulder compared to the non-dominant shoulder demonstrated no difference in hazard of arm injury (HR: 1.30 (0.59-2.83)). Males that had decreased total ROM on their dominant shoulder compared to the non-dominant shoulder demonstrated no difference in hazard of arm injury (HR: 0.77 (0.33-1.81).[22]

Swimming: Decreased shoulder flexion on the dominant shoulder did not demonstrate increased shoulder injury risk (OR 0.96 [0.918-1.004]) in competitive swimmers. Low shoulder external rotation (swimmers with <93° of external rotation) or high shoulder external rotation (swimmers with ⩾100° of external rotation) both demonstrated increased risk of shoulder injury (Low: OR 11.1 [2.4-51.6]; High: OR 5.9 [1.3-28.05]) in competitive swimmers.[27]

Baseball: Among 296 professional baseball pitchers, insufficient external rotation, defined when a pitcher had 90° of abduction in the scapular plane of the throwing shoulder that was at least 5° greater than the non-throwing shoulder, demonstrated an increased risk of shoulder injury (OR: 2.2 [1.2-4.1]) and shoulder surgery (OR: 4.0 [1.5-12.6]). Total rotational deficit (OR:1.5 [0.8-2.8]; OR: 0.8 [0.3-2.1]), GIRD (OR: 0.6 [0.2-1.5]; OR: 0.5 [0.1-1.7]), and flexion deficit (OR: 0.6 [0.2-1.4]; OR: 0.7 [0.2-2.3]) demonstrated no significant difference in shoulder injury or surgery respectively.[5]

Cricket: In a sample of 115 female cricketers, dominant shoulder internal rotation ROM (OR: 0.98 [0.94-1.01]) and total ROM (OR: 0.99 [0.97-1.01]) demonstrated no difference in arm injury odds.[32]

STRENGTH

Decreased dominant shoulder isometric absolute (OR: 10.70 [1.2-95.6] per 10 N) and body weight normalized strength (OR: 1.2 [1.0-1.4] per 0.1 N/kg) demonstrated increased risk for shoulder injury in handball players, irrespective of sex.[20] Decreased ratio between the dominant shoulder external and internal rotation shoulder strength (OR 1.2 [1.1-1.5]) demonstrated an increased risk of shoulder injury in handball players.[20] In another handball study of 344 players (Female: 172; Male: 172) when stratified by sex, females that had decreased isometric external rotation and internal rotation strength on their dominant shoulder compared to the non-dominant shoulder demonstrated increased hazard of arm injury (External Rotation: HR: 2.37 [1.03-5,44]; Internal Rotation: HR: 2.40 [1.06-5.61]). Males

Table 3. Risk of Bias Scores

Author	Study Participation	Study Attrition	Prognostic Factor Measurement	Outcome Measurement	Study Confounding	Statistical Analysis and Reporting	Overall Score
Achenbach et al. 2019	Moderate	High	Moderate	Moderate	High	Moderate	Moderate
Asker et al. 2020	Low	Low	Low	Low	Low	Low	Low
Asker et al. 2022	Low	Moderate	Low	Low	Low	Low	Low
Bullock et al. 2022	Low	Low	Low	Low	Low	Low	Low
Edouard et al. 2013	Low	Low	Low	Low	Low	Low	Low
Feijen et al. 2020	Low	Moderate	Moderate	Low	Moderate	Low	Moderate
Johansson et al. 2021	Low	Moderate	Low	Low	Low	Low	Low
Johansson et al. 2022	Low	Moderate	Low	Low	Low	Low	Low
Lawrence et al. 2016	Moderate	Moderate	Moderate	Low	Moderate	Low	Moderate
Matsuura et al. 2017	Low	High	Low	Low	High	Low	Moderate
McKenna et al. 2012	Low	Moderate	Moderate	Low	Low	Low	Low
Moller et al. .2017	Low	High	Low	Moderate	High	Low	Moderate
Murphy et al. 2019	Low	Moderate	Low	Low	Low	Low	Low
Owens et al. 2013	Low	Low	Low	Low	Low	Low	Low
Owens et al. 2014	Low	Low	Low	Low	Low	Low	Low
Plummer et al. 2022	Low	Moderate	Low	Low	Low	Low	Low
Struyf et al. 2014	Low	Moderate	Low	Low	Low	Low	Low
Walker et al. 2012	Moderate	Moderate	Low	Moderate	Low	Low	Moderate
Wilk et al. 2015	Low	Low	Low	Low	Low	Low	Low

with decreased isometric external rotation and internal rotation strength on their dominant shoulder compared to the non-dominant shoulder demonstrated no difference in hazard of arm injury (External Rotation: HR:1.02 [0.44-2.36]; Internal Rotation: HR: 0.74 [0.31-1.75]).[22] A smaller study (n=16) of female handball players demonstrated a significant increase in relative risk of shoulder injury when an overall muscular imbalance was present within the rotator cuff RR: 2.57 (1.60-3.54).[23]

Increased posterior shoulder muscle endurance on the dominant shoulder demonstrated decreased shoulder injury risk (OR 0.96 [0.916-0.998]) in competitive swimmers.[25]

Dominant shoulder internal rotation strength (OR: 1.00 [0.98-1.02]) and total ROM (OR: 0.99 [0.97-1.01]) or external rotation strength (OR: 0.98 [0.96-1.01]) demonstrated no difference in arm injury odds in female cricketers.[32]

Asymmetric hip strength demonstrated increased risk of shoulder injuries (RR 1.24 [1.06-1.46]) in professional pitchers.[19]

BEHAVIORAL FACTORS

PAIN PROFILE

Youth baseball pitchers that had a history of shoulder pain (OR 3.34 [2.16-5.17]) or elbow pain (OR 1.53 [1.00-2.31]) demonstrated increased risk of sustaining a shoulder injury.[18]

PREVIOUS INJURY

A previous trunk or lower extremity injury in the same season increased hazard of shoulder injury (HR 2.6 [1.2-5.6]) in professional baseball pitchers.[17] Sustaining a previous shoulder injury increased hazard of subsequent shoulder injury (HR 9.3 [1.1-83]) in professional baseball pitchers.[17]

PSYCHOLOGICAL FACTORS

There was no association in Athletic Identity Scores and shoulder injury (HRR 0.89 [0.36-2.20]) in competitive adolescent tennis players.[29]

ENVIRONMENTAL FACTORS

PHYSICAL ENVIRONMENT

American football players that played on grass demonstrated an increase in shoulder injury rates (Incidence rate ratio 1.36 [1.02-1.81]).[33]

SPORT SPECIFIC FACTORS

TRAINING LOAD

Increased acute:chronic workload ratio increased shoulder injury risk (OR 4.31 [1.001-18.537]) in competitive swimmers.[25]

Each workload spike in competition (HRR 1.26 [1.15-1.39]), fitness training (HRR 1.18 [1.09-1.27]), and or training/competition (HRR 1.22 [1.12-1.34]) increased shoulder injury hazard in tennis players.[28]

Increased training hours between 16 and 36 hours a week demonstrated increased shoulder injury risk (OR 2.00 [1.07–3.92]) in youth baseball players.[18]

Increasing training load by over 60% per week, demonstrated increased hazard of shoulder injury (HR 1.91 [1.00-3.70]) in youth handball players.[24]

SHOULDER INJURY PREVENTION PROGRAMS

Incorporating shoulder injury prevention programs reduced hazard (HRR 0.44 [0.29-0.68]) of shoulder injuries in handball players.[21]

DISCUSSION

Nineteen studies met the inclusion criteria for this review. There were a number of studies excluded because of the presence of shoulder pain at baseline or not able to be determined as described by the authors, and data that were not able to be separated out specific to shoulder as many investigated arm pain or combined both shoulder and elbow pain within their data. The risk of bias among the included studies was rated from moderate to low overall with no single study being identified as high risk of bias. Additionally, no study had more than two areas scored as high, with the areas of study attrition and study confounding being the only areas for any studies that were rated as high risk of bias.

Within the included studies, the first-time incidence of shoulder pain among athletes was found to be associated with the following risk factors; ROM, strength, pain, previous injury, and training load. It is important to note that these variables were investigated among various overhead sports, each requiring unique demands of the shoulder complex. Methods for quantifying these variables were not consistent among all studies. For example, strength was measured using different techniques such as handheld dynamometers and isokinetic testing devices, differing types of strength were also quantified such as isometric, eccentric, and reported in a variety of formats such as ratios, normalized to body weight, and absolute strength. Additionally, none of the 19 studies utilized the same definition for injury and or pain, with variations including location, time missed from competition or practice, needing to seek care from a medical provider, or utilizing a specific outcome measure. Inconsistencies in the definition of injury or pain make it difficult to move forward in this area of research regarding risk factors associated with shoulder injuries or pain and there needs to be a shift towards improving this shortcoming.[35]

Range of motion results exhibited the unique demands of each sport examined as they relate to risk factors. The risk factors for handball were seen in specific ranges of external rotation while among swimmers it was low and high shoulder external rotation that increased injury risk. Baseball players had increased risk around a variety of ranges including horizontal adduction, internal rotation, and ex-

ternal rotation. These results suggest that there may be value in athletes exhibiting a certain degree of ROM specific to their sport and its demands on the shoulder complex to prevent shoulder injury. The concept of ROM requirements for a specific sport and position has been widely studied among baseball pitchers where the incidence of shoulder and elbow injuries is significantly greater for those with glenohumeral joint external rotation and internal rotation asymmetries compared to the non-throwing shoulder.[5,36,37]

Strength was also examined among the same three sports as ROM. A decrease in strength, whether compared bilaterally, as a ratio, or below normative values when available, has long been thought to be a risk factor for injury. Examining various forms of strength throughout the entire kinetic chain is often part of various screening mechanisms for athletes and may form a foundation for the development of broad or specific training programs throughout the course of their season designed to reduce the risk of injury.[13] Among handball players increased risk was associated with decreased isometric absolute strength, bodyweight normalized strength, and the ratio of external to internal rotation strength all compared to the non-dominant side. Reduced endurance of the posterior shoulder musculature was more revealing of risk for swimmers while among professional baseball pitchers it was asymmetrical hip strength that increased the risk of shoulder pain.

Having experienced pain in the elbow or shoulder or having a previous upper or lower extremity injury also resulted in an increased risk of shoulder injury among adolescent and professional baseball pitchers respectively. The relationship between previous injuries, whether it be to the shoulder, elbow, lower extremity, or trunk has not been extensively studied. Evidence of this risk factor is primarily seen in youth and professional baseball pitchers. The hypothetical rationale for this phenomenon is found within the extreme demand of the entire kinetic chain in order to achieve high pitch velocity. A “weak link” in the kinetic chain from a prior injury along with fatigue, over the course of an exposure or season, may increase the load on the upper extremity, particularly the shoulder and elbow.[17,38,39]

Examining the modifiable risk factors may assist with the development and implementation of injury prevention programs for overhead athletes. A systematic review by Wright et al.[6] investigating the effectiveness of shoulder injury prevention programs in overhead athletes identified only three of the seven studies actually being able to reduce injury in the overhead athlete population.[40-42] Modifiable risk factors included in the prevention programs consisted of strength and mobility in two[40,42] of the studies and strength only in one[41] of the studies. Both strength and ROM are modifiable risk factors identified through the current review of the literature in both the handball and baseball population. One modifiable risk factor that appeared across baseball, handball, swimming, and tennis was training load.[18,24,25,28] There are many variables that factor into an accurate account of training load for athletes, which is often times under estimated. Examining exposure and dose as part of training load is a good first step but requires a detailed approach to each athlete and their specific position/sport demands .[43-45] Although not something that could be implemented from an athletes training perspective, awareness and monitoring of training load by the coaching and sports medicine staff, where available, could help to further mitigate shoulder injuries.

The results of the current review suggest that even among overhead athletes, there are not only unique risk factors for shoulder pain but each of those risk factors is different for each sport. Although this may appear intuitive, these findings support the need for individualization of sports screening and injury prevention programs among different overhead sports and positions where appropriate. Considerations for moving forward in this area of research have been provided as they relate to risk factors associated with shoulder pain and injury within the athletic population based on the findings of the current study. (Table 4).

LIMITATIONS

One of the limitations of this study is the restrictive inclusion and exclusion criteria to investigate the specific aim of this study. Additionally, being able to determine studies where athletes were not experiencing pain or injury at baseline was not always clear as well as the variability in the definitions of injury and pain and how risk factors were measured. Finally, only studies published in the English language were included.

CONCLUSION

The results of this systematic review suggest that there are a number of modifiable risk factors associated with the new onset of shoulder pain among athletes from various overhead sports, including range of motion, strength, and training load. These findings may be used to tailor sport specific screens and injury prevention programs to address areas such as ROM, strength, and training load in order to mitigate shoulder injury risk. These findings are supportive of a “drilling down” approach to risk factors specific to body region, sport, and where applicable, position. Future research would benefit from determining and or adhering to specific definitions of injury and using these uniformly in methods used to quantify possible risk factors.

CONFLICTS OF INTERESTS

The authors report no conflicts of interest

TRIAL REGISTRATION

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Table 4. Key findings and considerations going forward in the area of risk factors associated with shoulder pain and injury in the athletic population

Key Findings	
Modifiable Risk Factors	**Range of motion -** depending on the sport, and position, both increased and decreased range of motion in certain movements have been shown to increase the risk of shoulder pain and or injury among handball, swimming, baseball and cricket athletes
	Strength - decreased strength as well as asymmetrical strength in local and regional shoulder musculature across various sports was shown to increase the risk of shoulder pain and or injury. Additionally, asymmetrical hip strength in professional baseball pitchers demonstrated an increased risk of shoulder injuries
	Training load - an increase in competition as well as training was shown to Increase shoulder pain and or injury risk among swimming, tennis, baseball, and handball athletes
Non-modifiable Risk Factors	**Local and or regional musculoskeletal pain -** history of pain in the elbow and shoulder of youth baseball players presents an increased risk for shoulder injury
	Previous injury - history of an injury at the trunk, lower extremity and shoulder increase the risk of shoulder injury among professional baseball pitchers
Considerations Moving Forward	
Utilize a consistent and well-defined definition of injury and pain using appropriate parameters	
Differentiate between pain and injury based on previously established and accepted definitions	
Separate data and findings into both shoulder and elbow categories when investigating risk factors related to “arm” pain and injury	
Clearly define and account for athletic exposures based on previously established and accepted definitions	
Utilize valid and reliable methods to objectively measure variables considered to be risk factors. Additionally, developing valid, reliable and meaningful methods that do not exist to quantity variables (ie. athlete fatigue, true pitch counts in baseball, etc.)	

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REFERENCES

1. Asker M, Brooke HL, Walden M, et al. Risk factors for, and prevention of, shoulder injuries in overhead sports: a systematic review with best-evidence synthesis. *Br J Sports Med*. 2018;52(20):1312-1319. doi:10.1136/bjsports-2017-098254

2. Caine DJ, Harmer PA, Schiff MA. *Epidemiology of Injury in Olympic Sports*. John Wiley & Sons; 2009. doi:10.1002/9781444316872

3. Struyf F, Tate A, Kuppens K, Feijen S, Michener LA. Musculoskeletal dysfunctions associated with swimmers' shoulder. *Br J Sports Med*. 2017;51(10):775-780. doi:10.1136/bjsports-2016-096847

4. Schwank A, Blazey P, Asker M, et al. 2022 Bern Consensus statement on shoulder injury prevention, rehabilitation, and return to sport for athletes at all participation levels. *J Orthop Sports Phys Ther*. 2022;52(1):11-28. doi:10.2519/jospt.2022.10952

5. Wilk KE, Macrina LC, Fleisig GS, et al. Deficits in glenohumeral passive range of motion increase risk of shoulder injury in professional baseball pitchers: a prospective study. *Am J Sports Med*. 2015;43(10):2379-2385. doi:10.1177/0363546515594380

6. Wright AA, Ness BM, Donaldson M, Hegedus EJ, Salamh P, Cleland JA. Effectiveness of shoulder injury prevention programs in an overhead athletic population: A systematic review. *Phys Ther Sport*. 2021;52:189-193. doi:10.1016/j.ptsp.2021.09.004

7. Clarsen B, Myklebust G, Bahr R. Development and validation of a new method for the registration of overuse injuries in sports injury epidemiology: the Oslo Sports Trauma Research Centre (OSTRC) overuse injury questionnaire. *Br J Sports Med*. 2013;47(8):495-502. doi:10.1136/bjsports-2012-091524

8. Escamilla RF, Andrews JR. Shoulder muscle recruitment patterns and related biomechanics during upper extremity sports. *Sports Med*. 2009;39(7):569-590. doi:10.2165/00007256-200939070-00004

9. Seroyer ST, Nho SJ, Bach BR, Bush-Joseph CA, Nicholson GP, Romeo AA. The kinetic chain in overhand pitching: its potential role for performance enhancement and injury prevention. *Sports Health*. 2010;2(2):135-146. doi:10.1177/1941738110362656

10. Waterman B, Owens BD, Tokish JM. Anterior shoulder instability in the military athlete. *Sports Health*. 2016;8(6):514-519. doi:10.1177/1941738116672161

11. Wolfe JA, Christensen DL, Mauntel TC, Owens BD, LeClere LE, Dickens JF. A history of shoulder instability in the military: where we have been and what we have learned. *Mil Med*. 2018;183(5-6):e158-e165. doi:10.1093/milmed/usx086

12. Liaghat B, Pedersen JR, Husted RS, Pedersen LL, Thorborg K, Juhl CB. Diagnosis, prevention and treatment of common shoulder injuries in sport: grading the evidence - a statement paper commissioned by the Danish Society of Sports Physical Therapy (DSSF). *Br J Sports Med*. 2023;57(7):408-416. doi:10.1136/bjsports-2022-105674

13. Tooth C, Gofflot A, Schwartz C, et al. Risk factors of overuse shoulder injuries in overhead athletes: a systematic review. *Sports Health*. 2020;12(5):478-487. doi:10.1177/1941738120931764

14. Page MJ, McKenzie JE, Bossuyt PM, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *Br Med J*. 2021;372:n71. doi:10.1136/bmj.n71

15. Losciale JM, Bullock GS, Collins GS, et al. Description, prediction, and causation in sport and exercise medicine research: resolving the confusion to improve research quality and patient outcomes. *J Orthop Sports Phys Ther*. 2023;0(7):1-7. doi:10.2519/jospt.2023.11773

16. Hayden JA, van der Windt DA, Cartwright JL, Côté P, Bombardier C. Assessing bias in studies of prognostic factors. *Ann Intern Med*. 2013;158(4):280-286. doi:10.7326/0003-4819-158-4-201302190-00009

17. Bullock GS, Thigpen CA, Noonan TK, Kissenberth MJ, Shanley E. Initial kinematic chain injuries increase hazard of subsequent arm injuries in professional baseball pitchers. *J Shoulder Elbow Surg*. 2022;31(9):1773-1781. doi:10.1016/j.jse.2022.04.016

18. Matsuura T, Iwame T, Suzue N, Arisawa K, Sairyo K. Risk factors for shoulder and elbow pain in youth baseball players. *Phys Sportsmed*. 2017;45(2):140-144. doi:10.1080/00913847.2017.1300505

19. Plummer HA, Cai Z, Dove H, et al. Hip abductor strength asymmetry: relationship to upper extremity injury in professional baseball players. *Sports Health*. 2023;15(2):295-302. doi:10.1177/19417381221078830

20. Achenbach L, Laver L, Walter SS, Zeman F, Kuhr M, Krutsch W. Decreased external rotation strength is a risk factor for overuse shoulder injury in youth elite handball athletes. *Knee Surg Sports Traumatol Arthrosc*. 2020;28(4):1202-1211.

21. Asker M, Hägglund M, Waldén M, Källberg H, Skillgate E. The effect of shoulder and knee exercise programmes on the risk of shoulder and knee injuries in adolescent elite handball players: a three-armed cluster randomised controlled trial. *Sports Med Open*. 2022;8(1):91. doi:10.1186/s40798-022-00478-z

22. Asker M, Waldén M, Källberg H, Holm LW, Skillgate E. Preseason clinical shoulder test results and shoulder injury rate in adolescent elite handball players: a prospective study. *J Orthop Sports Phys Ther*. 2020;50(2):67-74.

23. Edouard P, Degache F, Oullion R, Plessis JY, Gleizes-Cervera S, Calmels P. Shoulder strength imbalances as injury risk in handball. *Int J Sports Med*. 2013;34(7):654-660. doi:10.1055/s-0032-1312587

24. Møller M, Nielsen RO, Attermann J, et al. Handball load and shoulder injury rate: a 31-week cohort study of 679 elite youth handball players. *Br J Sports Med*. 2017;51(4):231-237. doi:10.1136/bjsports-2016-096927

25. Feijen S, Struyf T, Kuppens K, Tate A, Struyf F. Prediction of shoulder pain in youth competitive swimmers: the development and internal validation of a prognostic prediction model. *Am J Sports Med*. 2021;49(1):154-161. doi:10.1177/0363546520969913

26. McKenna L, Straker L, Smith A. Can scapular and humeral head position predict shoulder pain in adolescent swimmers and non-swimmers? *J Sports Sci*. 2012;30(16):1767-1776. doi:10.1080/02640414.2012.718092

27. Walker H, Gabbe B, Wajswelner H, Blanch P, Bennell K. Shoulder pain in swimmers: a 12-month prospective cohort study of incidence and risk factors. *Phys Ther Sport*. 2012;13(4):243-249. doi:10.1016/j.ptsp.2012.01.001

28. Johansson F, Cools A, Gabbett T, Fernandez-Fernandez J, Skillgate E. Association between spikes in external training load and shoulder injuries in competitive adolescent tennis players: the SMASH cohort study. *Sports Health*. 2022;14(1):103-110. doi:10.1177/19417381211051643

29. Johansson F, Tranaeus U, Asker M, Skillgate E, Johansson F. Athletic identity and shoulder overuse injury in competitive adolescent tennis players: the SMASH cohort study. *Front Sports Act Living*. 2022;4:940934. doi:10.3389/fspor.2022.940934

30. Owens BD, Campbell SE, Cameron KL. Risk factors for posterior shoulder instability in young athletes. *Am J Sports Med*. 2013;41(11):2645-2649. doi:10.1177/0363546513501508

31. Owens BD, Campbell SE, Cameron KL. Risk factors for anterior glenohumeral instability. *Am J Sports Med*. 2014;42(11):2591-2596. doi:10.1177/0363546514551149

32. Murphy MC, Chivers P, Mahony K, Mosler AB. Risk factors for dominant-shoulder injury in elite female Australian cricket players: A prospective study. *Transl Sports Med*. 2020;3(5):404-414. doi:10.1002/tsm2.158

33. Lawrence DW, Comper P, Hutchison MG. Influence of extrinsic risk factors on national football league injury rates. *Orthop J Sports Med*. 2016;4(3):2325967116639222. doi:10.1177/2325967116639222

34. Struyf F, Nijs J, Meeus M, et al. Does scapular positioning predict shoulder pain in recreational overhead athletes? *Int J Sports Med*. 2014;35(1):75-82. doi:10.1055/s-0033-1343409

35. Bahr R, Clarsen B, Derman W, et al. International Olympic Committee consensus statement: methods for recording and reporting of epidemiological data on injury and illness in sport 2020 (including STROBE Extension for Sport Injury and Illness Surveillance (STROBE-SIIS)). *Br J Sports Med*. 2020;54(7):372-389. doi:10.1136/bjsports-2019-101969

36. Wilk KE, Macrina LC, Fleisig GS, et al. Deficits in glenohumeral passive range of motion increase risk of elbow injury in professional baseball pitchers: a prospective study. *Am J Sports Med*. 2014;42(9):2075-2081. doi:10.1177/0363546514538391

37. Wilk KE, Macrina LC, Fleisig GS, et al. Correlation of glenohumeral internal rotation deficit and total rotational motion to shoulder injuries in professional baseball pitchers. *Am J Sports Med*. 2011;39(2):329-335. doi:10.1177/0363546510384223

38. Bullock GS, Menon G, Nicholson K, Butler RJ, Arden NK, Filbay SR. Baseball pitching biomechanics in relation to pain, injury, and surgery: A systematic review. *J Sci Med Sport*. 2021;24(1):13-20. doi:10.1016/j.jsams.2020.06.015

39. Matsuura T, Iwame T, Suzue N, Arisawa K, Sairyo K. Risk factors for shoulder and elbow pain in youth baseball players. *Phys Sportsmedicine*. Published online 2017:1-5. doi:10.1080/00913847.2017.1300505

40. Andersson SH, Bahr R, Clarsen B, Myklebust G. Preventing overuse shoulder injuries among throwing athletes: a cluster-randomised controlled trial in 660 elite handball players. *Br J Sports Med*. 2017;51(14):1073-1080. doi:10.1136/bjsports-2016-096226

41. Østerås H, Sommervold M, Skjølberg A. Effects of a strength-training program for shoulder complaint prevention in female team handball athletes. A pilot study. *J Sports Med Phys Fitness*. 2015;55(7-8):761-767.

42. Shitara H, Yamamoto A, Shimoyama D, et al. Shoulder stretching intervention reduces the incidence of shoulder and elbow injuries in high school baseball players: a time-to-event analysis. *Sci Rep*. 2017;7:45304. doi:10.1038/srep45304

43. Impellizzeri FM, McCall A, Ward P, Bornn L, Coutts AJ. Training load and its role in injury prevention, part 2: conceptual and methodologic pitfalls. *J Athl Train*. 2020;55(9):893-901. doi:10.4085/1062-6050-501-19

44. Impellizzeri FM, Menaspà P, Coutts AJ, Kalkhoven J, Menaspà MJ. Training load and its role in injury prevention, part I: back to the future. *J Athl Train*. 2020;55(9):885-892. doi:10.4085/1062-6050-500-19

45. Impellizzeri FM, Shrier I, McLaren SJ, et al. Understanding training load as exposure and dose. *Sports Med*. 2023;53(9):1667-1679. doi:10.1007/s40279-023-01833-0