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Prevalence and mechanisms of injuries in water polo: a systematic review

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ABSTRACT

Objective To summarise the information available in the literature on the prevalence of injuries in water polo and injury risk factors.

Methods Protocol was registered on Open Science Framework. MEDLINE, CINAHL, Embase and SPORTDiscus databases were searched for keywords relating to water polo and injuries on 3 February 2021. References were searched for additional studies. Only original research papers in English or French were included, and studies without an injured group were excluded. A data extraction file was made based on the Cochrane Collaboration recommendations. Study quality was evaluated with the Newcastle-Ottawa scales for cohorts and a modified version for cross-sectional studies.

Results The initial search yielded 581 articles, with 5 more added from reference lists, but only 41 remained after removing duplicates and applying inclusion/exclusion criteria. Thirty-one articles identified the head, fingers and shoulders as the most common sites of injury. Ten articles on mechanism of injury focused mainly on the shoulder, with degenerative changes, posture, scapular alignment, strength, flexibility and overhead shooting kinematics as the main injury risk factors. Publication types included cohort studies, cross-sectional studies, and one case series.

Conclusions Most traumatic injuries affect the hands and the head from unexpected contact with the ball or opponents. Conversely, training injuries seem to affect mainly the shoulder area. Low level evidence suggests a correlation between shoulder injuries and lack of strength or flexibility as well as large volumes of overhead throwing. Further prospective research is needed to investigate risk factors for other body areas.

Key messages

What is already known

- Previous literature showed shoulder injuries were highly prevalent in high-level male water polo athletes.
- Previous literature identified risk factors for shoulder injuries were throwing volume, flexibility, strength and scapular dyskinesia.

What are the new findings

- Current review identified water polo injury prevalence to be high among Olympic sports 9.7%–19.4%, with the head and fingers as the most common injury sites.
- Current evidence on risk factors is lacking, with only two prospective studies identified of good quality.

INTRODUCTION

Water polo is a sport that consists of two teams of six players and a goalkeeper competing against each other by crossing a pool and shooting the ball into the opponent's net. The men's game is played in a pool area 30 m long by 20 m wide with a larger and heavier ball (71 cm diameter and 450 g). The women's game is played in a 25 m long by 15–20 m wide area[1] with a smaller ball (67 cm diameter and 400 g).[2] The action of the game requires many short sprinting bouts of swimming totalling upwards of 1000 m per game, grappling against opponents, maintaining a vertical position by treading the water and shooting and passing the ball for four quarters of 8 min each.[3 4] This makes the athletes both vulnerable to acute traumatic injuries from contact with opponents and to overuse injuries from the large number of repetitions of swimming and overhead throwing.[5 6] Injury surveillance studies in multisport events such as the Olympics and FINA World Championships have confirmed that most of the traumatic injuries occur in competition for this sport (>70%) rather than training.[7–13] For this reason, a skilled medical support staff is essential to providing water polo athletes with a safe environment and to treat injured players.[14] A gap remains in identifying the prospective epidemiology of injuries outside of competition in this sport.

Previous studies published on injuries in water polo have outlined the location and types of injuries.[6 15] They have pointed out that common traumatic injuries affect the face and hands[16] whereas overuse injuries most frequently occur in the shoulders and knees.[4 17] However, previous reviews are mainly focused on male elite players, and did not describe injury prevalence across sexes and competition levels. Only two reviews were systematic with their search parameters, and both focused exclusively on shoulder injuries.[6 15] Furthermore, only one review had systematically summarised information from original research investigating shoulder risk factors.[6] Therefore, a systematic review is required to examine the extent of injuries and risk factors in water polo across all anatomical sites. The primary objective of this systematic review was to summarise the information available in the literature on the prevalence of injuries in water polo and associated risk factors.

METHODS

The methodology for this systematic review was based on the Preferred Reporting Items for Systematic Reviews and Meta-Analysis guidelines,[18] and the data extraction process was informed from the Cochrane Collaboration recommendations.[19] The protocol for this review was registered at Open Science Framework and can be accessed at 10.17605/OSF.IO/2ZHFA.

Information sources

Four databases were searched on 3 February 2021 to identify relevant papers: MEDLINE (1946–…), Embase (1947–…), CINAHL complete and SPORTDiscus complete. The primary keyword strings were 'water polo OR waterpolo' and 'injury'. Associated Medical Subject Headings terms were identified by a professional librarian and included to avoid missing relevant papers. An example of a search strategy for MEDLINE is provided in the online supplemental figure 1. Reference lists from the review studies were searched manually to identify further relevant articles.

Eligibility criteria

Peer-reviewed original research articles about water polo players were included if written in French or in English. The subjects were included for both men and women of all available age groups, and of all available competition levels. Articles on musculoskeletal injuries and concussions were considered for inclusion if they aligned with the definitions of Clarsen *et al*[20] for health problems as 'any condition that you consider to be a reduction in your normal state of full health […]'. For observational multisport studies, data from water polo injuries were included only if they were presented separately from the other sports. Studies with a focus on nutrition, anthropometry, physiology, bone density or woman's health were excluded. Conference abstracts, review papers and articles without original injury data were excluded. Finally, risk factor studies that did not include an injured group for comparison were excluded.

Study selection

Two reviewers screened through all of the titles and abstracts to determine if full-text articles would be obtained. The first 20 articles were scanned for any disagreements in defining the eligibility criteria. After consensus, each abstract was then screened independently. The authors (FC and SR) met to discuss discrepancies and reached consensus for identification

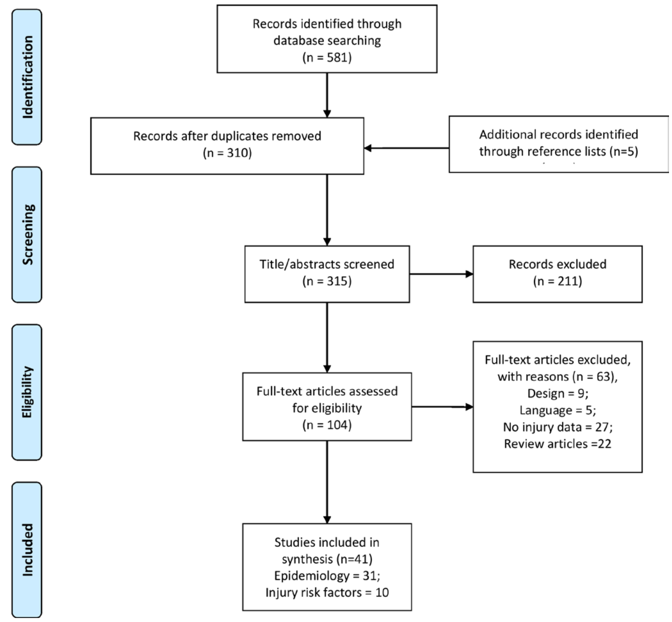

Figure 1 Article selection flow diagram.

of full-text articles to be read. Next, full-text articles were independently reviewed using a similar process, and consensus was reached between the authors on the final list of articles included for review (see figure 1, detailed exclusion reasons in online supplemental table 2).

Data extraction

A data extraction form was used to select key information including sample size, gender, participant age, competition level, prevalence, body area and types of injuries, duration of the study, injury definitions as well as confounding measures. Data were collated independently by two authors (FC and HB).

Study quality assessment

Study quality was assessed using the Newcastle-Ottawa Scale (NOS) for cohort studies, as well as the NOS adapted for cross-sectional studies (online supplemental figures 2 and 3).[21] The NOS for cross-sectional studies was necessary to assess the quality of most risk factor studies, which were cross-sectional in nature as opposed to the designs most common for injury prevalence research (retrospective and prospective surveys or observational cohorts) (online supplemental table 1). The NOS for cohort studies includes eight criteria on which to assess the study design based on participant selection (4 points), comparability of findings (2 points) and description of outcomes (3 points). The NOS adapted for cross-sectional studies modifies two elements, asking specifically about sample size selection and statistical analysis for a maximum of 10 points. Articles were scored independently by two reviewers (FC and HB) and consensus was reached on scoring without need for a third party.

Statistical analysis

No statistical analyses were performed to aggregate findings due to a lack of sufficiently similar methods between studies. Findings were grouped by similar populations and ranges of values were provided to summarise the data.

RESULTS

The initial search yielded a total of 581 articles (figure 1). After removing duplicates, 310 abstracts remained. Five more articles were added from reference lists of review papers. After title and abstract screening, 104 full-text articles were evaluated for eligibility. Ultimately 41 articles were included with 31 articles examining the presence of injuries (table 1) and 10 studies examining injury risk factors (table 2). Injuries were described in terms of prevalence, or the number of injuries present as a percentage of the number of athletes at one given time.[22] They were also described as period prevalence, or the proportion of athletes in a defined window of time.[22] Other authors described injuries in terms of incidence, which is the number of new cases per total athletes in a fixed window of time.[22] A fourth method is to describe injury rates, where the number of new cases is divided by athlete exposures.[22] Original research describing water polo injury prevalence scored median 8/9 on the NOS for cohorts (range between 6 and 9).[7–14 23–35] For cross-sectional designs, the median modified NOS score was 6/10 (range between 4 and 9).[36–45] Original research investigating risk factors scored 9/9 for both cohort studies,[46 47] and a median 7/10 for cross-sectional studies (range between 3 and 10).[2 48–54]

Injury surveillance data

Four cohort studies[7–9 13] obtained injury data from implementing surveillance programmes during the Olympic Games of 2004 through 2016. At the Athens 2004 Olympics, an injury rate of 63/1000 player×hours was observed for water polo males compared with the overall team sports average of 54/1000 player×hours. In the same period, one single injury was recorded in the female participants.[9] During the 2008 Beijing Olympic Games, 2012 London Olympic Games and 2016 Rio de Janeiro Olympic Games, period prevalence ranged from 9.7%–19.4% for water polo versus 9.6%–12.9% for the overall average for all sports.[7 8 13] Water polo males had higher injury prevalence than females (16%–22.7% vs 8.7%–14.4%).[31] This high period prevalence is echoed in the findings from World Championships 2009 through 2015, where the average was 16.2% (mean age 25±5 years).[12]

During the 1994 *Australian University Games,* 13.1% of collegiate level water polo participants sustained an injury, compared with the overall sports average period prevalence of 19.5%.[14] Three retrospective chart analyses[26 29 33] further investigated collegiate athletes (age 18–22). MacIntosh *et al* found an injury rate of 141 injuries/1000 player×years in competitive water polo compared with the overall average of 84/1000 player×years in more than 20 other sports (eg, squash, downhill ski, gymnastics, basketball). Furthermore, water polo represented 11.9% of all injuries recorded over the 18 years of the period analysed.[29] Sallis *et al* found that female collegiate water polo players had an injury rate of 18.4 injuries/100 player×years versus their male counterparts with 7.1/100 player×years. This is much lower than the overall all-sport average for women of 52.5/100 player×years or men of 47.7/100 player×years.[33] Furthermore, Hame *et al* found that male players were twice as likely to sustain primary fractures as females (p=0.03).[26] Female players also developed stress fractures, which were not recorded in the male players.

Finally, one cohort study[30] followed a large sample of high school athletes (age 13–18)[25] from 24 different sports over 1 year. It found no injuries in the female water polo players and only two in the boys (5% of participants). This was much lower than the all-sports average period prevalence of 22%.[30]

Injury types and distribution

Head and neck

Given the contact nature of water polo, competition traumatic injuries to the head and face are the most frequent (table 3). Commonly reported injury types across player levels are contusions, lacerations and fractures (0.57/player×year),[44] as well as orofacial or dental (prevalence 21%–57.9%)[40 43 45] and ophthalmic injuries (0.45/1000 male player×matches).[35] These contact injuries are the most common reason for consultation in the emergency departments (53.6% of all injuries).[25] Perforated ear drums are now less common as a result of improved equipment, more specifically the addition of a hard perforated plastic piece that protects the external ear.[23] Blumenfeld *et al*[36] and Black *et al*[24] both specifically investigated concussions in their studies. The first authors conducted an electronic survey targeting members of USA Water Polo.[24 36] From their 1519 responders, 36% reported a previous concussion (43.5% in females vs 30.8% in males, p=0.01), with an average of 2.1±0.1 episodes during their career. This number was higher for goalkeepers at 47% of respondents with an average of 2.5±0.2 episodes. In a chart review conducted on Canadian university athletes, Black *et al*[24] did not find any reported concussion for either male or female water polo athletes. No other author investigated concussions specifically, but Junge *et al* reported that the only injury from female water polo during the 2004 Athens Olympic Games was a concussion.[9]

Upper extremity

Injuries to the hands are also frequent given contact with opponents and the ball (13.6%–23.1% period prevalence,[9–11 23 39] table 3). They include sprains to the finger interphalangeal joints and thumbs, fractures of the metacarpals and phalanges and a web space tear injury typical to the sport.[44] Outside of competition injuries, the shoulder is commonly cited as the most common site of injury with 6.1%–13.6% period prevalence.[1 3–5 15 16 28 55–59] The types of shoulder injuries in water polo include overuse injuries occur due to repetitive swimming/

Table 1 Epidemiological studies in water polo

Reference	Design	Participants	Outcome	Key findings
Annett *et al*[23]	Retrospective cohort	77 males from national team, mean 20 years old	13-year retrospective chart analysis of documented injuries	Incidence of injuries 1.16/1000 hours; 24.1% shoulder, 15.5% face, 14.7% hand, 11.5% elbow; 73.4% acute, 26.6% overuse, 20.5% chronic (>6 weeks)
Black *et al*[24]	Retrospective cohort	28 males and 22 females from collegiate level	3-year retrospective chart analysis of concussions	No injuries recorded
Blumenfeld *et al*[36]	Cross-sectional	895 males and 602 females (and 22 undefined sex) from high school to master's club levels, mean 30 years old	Retrospective survey of life-long concussion injuries	36% overall lifetime prevalence with average 2.14±0.07 episodes; 30.8% males 2.2±0.12 episodes; 45.5% females 2.06±0.08 episodes; 47% goalies with 2.49±0.18 episodes;
Cunningham and Cunningham[14]	Prospective cohort	382 males and females from collegiate level	Prospective injury surveillance during 1 week	Period prevalence 13.1%
De Castro-Maqueda and Amar-Cantos[37]	Cross-sectional	285 males and 202 females from club teams, mean 24±8 years old	Retrospective survey of injury over the last 10 years	10-year prevalence 98.4% shoulder injury, 87% sunburn, 56% groin injury, 23.7% had fracture, 4.2% hypothermia, 2% no injury
Ellapen *et al*[38]	Cross-sectional	100 males of high school level, 15–17 years old	Retrospective survey of pain over the last 12 months	72% prevalence; Incidence 2.49/1000 player×hours; shoulders 51%, vertebral column 18%, upper limb 6%, knee 24%, lower limb 1%
Elliott[39]	Cross-sectional	13 males from national team, mean 28 years old (no injury data for 12 controls)	Retrospective survey of lifetime injuries	Lifetime prevalence 85%; 62% shoulder, 50% hand and finger, 18% groin strain
Engebretsen *et al*[7]	Prospective cohort	156 males and 104 females from national teams	Prospective injury surveillance during 17 days	Period prevalence 13.1% overall; female prevalence 8.7%; male prevalence 16%
Forrester[25]	Retrospective cohort	256 males and 158 females, 73.5% age 13–18 from high school and college	Retrospective chart analysis of emergency department admissions 2000–2019	Head and neck 53.6% of all injuries (56.9% male and 48.1% female), upper extremity 31.1% (29.7% male and 33.6% female), lower extremity 6.5% (6.1% male and 7.2% female); laceration 19.4% (27.3% male and 6.6% female); strain or sprain 17.8% (14.1% male and 23.8% female); contusion or abrasion 17.6% (17.3% male and 18% female); fracture 13% (14% male and 11.3% female); internal organ 8.4% (4.8% male and 14.3% female but seems to cross-over with concussion); dislocation 5.5% (6.1% male and 4.6% female); concussion 4.8% (6.1% male and 4.6% female); others 13.4%
Galic *et al*[40]	Cross-sectional	59 males, mean 12.9±3.2 years old	Retrospective survey of lifetime injuries	Of all respondents, 28.8% had had orofacial injuries, 18.6% dental injuries, only 5.1% wear mouth guards
Goes *et al*[41]	Cross-sectional	36 males and 26 females, mean 23.4±5.1 years old and 11.5±6.1 years water polo experience	Retrospective survey of lifetime injuries	Injury counts joint injury 51, muscle injury 43 and tendinopathy 38; shoulders were 65.8% of tendinopathies, 46.5% of muscle injuries and 31.4% of joint injuries

Continued

Table 1 Continued

Reference	Design	Participants	Outcome	Key findings
Gradidge *et al*[42]	Cross-sectional	36 males from high school level, mean 17±1 years old	Retrospective survey of lifetime injuries	Lifetime prevalence 55%; period prevalence <1 month 13%; shoulders 25% previous versus 8.3% recent injuries; elbow 11% previous injuries; back 6% previous injuries
Hame *et al*[26]	Retrospective cohort	5900 multisport males and females from collegiate level	15-year retrospective chart analysis of fractures	Incidence rate of fractures 0.04–0.05/athlete×year for males versus 0.01–0.02/athlete×year for females; significant sex difference (p=0.03)
Hams *et al*[27]	Retrospective and prospective cohorts	90 males and 128 females from professional league, mean 20.6±3.7 and 19.3±2.9 years old respectively	Retrospective chart review of self-report shoulder injuries in last 4 years AND 3-year prospective injury surveillance	Incidence 0.65/1000 athlete×exposure; retrospective 4-year prevalence: 25% shoulder, 17% thoracic and lumbar spine, 15% hand/wrist/finger, 10% knee, 9.6% pelvis/hip, 9.2% elbow; prospective 3-year prevalence: 16% shoulder, 10.5% lumbar, 10.5% hip/groin, 10.5% hand, 9% elbow, 8.3% knee
Hersberger *et al*[43]	Cross-sectional	355 males and 60 females from junior to national level, mean 30 years old	Retrospective survey of lifetime dental injuries	Lifetime prevalence 103 arm and fingers, 72 lip injuries; 87 tooth injuries
Jerolimov and Jagger[44]	Cross-sectional	102 males from professional league, mean 22±4 years old	Retrospective survey of injuries during professional career	Incidence 0.57/player×year; 48% lips, 13% tongue, 9% cheek, 8% broken tooth
Junge *et al*[9]	Prospective cohort	Males and females from national teams	Prospective injury surveillance during 1 month	Period prevalence 9.7%; Incidence 23.8/1000 hours; injury types fracture and dislocation
Junge *et al*[8]	Prospective cohort	259 males and females from national teams	Prospective injury surveillance during 1 month	Incidence 21/1000 player×matches (95% CI, 11 to 31); 56% head, 28% upper extremity, 11% trunk, 6% lower extremity
Kim and Park[28]	Prospective cohort	73 males from national team programme, mean 24.4±3.4 years old	Prospective injury surveillance during 8 years	Injury rates 2.06/1000 hours (95% CI 1.77 to 2.34); proportion of injuries to the shoulder (25.2%), lumbosacral (14.4%), elbow (10.9%) and neck (8.9%) most common; injury types proportion were joint sprain (31.2%), muscle injury (28.3%) and tendinopathy (14.4%) most common
MacIntosh *et al*[29]	Retrospective cohort	Males from collegiate level	17-year retrospective chart analysis	Proportion 11.9% of all injuries from 25 sports; incidence=7/1000 player×years for recreational versus 141/1000 player×years competitive
McLain and Reynolds[30]	Prospective cohort	36 males and 16 females from high school level	Prospective injury surveillance during 1 year	Period prevalence boys 5.6% versus girls 0%; incidence 6.34/1000 hours
Mountjoy *et al*[10]	Prospective cohort	235 males and 226 females from national teams	Prospective injury surveillance during 14 days	Incidence 89.4/1000 male players and 101.82/1000 female players; 9 head and face, 8 arm/elbow, 6 shoulder, 6 wrist/hand, etc
Mountjoy *et al*[11]	Retrospective cross-sectional and prospective cohort	208 males and 208 females from national teams, mean 25±5 years	4-week retrospective survey and prospective injury surveillance during 14 days	1-month prevalence 41.9% (36.6% male and 46.6% female); counts during event 65 injuries (33 males and 32 females); incidence 1.1/100 athlete×days

Continued

Table 1 Continued

Reference	Design	Participants	Outcome	Key findings
Mountjoy *et al*[31]	Retrospective cohort	1456 males and 1248 females from national teams	Repeated prospective injury surveillance	Period prevalence 14.1% Incidence 56.2±6.7/1000 hours; 25.6% head, 16.1% hand, 12.7% trunk, 11.3% shoulder
Prien *et al*[12]	Retrospective cross-sectional and prospective cohort	415 males and females from national teams, mean 22±5 years old	4-week retrospective survey and prospective injury surveillance during 14 days	1-month prevalence 19.9%; prevalence during event 23.1%
Rugg *et al*[32]	Retrospective cohort	40 males and 41 females from collegiate level	7-year retrospective database analysis of upper extremity injuries	Period prevalence 35% upper extremity injuries for males versus 39% for female players; males 22.5% shoulder, 2.5% elbow and 10% wrist and hand; females 19.4% shoulder, 9.8% elbow and 9.8% wrist and hand
Sallis *et al*[33]	Retrospective cohort	Males and females from collegiate level, age 18–22 years old	9-year retrospective database analysis	Incidence 18.38/100 player×years (females) versus 7.10/100 player×years (males); incidence/100 player×years by area: shoulders 8.09 (female) versus 3.4 (male), knee 2.94 (female) versus 0.93 (male)
Soligard *et al*[13]	Prospective cohort	154 males and 104 females from national teams	Prospective injury surveillance during 17 days	Period prevalence 19%
Toohey *et al*[34]	Prospective cohort	6 males and 36 females from national team, mean male 19.9±3.4 and 20.8±4.1, respectively	Prospective injury surveillance over 8 months	Injury counts 74 ; 23% shoulder, 16.2% elbow, 13.5% lumbar; 21.6% impingement, 18.2% sprain, 16.2% strain
Youn *et al*[35]	Retrospective cohort	Males and females from collegiate level, age 18–22 years old	Retrospective chart analysis of ocular injuries	Incidence 0.45/1000 male player×matches versus 0/1000 female player×matches
Zamora-Olave *et al*[45]	Cross-sectional	224 males and 123 females from club teams, 10 years old to senior	Retrospective survey of orofacial injuries over the last 12 months	Period prevalence 57.9%

throwing, and traumatic due to contact with other players.[6] Overuse syndromes occur such as tendinopathies of the long head of biceps and the rotator cuff muscles, impingement syndromes, thoracic outlet syndrome, labrum degeneration, acromioclavicular joint degeneration and instability of the glenohumeral complex.[17] Pathologies from trauma would include labrum tears, rotator cuff tears, dislocations and fractures of the humerus and scapula.[58] Imaging studies showed that posterosuperior impingement syndromes are widely prevalent in symptomatic players.[49] In Klein *et al*,[2] water polo players showed significant differences in MRI for the infraspinatus (p=0.02), subscapularis (p=0.01) and posterior labrum (p=0.04) on their dominant arm compared with healthy controls. Only 8 of the 28 participants had shoulder pain at the time of the study.[2] Furthermore, when Galluccio *et al*[48] recently investigated shoulders of professional Italian athletes using dynamic ultrasound, they found that 38 of the 42 participants in their study showed anomalies on imaging, but that only 13 had pain at the time. Finally, injuries to the elbow medial complex (6%–18.2% period prevalence[9–11 23 39] occur because of the overhead throwing motion in water polo.[4]

Back and lower extremity

Six groups of authors have reported lower back injuries in their samples, with only two including female players,[10 34] with prevalence ranging between 0% and 14.4% (table 3).[10 23 28 34 42 44] Some of the proposed pathologies include degenerative changes to the facet joints from prolonged extension in a swimming posture, the throwing motion or contact from opponents.[1 3 4] Furthermore, the eggbeater swim stroke is a proposed mechanism of injury for common hip pathologies such as impingement issues and tendinopathies (0%–9.1% period prevalence).[16 55 57] The knees are prone to pathologies of the medial compartment or 'breaststroker's knee', mainly tibial collateral ligament sprains or tendinopathies of the adductors (0%–6.5% period prevalence).[3 4 16 25 55 57] The ankles and feet were not included in the results from previous reviews, although cohort studies found a prevalence of 4.5%–10.8%.[9–11]

Table 2 Publications on risk factors

Reference	Participants	Design	Outcome	Key findings
Galluccio *et al*[48]	42 males from professional league	Cross-sectional	Pain questionnaire as part of cross-sectional study	Shoulder pain prevalence 31.0%; dominant shoulder SST tear 21.4%; SSC tear 7.1%; LHB tear 0%; SST tendinopathy 19.1%; SSC tendinopathy 2.4%; LHB tendinopathy 16.7%; impingement 21.4%; subacromial bursitis 16.7%; SLAP tear 4.8%
Giombini *et al*[49]	7 males and 4 females from national team, mean 24 years old	Case series	MRI investigation of shoulder area	Postero-superior labral damage 11/11; increased signal intensity on the undersurface of the RC 11/11; postero-superior glenoid impingement of SST 11/11
Hams *et al*[47]	28 males and 48 females from national team, mean 20±3 years old	Cohort	Shoulder range of motion measured with goniometry and shoulder rotation strength measured with hand-held dynamometer	Prospectively injured athletes showed significantly lower total ROM (p=0.05), lower strength of ER (p=0.03) and IR (p<0.03)
Hams *et al*[46]	9 males and 6 females from national team, mean 18±1 years old	Cohort	Shoulder internal (IR) and external rotation (ER) strength measured with hand-held dynamometer	Prospectively injured athletes showed significantly lower ER and IR strength (p≤0.01) but no differences in ER/IR ratios; healthy IR 14.57 kgF versus 9.26 kgF, healthy ER 10.97 kgF versus 7.35 kgF, healthy ratios ER/IR 0.77 versus 0.81 (at 90–90 position); healthy IR 19.62 versus 14.56 kgF, healthy ER 14.50 versus 10.29 kgF, ER/IR ratio 0.75 versus 0.72 (in neutral)
Klein *et al*[2]	28 males from national league, mean 24 years old	Cross-sectional	MRI investigation of shoulder area	Dominant strength SSP 12.2±2.9 kgF, ISP 9.9±2.5 kgF, SSC 11.6±2.3 kgF; MRI positive findings: SSP 15/28 shoulders, SSC 15/28, ISP 12/28, labrum cranial 10/28 versus posterior 15/28 versus anterior 6/28, cysts 6/28, LHB 17/28, cartilage 9/28, AC changes 7/28, bursitis 25/28
Langner *et al*[50]	5 male and 8 female college level, age 18–23	Cross-sectional	MRI investigation of the hips	Abnormal alpha 9/16 female versus 9/10 male; abnormal lateral edge-centre angle 5/16 female versus 3/10 female; labral tears 8/16 female versus 8/10 male
Melchiorri *et al*[51]	53 males from national team, mean 24±3 years old, 17 injured	Cross-sectional	Video analysis to estimate joint angles and ball throwing speed	Ball speed injured 23.9±1.7 m/s versus 24.6±2.2 m/s; elbow angle release injured 147±8° versus 148±6°; throw time injured 150.6±28.2 ms versus 149.4±29.6 ms; shoulder angle injured 144±6° versus 138±5°; head height injured 55.1±8.7 cm versus 37.4±13.1 cm; trunk rotation time injured 140±18 ms versus 110±17 ms
Mukhtyar *et al*[52]	30 participants from national league, 17–35 years old, 14 injured	Cross-sectional	Static scapular alignment measured in neural and end range shoulder elevation	Rotary index healthy at 0° position 0.3975 versus 0.1379 (p<0.01); healthy at 45° position 0.2781 versus 0.2064 (p=0.04); healthy at 90° position 0.3144 versus 0.2743 (p=0.13)

Continued

Table 2 Continued

Reference	Participants	Design	Outcome	Key findings
Wheeler *et al*[53]	7 females from national team, mean 23 years old	Cross-sectional	Video analysis of practices and daily questionnaire of shoulder soreness	74% of shoulder soreness was explained by shooting volume and significant association also with decreased rest between reps; volume of shots per day 29±5 for squad selection versus 55±21 for team practices; more soreness in squad selection VAS (3.8±1) versus team practices VAS 2.9±0.4, p<0.05); rest between shots in squad selection 274±183 s versus team practice 148±50 s
Whiting *et al*[54]	13 males from national team, mean 27±3 years old, 7 injured	Cross-sectional	Three-dimensional video analysis with orthogonal views to estimate joint angles and ball release speed	Throw duration healthy 227±9 ms versus 241±11 ms; peak angular velocity healthy 1182±45°/s versus 1104±72°/s; elbow angle at release healthy 155±2° versus 155±3°; ball velocity healthy 19.3±0.5 m/s versus 19.9±0.7 m/s

AC, acromioclavicular; ER, external rotation; IR, internal rotation; ISP, infraspinatus; LHB, long head of biceps; RC, rotator cuff; ROM, range of motion; SSC, subscapularis; SST, supraspinatus; SLAP tear, superior longitudinal anteroposterior tear; VAS, Visual Analogue Scale .

Risk factors for injury

Nine of the 10 studies of risk factors with injured participants focused on the shoulder, with 7 cross-sectional[2 48–52 54] and 2 longitudinal cohort designs.[46 47] Half of these studies included female participants in their sample.[46 47 49 50 53] Cohort studies including both sexes have consistently reported more injuries occurring during competition than during training in national team players.[7 8 10 11 13 31] Junge *et al* estimated that two-thirds of injuries during the Olympic Games were suffered as a consequence of foul play, such as punching or kicking.[9]

Training volume

Volume of training is a major variable among external risk factors. Wheeler *et al*[53] published the only study to analyse the relationship between overhead throwing volume and shoulder soreness/pain. They counted the number of throws per player during Australian national team selection camps by filming and following seven female players from the senior squad. At the same time, daily questionnaires were filled to rate shoulder soreness on a 10-point numerical rating scale. Using linear regression, their model suggested that 74% of shoulder soreness was attributable to shooting quantity (R^2=0.743, p=0.01), with shorter breaks between shots also being a significant factor (p=0.03). They also found more soreness during the simulated competition week than during the skills-based selection camp (p<0.01).

Scapular kinematics

In 2014, Mukhtyar *et al* measured the scapular position of 30 water polo athletes before and after an intense practice.[52] They selected participants with diagnosed shoulder impingement (n=14) and selected a comparison group with no known shoulder pathologies or pain (n=16). At baseline, they found no differences between groups. However, after the training session, the group with shoulder impingement showed significantly decreased values for scapular abduction and upward rotation (rotary index 0.60 cm ±0.10 vs 0.24 cm ±0.07, p<0.05).

Mobility and asymmetries

Two studies[39 47] investigated the relationship between shoulder flexibility and injury or pain. In 1993, Elliott investigated the relation between flexibility and shoulder

Table 3 Reported period prevalence of water polo injuries per body area in national team athletes

	Period prevalence			
Body part	Surveys[39]	Chart review[23]	Cohort[9–11]	Cross-sectional
Head and neck	0%	20.2%	20.5%–53%	n/a
Shoulders	65%	24.1%	6%–13.6%	n/a
Elbows	0%	11.5%	6%–18.2%	n/a
Wrist/hands/fingers	50%	19.7%	13.6%–23.1%	n/a
Lumbar spine	0%	2.9%	0%–11.4%	n/a
Hips/groin	18%	7.1%	0%–9.1%	n/a
Knees	24%	3.6%	0%–3.1%	n/a
Ankles/feet	0%	1.7%	4.5%–10.8%	n/a

pain in 13 male athletes from the English national water polo team and compared their findings with a control group of 12 healthy volunteers.[39] They found that water polo players showed increased flexion (182±15° vs 158±11°, p<0.01) and decreased medial rotation of their dominant arm versus controls (46±12° vs 55±16°). However, they found no statistical correlations between shoulder pain and mobility differences. Recently, Hams *et al* investigated the relationship between flexibility measures at baseline and prospective injury in a group of 76 elite water polo players in Australia.[47] They found that injured athletes showed lower total range of motion of the dominant shoulder at baseline versus the uninjured players (mean difference=7.5°, OR 3.6, 95% CI 0.8 to 16).

Shoulder strength and muscle imbalances

Although other authors have published normative values on shoulder strength in water polo players,[60–63] only one group has included an injured sample in their studies.[46 47] Hams *et al* assessed shoulder strength in 15 national-level water polo athletes using a hand-held dynamometer and standardised measurement protocol. Players were followed-up over 6 months and comparison was made at the end of the study between the players that developed prospective injuries versus those that did not. The injured group showed 16.8% lower mean peak strength versus body weight in shoulder internal rotation on average (OR 13.8, 95% CI 2.2 to 88) and 12.5% less external rotation (OR 5.2, 95% CI 1 to 27.9). However, no group differences emerged in external rotation/internal rotation strength ratios.[46]

The water polo overhead throw technique

Whiting *et al* performed three-dimensional video analysis cross-sectionally of six healthy and seven injured members (rotator cuff tendinitis) of the US senior national team.[54] The injured group showed significantly longer throw duration (241±11 ms vs 227±9 ms, p<0.01), slower peak angular velocity (1104±72°/sec vs 1182±45°/sec, p<0.01) and slower angular velocity at release (652±51°/sec vs 738±41°/sec, p<0.01).

More recently, Melchiorri *et al*[51] conducted a study on the water polo penalty throw with a larger sample of national team males (17 with shoulder injuries and 36 healthy). They found no significant differences between the injured and non-injured groups in ball speed at release (overall mean 24.15 m/s), elbow angle at release (overall mean 150±8°), shoulder angle at release (overall mean 141±6°), head height (overall mean 48±11 cm) or throwing time (overall mean 151±27 ms). However, trunk rotation time was significantly higher for the injured than for the healthy subjects (140±18 ms vs 110±17 ms, p<0.05).[51]

Lower extremity

Langner *et al*[50] published the only investigation of the lower extremity. In their population of 13 water polo players with decreased hip-related quality of life, they found signs on MRI of femoro-acetabular impingement anatomy was high and labral tears were present in 8/13 participants. Cam morphology was present in 69.2% of water polo players, and 30.8% showed pincer morphology.[50] The authors propose that the motion of treading water is responsible for these changes.

DISCUSSION

The search yielded 31 articles focused on injury prevalence in water polo (including 12 observational cohorts) and 10 articles on risk factors. The populations observed include adolescents, collegiate, national team and professional players. Water polo injury prevalence is high, with the highest values found in national team players (16.2%–19.4%),[13 31] less in collegiate players (13.1%)[14] and lowest in adolescents (5.6%).[30] This trend may reflect the higher intensity and illegal physical contact that is proportional to higher competition levels. Rule changes will be necessary in order to decrease these foul play injuries, as evidence shows that they are still largely present in this sport at the international level.[31] Most injuries occur in competition situations, and affect predominantly the face and hands with lacerations, contusions and sprains/strains.[25] Concussion incidence should be high given the predominance of head contacts, but current evidence is conflicting. Available literature suggests that shoulder injuries are the primary overuse injury in this sport,[27] which is reflected by the available risk factor studies identified in this review. The primary causes of shoulder injuries investigated thus far are a lack of flexibility and weakness of the rotator cuff muscles,[47] as well as larger volumes of overhead throwing repetitions.[53] Surveillance data in teenagers (13–18) further suggests that most reports are overuse rather than traumatic in nature.[38 42] This suggests that the process of musculoskeletal adaptations to the demands of water polo may be a source of soreness in this age group in particular. Optimal training methods and planning must be sought to promote wellness and performance most notable in younger players.[64]

Sex comparisons

During the 2009 and 2013 FINA World Championships, women suffered very similar amounts of injuries to the male participants. Despite using similar methodology, surveillance data from the Olympics shows higher rates for male players.[9 13] Furthermore, male players were more likely to have time-loss injuries and more severe conditions.[31] Although the number of teams at the World Championships is equal for men and women, there are four less female teams at the Olympics.[8] Given that the response rates from the participating teams are inconsistent in these events,[31] the increased number of male teams may be the reason for higher recorded injury rates.

For collegiate athletes, Sallis *et al* found that women had nearly three times greater injury incidence rates, most significantly for the shoulder.[33] This study scored a perfect 9/9 on the NOS quality assessment. Therefore, the findings suggest a difference in exposures for the female players. This may be the consequence of lesser quality workload management for the women, or rather an under-representation of overuse injuries in male players. Including a surveillance method such as the Oslo Sports Trauma Questionnaire can be more sensitive to identify these injuries that do not require medical consultations.[20] Concussion findings in this population are inconsistent, but survey data suggests that women are more susceptible to this injury.[24 36] This is consistent with previous reviews[65 66] investigating sex differences in concussion incidence in sport, but authors have not determined whether this is the consequence of reporting bias or a true increased risk for women.

Player position

Limited information is available to compare injuries at different player positions. Nevertheless, Cecchi *et al* demonstrated that players in the 'centre' role receive the most hits to the head, but failed to record any concussions during their three-season study in collegiate men.[67] This is the direct consequence of their role in attempting to maintain a position in front of the opponent's net as they are wrestled out of their spot. Accidental blows from elbows or punching can occur during these grappling periods. This is also supported by surveillance data from Croatian male professional leagues, where players in the centre had more facial injuries on average (5.5/player).[44] Goalkeepers are also prone to injury from contact with the ball, rather than from other players.[36] In particular, balls rebounding on the posts of the net are prone to hit the goalkeepers on the head and are related to the higher incidence of concussions at this position.[36] Further research is needed to investigate these position-specific patterns, given that players on the perimeter swim longer distances in matches,[6] and one can expect more overhead throwing injuries in this subgroup.

Injury risk factors

Shoulders appear to be the most common area of overuse injuries in water polo players,[27 28] and original research on risk factors has focused extensively on this joint. Potential risk factors investigated include throwing volumes, strength, flexibility and proprioception and scapular alignment. The mechanical demands of the swimming, throwing and grappling nature of the sport appear to lead to predictable anatomical adaptations.[48 49] Although these changes on imaging are usually considered pathological, they did not correlate with clinical symptoms of shoulder pain in this group.[48] Currently, one single study was designed prospectively to evaluate the roles of flexibility and strength as risk factors in water polo.[47] They concluded that insufficient strength and lack of flexibility are related to injury, which supports previous hypotheses.[60–63 68] However, strength ratios between external and internal rotators of the shoulder were not statistically related to injury in their sample. Perhaps this is the result of testing shoulder strength in isometric contractions only, which does not mimic the action of the rotator cuff during overhead throwing.[37] When available, isokinetic dynamometry can provide more information about strength profiles for clinicians working with water polo players.

Preliminary findings from studies on overhead throwing kinematics show conflicting results. However, both research groups have observed an increased duration of the throwing action in injured players.[51 54] This suggests a decreased efficiency at coordinating a complex task such as throwing a ball while maintaining an upright position in the water. This can be the result of faulty technique, leading to increased stress on the shoulder.[69] Furthermore, the same patterns of inadequate throwing can lead to distraction injuries to the medial elbow complex, compression injuries to the lateral complex and to the olecranon and its fossa.[5] The eggbeater motion required to stay upright could also promote overuse syndromes such as tendinopathy of the dorsiflexors, periostitis and possibly compartment syndrome. Presently, no authors have reported the specific types of foot or ankle injuries seen in water polo players, and analyses of lower body risk factors are rare.[70 71]

Recommendations

In order for future research to allow for a meta-analysis of injuries in water polo, authors must provide unambiguous definitions of injuries.[72–74] Injury surveillance studies that scored lowest on the NOS failed to ascertain exposure and outcome distinctly. Thus, the injury incidence rates and prevalence should reflect data collected prospectively over long periods (>6 months) on players of both sexes, with a transparent methodology to avoid recall bias.[75] Authors should implement tools that are more sensitive to monitor overuse injuries such as the Oslo Sports Trauma Research Center questionnaire.[76] Consistency is important in methods, as the increasing rates of injury prevalence at major games (World Championships and Olympic Games) is likely a reflection of improved data collection alone.[31]

On the other hand, risk factor studies with lower quality scores rarely presented sample size calculations, and were limited to cross-sectional designs in all but one research group. A prospective design is crucial to understand the causal relationship between these variables and injury incidence.[47 77] Studies including younger players are lacking to understand the specific mechanisms of injury in this age group. Including specific estimates of training volume such as Wheeler *et al*[53] would add a needed layer of interpretation to the complex aetiology of injuries in water polo.[22]

CONCLUSION

Gaps remain in the water polo injuries literature, with a large body of narrative reviews and only two systematic reviews focusing exclusively on shoulder injuries. Although data are currently available to provide insight into these injuries for national team level players, limited information can be found for younger age groups.

Information is also inconclusive regarding sex comparisons. The current evidence suggests that shoulders are the source of most overuse injuries, and as such the bulk of risk factor investigations have focused on this area. Future research should include a prospective design to investigate the causal relationship between these risk factors and injuries.

Clinicians working with water polo players should be aware that monitoring shoulder strength and flexibility may provide insights about players at higher risk of injury. Programmes to maintain adequate range of motion and increase strength should be favoured throughout the year. Younger players may experience overuse injuries as a consequence of the adaptation process to the musculoskeletal demands of the sport. Consequently, careful planning of progressive exposure is necessary as well as targeted development programmes in this subgroup. Finally, available evidence shows that abnormal imaging findings are common in this population, both for the shoulder and hip areas. Clinicians should confirm that symptoms expressed by the patients match with the observed imaging to construct their rehabilitation plans.

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