Croteau F, Paradelo D, Pearsall D, Robbins S. Risk Factors for Shoulder Injuries in Water Polo: a Cohort Study. *IJSPT*. 2021;16(4):1135-1144. doi:10.26603/001c.25432

Original Research

# Risk Factors for Shoulder Injuries in Water Polo: a Cohort Study

Félix Croteau, MScPT[1] [a], David Paradelo, BSc[2], David Pearsall, PhD[3], Shawn Robbins, BScPT, PhD[4]

[1] School of Physical and Occupational Therapy, McGill University, Montreal, Quebec, Canada; Institut National du Sport du Québec, Montreal, Quebec, Canada, [2] Water Polo Canada, [3] Department of Kinesiology and Physical Education, McGill University, Montreal, Quebec, Canada, [4] School of Physical and Occupational Therapy, McGill University, Montreal, Quebec, Canada; Centre for Interdisciplinary Research in Rehabilitation, Layton-Lethbridge-MacKay Rehabilitation Centre

Keywords: shoulder, injury prevention, dynamometer, athlete, aquatic

https://doi.org/10.26603/001c.25432

International Journal of Sports Physical Therapy

Vol. 16, Issue 4, 2021

## Background

Very limited investigations have been conducted exploring risk factors for injury in water polo players. A gap remains in the literature regarding identification of variables that should be considered as part of player screening evaluations.

## Purpose

To estimate whether previous injury, changes in strength, range of motion (ROM) or upward scapular rotation (UR) are related to shoulder injuries in water polo players.

## Study Design

Descriptive cohort study

## Methods

Thirty-nine international-level players participated (19 males). Shoulder internal (IR) and external rotation (ER) peak torque was measured using an isokinetic device (CONtrex MJ). Shoulder ROM was measured passively using standard goniometry. Scapular UR was measured using a laser digital inclinometer. At baseline players were divided into groups: those with and without previous shoulder injuries. Independent t-tests and Mann-Whitney U tests were used to compare the study variables between groups. After nine months, a second analysis compared the same athletes, who were then grouped by those who had or had not sustained new injuries. Effect sizes were calculated with a Hedge's g. Chi squared analysis compared proportion of injured players with and without previous injury.

## Results

Eighteen participants (46%) had previous injuries at baseline. Players with a previous injury showed higher peak torques for IR (0.62±0.15 vs 0.54±0.13N/kg, p=0.04, g=0.60); larger loss of IR ROM (9.9±9.1 vs 4.1±7.5°, p=0.04, g=0.68), but no statistical difference in UR (p=0.70). After nine months, there were no statistical strength differences between groups. Loss of IR ROM was significantly higher in the injured group (9.8±9.8 vs 4.0±6.7°, p=0.04, g=0.68), as well as UR (13.0±3.0 vs 10.4±3.3°, p=0.01, g=0.81). History of previous injury was significantly related to developing a new injury (OR 6.5, p=0.02). Logistic regression found previous injury and UR most important contributors to injury risk.

## Conclusions

Previous injury, changes in IR ROM and UR are related to new shoulder injuries in water polo, but further variables such as rest, training load, or psychosocial factors may explain

a **Corresponding Author:**
Félix Croteau
Institut National du Sport du Québec
4141 avenue Pierre-de-Coubertin Montreal, Qc, Canada, H1V 3N7
(514) 255-1000, felix.croteau@mail.mcgill.ca; fax: (514) 255-6646.

the incidence of new injuries.

## Level of Evidence

Level 3

# INTRODUCTION

Water polo is a popular aquatic contact sport, and has the highest rates of injuries amongst other aquatic disciplines during competitions (16.2% to 19.4%).[1] Although the majority of observed traumatic injury incidence occur to the head and fingers during matches,[2] the most common overuse injury area is the shoulder.[3–5] In order to decrease shoulder injuries in water polo, a better understanding of their risk factors is necessary to target prevention measures.[6]

Lack of strength may be related to a higher risk of injury in this sport,[3] as well as deficits in external rotation (ER) strength relative to internal rotation (IR) strength.[7] Previous authors have shown that water polo players are stronger than healthy non-players in abduction, adduction, ER and IR ($p<0.05$)[8,9] and showed lower ratios of ER over IR rotation strength.[9,10] Recently, Hams et al[11] have shown that sub-elite players (national development group) who were weaker in isometric ER and IR at baseline testing were more likely to have new shoulder injuries occur over the following three seasons. Furthermore, no significant difference was found between injured and non-injured groups for ER to IR strength (ER:IR) ratios. However, as Hams et al. performed isometric tests, testing shoulder strength with isokinetic devices at higher speeds may replicate the muscle activity which occurs during the throwing action and may yield different findings.[12]

Lack of shoulder range of motion (ROM) has been shown to correlate strongly with shoulder injuries in swimming and overhead throwing sports.[13–16] Water polo players show greater ER, decreased IR, and increased total range of motion in their dominant shoulders compared to their contralateral side.[8,17] However, Elliott[18] found no statistical correlations between shoulder pain and ROM in a group of 13 male national team water polo players. In contrast, Hams et al[11] found that players in the injured group showed significantly less total range of motion (ER plus IR) ($p<0.05$). Thus, more evidence is needed to correlate injuries with ROM measures of the shoulder in water polo players.

Altered scapular posture is related to shoulder pain in throwing sports,[19,20] and it is hypothesized that the "head up" swimming pattern typical during water polo can also lead to impingement syndromes.[3] One group of authors found no differences between water polo players and healthy controls in scapular upward rotation (UR) using electromagnetic 3D kinematic measurements (frontal plane angle of the spine of the scapula vs a horizontal line).[21] Two-dimensional measurements of UR have also shown good to excellent reliability,[22] and have been implemented by other authors to assess water polo players. Mukhtyar et al[23] compared the scapular abduction position of healthy water polo players (n=16) to players with impingement symptoms (n=14) by measuring the distance between scapular angles and the spine after training. The group with shoulder impingement showed significantly decreased values for scapular abduction and UR ($p<0.05$) at 45° or more of shoulder abduction.[23] However, Witwer et al[8] did not observe these patterns of decreased upward rotation in a cohort of 31 collegiate water polo players (12 males and 19 females) in a rested state.

Previous researchers have investigated strength, ROM,[11,17] scapular alignment,[23] throwing variables,[24,25] and shooting volume[26] as potential risk factors for shoulder injuries. However, only one investigation was performed prospectively on sub-elite players, and none in other age groups. Therefore, the causal relationship between injuries and these variables remains unclear. Strength and ROM were the only variables measured in relation to shoulder injury incidence. Additional understanding of risk factors is necessary to inform effective injury prevention strategies in this sport. Therefore, the purpose of this study was to estimate whether previous injury, changes in strength, ROM or UR are related to shoulder injuries in water polo players. A secondary objective was to compare sex differences among these risk factors. Given previous findings, it was expected that weaker players with less ROM and less upward rotation of the scapulae would be at higher risk of injuries.

# METHODS

## SUBJECTS

Nineteen male and twenty female water polo players from the Canadian senior national team were selected for this cohort study. Participants had to have a minimum of five years of experience, and be training full-time in a high-level competition environment (at least five practices per week). Subjects with a history of shoulder injury or surgery were included if they were able to participate fully in all team training sessions at the beginning of the study. A formal sample size calculation was not performed because all members of the senior national teams in Canada were recruited (n=39). Further recruitment would have required the addition of lower level players that did not represent the target population. Data were collected at the training center at the Institut National du Sport du Québec in Montreal, Canada. This study received ethics approval from McGill University Ethics Institutional Review Board, in compliance with the Helsinki Declaration. All participants signed informed consent to take part in the study.

## PROCEDURES

Demographic data were collected for age, body mass index (BMI), hand dominance, player position and training setting. Shoulder passive ROM was assessed in ER and IR using a standard goniometer. Shoulder strength was assessed with an isokinetic device for ER and IR. Scapular UR was assessed with a digital inclinometer.

RANGE OF MOTION

Participants were positioned in supine, with the shoulder in 90° of flexion and abduction (Figure 1). A small lift was placed under the elbow to align the humerus parallel to the ground. The fulcrum was placed distally to the patient on the elbow, with the reference arm perpendicular to the arm and the measurement arm aligned with the styloid process of the ulna. The participant's shoulder was then brought passively into the maximal tolerated ER, and a measure was taken at the end position. The shoulder was then brought back to the resting neutral position, and the procedure was repeated to take a second measurement. The evaluator then changed sides to measure the contralateral shoulder using the same procedure. Next, the evaluator returned to the starting side and measured shoulder IR twice using the same procedure, which was finally repeated on the contralateral shoulder.

Shoulder ER ROM was obtained by taking the average of the two measurements. This was repeated for IR. Shoulder total range of motion was calculated as the sum of both ER and IR for each shoulder. Internal rotation loss was defined as the difference between shoulder IR from the dominant side compared to the non-dominant side.[27] External rotation gain was defined as the difference between shoulder ER of the dominant side with the non-dominant side.[27] Similar methods for measuring shoulder ROM have demonstrated very good inter-rater (intra-class correlations of 0.97 (ICC); 95%CI=0.89,0.99) and intra-rater reliability (ICC=0.95; 95%CI=0.87,0.98).[28]

**Figure 1: Participant setup for shoulder IR ROM measurement.**

**Figure 2: Participant setup for shoulder ER and IR strength measurements.**

STRENGTH

Shoulder IR and ER strength was measured using a CON-TREX® isokinetic dynamometer (CON-TREX MJ; CMV AG, Dübendorf, Switzerland) with a protocol of 90°/s concentric/concentric contractions with a maximum torque tolerance of 250Nm sampled at 4000Hz. Participants were measured in supine with the shoulder placed in 90° of flexion and abduction to replicate the throwing position (Figure 2). All measurements were taken in the afternoon before practice to avoid testing in a fatigued state. Eccentric contractions were not employed to avoid muscle soreness prior to training. Participants were provided with an opportunity to perform 10 sub-maximal repetitions of IR and ER of the non-dominant side as a warm up. After a one minute break, participants were asked to "push against the machine as hard as [they] can" for five repetitions. Verbal encouragement was provided throughout the testing procedure. After a two minute break, the procedure was repeated on the dominant side.

Shoulder torque values provided by the CON-TREX® software were gravity-corrected. A custom RStudio[29] script was written to filter only the values measured at the target test speed of 90°± 0.5°/s. The peak value was identified as the maximum value recorded within this filtered subset and used for the rest of the analysis in the study. Measures of relative torque were calculated by dividing the absolute values by the participants' body weight. Ratios were obtained by dividing the peak ER torques by the peak IR torques. Between-days repeatability of isokinetic dynamometers is very good to excellent for shoulder assessments (ICC = 0.85,0.97).[30]

SCAPULAR ALIGNMENT

Scapular UR was measured using a Halo™ digital inclinometer (model HG1, HALO Medical Devices, Australia) after performing the dynamometer testing and with the participant standing with their shoulder in a 90° of abduction position (Figure 3). Scapular orientation was measured in the frontal plane only, and measurement of upward rotation was estimated by placing the fulcrum on the superior angle of the scapula and estimating the angle between the tip of the acromion and the horizontal plane. The participants were given 30 seconds to bring their arms down to rest, and the measure was repeated after the participants performed another 90° abduction movement. This was then repeated for the contralateral shoulder. Scapular UR was calculated by taking the average of the two measurements. This method was described previously to be reliable (ICC

0.81-0.94),[31] and the position of shoulder abduction at 90° was preferred to identify differences.[23]

### INJURY SURVEILLANCE

Injuries were defined in accordance with established consensus statements as any musculoskeletal injury or concussion for which the athletes required a consultation with a health care practitioner.[32] In order to establish previous injury counts at baseline, a database of medical records was reviewed with a focus on shoulder injuries that had occurred in the prior 12 months. This database is linked with the participants' electronic medical record (EMR), where every consultation with a sports medicine doctor, physiotherapist, or other health care practitioner had been entered and labelled for the corresponding injury accordingly. The EMR is maintained on a secure server with password encryption according to standards established by the *Collège des Médecins du Québec*. For the new injury incidence, an online surveillance program Hexfit™ (Hexfit Solutions Inc, Canada) was used to collect daily information on training loads and overuse injuries longitudinally for nine months of normal training and competitions. The system automatically flagged athletes who reported pain during training, and they were then contacted by the lead researcher to confirm that the injury qualified as per the study inclusion criteria. This method has been shown to be reliable in the past with a population of water polo players.[33]

### ANALYSIS

Given the small sample available for this study, groups were dichotomized at baseline by those who had sustained a previous shoulder injury and those who had not. An additional analysis was done after nine months follow-up to compare players with new injuries versus no new injuries. Most variables showed close to normal distributions, except for strength variables. Therefore, independent t-tests were applied to compare dominant shoulder ROM and UR variables between healthy and injured players. Range of motion comparisons were made for range into ER and IR, total range of motion, ER gain and IR loss compared to the non-throwing shoulder. Mean UR was compared for scapular alignment differences. Mann-Whitney U tests compared relative dominant shoulder strength and strength ratios between the healthy and injured groups. The variables compared were average relative peak torque in ER and IR as well as ER:IR ratios. Effect sizes were calculated to compare group means with a Hedges *g* correction approach given the sample size, with small effect described as values <0.2, medium effect <0.5 and large effects >0.8.[34] Male and female players were compared as groups using the same approach. A chi-square analysis compared the proportions of players with a new injury vs a previous injury.

A logistic regression was performed to estimate the relative impact of the risk factors on new injuries in an exploratory analysis. The dependent variable was the development of a new injury over the nine month follow-up (1=injury, 0= no injury). In the first step, a history of previous injury was entered as a confounding variable (1=previous injury, 0=no previous injury). Next, a strength, ROM or UR variable was entered to determine if they related to the development of injuries over the nine month follow-up. Separate models were created for each strength, ROM or UR variable. The optimal model was decided as that which included only significant coefficients, provided the highest pseudo-R$^2$ value, and minimized the residual deviance. Odds ratios with 95% confidence intervals (CI) were also calculated for the variables included in the model based on the logit of the coefficients.

**Figure 3: Participant setup for scapular UR measurements.**

## RESULTS

Nearly half of the participants in the study (18/39) had sustained a previous shoulder injury at baseline. Demographic variables were similar for the previously injured vs previously healthy groups in terms of age, sex, BMI, hand dominance, and training setting (Table 1). However, there were no goalies with previous shoulder injuries.

Observations comparing dominant to non-dominant sides showed increased dominant shoulder ER ROM (105±11° vs 98±11°, p=0.01) and decreased IR (53±11° vs 59±10°, p<0.01). There was however no difference in total range of motion (p=0.98). Furthermore, there were no significant differences in strength (p=0.58-0.70) or UR (p=0.99). Findings for group comparisons of strength, ROM and UR can be found in Table 2 and Table 3.

The previously injured group showed no significant differences in shoulder ROM into ER, IR or in total range of motion. However, athletes with a previous injury showed greater IR loss on the dominant shoulder (moderate ES g=0.68, 95%CI=0.03, 1.34) and higher mean relative IR strength (moderate effect size (ES), *g*=0.60; 95%CI=-0.05, 1.25). The ER:IR ratios were not significantly different between groups (Table 2). No significant difference was observed in UR.

At the nine month follow-up, players were once again divided into two groups based on the presence of a new shoulder injury (Table 3). Three players from the men's team quit the program during the study, but had already developed new shoulder injuries before they left. Therefore, they were

**Table 1: Baseline demographic data**

| Variable | | Previous Injury (n=18) | No Previous Injury (n=21) | New injury (n=19)* | No new injury (n=20) |
|---|---|---|---|---|---|
| Mean Age, years (SD) | | 23.4 (4.3) | 22.8 (2.9) | 22.5 (4.1) | 22.7 (3.0) |
| Male (%) | | 10 (56%) | 9 (43%) | 9 (47%) | 10 (50%) |
| Mean BMI (SD) | | 25.2 (3.2) | 24.7 (2.2) | 25.0 (3.2) | 24.9 (2.2) |
| Hand dominance (frequency) | Right | 17 | 20 | 18 | 19 |
| | Left | 1 | 1 | 1 | 1 |
| Player position (frequency) | Goalie | 0 | 7 | 2 | 5 |
| | Set | 9 | 6 | 9 | 6 |
| | Driver | 9 | 8 | 8 | 9 |
| Training setting (frequency) | National center | 5 | 8 | 6 | 7 |
| | Professional | 9 | 7 | 9 | 7 |
| | College | 4 | 6 | 4 | 6 |

*The groups were classified after the nine month follow-up into those who developed prospective injuries and those that remained healthy

**Table 2: Mean physical factors of the dominant shoulder for athletes with previous injuries and results of statistical comparisons.**

| Variable | | Previous injury (n=18) | No previous injury (n=21) | Significance (p-value) | Effect size *g* [95% CI] |
|---|---|---|---|---|---|
| Strength | ER (Nm/kg) | 0.43 (0.10) | 0.38 (0.11) | 0.12 | 0.45 [-0.20, 1.09] |
| | IR (Nm/kg) | 0.62 (0.15) | 0.54 (0.13) | 0.04 | 0.60 [-0.05, 1.25] |
| | ER/IR ratio | 0.70 (0.10) | 0.72 (0.11) | 0.60 | -0.16 [-0.79, 0.48] |
| ROM | ER (°) | 105.1 (11.0) | 104.8 (11.6) | 0.93 | 0.03 [-0.61, 0.67] |
| | IR (°) | 52.0 (10.2) | 52.9 (11.7) | 0.80 | -0.08 [-0.72, 0.56] |
| | Total rotation(°) | 157.1 (12.5) | 157.7 (14.7) | 0.90 | -0.04 [-0.68, 0.60] |
| | ER gain (°) | 7.7 (8.3) | 5.1 (8.6) | 0.35 | 0.30 [-0.34, 0.94] |
| | IR loss (°) | 9.9 (9.1) | 4.1 (7.5) | 0.04 | 0.68 [0.03, 1.34] |
| Scapular alignment | UR (°) | 11.4 (3.0) | 11.8 (3.7) | 0.70 | -0.12 [-0.76, 0.52] |

ER = external rotation, IR = internal rotation, ER:IR = ratio of external over internal rotation, ROM = range of motion, UR = upward rotation.

classified into the group with new injuries (n=19). A chi-square test confirmed that the players that had a previous injury were significantly more likely to develop new injuries (71.4% vs 27.8%, p=0.02). Furthermore, dominant shoulder IR loss was significantly higher in the group with new injuries (p=0.04, ES=0.68). Relative strength values were not different between groups, but UR was significantly greater in the group with new injuries (p<0.01, ES=0.81).

Sex comparisons showed that female players demonstrated higher total range of motion in rotation (p=0.02, ES g=0.75). Males were much stronger than the female players in both ER and IR, respectively (p<0.01, large ES g=2.03, 2.04), but ER:IR ratios were not different (Supplemental Table 1). No other variables were significantly different between sexes.

The best model fit to explain new injuries included previous injuries and UR (Table 4). This model minimized residual deviance (37.04) and maximized the pseudo-$R^2$ value using the Nagelkerke method ($R^2$=0.47). The odds ratios (OR) for history of previous injury are 6.5, (95%CI=1.6, 26.4), and increased UR was related to more likelihood of developing a new injury (OR=1.5, 95%CI=1.1, 2.0) after accounting for a previous injury. No other variables were significantly related to new injuries in the logistic regression analyses.

## DISCUSSION

Overall, this study showed that shoulder ER and IR ROM, strength, and UR are risk factors associated with shoulder injuries in water polo. At baseline, players with previous injuries demonstrated statistically significantly increased IR strength and loss of IR ROM on the dominant side. After nine months (and redistribution into injured/uninjured groups) strength measurements were not significantly different, but rather IR loss (greater in injured athletes) and

**Table 3: Mean physical factors of the dominant shoulder for athletes with new injuries** and results of statistical comparisons**

| Variable | | New injury (n=19) | No new injury (n=20) | Significance (p-value) | Effect size *g* [95% CI] |
|---|---|---|---|---|---|
| Strength* | ER (Nm/kg) | 0.40 (0.11) | 0.41 (0.10) | 0.92 | -0.14 [-0.77, 0.50] |
| | IR (Nm/kg) | 0.59 (0.14) | 0.56 (0.15) | 0.52 | 0.18 [-0.46, 0.81] |
| | ER/IR ratio | 0.68 (0.12) | 0.74 (0.08) | 0.09 | -0.61 [-1.26, 0.04] |
| ROM | ER (°) | 104.9 (10.9) | 105.1 (11.7) | 0.96 | -0.02 [-0.65, 0.62] |
| | IR (°) | 49.9 (10.1) | 54.9 (11.4) | 0.16 | -0.45 [-1.09, 0.19] |
| | Total rotation(°) | 154.8 (12.6) | 160.0 (14.3) | 0.24 | -0.37 [-1.01, 0.27] |
| | ER gain (°) | 7.7 (8.4) | 5.0 (8.5) | 0.33 | 0.31 [-0.33, 0.95] |
| | IR loss (°) | 9.8 (9.8) | 4.0 (6.7) | 0.04* | 0.68 [0.03, 1.33] |
| Scapular alignment | UR (°) | 13.0 (3.0) | 10.4 (3.3) | 0.01* | 0.81 [0.15, 1.47] |

*Strength variables were not normally distributed and groups were compared with Mann-Whitney test.

** Three male athletes quit water polo during the study follow-up period, and were included in the prospective injured group because they had prior injuries.

ER = external rotation, IR = internal rotation, ER:IR = ratio of external over internal rotation , ROM = range of motion, UR = upward rotation.

**Table 4: Significance of risk factors in a logistic regression with previous injury as a confounder**

| Variable | Coefficient | p-value | $R^2$ (Nagelkerke) |
|---|---|---|---|
| Sex=male | -0.42 | 0.57 | 0.25 |
| Relative external rotation strength | -4.54 | 0.23 | 0.28 |
| Relative internal rotation strength | -0.72 | 0.78 | 0.24 |
| Ratio external/internal rotation strength | -7.07 | 0.08 | 0.34 |
| External rotation flexibility | -0.01 | 0.92 | 0.24 |
| Internal rotation flexibility | -0.05 | 0.15 | 0.30 |
| Total rotation flexibility | -0.03 | 0.22 | 0.28 |
| External rotation gain | 0.03 | 0.51 | 0.25 |
| Internal rotation loss | 0.07 | 0.17 | 0.29 |
| Scapular upward rotation | 0.39 | 0.01 | 0.47 |

Previous injury was entered as the first confounder, and then a separate model was created with each variable above.

UR showed a positive association. Largely, the most important predictor of new injury was the presence of a previous injury, with a 6.5 times increased odds of developing a new injury with this risk factor. Finally, male players showed higher strength values and less total ROM than their female counterparts.

Measures of relative IR strength were the only strength variable correlated with previous injury, and no strength variables were associated with new injury. In their group, Hams et al[35] found that high-level Australian water polo players with lower isometric strength had an association with new injuries. In the present study, relative IR strength was significantly higher for the group with previous injuries, but was not related to new injuries. The higher values of dominant shoulder strength for athletes with previous injuries may reflect that they may have been more likely to be performing targeted strengthening exercises to avoid new injuries, and thus demonstrated stronger test values. Consistent with Hams et al,[11] ER:IR strength ratios were not associated with new injuries, which suggests that asymmetries in rotator cuff strength may not be as widely present as was once suspected in this population.[3]

A greater loss of IR ROM was significant in the injured groups at baseline and after nine months. All other measures of ROM were otherwise similar between healthy and injured groups, and consistent with previous authors.[8,18] The loss of IR ROM may impact the players' ability to decelerate the overhead throws, and put more mechanical stress on the rotator cuff muscles. Over time, this can lead to pathologies such as those observed in this population with MRI which affect the postero-superior area of the glenohumeral joint.[36–38] A loss of shoulder IR ROM may also decrease the mechanical efficiency of the pulling motion of swimming, where players would need to increase scapular tilting to bring the arm in an optimal mechanical position. This in turn can lead to an increase in mechanical stress on the anterior structures of the shoulder such as the acromioclavicular joint and the brachii.[39]

The injured group at follow-up showed a significantly higher dominant shoulder mean UR. This variable was also a key factor in the logistic regression model, showing that increasing UR contributes to the risk of sustaining an injury. Based on previous studies, it would rather have been expected to find decreased values in the injured group.[40] These findings may be the result of limiting measurement to static positions where the range of values observed was narrow. Active movement measured with three-dimensional kinematic equipment would be more precise. Furthermore, Mukhtyar et al[23] found significant differences between injured and non-injured water polo players only when the players were in a fatigued state after training. The task of repeated shoulder rotations on the isokinetic dynamometer may not have stressed the scapulo-thoracic musculature sufficiently, and may not have induced the type of fatigue expected after water polo training.

The male players showed significantly higher relative strength compared to the female players in both ER and IR. This can be the result of different training methods, or a reflection of the more physical demands of the sport in the men's style of play. Given that female players use a smaller and lighter ball, this may decrease the impact of lower strength on their ability to generate powerful overhead throws, but comparisons between sexes are lacking in the literature. The increased ROM that the female players demonstrated may be advantageous to accelerate the ball over a larger distance before throwing. However, this increased ROM may be an added risk factor for specific types of shoulder pathologies affecting joint stability.[41]

The study is limited in its generalizability given the small sample size. However, this sample included the entire population of international level water polo players in Canada, and the findings remain important for this group. A twelve-month follow-up was planned, but confinement due to COVID-19 pandemic interrupted all training activities after nine months. Secondly, a test of eccentric ER strength using the isokinetic dynamometer would allow to calculate a functional ratio of strength at the shoulder that resembles the throwing motion more closely (concentric IR to eccentric ER. In this study, this method was not chosen in order to limit fatigue before training sessions. Further studies investigating strength should consider this approach. Third, the methodology for measuring UR was optimal in the training setting, but it cannot yield information about active range of motion. In addition to taking all the measurements after training, future research should include a more substantial fatigue protocol to explore the conclusions of Mukhtyar et al.[23] Finally, other important risk factors were not considered, such as training volume and psychological factors.[42]

## CONCLUSION

In conclusion, the results of the current study indicate that a history of previous injury, as well as measures of shoulder IR and UR were most strongly associated with risk for sustaining a new injury in a sample of international level players of both sexes. This study adds to a small body of Level 2[43] literature on risk factors for shoulder injuries in water polo. These findings indicate that monitoring shoulder ROM, UR, and strength should be considered as core elements of an injury prevention program for water polo players. Additional studies which investigate the effectiveness of different protocols to optimize strength ratios and ROM are needed to guide these programs.

## CONFLICTS OF INTEREST

None to declare

## FUNDING

Research, Innovation and Dissemination of Information Program (PRIDI)

Submitted: January 23, 2021 CDT, Accepted: April 17, 2021 CDT

# REFERENCES


1. Mountjoy M, Miller J, Junge A. Analysis of water polo injuries during 8904 player matches at FINA World Championships and Olympic games to make the sport safer. *Br J Sports Med*. 2019;53(1):25-31.

2. Junge A, Engebretsen L, Mountjoy ML, et al. Sports injuries during the Summer Olympic Games 2008. *Am J Sports Med*. 2009;37(11):2165-2172. doi:10.1177/0363546509339357

3. Miller AH, Evans K, Adams R, et al. Shoulder injury in water polo: A systematic review of incidence and intrinsic risk factors. *J Sci Med Sport*. 2018;21(4):368-377.

4. Hams A, Evans K, Adams R, et al. Epidemiology of shoulder injury in sub-elite level water polo players. *Phys Ther Sport*. 2019;35:127-132.

5. Kim HC, Park KJ. Injuries in male and female elite aquatic sports athletes: an 8-year prospective, epidemiological study. *J Sports Sci Med*. 2020;19(2):390-396.

6. van Mechelen W, Hlobil H, Kemper HC. Incidence, severity, aetiology and prevention of sports injuries. A review of concepts. *Sports Med*. 1992;14(2):82-99. doi:10.2165/00007256-199214020-00002

7. Webster MJ, Morris ME, Galna B. Shoulder pain in water polo: a systematic review of the literature. *J Sci Med Sport*. 2009;12(1):3-11.

8. Witwer A, Sauers E. Clinical measures of shoulder mobility in college water-polo players. *J Sport Rehab*. 2006;15(1):45-57.

9. McMaster WC, Long SC, Caiozzo VJ. Isokinetic torque imbalances in the rotator cuff of the elite water polo player. *Am J Sports Med*. 1991;19(1):72-75. doi:10.1177/036354659101900112

10. Colville JM, Markman BS. Competitive water polo. Upper extremity injuries. *Clin Sports Med*. 1999;18(2):305-312, vi. doi:10.1016/s0278-5919(05)70146-0

11. Hams A, Evans K, Adams R, et al. Reduced shoulder strength and change in range of motion are risk factors for shoulder injury in water polo players. *Phys Ther Sport*. 2019;40:231-237.

12. Zanca GG, Oliveira AB, Saccol MF, Ejnisman B, Mattiello-Rosa SM. Functional torque ratios and torque curve analysis of shoulder rotations in overhead athletes with and without impingement symptoms. *J Sports Sci*. 2011;29(15):1603-1611. doi:10.1080/02640414.2011.608702

13. Black GM, Gabbett TJ, Cole MH, Naughton G. Monitoring workload in throwing-dominant sports: a systematic review. *Sports Med*. 2016;46(10):1503-1516. doi:10.1007/s40279-016-0529-6

14. Hibberd EE, Oyama S, Spang JT, Prentice W, Myers JB. Effect of a 6-week strengthening program on shoulder and scapular-stabilizer strength and scapular kinematics in Division I collegiate swimmers. *J Sport Rehab*. 2012;21(3):253-265. doi:10.1123/jsr.21.3.253

15. Byram IR, Bushnell BD, Dugger K, Charron K, Harrell FEJ, Noonan TJ. Preseason shoulder strength measurements in professional baseball pitchers: identifying players at risk for injury. *Am J Sports Med*. 2010;38(7):1375-1382. doi:10.1177/0363546509360404

16. Burkhart SS, Morgan CD, Kibler WB. The disabled throwing shoulder: spectrum of pathology Part I: pathoanatomy and biomechanics. *Arthroscopy*. 2003;19(4):404-420. doi:10.1053/jars.2003.50128

17. Segawa E, Komori Y, Hojo T. The relationship between shoulder injuries and flexibility, shoulder range of motion characteristics in elite male Japanese water polo players. *Jap J Phys Fit Sports Med*. 2017;66(4):263-269.

18. Elliott J. Shoulder pain and flexibility in elite water polo players. *Physiotherapy*. 1993;79(10):693-697. doi:10.1016/s0031-9406(10)60004-1

19. Burkhart SS, Morgan CD, Ben Kibler W. The disabled throwing shoulder: spectrum of pathology Part III: the SICK scapula, scapular dyskinesis, the kinetic chain, and rehabilitation. *Arthroscopy*. 2003;19(6):641-661. doi:10.1016/s0749-8063(03)00389-x

20. Lawrence RL, Braman JP, Ludewig PM. The impact of decreased scapulothoracic upward rotation on subacromial proximities. *J Orthop Sports Phys Ther*. 2019;0(0):1-40.

21. Turgut E, Yildiz TI, Demirci S, et al. Shoulder kinematics and mobility adaptations in water-polo players. *J Sports Med Phys Fitness*. 2018;58(9):1264-1268.

22. Johnson MP, McClure PW, Karduna AR. New method to assess scapular upward rotation in subjects with shoulder pathology. *J Orthop Sports Phys Ther*. 2001;31(2):81-89.

23. Mukhtyar FR, Mitra M, Kaur A. The effects of intense practice sessions on the scapular kinematics of elite water polo players with and without impingement syndrome. *Ind Jour of Physioth and Occupat Therapy - An Inter Jour*. 2014;8(2):189. doi:10.5958/j.0973-5674.8.2.084

24. Melchiorri G, Padua E, Padulo J, et al. Throwing velocity and kinematics in elite male water polo players. *J Sports Med Phys Fit*. 2011;51(4):541-546.

25. Whiting WC, Puffer JC, Finerman GA, Gregor RJ, Maletis GB. Three-dimensional cinematographic analysis of water polo throwing in elite performers. *Am J Sports Med*. 1985;13(2):95-98. doi:10.1177/036354658501300203

26. Wheeler K, Kefford T, Mosler A, et al. The volume of goal shooting during training can predict shoulder soreness in elite female water polo players. *J Sci Med Sport*. 2013;16(3):255-258.

27. 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

28. Kolber MJ, Hanney WJ. The reliability and concurrent validity of shoulder mobility measurements using a digital inclinometer and goniometer: a technical report. *Int J Sports Phys Ther*. 2012;7(3):306-313.

29. *RStudio: Integrated Development Environment for R [Computer Program]. Version 1.2.1335*. Boston, MA: RStudio, Inc; 2018.

30. Papotto BM, Rice T, Malone T, et al. Reliability of isometric and eccentric isokinetic shoulder external rotation. *J Sport Rehab*. 2016;25(2):01.

31. Watson L, Balster SM, Finch C, et al. Measurement of scapula upward rotation: a reliable clinical procedure. *Br J Sports Med*. 2005;39(9):599-603.

32. 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.

33. Menaspa MJ, Menaspa P, Clark SA, et al. Validity of the Online Athlete Management System to assess training load. *Int J Sports Physiol Perform*. 2018;13(6):750-754.

34. Ellis PD. *The Essential Guide to Effect Sizes : Statistical Power, Meta-Analysis, and the Interpretation of Research Results*. Cambridge; New York: Cambridge University Press; 2010. doi:10.1017/cbo9780511761676

35. Hams A, Evans K, Adams R, et al. Shoulder internal and external rotation strength and prediction of subsequent injury in water-polo players. *Scand J Med Sci Sports*. 2019;29(9):1414-1420.

36. Klein M, Tarantino I, Warschkow R, et al. Specific shoulder pathoanatomy in semiprofessional water polo players: A magnetic resonance imaging study. *Ortho J Sports Med*. 2014;2(5).

37. Giombini A, Rossi F, Pettrone FA, et al. Posterosuperior glenoid rim impingement as a cause of shoulder pain in top level waterpolo players. *J Sports Med Phys Fitness*. 1997;37(4):273-278.

38. Galluccio F, Bellucci E, Porta F, et al. The waterpolo shoulder paradigm: results of ultrasound surveillance at poolside. *BMJ Open Sport Ex Med*. 2017;3(1):e000211. doi:10.1136/bmjsem-2016-000211

39. Cowderoy G. Impingement syndromes and microinstability of the shoulder in athletes. *J Med Imaging Radiat Oncol*. 2009;53:A183.

40. Green RA, Taylor NF, Watson L, et al. Altered scapula position in elite young cricketers with shoulder problems. *J Sci Med Sport*. 2013;16(1):22-27.

41. Wilk KE, Macrina LC, Arrigo C. Passive range of motion characteristics in the overhead baseball pitcher and their implications for rehabilitation. *Clin Orthop Relat Res*. 2012;470(6):1586-1594.

42. Bittencourt NFN, Meeuwisse WH, Mendonça LD, et al. Complex systems approach for sports injuries: moving from risk factor identification to injury pattern recognition—narrative review and new concept. *Br J Sports Med*. 2016;50(21):1309-1314.

43. Ebell MH, Siwek J, Weiss BD, et al. Strength of recommendation taxonomy (SORT): a patient-centered approach to grading evidence in the medical literature. *J Am Board Fam Pract*. 2004;17(1):59-67.

# SUPPLEMENTARY MATERIALS

## Supplementary Materials

Download: https://ijspt.scholasticahq.com/article/25432-risk-factors-for-shoulder-injuries-in-water-polo-a-cohort-study/attachment/65149.docx