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Is Reduced Shoulder Internal Rotation a Risk Factor for Shoulder Injuries in Water Polo? A Prospective Study of Elite Water Polo Athletes

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Abstract

The present prospective study aimed to determine whether pre-season shoulder reduced range of motion (ROM) can be used to identify athletes at risk of future shoulder musculoskeletal injury. We assessed the shoulder internal (IR) and external rotation (ER) ROM of 27 elite water polo players during the pre-season. Their injuries were recorded for 1 year post measurement by the medical staff of their team. A total of 15 shoulder injuries were recorded. There was a difference (p=0.10) in internal rotation ROM of the right shoulder between the prospectively injured (avg=48.75) (t (20) = -2.018, p = 0.057 > 0.05) and no injury groups (avg=57.19). Specifically, IR ROM <55 degrees appeared to be related to future injury. Pre-season reduced shoulder IR may be a predictor for future shoulder injury in water polo athletes. Increasing the ROM in the internal rotation of the shoulder may reduce future episodes of shoulder injury in water polo players, although further investigation of other risk factors in a larger sample size is required.

Keywords: Water polo; Range of movement; Injury

Introduction

Water polo is the oldest and longest running team sport in the history of the Olympic Games. Modern water polo is a combination of swimming, ball throwing, and wrestling. It is a highly demanding sport, as it has alternations of high-and low-intensity physical activity for about an hour [1]. It seems that water polo has become more demanding than before, requiring even higher levels of stamina [2]. This fact, in correlation with the amount of training, repetitive movements, and the short period of recovery [3], constitutes important risk factors for acute and chronic injury during the game [4]. Even though water polo is a popular competitive sport worldwide, there is a deficit in prevention of injuries research. Water polo-related injuries have been constantly increasing over the years [5], with shoulder injuries presenting in 50% of all injuries [6]. Existing surveys in the literature correlate reduced range of motion with shoulder injuries in throwing sports, such as baseball and softball. A study showed that reduced shoulder's internal rotation constitutes an important injury risk factor in baseball and softball athletes [7]. Another study also demonstrated that a deficit in the shoulders' internal rotation is associated with biomechanical changes in baseball athletes' shoulders [8,9] showed that patients with subacromial impingement syndrome presented with an internal rotation deficit and tightness of the posterior capsule. There seems to be a correlation between shoulder's injuries in athletes of throwing sports, such as water polo, and the lack of internal rotation [10,11]. The aim of the present study was to explore whether reduced shoulder range of motion in water polo players constitutes a risk factor for shoulder injury. We investigated the possible correlation between reduced shoulder internal rotation and the probability of shoulder injury in water polo athletes. We assessed whether the reduction in passive internal rotation of the shoulder constitutes an injury risk factor.

Methods

The study included 27 athletes, equally distributed in terms of gender (Table 1), with an average of 14 years of experience in sports. Athletes with less experience were excluded. Athletes who had undergone surgery in the upper extremity or who were in a recovery phase from an injury were excluded. The survey included athletes who were Greek, Croatian, Canadian, and Australian, competing at the highest level by participating in the National, European, World, and Olympic Games. As shown in Table 1, most athletes were right-handed. Regarding their position in the competition pool, about half of the athletes were field players. About 50% of the athletes in the survey stated that they had been injured on their shoulders [12] in the current athletic season. Most of the injured athletes reported injuries on the right shoulder [8], with mainly tendinitis of the supraspinatus muscle, which kept them out of games for 1-3 weeks. Most athletes had a history of injury to the right shoulder, mainly tendinitis of the supraspinatus muscle [5], glenoid labrum tear [4], and tear on the supraspinatus tendon [4]. The athletes generally had a history of injury to the right side or to the hip and other parts of the body, including intervertebral disc degeneration, acetabulofemoral impingement, strains, tears, and fractures.

Table 1: Demographic characteristics of participants.

Demographic Characteristics	Categories	N	f%
Gender	Female	15	55.56
	Male	12	44.44
Position	Driver/Winger	13	48.15
	Goalkeeper	5	18.52
	Center	5	18.52
	Defender	4	14.81
Dominant hand	Right	25	92.59
	Left	2	7.41

N: Frequency, f%: Relative frequency.

An experimental prospective quantitative study was conducted using recorded data and a questionnaire. A quantitative study was considered appropriate, as the phenomena studied were measurable. The sample of the research was large, and based on the research question that was presented, it was necessary to investigate the relationship between the variables [12]. In general, quantitative research can yield a large volume of information [13], offer mathematical analysis of the phenomena [14], and draw generalized conclusions about the population of the study [15], if sampling is impartial [16]. The data analysis was performed using the statistical program IBM SPSS 24 with the parallel use of Microsoft Office Excel 2016. The quantitative variables of the research were presented with mean values and standard deviations, as well as the quantitative ones with frequencies and percentages. To check the normality of quantitative variables, the Shapiro-Wilk test was used at a significance level of 5%. The original hypothesis is that the variables follow the normal distribution, while they do not follow the alternative distribution. Since the normality in degrees of motion was recorded in almost all cases, for the control of differentiation of mean values of the quantitative variable in dichotomous categories, the parametric control "independent samples t-test" was used, with an importance level of 10%.

The ROM measurements were performed with a digital joint's goniometer, which has greater reliability and validity than the analog [17]. The device used was a Halo digital goniometer (Halo Medical Devices, 30 Harvey Street Vaucluse, Sydney, New South Wales 2036, Australia). The means of two attempts of the external and internal rotation measurements of both upper extremities were calculated as the results.

Results

Demographic characteristics

Table 1 lists the qualitative demographic characteristics of the respondents. Regarding the gender of the participants, 55.46% (N=15) were women and 44.44% (N=12) were men. Regarding the position played in the sport field, 48.15% (N = 13) of the respondents were drivers/wingers, 18.52% (N = 5) were goalkeepers, and 14.81% (N = 4) were centers and defenders. In total, 92.59% (N = 25) of the participants were dominantly right-handed, and 7.41% (N = 2) were dominantly left-handed.

Shoulder movements

The ranges of motions, referring to the movements of the shoulders of the respondents, are displayed in Table 3. Among the participants, we recorded an average external rotation of 106.26 ± 10.80 degrees in the right shoulder and 98.33±10.40 degrees in the left shoulder. The internal rotation was 60.11 ± 9.56 degrees in the left shoulder and 55.67±10.22 degrees in the right shoulder. This year's injuries to the shoulder. Table 4 lists survey items and responses concerning the present year's injuries experienced to the shoulder by the respondents. About 51.90% (N=14) did not have any injuries during the survey period, in contrast to the remaining 48.10% (N=13) who reported injuries. The respondents experienced various types of injuries during the surveyed year, with 61.50% (N=8) reporting supraspinatus

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tendinitis, 15.40% (N=2) indicating a tear of the supraspinatus tendon, and 7.70% (N=1 each of 5 respondents total) each stating a total tear of the supraspinatus tendon, a tear of the infraspinatus tendon, infraspinatus tendinitis, tendinosis of supraspinatus tendon, and tendinitis of the biceps muscle (long head). Further, due to their injuries, 30.77% (N=4) had a week of absence from training, 15.38% (N=2) had 2 weeks of absence, and 15.38% (N = 2) reported 20 days of absence. Five respondents reported 3, 6, 10, 30, and 180 days of absence (7.69%, N = 1 each). Most respondents (66.67%, N = 8) reported being injured on the right side of the shoulder, and 33.33% (N = 4) had injuries to the left shoulder.

Table 2: Demographic quantitative characteristics.

Demographic Elements	AV	SD
Age	25.48	4.64
Years of training	14.37	4.35

AV: Average, SD: Standard deviation.

Table 3: Shoulders movements.

Shoulder Movements	AV	SD
External rotation of the right shoulder	106.26	10.8
External rotation of the left shoulder	98.33	10.4
Internal rotation of the left shoulder	60.11	9.56
Internal rotation of the right shoulder	55.67	10.22

AV: Average, SD: Standard Deviation.

Table 4: This year's injuries to the shoulder.

This Year's Injuries	Categories	N	f%
This year injuries	No	14	51.9
	Yes	13	48.1
Type of this year's injury	Tendinitis supraspinatus	8	61.5
	Tear of the supraspinatus tendon	2	15.4
	Total tear of the supraspinatus tendon	1	7.7
	Tear of the infraspinatus tendon	1	7.7
	Infraspinatus tendinitis	1	7.7
	Tendinosis of the supraspinatus tendon	1	7.7
	Tendinitis of the biceps muscle (long head)	1	7.7
Absence from training	7 days	4	30.77
	14 days	2	15.38
	20 days	2	15.38
	3 days	1	7.69
	6 days	1	7.69
	10 days	1	7.69
	30 days	1	7.69
	180 days	1	7.69
Side of this year injury	Right shoulder	8	66.67
	Left shoulder	4	33.33

N: Frequency, f%: Relative frequency.

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Old injuries to the shoulder

Table 5 presents previous shoulder injuries. We observed that 62.96% (N=17) had been injured in the past. The participants indicated more than one type of previous injury each: 29.40% (N=5) stated that they had tendinitis of the supraspinatus, 23.50% (N=4) had glenoid labrum tear and infraspinatus tendon, 17.60% (N=3) had tendinosis of the supraspinatus tendon, 11.80% (N=2) had a tear of the infraspinatus tendon, and one respondent each (5.90% (N=1) had a tear of the biceps tendon, subluxation of the shoulder and glenoid labrum tear, tendinitis of the biceps muscle (long head), and a tear of the infraspinatus tendon. Overall, and 69.23% (N=9) of the participants had old injuries to the right shoulder, and 46.20% (N=6) to the left. As shown by the proportion of the responses to the last item (old injury side), some athletes were injured on both shoulders.

Table 5: Old injuries to the shoulder.

Old Injuries	Categories	N	f%
Old injuries on the shoulder	Yes	17	62.96
	No	10	37.04
Old injury types	Tendinitis supraspinatus	5	29.4
	Glenoid labrum tear	4	23.5
	Tear of the infraspinatus tendon	4	23.5
	Tendinosis of the supraspinatus tendon	3	17.6
	Tear of the infraspinatus tendon	2	11.8
	Tear of the bicep's tendon	1	5.9
	Subluxation of the shoulder	1	5.9
	Tendinitis of the biceps muscle (long head)	1	5.9
	Tear of the infraspinatus tendon	1	5.9
Old injury side	Right shoulder	9	69.2
	Left shoulder	6	46.2

N: Frequency, f%: Relative frequency.

Other injuries

Table 6 presents the items referring to the other injuries of the respondents. As shown in the table, 88.89% (N=24) of the respondents had injuries to other parts of their body, with 85.71% (N=12) injured on the right side of the body (hips or hands) and 35.70% (N=5) injured on the left. The summary of the percentages in this survey item indicates that there were athletes who were injured on both sides. Regarding the types of injuries to other parts of the body, 29.20% (N=5) reported intervertebral disc degeneration and femoroacetabular impingement, 25% (N=6) stated muscle strain, 20.80% (N=5) stated tear of tendon, 16.70% (N=4) indicated fracture, 8.30% (N=2) said they had hip dysplasia. Five respondents reported chondromalacia, tendon surgery, displaced joint, intervertebral disc herniation, or cervical radiculopathy (4.20%, N=1 each).

Inferential statistics

To address the survey question "Is the number of degrees correlated to the probability of injury?", a new variable was created called "This year's injuries" and includes three categories: "Right shoulder Injury," "Left shoulder Injury," and "No Injury." The descriptive elements of this variable are presented in Table 7. In total, 53.8% (N=14) did not have any injury, the 30.8% (N=8) had injury to the right shoulder, and 15.4% (N=4) to the left. One participant had surgery on the shoulder, and he was excluded from the analysis.

To select the appropriate parametric or non-parametric test, regularity was checked. Table 8 presents the results of the regularity test using the Shapiro-Wilk test for the variables that referred to the movements of the shoulders in the subcategories of the variable "This year's injuries." The results supported the original hypothesis of regularity in all cases except for the variable "External rotation of the right shoulder-left shoulder injury" ($p = 0.017 < 0.05$).

Due to the existence of regularity in most of the cases, the parametric test "independent samples t-test" was used for the variables that referred to the movements of the shoulders over the variable "This year's injuries." For the variable cases that referred to the right shoulder (Right shoulder's external rotation & right shoulder's internal rotation), a comparison was made of

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the persons who were injured to the right shoulder or not injured at all (the team who were injured to the left shoulder was not taken under consideration). Similarly, in the cases of the variables that referred to the left shoulder (Left shoulder's external rotation & left shoulder's internal rotation), a comparison was made of the persons who injured to the left shoulder or not injured at all (the team who were injured to the right shoulder was not taken under consideration). The original hypothesis in every movement of the shoulder is that the average of the degrees is the same for both categories (Right/Left shoulder's injury, no injury at all), and the alternative is that some category is referred. Table 9 shows that at a significant level of 10%, the average of the variable "Right shoulder's internal rotation" of the persons who were injured in the right shoulder (AV = 48.75) is lower (t (20) = -2.018, p = 0.057 >0.05.) than the corresponding of the persons who were not injured at all (AV = 57.19). Table 10 presents the results of the estimation of the degrees of right shoulder's injury in internal rotation for the eight participants who were injured on the right shoulder. In 50% (N = 4) of the cases, the shoulder rotations ranged from 50 to 55 degrees, and 37.5% (N=3) of the cases had a rotation of less than 50 degrees. Only one respondent (12.5%, (N=1) had rotation in the range of 56–70 degrees.

Table 6: Other injuries.

Other Injuries	Categories	N	f%
Other injuries	Yes	24	88.89
	No	3	11.11
Side of the injury (hips, hands)	Right	12	85.7
	Left	5	35.7
Types of other injuries	Intervertebral disc degeneration	7	29.2
	Femoroacetabular Impingement	7	29.2
	Muscle strain	6	25
	Tear of tendon	5	20.8
	Fracture	4	16.7
	Hip dysplasia	2	8.3
	Chondromalacia	1	4.2
	Tendon surgery	1	4.2
	Displaced joint	1	4.2
	Intervertebral disc herniation	1	4.2
	Cervical radiculitis	1	4.2

N: Frequency, f%: Relative frequency.

Table 7: This year's injuries.

Categories	N	f%
Right shoulder injury	8	30.8
Left shoulder injury	4	15.4
No injury	14	53.8

N: Frequency, f%: Relative frequency.

Table 8: Regularity test results using Shapiro-Wilk test.

Movements	This Year's Injuries	Statistic	df	p
Right shoulder's external rotation	Right shoulder injury	0.946	8	0.666
	Left shoulder injury	0.714	4	0.017
	No Injury	0.925	14	0.255
Right shoulder's internal rotation	Right shoulder injury	0.87	8	0.15
	Left shoulder injury	0.811	4	0.123
	No Injury	0.954	14	0.622

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Left shoulder's external rotation	Right shoulder injury	0.889	8	0.228
	Left shoulder injury	0.927	4	0.577
	No Injury	0.887	14	0.073
Left shoulder's internal rotation	Right shoulder injury	0.911	8	0.364
	Left shoulder injury	0.85	4	0.227
	No Injury	0.961	14	0.733

Table 9: Test results of the "independent samples t-test" for movements* this year's injuries.

Movements	This Year's Injuries	N	AV	df	t	p
Right shoulder's external rotation	Right shoulder injury	8	109.88	20	1.305	0.207
	No Injury	14	103.57			
Right shoulder's internal rotation	Right shoulder injury	8	48.75	20	-2.018	0.057
	No Injury	14	57.79			
Left shoulder's external rotation	Left shoulder injury	4	105	16	1.569	0.136
	No Injury	14	96.14			
Left shoulder's internal rotation	Left shoulder injury	4	54.75	16	-1.23	0.237
	No Injury	14	61.29			

Table 10: Estimation of the degrees in the internal rotation on a right shoulder's injury.

Degrees	N	f%
<50	3	37.5
50-55	4	50
56-70	1	12.5
Total	8	100

N: Frequency, f%: Relative frequency

Discussion

Research findings from various studies indicate that intrinsic and extrinsic factors may affect the shoulder's biomechanics during swimming, leading to the development of shoulder pain [18]. Yanai and his research team (2000) studied the biomechanics of the shoulder during freestyle swimming and recorded that impingement was observed at 24.8% of the time of the stroke [19]. This research finding indicates a high potential for impingement. The pain on the shoulder of swimmers is usually considered to be related to the impingement of the supraspinatus tendon to the subacromial space, and it is called "swimmer's shoulder" [18]. It is difficult to interpret the pathophysiology of "swimmer's shoulder" in water polo players due to the limited research examining the kinematic and kinetic behavior of the shoulder in this population. The existing literature indicates that players who score and are asymptomatic develop a variety of shooting behaviors [20]. Various factors have been proposed to affect shoulder position and orientation during throwing, among which are problems with the rotational movements of the glenohumeral joint and stability loss [10,21]. Apart from the burden during swimming, water polo players burden their shoulders when throwing the ball, with an increase in the Internal rotation force and a relative reduction in the External rotation shoulder's throw force. The cause of the increase in the risk of injury to these athletes has been proposed to be due to insufficient ER force available for the deceleration of the humerus up to the phase that follows the throwing of the ball [22]. Despite the high tendency of injury to the shoulder in water polo players [23], the reasons for these injuries have not been studied in the current literature. This creates difficulties in both the prognosis of injuries and athletes' rehabilitation. Thus, health care professionals in water polo use the results of the literature referring to the range of motion of the shoulders of other throwing sports.

Previous studies have indicated that the high intensity shot to score a goal in water polo exposes the shoulder in a torque like that observed during the throwing of the ball in the sport of baseball [24]. Thus, due to the similarities in movement during the throw of the ball, the proposed factor's risks for injury to the shoulder in the sport of water polo are often explained by studies investigating injuries of the shoulder in the sport of baseball. Researchers have demonstrated that baseball athletes who develop loss of IR ROM and EXT ROM on the throwing shoulder develop a higher risk of future injury on the shoulder. Regardless of the similarities, this approach of using the research findings of other throwing sports does not recognize the unique physical requirement of throwing in the water. The aquatic environment of the game requires the water polo player to create throwing force without the existence of a stable support base, as the athlete is

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not capable of transferring the ground reaction forces through the body, thus reducing the contribution of the lower extremity to the kinetic chain of the throwing process. To create targeted injury prevention programs for water polo players and to prevent repetitive shoulder injuries, the risk factors for injury specific to these cases of athletes should be investigated through prospective studies.

These gaps in research indicate that there are many factors that have not been investigated regarding the injuries of water polo players [25]. The results of this study showed that about half of the athletes had an injury on the shoulder during the year of the survey, with the majority reporting injury on the right shoulder and the main reported injury being supraspinatus tendinitis, the glenoid labrum tear, and the tear of the infraspinatus tendon. Concerning the absence from training due to the injury, the majority recorded 1-3 weeks. As for the other injuries, most respondents stated that they had been injured in other parts of the body, mainly on the right side, with the most common injuries being intervertebral disc degeneration, femoroacetabular impingement, muscle strains, and fractures.

The results of the main research question revealed a correlation between the movements and the occurrence of an injury, with a statistically significant differentiation only in the internal rotation of the right shoulder. Specifically, the athletes who were injured to the right shoulder showed a greater risk of injury when the internal rotation was less than 55 degrees, with the significance of the test at 10%. The findings of this research confirm that shoulder's injury is the most common injury of water polo players, indicating the need for appropriate prevention and treatment programs for this injury. Most of the participants were right-handed and reported greater limitation of the range of motion on the right shoulder than on the left one, which indicates that the throwing hand is connected with the limitation of range of motion. This can be justified by the great strain of the shoulder during the throw and the many repetitions that lead to excess weight of the joint in combination with the overweight of swimming. As confirmed by the literature [7,23,26], we found that the external rotation of the shoulders was greater than the internal rotation, and the most frequent injury was the supraspinatus tendinitis, which is probably related to the pathophysiology of the "swimmer's shoulder." This study also identified a statistically significant relationship between the limitation of the range of motion and the development of an injury only during the internal rotation of the shoulder, which is consistent with the findings reported by Hams et al. [23]. This relationship may lead to a limited range of motion to internal rotation as a risk factor for developing an injury to the water polo players. The identification of these prognostic factors contributes to a better understanding of the injury and to finding more effective measures for eliminating the injury as well as its prompt rehabilitation. In fact, the work revealed, for the first time, a probable relationship between the degrees of range of motion and the risk of developing an injury. More specifically, range <55 degrees correlated with greater risk among the injured patients on the right shoulder, research finding that once again confirms the important position of range of motion in predicting the progress of water polo injuries. The correlation was significant at the level of 10% but not at 5%.

In their study, Hams et al. aimed to determine whether the shoulder's range of motion and strength could be used to identify athletes at risk for future shoulder injuries [23]. They mainly reported that before the start of the championship, water polo athletes with a difference of TROM≥7.5 degrees, strength ER ≤12.5%, and strength IR≤16.8% PBW had an increased possibility of shoulder injury in the next 12 months. Our survey results suggest that the reduced range of motion of the internal rotation of the shoulder is a prognostic factor of injury in water polo players, consistent with findings of surveys in other throwing sports [7,26,27] but different from the results of Hams et al.'s [25] survey, which correlated the injury with the loss in the total range of rotation, as well as with a reduced force for both internal and external rotators of the shoulder.

Further, in Hams et al.'s [23] study, the participants had average experience of 5.8 years, a level that is not considered high in Europe, and the survey did not focus on whether the position of the player (e.g., offensive, or defensive) can affect the development of an injury. In the present study, only professional athletes playing at the highest level were tested, with respondents having at least 14 years of experience in the sport of water polo, a characteristic that has not been previously investigated by other studies, including Hams et al. Thus, the present work is unique and very important, as its research findings can be used as a basis for further research that will significantly help health professionals (coaches, trainers, doctors, physiotherapists) to reduce injuries and establish rehabilitation protocols, as well as strengthening and stretching programs, to avoid injuries and their indirect consequences in professional sports. This specific survey provides a good base for the direction of the studies concerning the injuries on the water polo players and gives the possibility to health professionals not to depend on research and rehabilitation protocols and injuries preventions of other throwing sports.

This study has some limitations. Notably, the sample of the study was small (27 athletes), and it included middle-aged respondents. Athletes of different ages were not selected. Furthermore, most of the participants were drivers/wingers, and there was no variety of all positions (e.g., centers, defenders), and there was not a large sample of athletes who throw with the left upper extremity. These limitations may conceal the relationship between range of motion and age, as well as the position of the player. Finally, there was no connection of muscle strength and endurance with the range of motion, as demonstrated in the studies of other sports, a factor that seems to play a significant prognostic role in throwing sports and that should be investigated.

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