Isokinetic torque imbalances of shoulder of the french women””s national water polo team

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Keywords: Isokinetic ratio, Eccentric contraction, shoulder

ABSTRACT

Objective : Evaluate the shoulder isokinetic strength of high-level female water polo players.

Methods : Two groups were compared: a control group of noncompetitive females (n=10), and members of the the french women's national water polo (n=18). Isokinetic measurements focused on the shoulder internal rotators (IR) and external rotators (ER), the evaluations were realized at $60°·s^{-1}$ and $240°·s^{-1}$ in the concentric mode and at $60°·s^{-1}$ in the eccentric mode. Agonist–antagonist ratios (ER/IR) were calculated using the same speed and contraction mode for the agonist and antagonist muscle groups and the mixed ratio, combining peak torque (PT; N·m) of the ER in the eccentric mode at $60°·s^{-1}$ and PT of the IR in the concentric mode at $240°·s^{-1}$, was calculated.

Results : In concentric contraction, the PT of IR of the polo-players was stronger than controls ($p<0.05$). In eccentric contraction the PT of ER were greater in water-polo players ($p<0.05$). For the water-polo players, a difference between both sides was observed when comparing the PT at $60°·s^{-1}$ ($p<0.05$). No significant difference was found through the agonist–antagonist ratios between the dominant and the nondominant shoulders in both groups. Some players exhibit an altered mixed ratio.

Conclusion : Intensive engagement in playing water polo will lead to an asymmetry in terms of force, with a dominance of the internal rotors of the dominant shoulder that could be detrimental and leads to shoulder soreness.

Table 1: Mean physical characteristics of control and water-polo players

Table 2 : Isokinetic performance of D and ND shoulders corresponding to the whole population of the study.

Table 3: Isokinetic ratios for of water polo players and control group for the both shoulders

Table 4 : morphostatic results for water-polo players

INTRODUCTION

Water-polo is an intermittent and high-intensity team sport that requires a combination of technical, high physical fitness and tactical skills [1]. This activity presents asymmetric aspects, particularly during the passing and throwing motions [1]. Repetition of these dynamic motions and swimming result in a cumulative micro-trauma leading to shoulder soreness [2]. Shoulder soreness is the most common musculoskeletal complaint for water-polo players [3]. The relative increase in dominant shoulder external rotation observed in water-polo players suggests that levels of shoulder soreness would be a result of throwing actions rather than swimming which did not require high level of force of external rotators [4]. Moreover, the shoulder soreness is classicaly associated with impingement syndrome and increadsed shoulder mobility as a result of imbalances in rotator cuff muscles [5]. The shoulder injury prevention is a relevant challenge for trainer and need to be taken in account to enhance their team performance. Therefore, evaluation of shoulder muscle strength is of interest to prevent injury.

Measurement of isokinetic torque production remains the method of choice to assess peak muscle performance [6, 7, 8, 9, 10]. Quantitative establishment of the balance between the forces in rotator cuff muscles requires investigation of agonist/antagonist ratios [5]. Previous studies reported that water-polo players have greater internal than external rotation strength [11]. Female water-polo players experienced higher rates of shoulder injury than male players [12]. To our knowledge, isokinetics shoulder performance has not been investigated in high-level female players. It should be of intetrest to determine in muscle imbalance will be involved in this process.

In sports where overarm throwing plays an important role, isokinetic evaluations revealed a imbalance in muscle strength of the shoulder [9, 13, 14]. During throwing, there is a complementary action of concentric and eccentric contractions. The concentric action of internal rotators determines mainly the throwing velocity. The eccentric contraction of external rotators plays a key role and act as a brake during the final deceleration of the upper limb, thereby limiting the prounounced increase in distraction force [15]. The use of a mixed ratio (eccentric peak torque of external rotators divided by concentric peak torque of internal rotators) is therefore advocated [16]. Upon comparing various high-level sporting populations and control subjects, Forthomme et al. [17] observed a decreased mixed ratio (ER ecc/IR conc) for the individuals engaged in the throwing activities (volleyball, javelin, badminton, tennis) relative to control group. This altered ratio is the result of an increase in the peak torque performances of the IR in concentric mode without an increase of the ER in eccentric mode [18]. The lower limit of the mixed ratio among the control or non-participating individuals (who define the "normal" context) was set arbitrarily at 1.11 in previous studies that focus on throwing activities [19, 20, 21].

The aim of this study was to determine if there is an imbalance in muscle strength of the shoulder in high-level female water polo players. These various findings will allow elucidation of the impact of high-level engagement in women water-polo on the musculoskeletal system.

MATERIALS AND METHODS

Study design

Two groups were evaluated: a control group of noncompetitive females (n=10), and members of the the french women's national water polo team (n=18). Control subjects did not practice throwing activities and were matched for age (+/- 4 years), height (+/-5 cm) and weight (+/-4 kg). The evaluations were performed at the end of the first part of the season which should reflect training adaptations. The evaluations were always carried out in the morning, under identical conditions. The first evaluation consisted in morphostatic bilateral assessments (for the water polo players) and the second evaluation consist in isokinetic shoulder strength assessments. All the subjects provided signed informed consent prior to their participation. The protocol was conducted according to the Declaration of Helsinki.

Population

Subjects caracteristics were presented in table 1. All water-polo players were considered to be elite and highly trained at the time of testing (training duration >15h per week). Control subjects trained less than four hours of physical activity per week. All were right-hand dominant. None had a history of upper extremity injury, nor were they involved in regular upper arm activities.

-- Insert Table 1 here --

Isokinetic assessment

Isokinetic evaluations were performed using a CON-TREX dynamometer (CMV AG, Regensdorf, swiss). After a warm-up with an elastic band and arm cranking, subjects were familiarized with the test using 10 submaximal concentric repetitions at $120°\cdot s^{-1}$and three submaximal preliminary repetitions before each test speed data collection. Shoulders on both sides (dominant [D] and nondominant [ND]) of the subjects were assessed. The test was standardized to evaluate the right shoulder first. Measurements focused on the shoulder internal rotators (IR) and external rotators (ER). Subjects were placed in a supine position, with the arm abducted at 90° in the frontal plane and the elbow flexed at 90° [22]. To maximize the stability, the thorax and the elbow of the subject were stapped. The range of motion was standardized at between 50° of internal rotation and 70° of external rotation. The isokinetic speeds selected were $60°\cdot s^{-1}$ (three repetitions of testing) and $240°\cdot s^{-1}$ (twenty repetitions of testing) in the concentric mode and $60°\cdot s^{-1}$ (four repetitions of testing) in the eccentric mode. Successive testing velocities were separated by 90 seconds of rest. The isokinetic testing procedure enabled the measurement of absolute peak torque (PT; N·m) and total work (joules). Agonist–antagonist ratios (ER/IR) were calculated using the same speed and contraction mode for the agonist and antagonist muscle groups. A mixed ratio (combining ER PT in the eccentric mode at $60°\cdot s^{-1}$and IR PT in the concentric mode at $240°\cdot s^{-1}$) was also calculated [19]. The subjects were instructed and encouraged to reach the highest possible force level during these tasks but they did not receive any visual feedback .

Morphostatic bilateral assessments.

Internal and external passive glenohumeral rotations

Goniometric range-of-motion measurements of internal and external rotation of the dominant and the nondominant glenohumeral joint were made by the same physical therapist. Each subject was positioned supine on a table with the scapula stabilized, the humerus abducted to 90°, and the glenohumeral joint in neutral rotation. We then passively rotated the forearm of the subject to maximal external and internal rotation positions. The sides of a goniometer were placed along the ulnar border and perpendicular to the floor. The authors recorded maximal internal rotation when a firm end point was reached at the glenohumeral joint, just before the scapula protracted or the shoulder rotated up and off the table. External rotation measurement was recorded when a firm end point was reached, just before the back arched [23].

Scapular static position on the thorax

The subject stood, with arms at their side in resting condition. The examiner measured the distance (cm) between the spine of the scapula proximal border and the corresponding spinous process [24].

Forward presenting shoulder

The player was supine, with arms at their side, palms facing downward. A measurement was taken to quantify the distance (cm) between the posterior edge of the acromion and the table [25].

Statistical Analysis

All data are presented as means ± SD. The Shapiro–Wilk normality test was used to check the normal distribution of the data. A Student unpaired t test was used to identify differences between the control group and the water-polo players. The paired Student *t* was used to identify the significant differences between D and ND shoulders for the water-polo players group. All statistical analyses were carried out with the SPSS statistical package (version10, Chicago, IL) and $p<0.05$ was used as the accepted level of significance.

RESULTS

Isokinetic assessment

The comparison of isokinetic parameters of both groups are presented in table 2. In concentric contraction, the IR peak torque was stronger in water-polo players at velocities of $60°\cdot s^{-1}$ and $240°\cdot s^{-1}$ compared to control group (respectively +50% and +39% for D side and +46% and +30% for ND side). The control group displayed a lower total work over the exercices realized at $240°\cdot s^{-1}$ than the water-polo players ($P<0.05$). For the water-polo players, there was a difference between D and ND sides when comparing the PT developed by the IR at $60°\cdot s^{-1}$ ($P<0.05$). No difference between both groups and sides was observed for concentric contraction of ER at $60°\cdot s^{-1}$ and $240°\cdot s^{-1}$.

In excentric contraction, no difference was observed between both groups and sides for IR. The peak torque of ER was greater in water-polo players by 44% for D side and 38% for ND side ($p<0.05$).

No difference was found through the agonist–antagonist ratios between the D and the ND shoulders and the two groups (table 3). However, 16% of water-polo players presented a mixed ratio below 1.11 (range: 0.93 – 1.07) wheras no subject have ratio below 1.11 in the control group.

Morphostatic measurements :

The morphostatic measurements realized in water-polo players have shown a change in the glenohumeral joint movement (table 4). External passive glenohumeral rotation of the D shoulder was greater compared to the ND side ($P<0.05$). No significant difference was observed when we compared the other measures (IR glenohumeral mobility, spine of scapula/spinous process, forward presenting shoulder).

DISCUSSION

The results showed that intensive engagement in playing water polo will lead to an asymmetry in terms of force, with a dominance of the internal rotors of the dominant shoulder. The isokinetic performances of the water polo-players was stronger than controls. No difference was found through the agonist–antagonist ratios between the D and the ND shoulders and the two groups.

Peak torque measurements

Measurement of isokinetic torque production remains the preferred technique to assess peak muscle strength and to calculate the balance between agonist and antagonist groups [9]. Of all the positions described for shoulder muscle assessment of athletes in the cocking phase of throwing, the dorsal decubitus position with a shoulder adduction of 90° is considered to be the most suitable, while a seated position with 45° of shoulder adduction in the plane of the scapula (known as the modified Davies position) is thought to be the most relevant when it comes to pathologies [22]. Moreover, the position used in our study was assoicated with higher reproductibility and reliability for internal and external rotators [22].

Although isokinetic protocols are increasingly standardized (posture, saved settings, repetitions), the question concerning the speed of execution does not seem to have reached consensus yet. However, we believe that in the context of expertise, it is essential to take this element into account. An unsuited speed to the physical abilities of the subjects could lead to wrong conclusions. In our study, 3 subjects from the control group did not reach the faster speed (i.e. $240°\cdot s^{-1}$) and were excluded from the protocol. Faster is the velocity, smaller is the isokinetic phase. According to Osternig [26], for speeds of $300°\cdot s^{-1}$, the working phase at a constant speed does not exceed 55% of the range of motion (leg extension motion). This makes the interpretation of the results obtained during high-speed tests very random. We believe that beyond $240°\cdot s^{-1}$ with sedentary subjects, the part of the curve that is truly isokinetic is not large enough for the test carried out to be significant. Speeds close to $180°\cdot s^{-1}$ are probably best suited for the evaluation of the shoulder joint.

The main difference between water-polo players and control subjects is that the dominant shoulder of water-polo players is stronger than the non dominant shoulder. This imbalance had already been observed in previous studies [23, 24, 27]. This imbalance has been observed in men swimmers but not in women suggesting that the swimming practice per se favorise the imbalance of shoulder strength [23]. The muscular performance of our female players is close to those recorded in women who participate in throwing sports [21]. Therefore, it seems that imbalance observed in our study is the result of the the practice of high-level swimming and is probably accentuated by the throwing of repetitions.

Agonist/antagonist ratios

Quantitative establishment of the balance of the force between muscles with opposing actions requires investigation of the agonist/antagonist ratios [6]. Our results revealed a significant difference in the muscle performances between the two shoulders of our players whereas no difference were observed for the different ratios. Investigation of agonist/antagonist ratios is typically of the concentric contraction alone. The ratio observed in our study were in accordance with previous studies [9, 21]. However, use of the shoulder involves concentric as well as eccentric movements. A mixed ratio imbalance, reflecting weakness of the ER, would constitute the main risk factor for shoulder tendon pain [28]. Change in the agonist/antagonist balance with athletes is manifested particularly in the mixed ratio, with values that are consistently lower than the limit defined for healthy subjects [19]. The increase in the concentric force of the IR therefore does not appear to be proportionately compensated for by the braking action of the ER. Regarding the mixed ratios, some of the players exibit lower ratio (ratio lower than 1.11) compared to the other players. Such a profile could prove to be detrimental in terms of tendon lesions of this joint. Specific muscle training performed each week with gym equipment could be a reason for this. Most of the exercises used during gym session aim to developp IR peak torque and eccentric contraction exercises of ER was never used. Moreover, the exercises are performed at high intensity levels that promote peak force production by the internal rotors, the performance speeds are slow and close to those used for the isokinetic evaluation (60°/s). An imbalance of force between antagonist muscles triggers an abnormal excursion of the humeral head in the glenoid cavity, which can lead to impingement or instability [29]. More typical for purely concentric ratios, most studies have confirmed the relative weakness of the ER relative to the IR [5, 8, 10, 28]. This has proven to be detrimental to functioning of the shoulder area: the external rotors play an essential role at the end of the cocking phase since, by keeping the humeral head in the glenoid cavity, they limit tensioning of the interior glenohumeral ligament [30]. At the biomechanical level, the integration of eccentric contraction of the ER in the establishment of the agonist/antagonist relationship seems obvious. Eccentric engagement of the posterior muscle girdle ensures a protective role upon throwing: the braking action limits the anterior translation of the humeral head upon powerful concentric contraction of the IR.

Morphostatic assements

The clinical examination showed a significant change in IR glenohumeral mobility: 124.1 ±8.9° for the dominant shoulder (D) *vs*. 114.3 ±7.5° for the non dominant side (ND, $p<0.05$). In keeping with the literature [31, 32], we observed an increased range of external rotation and a decreased range of internal rotation [33]. This change could be explained by the repetitive nature of the throws, since with this action the external rotors convert their concentric contraction for the cocking phase into an eccentric control during the final stages of arm deceleration. This hypermobility is not a problem in itself, but it can become one when muscle fatigue sets in. At the end of training, for example, the shoulder may be engaged without the humeral head necessarily being centered [34]. It is at this stage that a player can injure their periarticular structures, thereby triggering a painful condition. As for the other tests, our measurements did not reveal any differences between the shoulders. The results of these clinical tests must be interpreted with caution since some studies have raised the possibility that there is no connection between the results of these evaluations and the pain or the severity of the injury. Conversely, the isokinetic data underscores that there are substantial differences between the two shoulders.

Pratical applications

Wilk et al. 2002 [35] and Kibler 2003 [29] suggest to use concentric and eccentric ER strengthening exercises at the conclusion of a preventative and curative athlete’s shoulder treatment to compensate for the weakness of the posterior girdle. They emphasize that an adequate compensatory strengthening of the antagonists (ER) does not seem to be detrimental to on-field performance [10]. We believe that preventive strengthening of the ER for concentric and eccentric contraction modes, while keeping the IR in shape, would avoid an agonist/antagonist imbalance, without harming the overall competitive performance. We suggest to use analytic movements to strengthen ER. A specific work outside of the water should used because the water did not offer solid support to better control the movement.

Studies pertaining to rebalancing of the ratios, the development of performance and the extent of shoulder injury should be considered.

Conclusion

Intensive engagement in playing water polo will lead to an asymmetry in terms of force, with a dominance of the internal rotors of the dominant shoulder. The players also present greater peak torque force of external rotor compared to control subjects when assessed during eccentric contraction. Some players present low mixed ratio that could be detrimental in terms the susceptibility toward shoulder tendon lesions.

Disclosure of interest

The authors declare that they have no competing interest.

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Table 1: Mean physical characteristics of control and water-polo players

	Control (n=10)	Water-polo players (n=18)
Age (years)	22 ± 2	22 ± 3
Height (cm)	167 ± 10	172 ± 8
Weight (kg)	62 ± 5	67 ± 10
Dominant hand		
right	10	18
left	0	0

Values are presented as mean ± SD. No difference was osberved between the groups.

Table 2 : Isokinetic performance of D and ND shoulders corresponding to the whole population of the study.

Motion	Control (n=10)		Water-polo players (n=18)	
peak torque	D Side	ND Side	D Side	ND Side
IR CON 60 (N·m)	24.9 ±4.7 †	23.5 ±4.6 †	37.3 ±9.6	34.4 ±8.5*
ER CON 60 (N·m)	18.1 ±2.7	18.7 ±2.1	23.6 ±9.5	24.4 ±5.1
IR CON 240	22.9 ±2.1 †	23.2 ±1.9 †	31.9 ±5.9	30.2 ±6.1
ER CON 240	17.8 ±1.6	18.8 ±1.4	20.9 ±3.4	21.3 ±4.1
IR ECC 60	27.4 ±2.4	26.8 ±2.1	29.9 ±7.2	29.5 ±7.2
ER ECC 60	28.1 ±1.9 †	29.1 ±1.2 †	40.6 ±10.3	40.1 ±9.4
Total work (J)	D Side	ND Side	D Side	ND Side
IR CON 240	572.2 ±57.7 †	545.4 ±63.5 †	1033.9 ±200.4	981.4 ±210.1
ER CON 240	463.8 ±35.9 †	428.6 ±46.5 †	636.9 ±124.4	645.1 ±141.1

Values are presented as mean ± SD.
ER, External Rotators, IR, Internal Rotators; Con 60 = $60°\cdot s^{-1}$, concentric mode; Con 240 = $240°\cdot s^{-1}$, concentric mode; Ecc 60 = $60°\cdot s^{-1}$, eccentric mode;.† $p<0.05$ between the control and water-polo players. * $p<0.05$ between the D and ND shoulders.

Table 3 : Isokinetic ratios of water polo players and control group for the both shoulders

Motion	Control (n=10)		Water-polo players (n=18)	
	D Side	ND Side	D Side	ND Side
ER / IR concentric ratios				
Angular velocity of 60° /s	0.73 ±0.16	0.79 ±0.14	0.63 ±0.11	0.70 ±0.12
Angular velocity of 240° /s	0.77 ±0.07	0.81 ±0.08	0.66 ±0.09	0.71 ±0.12
Mixed ratio				
ER ecc 60°/s / IR con 240°/s	1.23 ±0.06	1.26 ±0.09	1.27 ±0.21	1.32 ±0.23
Mixed ratio <1.11 (%)	0	0	16	0

Values are presented as mean ± SD. Con, concentric mode; Ecc, eccentric mode; ER, External Rotators, IR, Internal Rotators. Conc 60°·s^{-1} = 60°·s^{-1} , concentric mode; Conc 240°·s^{-1} = 240°·s^{-1} , concentric mode; Ecc 60 = 60°·s^{-1} , eccentric mode. No difference was osberved between the groups.

Table 4 : morphostatic results for water-polo players

	Dominant shoulder	Non dominant shoulder
IR glenohumeral mobility (°)	55.5 ±12.8	57.8 ±13.2
ER glenohumeral mobility (°)	124.1 ±8.9	114.3 ±7.5*
Spine of scapula/spinous process (cm)	7.5 ±2.1	7.1 ±1.8
Forward presenting shoulder (cm)	6.6 ±0.9	6.7 ±0.8

Values are presented as mean ± SD. IR, internal rotators. ER, external rotators. * p<0.05 between the D and ND shoulders.