0363-5465/98/2626-0247$02.00/0
THE AMERICAN JOURNAL OF SPORTS MEDICINE, Vol. 26, No. 2

Humeral Torsion in the Throwing Arm of Handball Players*

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ABSTRACT

Sport-specific upper extremity strain, mostly unilateral, during growth may lead to adaptations in soft tissue and bone. We investigated 51 male professional handball players between 18 and 39 years of age (average, 27 years), 39 right-handed and 12 left-handed. Thirty-eight players had no shoulder problems, and 13 had chronic shoulder pain. Humeral retrotorsion was determined by radiograph. The differences between the throwing and contralateral arms were compared with those of 37 controls who had no history of unilateral strain either through sports or profession. Standard statistical analysis was performed using the *t*-test. The retrotorsional angle of the humerus in the handball professionals' throwing arm was an average of 9.4° larger in the dominant side than in the nondominant, with a side-to-side difference up to 29°. In the control group, no statistically significant difference was found. In the group without chronic shoulder pain, the side-to-side difference was an average of 14.4° more in the throwing arm than the other side. Players with chronic shoulder pain did not exhibit this increase, even showing an average decrease of humeral retrotorsion of 5.2° in the throwing arm. The humeral retrotorsion increase can be explained as an adaptation to extensive external rotation in throwing practice during growth. Athletes who do not adapt this way seem to have more strain on their anterior capsules at less external rotation and develop chronic shoulder pain because of anterior instability.

The Olympic discipline of *team handball* (as it is called in the U.S.) or just *handball* (as it is called everywhere else) is a fast-moving sport that combines certain elements of basketball, soccer, and hockey.[10,29] The idea of the game is to move a "cantaloupe-sized"[10] leather ball (circumference, 58 to 60 cm) down the court by dribbling and passing, but instead of throwing the ball into a basket, it has to be thrown past a goalkeeper and into a goal. Handball has been compared with basketball without baskets, ice hockey without sticks and ice, water polo without water, and indoor soccer without kicking.[20]

The teams consist of seven players each, including the goalkeeper. The offensive team has to move the ball down the court by running with it, dribbling it, and passing it among teammates, and finally throwing it into the goal from behind a 6-meter line (Fig. 1) or while still in the air after jumping from behind this line before touching the floor (Fig. 2). The defensive team tries to interfere by blocking the ball (Fig. 1) or disturbing the opponent while he is trying to catch a ball. Hitting, pushing, holding, and tripping an opponent are not allowed and may result in a free throw and a warning, or a 2-minute suspension in case of unusually rough play. Yet, there is still a lot of pushing and shoving going on (Fig. 3).

Since handball is a throwing sport as well as a body-contact sport, large demands are placed on the shoulder joint, especially on the capsulolabral complex as a joint stabilizer. In a season of practice and competition, each player performs at least 48,000 throwing motions,[18] with the ball weighing 425 to 475 g and at throwing speeds up to 130 km/hr.[8] These forces will affect the joint, especially during the cocking phase of the throw. In addition, the defense will strain the shoulder by charging the arm (Fig. 3).

The incidence of acute or chronic shoulder pain in handball players has been reported as being between 30% and 45%.[14,22] The main reason for chronic shoulder pain in handball—like many other overhead sports—is secondary subacromial syndrome due to primary shoulder instability.[18,28]

When comparing the maximal amount of external shoulder rotation in the throwing arm of handball players with that of the nondominant side, in almost every handball player an increase of external rotation can be found in

* Presented at the 2nd World Congress on Sports Trauma/22nd annual meeting of the AOSSM, Lake Buena Vista, Florida, June 1996.

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Neither the author nor the related institution has received any financial benefit from research in this study.

Figure 1. Throw at the goal from behind the 6-meter line, defensive team trying to block.

Figure 2. Throw at the goal while still in the air after jumping from behind the 6-meter line.

Figure 3. Defensive action that results in a free throw.

the throwing arm, with an average difference of about 10° to 15° (Fig. 4).[23] This fact by itself is not surprising, because it could be explained by anterior laxity due to chronic overuse, i.e., stretching the joint capsule and ligaments. If anterior laxity were indeed the sole cause for the difference in external rotation ability, however, the amount of internal rotation would not be affected. Yet, among our subjects, we observed a considerable reduction of maximal internal rotation of the dominant arm (Fig. 5).[24] Differences of about the same magnitude (approximately 10°) have been reported for athletes in unilateral overhead or throwing sports like tennis[4,5,13] or baseball.[2,19] In the literature, these findings have been explained by a tightening of the posterior capsule by means of fibrotic changes[5]; however, a plausible explanation for this shrinking has not yet been established, since the athletes use their arms normally in everyday life without avoiding movements involving internal rotation (e.g., hygiene care).

One aim of the present study was to investigate whether this lateral difference can be explained by an osseous component, i.e., a side-to-side difference in the torsional angle of the humerus. (As compared with the axis of the elbow joint, the humeral head is directed inward and backward. This is called retroversion of the humeral head or retrotorsion of the humerus, respectively.[26] The angle measured is the acute angle between the axis of the elbow joint and the axis of the humeral head.) The second aim was to investigate whether the existence or nonexistence of such a side-to-side difference could be a major factor in the occurrence of chronic shoulder problems in handball players.

MATERIALS AND METHODS

To investigate these questions, the angle of humeral retrotorsion was determined in both shoulders of 51 male handball professionals, 39 of them right-handed and 12 left-handed (Tables 1 and 2), between June 1992 and October 1996. Forty-five were first-league players, 34 of them had played on their national handball teams. The remaining six were players of junior national teams: one from Poland, one from Hungary, and the other four from Germany. The players ranged in age from 18 to 39 years (average, 27; SD, 5.0). All of them had started competitive handball before the age of 10. They had to have at least 5

Figure 4. A right-handed handball player shows maximal external rotation is increased on the right side (dominant arm).

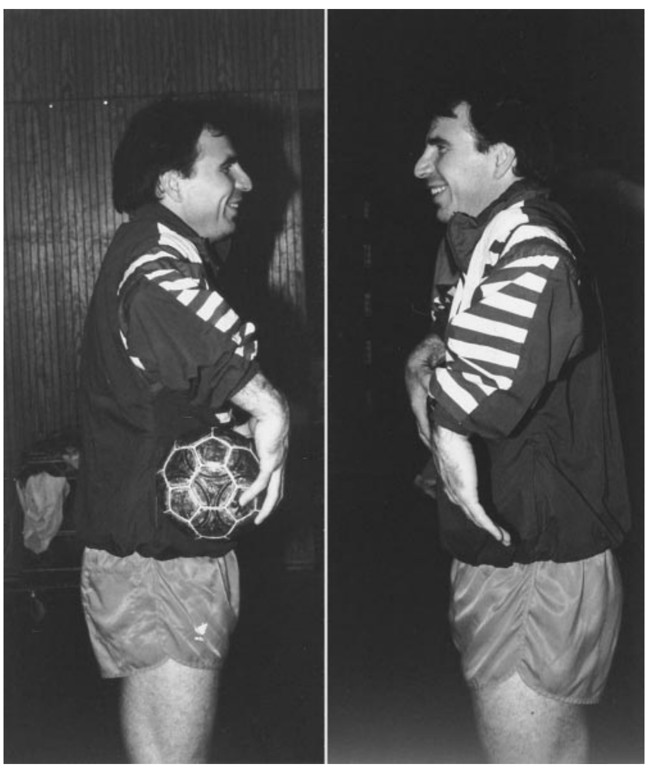

Figure 5. Same player as in Figure 4 shows deficit of internal rotation of the right (dominant) shoulder.

years of team competition to be included in our study. Thirty-eight of them had no history of shoulder problems, and 13 players complained of chronic shoulder pain. In clinical examination, all of these 13 players demonstrated signs of mild anterior laxity, showing positive apprehension and relocation tests, but without being aware of any instability.

TABLE 1
Humeral Retrotorsion in Professional Handball Players Without Chronic Shoulder Pain (in Degrees)

	Age (years)	Handedness	Throwing arm	Contralateral arm	Difference
	30	r	49	34	15
	22	r	66	48	18
	20	r	58	46	12
	28	l	35	32	3
	24	r	32	10	22
	35	r	37	21	16
	29	l	52	29	23
	34	r	34	29	5
	29	l	50	36	14
	25	r	63	52	11
	25	r	52	37	15
	20	r	49	31	18
	19	r	58	34	24
	22	r	38	25	13
	25	r	40	29	11
	31	r	45	18	27
	28	l	48	38	10
	27	r	55	48	7
	28	r	70	56	14
	28	r	53	40	13
	19	r	39	31	8
	18	r	63	53	10
	37	r	58	37	21
	24	r	56	46	10
	29	r	47	32	15
	36	r	45	38	7
	24	r	57	41	16
	29	r	46	30	16
	28	r	50	35	15
	21	r	42	27	15
	28	l	38	20	18
	20	l	40	30	10
	33	r	59	30	29
	23	r	47	28	19
	26	r	44	29	15
	29	r	61	43	18
	29	r	55	48	7
	25	r	34	27	7
Mean	26.5		49.08	34.68	14.39
SD	4.87		9.78	10.18	5.95

The same measurements were performed on a control group of 37 male subjects, all well above the age of epiphyseal closure (Table 3). None of those included in the control group had participated in any unilateral athletic discipline like throwing or racket sports as youngsters or had performed any unilateral manual labor while growing up. They suffered from no severe systemic illness, bone lesions, or shoulder instability. Each subject and control was examined once.

The osseous component was studied in terms of humeral retrotorsion, which was determined by a special radiographic technique that was first published in 1982.[26] In this technique, the upper arm is imaged in two defined planes: Plane I is the standard AP view in 40° of external rotation. This view is used to determine the angle of the

TABLE 2
Humeral Retrotorsion in Professional Handball Players with Chronic Shoulder Pain (in Degrees)

	Age (years)	Handedness	Throwing arm	Contralateral arm	Difference
	31	r	37	38	−1
	30	r	36	43	−7
	27	l	28	49	−21
	32	l	45	46	−1
	18	l	36	36	0
	39	r	27	22	5
	28	r	56	54	2
	31	l	31	50	−19
	23	r	34	33	1
	28	l	34	47	−13
	31	l	36	47	−11
	21	r	32	25	7
	27	r	29	38	−9
Mean	28.15		35.46	40.62	−5.15
SD	5.35		7.75	9.73	8.93

TABLE 3
Humeral Retrotorsion in Control Group (in Degrees)

	Age (years)	Handedness	Dominant arm	Contralateral arm	Difference
	41	r	36	38	−2
	43	r	39	37	2
	25	r	44	31	13
	27	r	41	34	7
	56	l	44	46	−2
	71	r	46	28	18
	47	r	44	45	−1
	61	r	45	42	3
	35	r	42	48	−6
	41	r	42	53	−11
	74	l	40	39	1
	72	r	37	39	−2
	51	l	47	47	0
	57	r	41	35	6
	43	r	47	39	8
	58	r	34	45	−11
	50	r	36	44	−8
	44	r	48	48	0
	41	r	45	37	8
	45	r	36	29	7
	61	r	36	34	2
	20	r	46	34	12
	38	r	36	30	6
	42	l	48	48	0
	38	r	47	48	−1
	37	r	40	34	6
	27	r	44	45	−1
	55	r	44	36	8
	49	r	48	37	11
	59	l	41	39	2
	53	r	34	33	1
	44	r	47	40	7
	36	r	30	26	4
	58	r	34	42	−8
	45	r	34	48	−14
	41	r	48	47	1
	43	r	43	44	−1
Mean	46.70		41.46	39.70	1.76
SD	12.69		5.08	6.76	6.97

neck shaft. For plane II, the arm is placed in a special holding device (Fig. 6). The axis of the elbow joint is positioned parallel to a marker bar on the table. The upper arm is tilted laterally at an angle of 15° to prevent the contour of the elbow joint from being projected over that of the humeral head. In this plane the projected torsional angle of the humerus is measured (Figs. 7 and 8). The true torsion values can be obtained from a correction table[25] similar to the one used by Rippstein[28] in determining femoral antetorsion. The validity of this radiographic method was proven to be very high (correlation between angles measured on bone directly and determined by radiography: $r = 0.97$).[26]

Radiographs of all subjects were made using a Philips BT - S4 machine (Eindhoven, Holland) on AGFA Crurix RP1L film (AGFA Co., Köln, Germany) with a film-to-focus distance of 100 cm (44 kV per 22 mA). Interindividual variation in positioning the patient was minimized by having this standardized procedure implemented by the same operator and device for each patient. The interpretation of each film was done by the author to ensure consistency. The differences between the throwing and contralateral arms were compared with those of the controls who had no history of unilateral strain. Standard statistical analysis was performed using a one-tailed or two-tailed t-test, respectively, on the values obtained. The threshold was set at the 0.01 level of statistical significance.

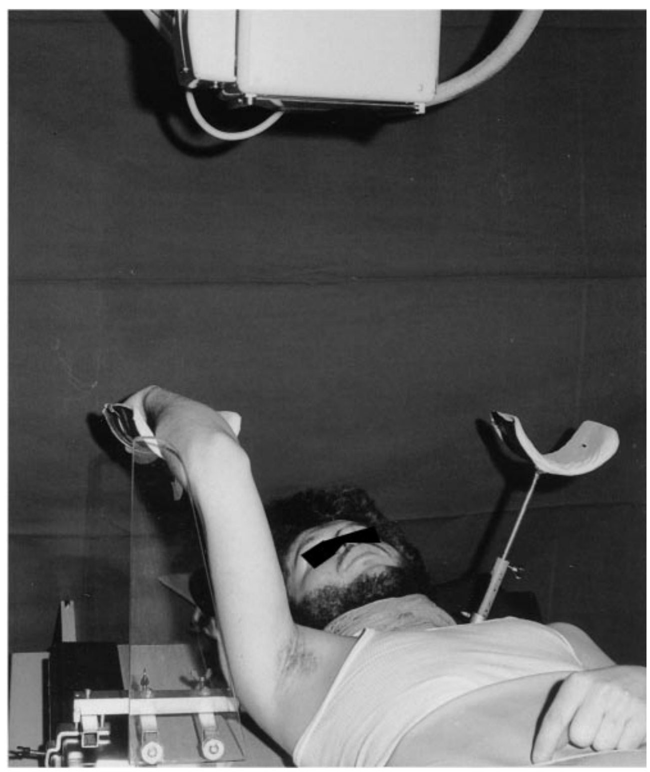

Figure 6. Special holding device for radiograph in plane II.

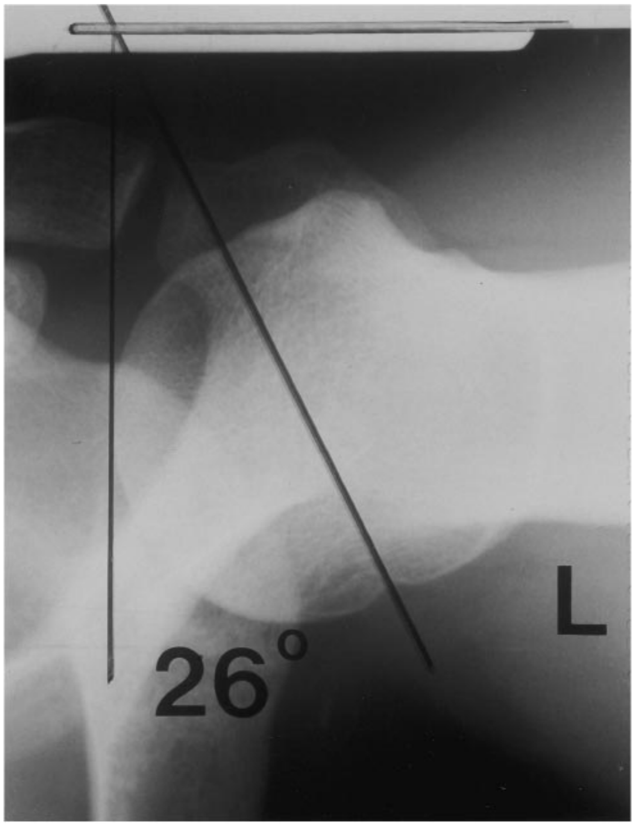

Figure 7. Axial view in a special radiographic technique.[25] Projected angle of humeral retrotorsion of the left (nondominant) shoulder in a right-handed handball player.

RESULTS

The retrotorsional angle of the humerus in the throwing arm of the handball professionals was found to be an average of 9.4° larger in the dominant side than in the nondominant with a side-to-side difference ranging from 29° to −21° (Tables 1 and 2). The side-to-side difference is significant ($P < 0.01$). In the control group, however, no statistical significance was found ($P = 0.134$), the average increase being only 1.8° (Table 3). This finding is in line with those of Kronberg et al.,[17] who reported an average increase of 4° in the dominant arm of 50 nonathletes.

In the group of 38 handball players without chronic shoulder pain, the side-to-side difference was much more pronounced. In this group, humeral retrotorsion was increased by an average of 14.4° in the throwing arm as compared with the other side, the differences ranging from 3° to 29° (Table 1). This average side-to-side difference is even higher than the average side-to-side difference found between all handball professionals and the control group ($P < 0.01$).

The group of 13 handball players with chronic shoulder pain, on the other hand, did not exhibit this increase. They even showed an average decrease of humeral retrotorsion of 5.2° in the throwing arm as compared with the contralateral side ($P = 0.0596$) (Table 2). The side-to-side differences between the group of players with chronic shoulder pain ($N = 13$) and the group without chronic shoulder pain ($N = 38$) was again statistically significant ($P < 0.01$).

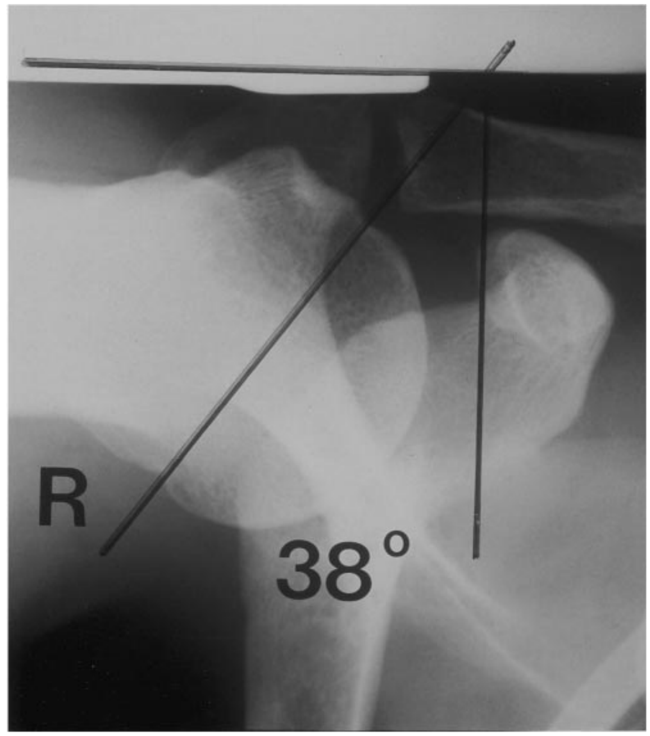

Figure 8. Axial view of the right shoulder, same player as in Figure 7: substantial increase of humeral retrotorsion on the dominant side.

When comparing the average retrotorsional values between the dominant arms of the handball professionals without any chronic shoulder pain with those of the control group, the average increase in the handball players' retrotorsional values amounts to 7.62°. This difference is significant ($P < 0.01$). Our data show no significant difference between the group of handball players with chronic shoulder pain and the control group ($P = 0.02$).

DISCUSSION

The present findings demonstrate that the development of capsular laxity does not always constitute a satisfactory explanation for increased external shoulder rotation ability in handball players. Instead, the importance of the osseous component, the humerus, is strongly suggested by our measurements.

The motivation to investigate a possible osseous component in the lateral rotational differences was twofold. First, it has been demonstrated that there is a relationship between bone growth and unilateral strain,[11,15] and second, it has been shown that humeral retrotorsion is subject to change during growth until maturity is reached.[16]

A large amount of humeral retrotorsion allows for more

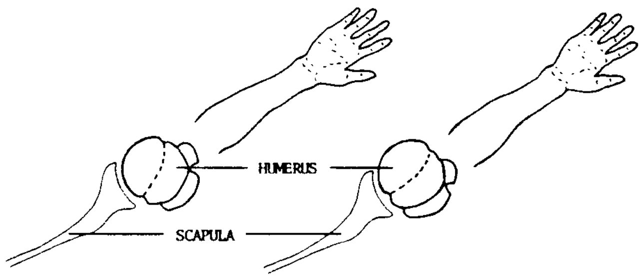

Figure 9. Position of the humeral head with respect to the glenoid cavity in external rotation of the arm: effect of higher (left) and lower (right) angle of humeral retrotorsion.

external rotation of the shoulder joint before the humeral head is constrained by the anterior capsule and the glenohumeral ligaments (Fig. 9). It therefore enables the handball player to extend the cocking phase and thus further accelerate the throw.

The angle of humeral retrotorsion will also affect the amount of internal rotation of the respective shoulder. A larger angle will lead to an earlier restraint of the humeral head by the posterior capsule and thus limit internal rotation. This serves as a sufficient explanation for the deficit in internal rotation that is observed in the throwing arm of handball players. Additional contracture of the posterior capsule, as suggested by Abrams,[1] Chinn et al.,[5] and Field and Altchek,[7] is thus possible, but by no means necessary.

A closer look at anatomic research shows that osseous adaptation processes are not unusual. According to Wolff,[31] all bone growth is determined by functional forces. Biopositive reactions of the bone through unilateral use of the arm have been shown in the literature. For example, as an adaptational process in the dominant arm of tennis professionals, Jones et al.[11] found a widening of cortical thickness of the humeral shaft by 34.9% in men and 28.4% in women. Krahl et al.[15] in 1994 reported a limb lengthening in tennis professionals' dominant arms due to unilateral strain.

Specifically, it has been demonstrated that humeral torsion can be increased by muscular action.[6,9,16] One hundred years ago, in 1897, Hultkrantz[9] already knew that ". . . the way of living, activities (e.g., throwing), influence the individual transformation of the humeral bone."

Wermel[30] showed in 1935 that there is a relationship between the function of the "hand" and humeral torsion in rabbits by cutting off certain muscles during animal growth and later comparing humeral torsion between the operated and nonoperated sides. He found torsional differences up to 37.5°

In the U.S., Evans and Krahl[6] performed studies on the relationship between humeral torsion and the muscle tension of the rotators. They described humeral torsion as the result of an interaction of two factors: an evolutionary or hereditary (genetic) one they called *primary torsion* and an ontogenetic or *secondary torsion* produced by muscular forces. Krahl[16] found that "Contractions of the humeral rotators tend to cause a turning of the shaft with respect to the proximal epiphysis. Although [these forces are] too weak to produce displacement [of the epiphyseal disk], they may well have a formative influence in directing the growth of new bone in a spiral fashion." He concluded that an increase in muscle tension of the external rotators leads to lateral rotation of the distal humerus and thus to increased humeral retrotorsion. According to the investigations performed by Krahl, the amount of secondary torsion produced by muscle forces differs from individual to individual because of the different muscle force exerted, and primary torsion is genetically determined in humans without much variation.[16]

A Japanese study that was recently published suggests that muscle forces induced by excessive throwing practice alone may be much more powerful than previously known. Kanematsu et al.[12] even reported displacements of the humeral epiphysis in Little League baseball pitchers that led to neck deformity and longitudinal growth disturbance. In their opinion, this disorder of bone formation was caused by repetitive mechanical stress to the proximal humeral epiphysis during growth.

The increase of humeral retrotorsion in the throwing arm of handball players described here can be looked at as a process of adaptation to excessive external rotation in throwing practice during growth. The actual occurrence of torsional adaptation in athletes had never been documented until the preliminary results of the present study were published in 1995.[21] Just recently, however, these findings were confirmed by a similar study about torsional changes in the dominant arm of baseball pitchers, the increase in retroversion of the humeral head averaging 11.75°.[3] This magnitude is comparable with that of the present study.

The increase of humeral retrotorsion in the throwing arm of handball players allows more external rotation of the shoulder before the humeral head puts excessive strain on the anterior capsulolabral complex and thus may lead to anterior instability. An increase of humeral retrotorsion could thus be interpreted as a protection mechanism for the anterior capsulolabral complex. Therefore, the torsion values for those athletes with chronic shoulder pain were examined more closely. It turns out that in this group the torsion in the dominant arm does not significantly differ from that of the nondominant arm. It seems safe to conclude that these players' dominant arms failed to undergo the adaptation process. Even though one can only speculate about the reasons for this, it is reasonable to assume that these players either did not start their specific throwing practice early enough in their lives or that the amount of strain on the epiphyseal plate was insufficient for an osseous reaction to occur. This hypothesis is supported by an observation of two older players (44 and 58 years of age) who acquired their handball skills in the 1960s, i.e., at a time when intensive practice did not start at as early an age as it does nowadays. These players do not exhibit any significant side-to-side difference in humeral retrotorsion even though they were good enough to play on their respective national teams.

CONCLUSION

The increase of humeral retrotorsion in the throwing arm of handball players seems to be an adaptational process due to extensive external rotation in throwing practice during growth. This increased retrotorsion allows more external rotation of the shoulder before the humeral head puts excessive strain on the anterior capsulolabral complex and thus may lead to anterior instability. An increase of humeral retrotorsion could thus be interpreted as a protection mechanism for the anterior capsulolabral complex.

Those athletes who—by some as yet unknown reason—do not exhibit this biopositive response to practice in childhood seem to have more strain on their anterior capsules at an earlier degree of external rotation. Thus, they might be prone to develop chronic shoulder pain due to anterior instability.

The question of whether the torsional changes observed correlate with the starting age of playing handball or the intensity of practice strain cannot be provided with a definite answer by this study because, besides the fact that only top national and international handball professionals were included, the exact number of practice hours or the extent of practice intensity over the years could not be exactly recorded retrospectively. Future prospective studies shall be designed to further explore this question.

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