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GIRD syndrome in male handball and volleyball players: Is the decrease of total range of motion the turning point to pathology?

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Abstract.
BACKGROUND: Adaptations in glenohumeral range of motion may affect overhead athletes and lead to shoulder pathologies.
OBJECTIVE: The purpose of this study was to evaluate glenohumeral internal rotation deficit (GIRD) and postero-superior impingement among male handball and volleyball players and the relationship between these pathologies and training level (amateur vs. professional), position (attack vs. no attack), experience ($>$ 5 years vs. $<$ 5 years) and sports.
METHODS: Sixty-seven handball players and 67 volleyball players with a mean age of 25 [$\pm$ 5] years were included. The range of motion including external and internal rotation in 90° abduction of the dominant and non-dominant shoulder was measured of each examined athlete. Visual analogue scale, disabilities of the shoulder and hand score, constant score and subjective shoulder value were recorded. The athletes were examined for postero-superior impingement and abduction force was measured with an isokinetic dynamometer.
RESULTS: Internal rotation was significantly lower and external rotation was significantly greater in the dominant arm for both sports. 72% presented with GIRD. GIRD was more prevalent in athletes active for $>$ 5 years (odds ratio (OR) 3), in those training $>$ 3 times per week (OR 1.4) and in handball players (OR 2.7). 24% presented with postero-superior impingement. Players active for $>$ 5 years (OR 1.22), professionals (OR 1.14), volleyball players (OR 1.19), offensive players (OR 2.2) and athletes with GIRD $>$ 10° (OR 1.5) showed a higher prevalence of postero-superior impingement.
CONCLUSION: GIRD is a common phenomenon in handball and volleyball players. Offensive players are frequently suffering from postero-superior impingement. GIRD $>$ 10° leads in nearly 75% of the athletes to a decrease of total range of motion and a high rate of postero-superior impingement. Thus, a decreased range of motion seems to be the turning point from adaptation to pathology. Therefore, regular controls of range of motion and countermeasures by means of stretching the posterior shoulder joint should be integrated in the training content.

Keywords: GIRD syndrome, internal impingement, handball, volleyball, glenohumeral internal rotation deficit, SLAP lesion

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1. Background

Shoulder injuries are common in overhead sports such as handball, tennis, volleyball or baseball as the overhand throwing or serving motion produces large loads and forces on the joint tissues as a result of the high velocities and large range of motions. Various studies have documented that in the dominant arm compared with the non-dominant arm the magnitude of glenohumeral internal rotation (IR) is decreased and the magnitude of glenohumeral external rotation (ER) is increased in most throwing athletes [1–4]. Understanding these adaptive changes is important in the prevention and treatment of specific injuries. Some described changes in the throwing shoulder are tightening of the posterior capsule, stretching of the anterior capsule and changes in muscle balance [5–8]. Even bony changes like an increased retroversion of the humeral head in skeletally immature overhead athletes are reported [9,10]. These modifications contribute to the phenomenon of decreased shoulder internal rotation which has been termed glenohumeral internal rotation deficit (GIRD) syndrome [1,6,11,12] and cause altered glenohumeral arthrokinematics by shifting the instant center of rotation of the humeral head to an antero-superior position on the glenoid fossa during forward flexion [5] and a postero-superior position with ER and cocking [13–15]. In 1993, Walch et al. created the term "postero-superior impingement" (PSI) to describe this intraarticular pathology found in magnetic resonance imaging (MRI) of overhead athletes [16]. During late cocking the greater tuberosity impinges against the glenoid rim and causes lesions to the postero-superior labrum and articular side of the supraspinatus (SSP) tendon.

The purpose of this study was to evaluate glenohumeral internal rotation deficit (GIRD) and postero-superior impingement (PSI) among male handball (HBP) and volleyball (VBP) players and the relationship between these pathologies and training level (amateur vs. professional), position (attack vs. no attack), experience (> 5 years vs. < 5 years) and sports.

2. Materials and methods

In total 6 handball and 6 volleyball teams of different proficiency levels were included in this epidemiological, cross-sectional study and were examined between January and December 2018. Institutional review board approval was obtained prior to commencing the study. A statistical power analysis was performed using G*Power 3.1 [17]. The minimum number of athletes was set to be $n = 128$ ($\beta > 0.8$). All athletes signed informed consent and approved the use of their data for scientific purposes.

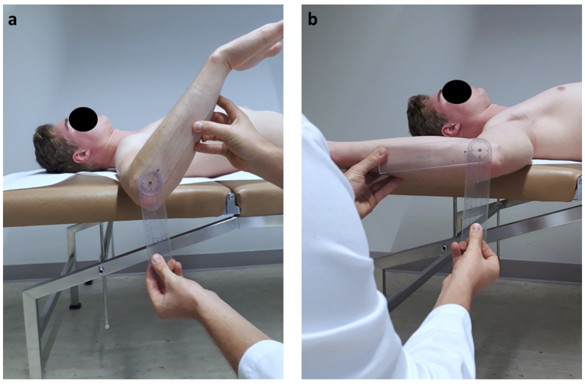

Fig. 1. Measurement of external and internal rotation in 90° abduction using a goniometer with the athlete lying in supine position on a treatment table to prevent scapulothoracic movement.

2.1. *Questionnaire and physical examination*

All players were asked to complete a questionnaire regarding their demographics, prior injuries or operations, presence of pain, age at which they started to play, number of training sessions per week, field position and arm dominance. Range of motion (ROM) including external (ER) and internal rotation (IR) in 90° abduction of the dominant and non-dominant shoulder was measured using a goniometer with the athlete lying in supine position on a treatment table to prevent scapulothoracic movement (Fig. 1). All measurements were performed towards the end of the season as Dwelly et al. [18] showed a changing incidence of GIRD throughout the season and after warm-up in a cohort of baseball players. GIRD was defined as an IR difference $\geqslant 5°$ compared to the non-dominant arm. Visual analogue scale (VAS) for pain, quick disabilities of the shoulder and hand (DASH) score, constant score (CS) and subjective shoulder value (SSV) were recorded. In addition, a standardized physical examination was performed by a single examiner using the Supine-Flexion-Resistance-Test in order to detect a possible lesion of the superior labrum anterior-to-posterior (SLAP) complex and the Jobe-Test for possible SSP pathologies. Further standardized tests for other shoulder disorders like acromioclavicular joint pathologies or scapular dyskinesia were also performed. If SLAP or SSP testing was positive the athlete was counted as pos-

Table 1
Baseline characteristics

	Handball	Volleyball	Total
Number of athletes included	67	67	134
Age in years [SD]	25 [± 6]	26 [± 5]	25 [± 5]
Position (attack/no attack)	32/35	37/30	69/65
Training frequency (3 ⩽/> 3)	29/38	32/35	61/73
Experience in years [SD]	17 [± 5]	10 [± 5]	14 [± 6]
Handedness (left/right)	9/58	4/63	13/121
GIRD (yes [percentage]/no)	55/12 [**82%**]	42/25 [**63%**]	97/37 [**72%**]
PSI (yes [percentage]/no)	15/52 [**22%**]	17/50 [**25%**]	32/102 [**24%**]

SD: standard deviation; GIRD: glenohumeral internal rotation deficit; PSI: postero-superior impingement.

Table 2
Measurements of glenohumeral internal rotation, external rotation, and total range of motion in degrees with regard to sport and considering all examined athletes

	Handball			Volleyball			All athletes		
	Mean	SD	p	Mean	SD	p	Mean	SD	p
Dominant arm									
IR at 90° [degrees]	71	12		74	10		72	11	
ER at 90° [degrees]	103	8		95	10		99	10	
Total ROM [degrees]	174	15		169	14		172	15	
Non-dominant arm									
IR at 90° [degrees]	81	9		80	10		81	10	
ER at 90° [degrees]	92	5		91	7		92	6	
Total ROM [degrees]	174	11		171	12		173	12	
Differences									
GIRD [degrees]	11	9	$p < 0.01$	6	7	$p < 0.01$	8	8	$p < 0.01$
ERG [degrees]	11	7	$p < 0.01$	4	6	$p < 0.01$	7	7	$p < 0.01$

ER: external rotation; ERG: external rotation gain; GIRD: glenohumeral internal rotation deficit; IR: internal rotation; p: P-value; ROM: range of motion; SD: standard deviation.

itive for PSI. Finally, abduction force of the dominant and non-dominant arm was measured at 90° abduction with an isokinetic dynamometer.

2.2. Inclusion and exclusion criteria

Inclusion criteria were: same level of competitiveness over the last two years.

Exclusion criteria were: age under 18 years; history of shoulder surgery; history of shoulder dislocation; and overhead worker.

2.3. Statistical analysis

Statistical analysis was performed with SPSS version 22 (IBM, Armonk NY, USA) using the independent samples Mann-Whitney U-test and the Kruskal-Wallis test. Quantitative variables were described by means, standard deviations, minimums and maximums. Normal distributions were tested by the Shapiro-Wilk. In order to determine factors affecting the prevalence of GIRD syndrome and internal impingement the odds ratios (OR) for the following parameters were calculated: training level (amateur vs. professional), position (attack vs. no attach), experience (> 5 years vs. < 5 years) and sports (handball vs. volleyball).

P values ⩽ 0.05 were considered to be significant.

3. Results

A total of 134 out of initially 157 male over-head athletes (67 handball players (HBP) and 67 volleyball players (VBP)) were included after the exclusion criteria were applied. Athletes with four or more training sessions per week were classified as "professionals" whereas players with three or fewer sessions per week were classified as "amateurs". The players' positions were dichotomized in "attack" and "no attack". Baseline characteristics are summarized in Table 1.

In both HBP and VBP there was a significant difference in IR and ER at 90° abduction between the dominant and non-dominant arm (IR HBP 71 ± 12° vs. 81 ± 9° [$p < 0.001$], IR VBP 74 ± 10° vs. 80 ± 10° [$p < 0.001$]; ER HBP 103 ± 8° vs. 92 ± 5° [$p < 0.001$], ER VBP 95 ± 10° vs. 91 ± 7° [$p = 0.02$]). Total ROM

Table 3
Measurements of glenohumeral internal rotation, external rotation, and total range of motion in degrees for different levels of GIRD

	No GIRD ($n = 37$)			GIRD 1–10° ($n = 74$)			GIRD > 10° ($n = 23$)		
	Mean	SD	p	Mean	SD	p	Mean	SD	p
Dominant arm									
IR at 90° [degrees]	77	9		74	8		59	13	
ER at 90° [degrees]	96	11		100	9		102	10	
Total ROM [degrees]	173	15		174	12		163	18	
Non-dominant arm									
IR at 90° [degrees]	76	10		84	8		70	15	
ER at 90° [degrees]	91	8		92	6		92	5	
Total ROM [degrees]	167	13		175	10		173	12	
Differences									
GIRD [degrees]	0		$p = 0.40$	9	1	$p < 0.01$	21	7	$p < 0.01$
ERG [degrees]	4	2	$p = 0.04$	8	7	$p = 0.04$	11	9	$p = 0.04$

ER: external rotation; ERG: external rotation gain; GIRD: glenohumeral internal rotation deficit; IR: internal rotation; p: P-value; ROM: range of motion; SD: standard deviation.

Table 4
Percentage and odds ratio for GIRD and PSI taking into account different influencing parameters

	GIRD		PSI	
	Percentage	OR	Percentage	OR
Sports				
Handball	82	} 2.7	22	
Volleyball	63		25	} 1.2
Proficiency level				
Professional (> 3 sessions/week)	74	} 1.4	25	} 1.1
Amateur (⩽ 3 sessions/week)	68		23	
Activity				
> 5 years	75	} 3.0	24	} 1.2
⩽ 5 years	46		21	
Position				
Attack	72	} 1.0	26	} 2.2
No attack	72		14	
GIRD				
> 10°			30	} 1.5
1–10°			22	
No GIRD			22	
GIRD > 10° with decreased TROM			41	} 9.3
GIRD > 10° w/o decreased TROM			0	

GIRD: glenohumeral internal rotation deficit; OR: odds ratio; PSI: postero-superior impingement.

(TROM) i.e. ER at 90° plus IR at 90° was similar for both shoulders in VBP and HBP (HBP 174 ± 15° vs. 174 ± 11°, VBP 169 ± 14° vs. 171 ± 12°). Table 2 demonstrates the differences in shoulder ROM between the dominant and non-dominant arm.

Interestingly, TROM of the dominant arm compared to the non-dominant arm was significantly greater in athletes without GIRD (173 ± 15° vs. 167 ± 13° [$p = 0.04$]) was equal in players with GIRD up to 10° (174 ± 12° vs. 175 ± 10°) and was significantly decreased in individuals with GIRD > 10° (163 ± 18° vs. 173 ± 12° [$p = 0.04$]). 74% of all athletes with GIRD > 10° had a decreased TROM. Changes in ROM for no GIRD, GIRD up to 10° and GIRD > 10° are shown in Table 3.

Abduction force was slightly higher in the dominant shoulder compared to the contralateral shoulder without being statistically significant (14.2 kg vs. 13.8 kg [$p = 0.55$]).

Overall, 97 out of 134 (72%) athletes presented with GIRD syndrome. The percentage of GIRD syndrome was significantly higher in HBP than in VBP (82% vs. 63%, OR 2.7, $p = 0.01$). Athletes who were active for more than 5 years had a higher prevalence of GIRD (75% vs. 46%, OR 3, $p = 0.05$). In addition, the proficiency level affected the frequency of GIRD (74% in professionals vs. 68% in amateurs, OR 1.4). However, the occurrence of GIRD syndrome had no significant effect on VAS, DASH, CS, SSV and abduction force.

Overall, 32 out of 134 (24%) players presented with PSI. Professional athletes compared to amateurs (25% vs. 23%, OR 1.14), attacking players compared to defensive players (26% vs. 14%, OR 2.2, $p = 0.02$), VBP compared to HBP (25 vs. 22%, OR 1.19), athletes with GIRD greater than 10° compared to those without GIRD and those with GIRD under 10° (30% vs. 22%, OR 1.5) and players who have been active for more than 5 years compared to those active for less than 5 years (24% vs. 21%, OR 1.2) had a higher prevalence of PSI. Interestingly, 41% of those athletes presenting with GIRD greater than 10° in combination with decreased TROM of the dominant arm suffered from PSI compared to those with GIRD greater 10° without a decreased TROM (OR 9.3). In contrast, the prevalence of PSI in athletes with GIRD less than 10° and athletes without GIRD showed similar frequency (22% vs. 24%). Occurrence of PSI was associated with significantly higher average pain level (VAS 2 vs. 0.6 pts. [$p < 0.001$]), worse DASH score (8 vs. 2 pts. [$p < 0.01$]), inferior CS (95 vs. 98 pts. [$p < 0.001$]) and lower SSV (85 vs. 97% [$p < 0.001$]). The prevalence and OR of GIRD and PSI with regard to the different influencing factors are presented in Table 4.

Interestingly, none of the athletes in this cohort who began with overhead sports being an adult (age > 18 years) i.e. already having reached skeletal maturity presented a GIRD > 10° and only 12% had positive tests for PSI suggesting that skeletal immature athletes might be prone to develop higher levels of GIRD.

4. Discussion

The results of this study confirm that GIRD syndrome is a common phenomenon in overhead HBP and VBP. These findings are consistent with prior studies involving overhead athletes [1,4,19,20].

In this cohort we could show that offensive players show a higher prevalence of PSI. Seabra et al. also observed a higher prevalence for offensive players in a cohort of professional handball players due to their increased frequency of throwing [20]. To the best of our knowledge, a comparison of the prevalence in HBP vs. VBP as well as the influence of training frequency and overall experience has not been published yet.

To date, it still remains unclear whether soft-tissue adaptations, bony changes or a combination of both are causing GIRD. Already in 2003, Burkhart et al. postulated that the observed increase in ER and decrease in IR is a consequence of repetitive micro traumas [6,11]. These result in stretching of the anterior capsule of the glenohumeral joint and a postero-inferior capsular contracture which functions as the "essential lesion" in the development of GIRD. Tehranzadeh et al. performed a retrospective review of magnetic resonance arthrograms in six professional pitchers who had presented with pain and had been diagnosed with GIRD [21]. They noted that posterior capsular thickening was a clear and consistent finding in all six patients. Yamauchi et al. demonstrated with ultrasound elastography that not only thickness but also stiffness of the posterior capsule is increased in case of GIRD [8]. Interestingly, more recent data have shown that only capsular contracture but also posterior rotator-cuff tightness may contribute to GIRD [22]. These findings are supported by studies showing that GIRD can change up to 15% after a single throwing or pitching movement as the loss of IR is too quick for capsular contracture alone [23,24].

Some authors suggest that adaptive changes already occur before skeletal maturity in throwing athletes after observing that the most dramatic decrease of TROM occurs between 13 and 16 years which is the period when the physis undergoes rapid growth and may be particularly susceptible to the stress of throwing [21,25,26]. Crockett et al. and Kinsella et al. detected increased humeral retroversion in overhead athletes which resulted in changes of TROM allowing more ER and less IR. They suspect that these adaptations allow the thrower's shoulder to increase ER before the greater tuberosity impinges with the postero-superior labrum in the abduction ER (ABER) position.

Interestingly, in our cohort athletes who began with overhead sports being an adult showed a far lower prevalence of GIRD > 10° suggesting that skeletal immature athletes might be prone to develop higher levels of GIRD. Nevertheless, it remains unclear if this is due to osseous changes of the premature skeleton or simply due to longer sports activity and more advanced soft-tissue adaptations. All in all, both osseous and soft-tissue adaptations are likely to be involved in the development of GIRD; however, the relative importance of each is unknown and further clinical studies with complementary imaging are necessary.

In our cohort offensive players showed a larger internal rotation deficit than defenders. These findings are consistent with the literature [27]. Possible explanations for this observation are that offensive players require higher throwing force, as they shoot from a larger distance, and they throw more frequently than the other field positions. Another unanswered question is to what extent GIRD is a physiological adaptation and at what stage it becomes pathology.

In this study we observed that before a decrease of IR occurs – i.e. in players without GIRD – ER and thus TROM increases in the dominant arm. In the second stage IR decreases and the athlete shows GIRD without TROM being affected. When GIRD increases to over 10 degrees finally TROM is affected negatively. Therefore, we suggest that GIRD is a normal adaptive process up to 10° as we observed that the prevalence of PSI was similar in overhead athletes without GIRD compared to players with GIRD smaller than 10°. TROM is only decreased when GIRD increases to over 10 degrees. In these cases the prevalence of PSI significantly increased. Therefore, this seems to be the turning point when GIRD becomes pathology.

Our findings are supported by various experimental studies. After simulation of postero-inferior capsular tightness (with resultant GIRD) in cadaver shoulders GIRD as little as 5° resulted in translational changes in the humeral head including increased superior displacement of the humeral head in the ABER position whereas the amount of posterior translation decreased significantly starting at 10° GIRD [28]. Clabbers et al. [14] placed cadaver specimens after performing posterior capsular plication in the "late cocking" position to assess the relationship between posterior capsular tightness and changes in glenohumeral kinematics. The imbricated posterior capsule provoked a relative postero-superior migration of the humeral head and the new center of rotation lead to an increased contact along the posterior cuff and labrum. These observations can also be made during shoulder arthroscopy in patients with symptomatic PSI due to GIRD. Representative intraoperative images are shown in Fig. 2.

The main treatment for patients with GIRD remains posterior capsular stretching. There are several studies showing the effectiveness of physiotherapy including exercises such as cross-body stretch and sleeper stretch for posterior shoulder tightness [8,29–32]. In symptomatic overhead athletes who fail non-operative therapy shoulder arthroscopy can be performed to address possible intraarticular lesions. It is important to recognize that not all individuals with GIRD present with PSI and vice versa, thus these terms are not synonymous.

4.1. Limitations

There are several limitations to this study. First, athletes were defined as suffering from postero-superior

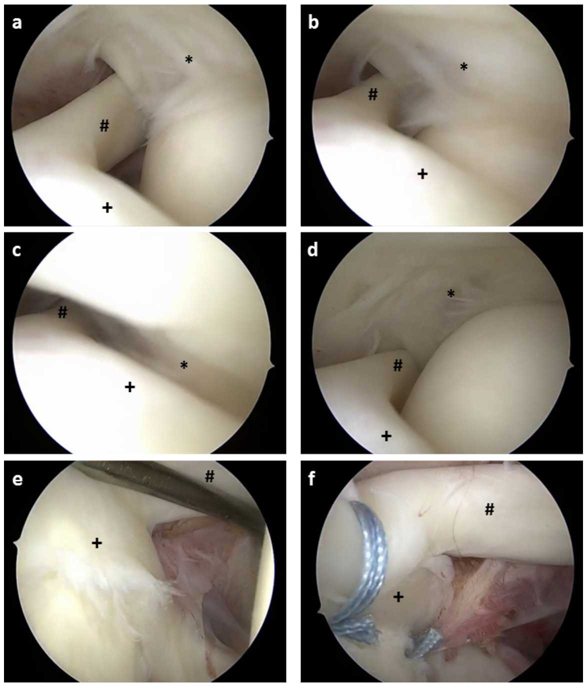

Fig. 2. Intraoperative arthroscopic images of a 31-year-old patient with GIRD of 20 degrees and a partial articular sided SSP tear in combination with a SLAP II lesion due to postero-superior impingement. (a–c) Intraarticular arthroscopic view of the postero-superior cuff (*), the biceps tendon (#) and the SLAP complex (+) with the patient's arm in ABER position of 0° (a), 45° (b) and 90° (c) showing the impingement of the postero-superior cuff against the SLAP complex at 90° ABER. (d) Intraarticular arthroscopic view of the partial articular sided SSP tear. (e) Intraarticular arthroscopic view of the SLAP II lesion. (f) Intraarticular arthroscopic view after SLAP repair with two knotless pushlock anchors. ABER abduction external rotation; GIRD glenohumeral internal rotation deficit; SLAP superior labrum anterior-to-posterior; SSP supraspinatus tendon.

impingement when either clinical SLAP or SSP testing was positive. However, no imaging was performed as ultrasound is not reliable for the diagnosis of partial SSP tears [33] and as the use of MRI is not realistic for such a large cohort to confirm the clinical suspicion. Therefore, as these tests do neither have 100% sensitivity nor 100% specificity there might be false negative and false positive results. Second there is no control group to examine the prevalence of GIRD and PSI in the normal population.

5. Conclusion

It has been shown that GIRD syndrome is a common phenomenon in overhead athletes. HBP appear to be more commonly affected than VBP. The proficiency level and the overall experience also influence the prevalence. Professional athletes, attacking players, VBP, players with GIRD greater than 10° and athletes who have been active for more than 5 years a higher prevalence of PSI. Therefore, the regular control of ROM should be integrated in the training content and countermeasures by means of stretching the posterior shoulder joint capsule should be recommended if patients. In our eyes the development of GIRD syndrome is a three step process. Overhead athletes perform repetitive extreme movements in the ABER position resulting first in an increased ER due to anterior capsule laxity. Later on soft-tissue adaptations of the posterior shoulder joint in combination with or without bony changes lead to the onset of GIRD. Finally, when GIRD increases to more than 10° soft tissue adaptations reach their limit and thus, TROM starts to decrease. These changes progress and provoke a relative postero-superior migration of the humeral head resulting in a new center of rotation and an increased contact along the posterior cuff and labrum causing shoulder pain in overhead athletes.

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Conflict of interest

None to report.

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