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Glenohumeral Internal Rotation Deficit in Young Asymptomatic Elite Swimmers

Jacopo Preziosi Standoli, PT*; Vittorio Candela, MD†‡; Marco Bonifazi, MD§; Stefano Gumina, PhD, MD†

*Department of Anatomy, Histology, Legal Medicine and Orthopaedics, Sant'Andrea Hospital, Sapienza, University of Rome, Italy; †Department of Anatomy, Histology, Legal Medicine and Orthopaedics, Polo Pontino, Sapienza, University of Rome, Italy; ‡ICOT, Latina, Italy; §Department of Medicine, Surgery and Neuroscience, University of Siena, Italy

Context: Glenohumeral internal rotation deficit (GIRD) may affect overhead athletes and contribute to shoulder injury.

Objectives: To assess data on passive shoulder range of motion (ROM) in young elite swimmers and to determine the prevalence of anatomical and pure GIRD (aGIRD and pGIRD, respectively) in a large sample size of asymptomatic elite swimmers with a new classification method.

Design: Cross-sectional study.

Setting: Research laboratory.

Patients or Other Participants: A total of 752 asymptomatic elite swimmers were recruited by voluntary participation (391 males and 361 females; mean age, 15.88 ± 2.31 years). Passive glenohumeral rotational ROM was measured bilaterally to investigate the prevalence of aGIRD and pGIRD. Evaluations were performed with athletes at rest before any training or competition.

Main Outcome Measure(s): Glenohumeral internal rotation deficit and associated aGIRD and pGIRD in elite youth swimmers by identifying a standard classification procedure.

Results: Glenohumeral internal rotation deficits were found in 136 participants (18.1%). Anatomical GIRD was present in 28 cases (3.7%), whereas pGIRD was observed in 108 cases (14.4%). No significant differences were found regarding GIRD between sex, age, age group, years of training, breathing side, and distance. Swimmers with pGIRD showed significantly less dominant internal rotation, total ROM, and external rotation gain ($P < .01$) than swimmers with aGIRD; conversely, swimmers with aGIRD showed significantly less nondominant internal rotation, external rotation, and total ROM than swimmers with pGIRD ($P < .01$).

Conclusion: Glenohumeral internal rotation deficit is a relatively common condition in asymptomatic elite youth swimmers; as to not overestimate this condition, aGIRD and pGIRD have to be distinguished. Although they play a role, the respiratory side, dominant limb, and crawl did not have a significant impact on an elite swimmer with GIRD.

Key Words: shoulder, swimming, overhead, upper limb

Key Points

- Glenohumeral internal rotation deficit (GIRD) is one of the most common musculoskeletal findings in overhead athletes and most often correlates with an increased incidence of shoulder injury.
- In patients with GIRD, there are a number of physiological adaptations that make athletes asymptomatic and well compensated.
- A thorough evaluation of all ranges following the proposed assignment algorithm allows for better discrimination between compensated and decompensated patients and those at a higher risk of injuries.

The shoulders of overhead athletes are susceptible to various pathologies (eg, instability, tendon degeneration and tears, superior labrum anterior-posterior lesions, and different forms of impingement) and adaptations. Several studies have demonstrated that overhead and throwing athletes could suffer a significant glenohumeral internal rotation deficit (GIRD) in the dominant arm, with a concomitant increase of external rotation (ER).[1–3] Glenohumeral internal rotation deficit has been reported as consequence of several factors: (1) osseous changes due to humeral head retroversion, (2) tightness of the posterior capsule, and (3) muscular adaptations (hypertrophy of internal rotators).[2,4,5]

Many of the observations made on deficits in shoulder internal rotation (IR) in athletes are from studies about pitchers; however, the mechanical stresses which the shoulder of throwers are exposed to are different from those of nonthrowing overhead athletes. Swimming is considered an overhead activity; the prevalence of shoulder pain in competitive swimmers ranges from 10% to 26%, and the percentage increases with increasing duration (number of years) and training volume of practice.[6–9] Swimmers have been described to have rounded shoulders and increased thoracic kyphosis, which may affect glenohumeral range of motion (ROM).[10] The high volume of training over the course of a swimmer's career could be responsible for alterations in the observed physical characteristics of swimmers due to adaptation to workloads.[8,11] All of this can predispose swimmers to the development of *swimmer's shoulder*, a general term for overuse injuries in swimming athletes, which includes subacromial impingement, rotator tendinosis, and biceps tendinosis. It is important to study the appearance of alterations in physical characteristics such as GIRD to understand the risk of injury and possible interventions.

Burkhart et al first described GIRD as a difference of 20° or more between the IR of the dominant and nondominant shoulder in throwing athletes.[2] Successively, several studies have lowered this threshold, setting the GIRD definition to greater than 18° of difference between sides.[12–16] This limit was first lowered in a study by Wilk et al, who demonstrated that a difference of 18° is associated with a 1.9 times increase in the probability of injury.[17] In their latest consensus, Kibler et al declared this limit acceptable as long as it is associated with a total ROM (TROM) of less than 5°.[13] This aspect is particularly important in a population such as swimmers who have distinctly symmetrical biomechanics in the stroke.

According to previous studies involving primarily baseball player populations, GIRD is associated with an increased risk of shoulder injury.[17–20] However, in 2 different studies, it was highlighted that GIRD might be a common finding in overhead athletes and not the expression of pathology.[16,21] Therefore, several authors prefer to put the adjective anatomical (aGIRD) or pathological (pGIRD) before the acronym GIRD.[2,12–17,19,21–23]

Anatomical GIRD is defined as a normal loss of IR alone, with an adequate ER gain (ERG) and no presence of a TROM deficit. The TROM deficit has been recently considered a difference between a TROM of the dominant and nondominant shoulder greater than 5°, and it has been related to a 2.5 times greater increase in injury risk.[16,17,24–26] However, a shoulder with *pGIRD* has a concomitant loss of TROM and an increased GIRD/ERG ratio; for this reason, it is considered to be a pathological condition, predisposing athletes to an increased risk of injury.

Current literature on GIRD prevalence in swimmers is limited.[27–38] In these studies, swimmers' IR ranges from 38° to 60°, while ER varies from 85° to 110°. Unfortunately, the analyzed samples are often constituted by few athletes, and the methodologies are not homogeneous. Considering the presence of asymptomatic subjects in this study, we decided to redefine pGIRD as *pure GIRD*, with the intention of extending this concept to all patients during the physical examination. Therefore, from now on, with the use of pGIRD, we will refer exclusively to the new definition of pure GIRD just declared.

The aim of our study was to assess data on passive shoulder ROM in young elite swimmers and investigate the possible association with anthropometric data and competitive practice routines. Furthermore, the study aim was also to determine the prevalence of aGIRD and pGIRD in a large sample size of asymptomatic swimmers with a new classification method. These data could improve our knowledge on GIRD epidemiology, etiopathogenesis, prevention, and treatment.

MATERIALS AND METHODS

Between 2016 and 2018, during the National Youth Swimming Championships, 752 young elite Italian swimmers were enrolled for this study. Recruitment was performed during the national championship by voluntary participation. Anthropometric characteristics (sex, height, weight, age, dominant limb, etc), swim training routine (years of training, stroke, distance, etc), presence of current musculoskeletal injuries, swimming characteristics (stroke, distance, side of breathing, etc), and any participation in other sports were obtained.

Figure 1. Internal rotation measurement.

Swimmers were sorted by sex (ie, male versus female), age (12 to 15 years, 16 to 19 years, and greater than 20 years), years of training (1 to 4 years, 5 to 10 years, and 11 to 15 years), stroke (major: perform only 1 stroke like the crawl, backstroke, breaststroke, or fly; mixed: perform medley or more than 1 stroke), distance (sprinter: 50 to 100 meters; mid-distance: 200 to 400 meters; long-distance: 800 to 1500 meters), and gesture (if it is symmetrical, not symmetrical, or mixed, like medley or more than 1 stroke).

The following inclusion criteria were used: at least 6 training sessions per week, 12 hours of weekly training, and no shoulder pain (collected through self-reporting on the presence of pain at the time of assessment and administration of the Quick Disabilities of the Arm, Shoulder, and Hand and its sport module, as previously reported), injury, or operation in the previous 12 months.[9] Exclusion criteria was a history of shoulder injuries, operations, or pain in the previous 12 months.

Passive glenohumeral rotation ROM was measured (in degrees) by placing each athlete in a supine position on a table. The first examiner was positioned laterally, and the athlete's humerus was supported on the surface with the arm at 90° of abduction and the elbow flexed at 90°. A digital goniometer was centered to the elbow, maintaining the fixed arm perpendicular to the table as documented by the bubble on the goniometer, and the moving arm was in line with the styloid process of the ulna. A second examiner was positioned behind the athlete to stabilize the scapula during testing by applying a posteriorly directed force to the coracoid. The humerus was then gently and passively moved into IR because no additional glenohumeral motion occurs unless the scapula moves or the examiner applies extra rotational stress (Figure 1). This procedure was repeated bilaterally 3 times on each side and by 3 different

Figure 2. External rotation measurement.

examiners. This method was found to be highly reproducible, with a test-retest reliability ranging from 0.92 to 0.98.[13,15,23–25] The intraclass correlation coefficient (ICC) was calculated to assess reproducibility, and it was estimated with a 95% CI. The ICC ranged from 0 to 1; *good* to *excellent* reliability was defined a priori as an ICC greater than 0.75. The same procedure was performed for the ER evaluation (Figure 2). Total range of motion was then calculated (in degrees) as the sum of the measured IR and ER for the dominant and nondominant side. The GIRD/ERG ratio was calculated similar to that as described by Burkhart et al by considering the ratio between the loss of IR (GIRD) and the consequent compensatory ERG.[5] Damage can occur when the ratio is greater than 1.

Similar to previous studies, pGIRD was defined as a threshold of 18° for GIRD (>18°), 5° for a TROM deficit (>5°), and a GIRD/ERG ratio greater than 1.[15–17,21,24,25] Figure 3 shows our decision-making diagram for defining aGIRD, pGIRD, and a normal pattern. Ethical approval for this study was waived by Sapienza University of Rome.

Statistical Analysis

A Shapiro-Wilk test was used to assess the normal data distribution. Categorical variables were calculated using frequencies and proportions, while continuous data were estimated by means, SDs, and ranges. Independent *t* tests were used to analyze differences between 2 groups (GIRD versus non-GIRD or pGIRD versus aGIRD). In addition, differences between 3 or more groups for all data were analyzed using a 1-way analysis of variance. Significance levels for multiple comparisons were adjusted using the Bonferroni procedure. A paired *t* test was performed to analyze mean differences among 1 group. A chi-square and Fisher exact test were conducted for statistical analysis of categorical data (aGIRD/pGIRD groups, sex, dominant side, distance, stroke, etc). Calculated *P* values were 2 sided, a *P* value of less than .05 was considered significant, and the range of CIs was 95%, when appropriate. The ICC was calculated to assess intratester and intertester reliability of the glenohumeral ROM measurement. Standard error of measurement (SEM; SEM $=$ average SD $\times \sqrt{[1 - \text{ICC}]}$) was calculated.

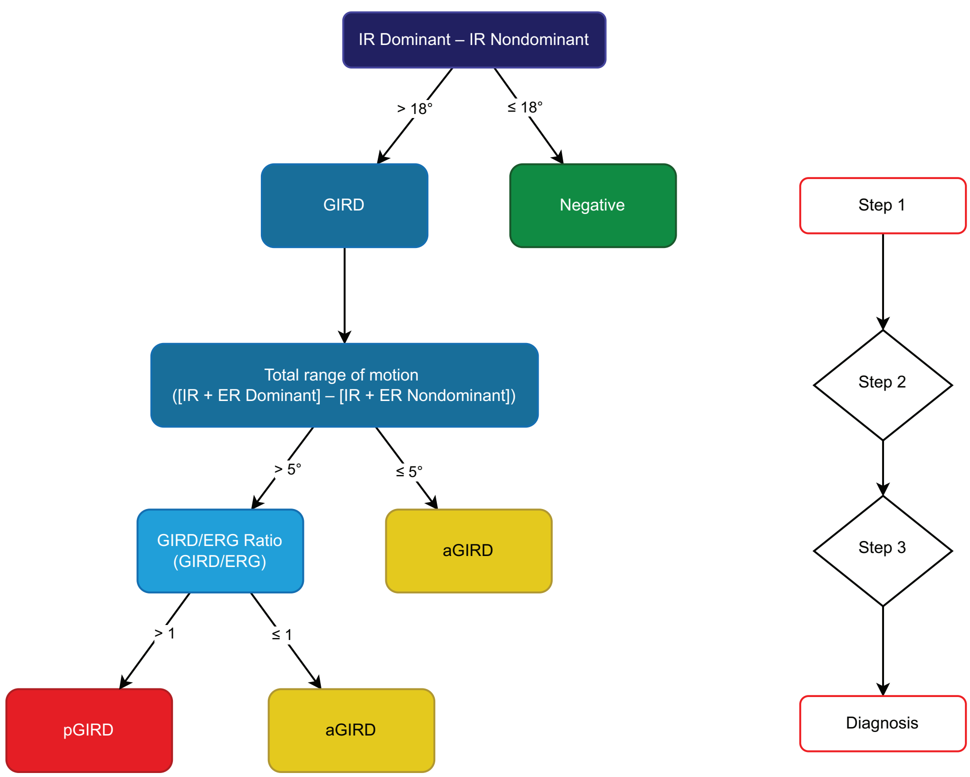

Figure 3. Starting from internal rotation (IR), we define glenohumeral internal rotation deficit (GIRD) if the difference is >18° (step 1). Results ≤18° are considered physiological. In step 2, we considered the total range of motion on both sides, and the difference was calculated. If this difference was ≤5°, the GIRD was defined as anatomical GIRD (aGIRD). However, if the difference was >5°, we proceeded to step 3. In step 3, the ratio between GIRD and the external rotation (ER) gain reached by the dominant arm compared with the nondominant one (ERG) was calculated. A ratio of ≤1 means that the ERG is sufficient to define an aGIRD. Conversely, with a ratio of >1, the GIRD exceeds the ERG, the proportion is unbalanced, and a pure GIRD (pGIRD) can be defined.

Table 1. Baseline Characteristics

	Total (N = 752)	Female (n = 361)	Male (n = 391)	
	Mean (SD)	Mean (SD)	Mean (SD)	*P* Value
Age, y	15.88 (2.31)	15.08 (1.97)	16.62 (2.36)	<.01
Weight, kg	62.33 (10.47)	54.9 (6.7)	69.2 (8.43)	<.01
Height, m	1.73 (0.09)	1.67 (0.06)	1.79 (0.07)	<.01
Body mass index, kg/m^2	20.67 (1.99)	19.75 (1.87)	21.51 (1.71)	<.01
Years of training	6.33 (2.66)	5.76 (2.34)	6.86 (2.82)	<.01
	N (%)	N (%)	N (%)	*P* Value
Age distribution, y				
12–15	357 (47.5)	232 (64.3)	125 (32)	<.01
16–19	342 (45.5)	120 (33.2)	222 (56.8)	
≥20	53 (7)	9 (2.5)	44 (11.3)	
Hand dominance				
Right	676 (89.9)	325 (90)	351 (89.8)	.84
Left	76 (10.1)	36 (10)	40 (10.2)	
Breathing side				
Right	464 (61.7)	196 (54.3)	268 (68.5)	<.01
Left	100 (13.3)	47 (13)	53 (13.6)	
Both	188 (25)	118 (32.7)	70 (17.9)	

The ICC ranged from 0 to 1; good to excellent reliability was defined a priori as an ICC greater than 0.75. Statistical analysis was performed using SPSS (version 25; IBM Corp).

RESULTS

Our study cohort was composed of 752 swimmers (391 male [52%] and 361 female [48%]). Intertester ICC results (IR [ICC = 0.96; 95% CI = 0.89 to 0.99; SEM = 1.73]; ER [ICC = 0.95; 95% CI = 0.81 to 0.98; SEM = 1.33]) and intratester ICC results (IR [ICC = 0.92; 95% CI = 0.85 to 0.96; SEM = 1.69]; ER [ICC = 0.88; 95% CI = 0.80 to 0.93; SEM = 1.74]) showed good to excellent reliability for all the parameters tested.

Table 1 shows the baseline characteristics of the studied group, and the *P* value shows analysis based on sex (female versus male). The mean IR, ER, and TROM of all swimmers is reported in Table 2. Significant statistical differences were found, in total, between the dominant and nondominant sides. A significantly greater IR ($P < .01$) and a lower ER ($P < .01$) were found in the nondominant side; TROM showed no statistical differences ($P > .05$).

Glenohumeral internal rotation deficit was found in 136 participants (18.1%); in particular, aGIRD was present in 28 cases (3.7%), and pGIRD was observed in 108 cases (14.4%). Table 3 shows the IR, ER, and TROM of swimmers with GIRD. No significant differences were found regarding sex, age, age group, years of training, breathing side, and distance between swimmers with and those without GIRD. Right-handed swimmers were found to have GIRD in the dominant side more frequently than left-handed swimmers ($P < .01$). No statistical difference was detected regarding stroke or gesture.

Concerning the GIRD group relative frequencies, pGIRD was found in 79.4% of GIRD cases (n = 108), whereas aGIRD was assessed in 20.6% (n = 28). Frequencies relative to GIRD types in the positive group are reported in Figure 4. The passive ROM of swimmers with GIRD is presented in Table 4. Among the GIRD group, swimmers with pGIRD showed significantly less dominant IR, TROM, and ERG ($P < .01$) than those with aGIRD; conversely, swimmers with aGIRD showed significantly less nondominant IR, ER, and TROM than swimmers with pGIRD ($P < .01$).

No significant differences were found considering sex, dominant side, breathing side, and distance ($P > .05$) related to aGIRD or pGIRD distribution. Age and years of training were found to be significantly correlated with the presence of GIRD. In total, swimmers with pGIRD in the nondominant side were found to be significantly older than those without GIRD (1.6 years; $P < .01$). Regarding years of training, swimmers with pGIRD in the nondominant side had trained for more years (2.1 years; $P < .01$). No statistical difference was detected regarding stroke; however, gesture swimmers, who mainly swim asymmetrical strokes (like the crawl or backstroke), were found to have statistically more frequent pGIRD on the dominant side ($P < .01$). When considering distance, GIRD was present in 17.2% of

Table 2. Passive Range of Motion (in Degrees) of Swimmers

	Total (N = 752)	Female (n = 361)	Male (n = 391)	
	Mean (SD)	Mean (SD)	Mean (SD)	*P* Value
IR dominant	59.16 (13.49)	60.4 (14.09)	58.01 (12.83)	<.01
IR nondominant	63.96 (13.12)	65.33 (13.02)	62.69 (13.11)	<.01
ER dominant	104.07 (12.37)	105.72 (12.43)	102.55 (12.12)	<.01
ER nondominant	100.27 (12.9)	101.29 (13.04)	99.33 (12.71)	.03
TROM dominant	163.23 (16.55)	166.12 (17.55)	160.56 (15.11)	<.01
TROM nondominant	164.23 (17.48)	166.63 (18.37)	162.01 (16.32)	<.01

Abbreviations: ER, external rotation; IR, internal rotation; TROM, total range of motion.

Table 3. Passive Range of Motion (in Degrees) of Swimmers With GIRD

	Total (N = 136)	Female (n = 65)	Male (n = 71)	
	Mean (SD)	Mean (SD)	Mean (SD)	*P* Value
IR dominant	56.171 (18.33)	55.07 (18.33)	57.18 (18.40)	.504
IR nondominant	69.94 (15.04)	69.93 (13.55)	69.95 (16.39)	.891
ER dominant	105.16 (12.32)	106.34 (11.51)	104.08 (13.01)	.281
ER nondominant	97.20 (14.40)	96.63 (14.65)	97.73 (14.25)	.659
TROM dominant	161.33 (18.83)	161.41 (20.30)	161.26 (17.52)	.961
TROM nondominant	167.14 (19.80)	166.56 (21.00)	167.68 (18.78)	.744
GIRD	25.51 (8.19)	25.04 (8.44)	25.95 (8.00)	.325
ERG	12.36 (11.23)	12.98 (11.93)	11.78 (10.62)	.537
GIRD/ERG ratio	3.39 (3.48)	3.08 (2.86)	3.67 (3.96)	.325

Abbreviations: ER, external rotation; ERG, external rotation gain; GIRD, glenohumeral internal rotation deficit; IR, internal rotation; TROM, total range of motion.

sprinters (n = 24/134), 19.4% of mid-distance swimmers (n = 87/449), and 14.8% of long-distance athletes (n = 25/169), but no significant difference in the presence of GIRD or aGIRD/pGIRD classification was found.

DISCUSSION

Our study was the first to evaluate the prevalence of GIRD in a large group of asymptomatic elite swimmers using a new diagnostic method that allows for the subclassification of GIRD into aGIRD and pGIRD considering compensation in the TROM. Glenohumeral internal rotation deficit overestimation is a frequent finding due to the applied evaluation method and sample heterogeneity. The prevalence of GIRD, when TROM compensation was not considered, was found to be up to 40% and up to 61% in different groups of baseball and handball players, respectively.[17,39–41]

In our sample, GIRD was found in about 20% of elite swimmers (18.1%); however, when considering the TROM, pGIRD decreased to 14.4%. This finding is justified by our sample composed of asymptomatic elite swimmers and by our decision-making protocol, which did not consider a shoulder IR deficit in which a TROM compensation is present as pathological.

Shoulder TROM evaluation in elite swimmers has been widely investigated. In 1997, Bak et al analyzed the TROM of 15 young elite swimmers and found that internal ROM of painful shoulders was reduced compared with that observed in those with no history of pain; however, no differences in external ROM were observed.[30] Later, Riemann and Holt evaluated 2 different samples composed of 144 and 70 asymptomatic young elite swimmers, respectively, and found that shoulder IR was significantly lower in the dominant side.[36,42] In their cohorts, TROM did not significantly differ, as in the dominant side a greater ER was measured.

A shoulder IR deficit of the dominant side is a frequent finding in clinical practice, as demonstrated by Roy et al in a series of healthy individuals.[43] Similar to previous studies, our study confirms these findings in a series of 752 young elite swimmers. Shoulder ER is required to achieve full shoulder elevation. Augmented passive ER reflects the functional adaptation necessary in the execution of a high-level swimming stroke.[7,44,45] As previously demonstrated by Johnson et al, the concomitant IR reduction is due to the internal rotator increased load and to the hypertrophic changes that occur in the internal rotator muscles compared with the external rotators to propel the body through water.[12]

In our group, GIRD prevalence was significantly higher in the dominant shoulder. This finding could be associated with the asymmetry of the swimming dominance, in particular to the breathing side while performing the crawl. McCabe et al found a significant difference in the pull phase, push phase, and depth of hand path of the ipsilateral shoulder of swimmers with a preferred breathing side, leading to

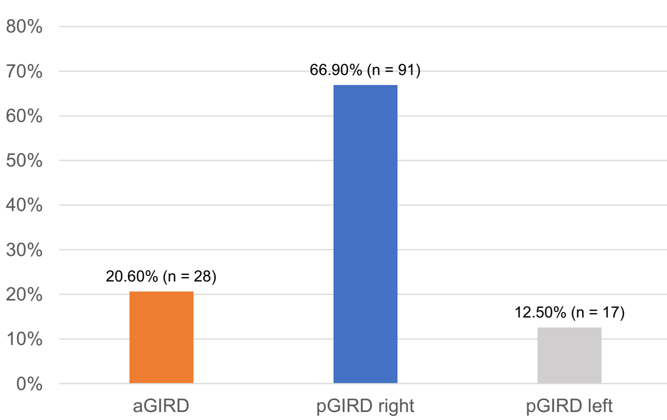

Figure 4. Distribution of glenohumeral internal rotation deficit (GIRD) patterns. Frequencies represent the relative percentage of anatomical GIRD, right pure GIRD, and left pure GIRD within the GIRD-positive group. Abbreviation: ROM, range of motion.

Table 4. Passive Range of Motion (in Degrees) of Swimmers in Total With GIRD According to GIRD Subclasses (aGIRD–pGIRD)

	aGIRD (n = 28)	pGIRD (n = 108)	
	Mean (SD)	Mean (SD)	*P* Value
IR dominant	65.21 (±22.95)	53.83 (±16.24)	<.01
IR nondominant	68.25 (±15.01)	70.38 (±15.08)	<.01
ER dominant	107.04 (±13.76)	104.67 (±11.94)	<.01
ER nondominant	86.75 (±18.19)	99.91 (±11.92)	<.01
TROM dominant	172.25 (±20.56)	158.49 (±17.35)	<.01
TROM nondominant	154.99 (±22.31)	170.29 (±17.91)	<.01
GIRD	24.67 (±10.14)	25.74 (±7.65)	<.01
ERG	26.61 (±13.79)	8.67 (±6.67)	<.01
GIRD/ERG ratio	0.92 (±0.31)	4.03 (±3.64)	<.01

Abbreviations: aGIRD, anatomical glenohumeral internal rotation deficit; ERG, external rotation gain; GIRD, glenohumeral internal rotation deficit; IR, internal rotation; pGIRD, pure glenohumeral internal rotation deficit; ER, external rotation; TROM, total range of motion.

functional asymmetry over time.[46] The breathing side is therefore more exposed to internal rotator muscle hypertrophy and posterior stiffness when the swimmer rolls up to the breathing side, resulting in a functional reduction of ROM.

Identifying athletes at risk of injuries based on ROM deficits is important because these deficits can be corrected.[47,48] When a ROM deficit such as GIRD is identified, it is reasonable to start treatment to correct the deficit to prevent injuries. Conservative treatment with stretching is the primary treatment for GIRD. There is good evidence to suggest that treating ROM deficits can reduce the risk of future injuries and improve associated conditions.[49] For example, early treatment may lead to fewer games lost in overhead athletes who are identified as having GIRD during preseason screening examinations.[50] The observations of Wilk et al suggest that injuries may be more likely associated with the ratio of GIRD to ERG when comparing the dominant and nondominant arms rather than simply the loss of IR.[17,19,26] Further research into this ratio and its relationship with injuries would be beneficial in determining if it can be used to stratify the risk of injuries.

In summary, identifying and treating ROM deficits, such as GIRD, in overhead athletes is important because these deficits can be corrected and may reduce the risk of future injuries. Conservative treatment with stretching is a safe, easy, and affordable option. Further research is needed to determine the optimal amount of stretching and the potential impact of overcorrecting for GIRD on injury risk and performance.

This study has several limitations. Only asymptomatic swimmers were recruited in this study, and no comparison with symptomatic swimmers was possible to determine if there was a significant difference between these 2 groups. This study considered only self-reported injuries and only extrinsic factors as possible causes of GIRD in swimmers. Further studies are needed to detect and discuss the impact of intrinsic factors. This was an observational and cross-sectional study, and as such, no longitudinal follow-up was performed.

CONCLUSIONS

Glenohumeral internal rotation deficit is a relatively common condition in elite swimmers; however, it is often not associated with any shoulder symptoms. In order to not overestimate this condition, aGIRD and pGIRD have to be distinguished. Finally, important aspects in swimming, such as the respiratory side, the dominant limb, and strokes such as the front crawl or the backstroke, did not play a significant role in determining young elite swimmers with GIRD.

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Address correspondence to Jacopo Preziosi Standoli, PT, Via di Grottarossa 1035, Roma, Italy. Address email to preziosistandoli@gmail.com.