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ORIGINAL ARTICLE

Does a land-based compensatory strength-training programme influences the rotator cuff balance of young competitive swimmers?

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Abstract
During the repeated execution of the swimming strokes, the shoulder adductor and internal rotator muscles have a tendency to become proportionally stronger when compared to their antagonist group. This can lead to muscle imbalances. The aim of this study was to examine the effects of a compensatory training programme on the strength and balance of shoulder rotator muscles in young swimmers. A randomized controlled trial design was used. Forty male swimmers took part in the study and were randomly divided into two groups: an experimental group ($n = 20$) and a training group ($n = 20$). A control group ($n = 16$) of young sedentary male students was also evaluated. The experimental group subjects participated in a 16-week shoulder-strength programme with Thera-Band® elastic bands; the training group was restricted to aquatic training. Peak torque of shoulder internal rotator and external rotator (ER) was measured at baseline and after 16 weeks. Concentric action at 1.04 rad s^{-1} (3 reps) and 3.14 rad s^{-1} (20 reps) was measured using an isokinetic dynamometer. The strength-training programme led to an improvement of the ER strength and shoulder rotator balance in the experimental group (data from both shoulders at 1.04 rad s^{-1}). Moreover, concentric action at 3.14 rad s^{-1} presented significant differences only for the dominant shoulder. Findings suggest that the prescribed shoulder-strengthening exercises could be a useful training option for young competitive swimmers. They can produce an increase in absolute strength values and greater muscle balance in shoulder rotators.

Keywords: *isokinetic strength, muscular balance, shoulder rotators, strength training*

Introduction

In competitive swimming, the propulsive forces responsible for total body displacement, especially in front crawl, backstroke, and butterfly, are mainly produced by the upper limbs, through arm adduction and shoulder internal rotation (Kluemper & Hazelrigg, 2006). By the repeated execution of these swimming strokes, the shoulder adductor and internal rotator (IR) muscles show a tendency to become proportionally stronger when compared to their antagonists (Weldon & Richardson, 2001). This could lead to a muscular imbalance, which, according to some authors, contributes towards developing an injury process (Blanch, 2004; Byram et al., 2010). Thus, to avoid injuries, preventive measures should be implemented (Johnson, Gauvin, & Fredericson, 2003).

Muscular imbalance describes a distinct level of muscular performance when compared to accepted normative values (Ellenbecker & Roetert, 2003; Schlumberger et al., 2006). This concept is employed in a variety of functional applications, considering that a divergent expression of muscular strength is a limiting factor to performance and may contribute to an increased risk of injury.

On the evaluation of strength parameters, one method that is often used to determine muscular imbalances includes the quantification of strength from peak torque (PT) attained by isokinetic testing (Schlumberger et al., 2006). In the shoulder joint,

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isokinetic evaluation allows access to values for both agonistic and antagonistic muscles recruited during shoulder rotation movement (Ellenbecker & Davies, 2000). Ratios are commonly used to characterize the proportionate relation between muscle groups (Cingel, Kleinrensinkb, Mulderc, Bied, & Kuiperse, 2007). These ratios, according to Ellenbecker and Roetert (2003), represent the quality of muscular balance, providing one of the key variables for diagnosing muscular balance/imbalance in any joint complex. The shoulder unilateral external rotation/internal rotation ratio (ER/IR ratio) is an important indicator in evaluating and interpreting the muscular function of the upper limbs (Ellenbecker & Davies, 2000).

The shoulder joint complex is characterized by a high degree of mobility; therefore, injury prevention programmes for swimmers may require significant dynamic stabilization. These programmes should not focus only on external rotation compensatory strengthening but also on all joint dynamic and static muscle group stabilizers. However, because of the importance of shoulder joint dynamic stabilizers (Johnson et al., 2003), absolute strength should not be considered equally relevant as the balance between the internal and external rotation muscles.

A significant portion of the evidence shows that confinement to aquatic training impels to shoulder rotator muscular imbalance (Batalha, Marmeleira, Garrido, & Silva, 2014; Batalha, Raimundo, Tomas-Carus, Barbosa, & Silva, 2013; Ramsi, Swanik, Swanik, Straub, & Maltacola, 2004). However, there is an absence of information on the shoulder rotator strength training for young swimmers. Studies that have approached compensatory training in swimmers only refer to the clinical aspects, such as the forward shoulder posture (Kluemper & Hazelrigg, 2006) and incidence of shoulder pain (Swanik, Swanik, Lephart, & Huxel, 2002). However, functional training is a part of most rehabilitation and prevention protocols that contain strength, endurance, agility, and neuromuscular control (Lephart & Henry, 1996). Also, there is a lack of information on the specificity of strength training towards the prevention of shoulder pain and muscular imbalance. Therefore, the aim of this study was to evaluate the effects of a compensatory strength-training programme on the strength and balance of the shoulder rotator muscles of young competitive swimmers. It was hypothesized that the integration of functional exercises into a preventive strength-training programme should improve strength and balance in shoulder rotator muscles, particularly in overhead sports such as swimming.

Methods

Subjects

Forty national level young male swimmers were firstly included. After the initial evaluation, they were randomly divided into two groups: an experimental group ($n = 20$) and a training group ($n = 20$). Another group of young male sedentary students ($n = 16$), with similar socio-demographic characteristics, joined as a control group (Table I) in order to control the influence of human maturation and growth on the study variables.

To be included in the experimental and training groups, participants should (i) not have a clinical history of upper limb disorders (especially affecting the shoulders), (ii) compete at the national level, (iii) undergo a minimum of 8 hours' training per week, and (iv) be aged between 14 and 15 years. Additionally, control group participants should (i) be aged between 14 and 15 years, (ii) neither take part in any organized sport nor be involved in informal sports sessions occurring more than twice a week, and (iii) not have a clinical history of shoulder disorders.

The overall objectives of the study were described to all the participants. Both the subjects and their legal guardians gave their written consent to the participation in the study. The Ethics Committee of the seeding Institution (proceeding 09002/2008) gave their approval on all procedures, which were under the Helsinki Declaration of 1975.

Isokinetic testing

Each subject visited our laboratory one week before pre-season testing to become familiarized with equipment and procedures. One week after this adaptation, the baseline evaluation was performed. Output values for IR and external rotator (ER) cuff isokinetic strength were obtained during concentric actions achieved in an isokinetic dynamometer (Biodex System 3 – Biodex Corp., Shirley, NY, USA). Subjects were seated and stabilized using Velcro straps in order to avoid compensatory trunk movements. They were positioned with their arms at 90° of abduction, 90° of elbow flexion, at the scapular plane, as proposed by other investigators (Julienne, Gauthier, Moussay, & Davenne, 2007; Tyler, Nahow, Nicholas, & McHugh, 2005). The subjects' position and joint alignment followed instructions defined by the isokinetic dynamometer (Biodex Medical Systems, 2000). The procedure was explained to all subjects before the start of testing, with emphasis on exerting maximal effort within each individual's tolerance. After 15 minutes' warm-up, with articular

Table I. Baseline characteristics of the subjects

	Experimental ($n = 20$)	Training ($n = 20$)	Control ($n = 16$)	P
Age (years old)	14.65 ± 0.49	14.45 ± 0.51	14.69 ± 0.48	0.291
Body mass (kg)	63.15 ± 7.68	61.73 ± 4.68	60.84 ± 10.69	0.696
Height (cm)	173.48 ± 6.87	170.79 ± 6.48	168.38 ± 6.19	0.074
Training time/day (min)	127.75 ± 37.57	126 ± 26.39	–	0.981
Training volume (km day^{-1})	5.23 ± 0.66	5.52 ± 0.31	–	0.842
% of predicted mature height	96.06 ± 2.09	95.27 ± 1.79	95.7 ± 1.99	0.444

Values expressed as mean ± SD; *P*-values of ANOVA.

mobilization and stretching, PT during three repetitions at 1.04 rad s^{-1} (60° s^{-1}) and 20 repetitions at 3.14 rad s^{-1} (180° s^{-1}) was recorded. A 1.04 rad s^{-1} speed was first performed for each upper limb (dominant shoulder (DS) and non-dominant shoulder (NDS)), followed by the 3.14 rad s^{-1}. Two trial repetitions at each speed were performed to prepare each subject for the test procedure. A two-minute rest period was allowed for subjects between speed tests. Standardized verbal instructions and encouragement were given to all subjects. The test began with the arm in full internal rotation, and by using a range of motion (ROM) of 0–90°. The ROM halts were used under the manufacturer's recommendations to ensure that identical ROM was tested bilaterally and during follow-up. Protocols and evaluations were all corrected for the effects of gravity.

All subjects that took part in pre-testing were also evaluated in the post-test period, 16 weeks after the pre-testing session. At least one day, and no more than three days, of rest was provided after the last training day of the post-testing session. Post-test procedures were exactly the same as those used during the pre-testing session.

The PT was used to characterize the strength values of shoulder rotator muscles, defined as the maximum torque produced by the shoulder at any point of the ROM (Perrin, 1993). To analyse shoulder rotator strength balance, the ER/IR ratio was calculated – the quotient between PT values of the ER/IR multiplied by 100 (Noffal, 2003). The available literature provides normative data of ER/IR ratio, ranging from 66% to 75% (Cingel et al., 2007; Ellenbecker & Roetert, 2003; Ramsi et al., 2004).

Training programme

The experimental group, alongside with the aquatic training, completed a specific strength-training programme during 16 weeks, with special emphasis on the ER muscles and shoulder stabilizers. Subjects used Thera-Bands® elastic resistance bands. The training programme was held three times a week and consisted of three different exercises (Figure 1).

Exercise 1: The subjects started the exercise in an anatomical reference position with slightly increased upper limb abduction and the elastic band in tension. The progression involved bilateral upper limb abduction and external rotation, until an angle of 50–60° was reached between the arms and the trunk.

Exercise 2: The subjects started at 90° of shoulder flexion in the scapular plane, with the elbow in total flexion and hands in total pronation above the shoulder girdle. The progression involved bilateral full extension of the elbow and total shoulder flexion.

Exercise 3: The starting position was identical to the description in Exercise 1. Subjects progressed to bilateral upper limb abduction at scapular plane until the end of the ROM, close to 160° of abduction.

The training programme only includes the number of exercises that are required to achieve muscle compensation and takes into account the limited time available for their completion (end of the warm-up period).

The initial training resistance was determined during two adaptation sessions with elastic bands and training techniques. Red elastic bands were determined as the initial load. All swimmers executed three sets of each exercise. The first two sets involved 20 repetitions each, with the last set performed until exhaustion. If swimmers were able to reach 30 repetitions in the final set, the level of training was increased by selecting the next resistance level (colour) of the elastic bands. This procedure was independently conducted for each exercise.

The training group was restricted to aquatic training and the control group did not perform any physical conditioning.

Maturational evaluation

To control potential confounding factors such as maturational status, the percentage of predicted mature height, based on the Khamis and Roche method (Khamis & Roche, 1994, 1995), was measured in all evaluation periods. This method uses height, body mass, and mid-parent stature.

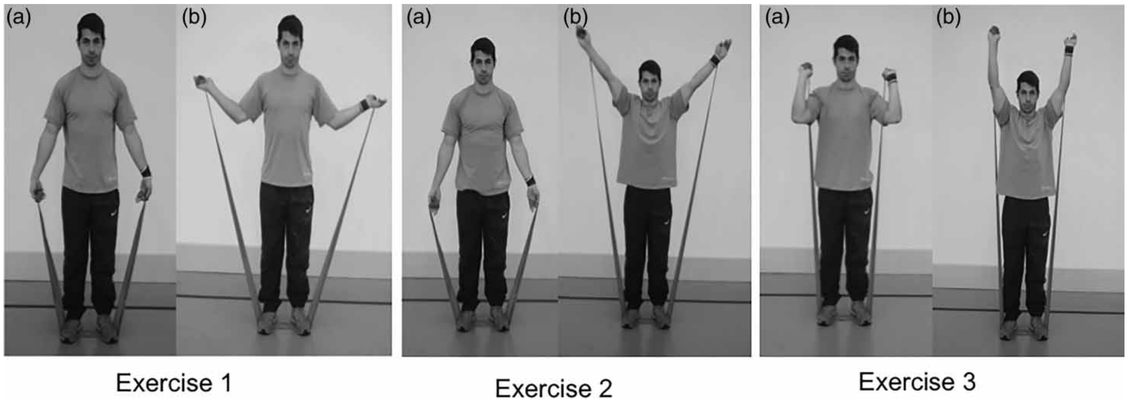

Figure 1. Exercises of the strength-training programme. (a) Initial position; (b) final position.

The following equation was used:

$$\begin{aligned}\text{Predicted adult stature} &= \text{intercept} \\ &+ \text{height}*(\text{height coefficient}) \\ &+ \text{body mass}*(\text{body mass coefficient}) \\ &+ \text{height}*\text{mid} - \text{parent stature}(\text{mid} \\ &- \text{parent stature coefficient}).\end{aligned} \quad (1)$$

The intercept and remaining coefficient values provided by Khamis and Roche (1994) consider individual chronological age. The average error for the male populations is 2.2 cm (Khamis & Roche, 1994).

Statistical analysis

The Kolmogorov–Smirnov normality test with Lillifors correction was initially used. Differences in baseline characteristics among the three groups were tested using analyses of variance (ANOVAs). The training effects within and between groups were evaluated using ANOVAs for repeated measures, adjusted to the baseline and maturation values used as covariates (ANCOVA), with Bonferroni *post hoc* tests. Effect sizes are reported as partial eta-squared (η_p^2), with cut-off values of 0.01, 0.06, and 0.14 for small, medium, and large effects, respectively (Cohen, 1988).

In addition to the *P*-values, we provided detailed statistics, including the mean and 95% confidence intervals, to better depict the change within each group between evaluation periods. The change to 16 weeks for a given group was defined as the increase or decrease from baseline to 16 weeks for that group. The training effect represents the differences between changes for two groups [treatment effect = (ΔExperimental G. – ΔControl G.)]. All analyses were performed with SPSS (version 18.0; SPSS Inc., Chicago, IL), and the significance level was set at $P \leq 0.05$ for all tests.

Results

Table II relates to the assessments made at 1.04 rad s^{-1} for the DS and the NDS. The results related to the differences between external rotation and unilateral ratios for the experimental group and the other groups, from baseline to 16 weeks, with corresponding moderate-to-large effect sizes should be highlighted. These results indicate that the training programme had a positive effect in muscle strength and balance of shoulder rotators.

Training effect differences between groups for the protocol conducted at 3.14 rad s^1 are presented in Table III. These results are similar to the previous ones, showing, once again, increased muscle strength and balance of the shoulder rotators, as a result of the performed training programme.

As a result of the assessment of maturity, no differences were found between groups at the evaluation times (baseline and 16 weeks).

Discussion

The aim of this study was to examine the effects of a strength-training programme on the strength and balance of the shoulder rotator cuff muscles in young swimmers. Our main finding shows that a compensatory strength-training programme has beneficial effects on the shoulder rotator cuff muscles, by increasing strength values (ER and IR) and reducing the differences in strength between the IR and ER. These differences have shown a tendency to become aggravated when swimmers are restricted to aquatic training (Ramsi et al., 2004).

Concerning the IR and ER strength, our results were similar to those obtained in other studies (Batalha et al., 2012; Ellenbecker & Roetert, 2003; West, Sole, & Sullivan, 2005). In fact, the ability to produce muscle strength with the IR is invariably greater than that of its antagonists (ER), resulting in

Table II. Comparative training effects on the PTs (N m) of IRs and ERs and ER/IR ratios (%) of DS and NDS at 1.04 rad s^{-1}

Dominant shoulder – 1.04 rad s^{-1}										
		Experimental G.			Training G.			Control G.		
Baseline (mean ± SD)	ER	28.61 ± 5.86[a]			26.36 ± 4.56[b]			23.19 ± 4.38[a,b]		
	IR	35.90 ± 7.71[a]			33.20 ± 8.13[b]			24.02 ± 5.04[a,b]		
	Ratio	79.69 ± 12.76[a]			79.39 ± 15.4[b]			96.54 ± 14.82[a,b]		
Changes at 16 weeks mean (95% CI)	ER	3.89 (2.14 to 5.64)			0.97 (−1.13 to 3.08)			0.57 (−0.67 to 1.81)		
	IR	2.63 (−0.78 to 6.03)			6.36 (3.76 to 8.97)			0.88 (−1.98 to 3.74)		
	Ratio	4.66 (−2.34 to 11.66)			−5.65 (−11.43 to 0.13)			−1.12 (−6.9 to 4.66)		
		Experimental vs. Training	*P*	ES	Experimental vs. Control	*P*	ES	Training vs. Control	*P*	ES
Training effects mean (95% CI)	ER	2.93 (0.10 to 5.76)	0.008	.117	3.32 (1.08 to 5.56)	0.001	.220	0.4 (−2.26 to 3.41)	0.894	.083
	IR	−3.73 (−8.42 to 0.96)	0.421	.080	1.57 (−2.14 to 5.27)	0.012	.211	5.47 (4.5 to 15.45)	0.002	.411
	Ratio	10.31 (0.34 to 20.29)	0.001	.271	5.78 (2.07 to 9.48)	0.214	.102	−4.53 (−8.23 to 8.82)	<0.001	.502
Non-dominant shoulder – 1.04 rad s^{-1}										
		Experimental G.			Training G.			Control G.		
Baseline (mean ± SD)	ER	25.57 ± 5.10			24.83 ± 4.49			22.38 ± 4.90		
	IR	35.47 ± 8.63[a]			33.30 (10.46)[b]			22.56 ± 5.28[a,b]		
	Ratio	72.09 ± 7.82[a]			74.56 ± 18.66[b]			99.20 ± 14.91[a,b]		
Changes at 16 weeks mean (95% CI)	ER	4.34 (2.92 to 5.75)			1.11 (−0.19 to 2.4)			−0.1 (−2.95 to 2.75)		
	IR	2.15 (−0.59 to 4.9)			4.41 (0.8 to 8.01)			0.32 (−2.34 to 2.97)		
	Ratio	7.39 (−2.58 to 17.37)			−5.77 (−13.92 to 2.38)			−1.78 (−13.24 to 9.58)		
		Experimental vs. Training	*P*	ES	Experimental vs. Control	*P*	ES	Training vs. Control	*P*	ES
Training effects mean (95% CI)	ER	3.23 (1.55 to 4.91)	0.015	.247	4.44 (1.26 to 7.62)	0.002	.255	1.21 (−2.45 to 4.87)	0.137	.022
	IR	−2.26 (−6.56 to 2.05)	0.931	.028	1.83 (−1.3 to 4.97)	0.033	.033	4.09 (−2.11 to 10.28)	0.026	.263
	Ratio	10.31 (0.34 to 20.29)	0.036	.222	9.17 (−4.79 to 23.14)	0.199	.026	−3.99 (−18.2 to 10.23)	0.001	.310

P-values for differences between groups after 16 weeks.

[a] $P < 0.05$ on baseline outcome between experimental and control.

[b] $P < 0.05$ on baseline outcome between training and control.

Table III. Comparative training effects on the PTs (N m) of IRs and ERs and ER/IR ratios (%) of ND and NDS at 3.14 rad s^{-1}

Dominant shoulder – 3.14 rad s^{-1}										
		Experimental G.			Training G.			Control G.		
Baseline (mean ± SD)	ER	24.29 ± 4.06			22.98 ± 4.07			21.75 ± 5.22		
	IR	32.97 ± 7.31[a]			29.83 ± 8.39[b]			21.59 ± 4.90[a,b]		
	Ratio	73.67 ± 5.86[a]			77.04 ± 12.99[b]			100.74 ± 21.98[a,b]		
Changes at 16 weeks mean (95% CI)	ER	4.6 (3.25 to 5.95)			1.79 (−0.47 to 4.06)			−0.36 (−2.83 to 2.1)		
	IR	4.33 (2.15 to 6.5)			6.23 (2.83 to 9.63)			0.1 (−3.66 to 2.11)		
	Ratio	3.8 (−2.57 to 10.16)			−8.38 (−12.99 to−3.77)			−1.66 (−12.75 to 9.44)		
		Experimental vs. Training	*P*	ES	Experimental vs. Control	*P*	ES	Training vs. Control	*P*	ES
Training effects mean (95% CI)	ER	2.81 (0.15 to 5.46)	0.007	.116	4.85 (2.32 to 7.38)	0.001	.304	2.04 (−2.04 to 6.12)	0.070	.046
	IR	−1.90 (−6.37 to 2.56)	1.000	.025	4.23 (0.43 to 8.03)	0.002	.290	6.13 (1.6 to 10.65)	<0.001	.452
	Ratio	12.18 (3.52 to 20.84)	0.020	.235	5.46 (−8.77 to 19.69)	0.016	.145	−6.72 (−18.54 to 5.04)	0.001	.388
Non-dominant shoulder – 3.14 rad s^{-1}										
		Experimental G.			Training G.			Control G.		
Baseline (mean ± SD)	ER	22.16 ± 4.09			22.00 ± 3.70			20.07 ± 3.49		
	IR	34.09 ± 8.17[a]			29.80 ± 8.27[b]			21.40 ± 5.69[a,b]		
	Ratio	65.00 ± 12.04[a]			73.83 ± 13.68[b]			93.79 ± 18.67[a,b]		
Changes at 16 weeks mean (95% CI)	ER	3.49 (2.25 to 4.74)			2.98 (1.56 to 4.4)			−0.28 (−2.28 to 1.73)		
	IR	1.41 (−0.69 to 3.51)			4.03 (1.88 to 6.17)			−0.1 (−2.26 to 2.06)		
	Ratio	7.25 (0.48 to 13.57)			0.01(−5.69 to 5.71)			−0.88 (−11.72 to 9.96)		
		Experimental vs. Training	*P*	ES	Experimental vs. Control	*P*	ES	Training vs. Control	*P*	ES
Training effects mean (95% CI)	ER	0.51 (−1.33 to 2.36)	0.945	.008	3.77 (1.97 to 5.57)	0.008	.267	3.26 (0.37 to 6.14)	0.019	.196
	IR	−2.62 (−5.34 to 0.1)	0.665	.081	1.51 (−0.29 to 3.31)	0.035	.141	4.13 (1.01 to 7.24)	0.001	.247
	Ratio	7.24 (−1.96 to 16.45)	0.936	.008	8.13 (−5.34 to 21.62)	0.601	.018	0.89 (−9.14 to 10.92)	0.113	.071

P-values for differences between groups after 16 weeks.
[a]$P < 0.05$ on baseline outcome between experimental and control.
[b]$P < 0.05$ on baseline outcome between training and control.

higher PT values. Our results also showed that for all groups and for both protocols used, IR values were always higher when compared to ER values. Overall, this was to be expected, if we consider that the muscle groups that produce the IR of the shoulder joint are not only greater in number but are also anatomically larger and naturally stronger (Dark, Ginn, & Halaki, 2007).

This fact supports the use of the ER/IR ratio and the attempt to set normative values in order to characterize the proportional relations between muscle groups (Ellenbecker & Roetert, 2003). At an angular velocity of 1.04 rad s^{-1}, it should be noted that our results were comparable on both DS and NDS (Table II). The ER strength values for the experimental group showed a marked increase, and tend to differ with moderate-to-large effect sizes, when compared to both the training and control groups. For the IR strength values, the increment for the training group over the 16-week period (6.36 N m for the DS and 4.41 N m for the NDS) was higher when compared to the experimental group (2.63 N m for the DS and 2.15 N m for the NDS). There is an understanding that functional strength exercises enable the improvement of the neuromuscular capacity (intra- and inter-muscular coordination) (Swanik et al., 2002). Given our results, we suspect that the ER strength training in the experimental group has somehow changed the usual pattern of neuromuscular function. However, further studies are needed to clarify the issue on neuromuscular coordination, including electromyographic analysis of the shoulder rotators before and after the strength-training programme.

The most notable results are a consequence of the previously mentioned strength value increases. They show significantly higher ER/IR ratios for the experimental group. Since, no differences were found between the maturity levels of the different groups and unilateral ratios characterize the quality of muscular balance (Ellenbecker & Roetert, 2003), the strength-training programme promoted greater muscle balance. The values of ER/IR ratios in both limbs are increased with significant differences and moderate-to-large effect sizes between the experimental and the remaining groups. These results are indeed very important because we have to consider that on this specific age, competitive swimmers have a considerable increase of the training volume. Thus, a preventive strength-training programme might be considered important.

For the training group that was restricted to aquatic training, the ratio values at 3.14 rad s^{-1} were totally different, since on both DS and NDS values, the differences from baseline to 16 weeks were always negative (−5.65% and −5.77%, respectively, for the DS and the NDS). These results clearly support the findings of our previous research (Batalha et al., 2013), which showed that extensive aquatic training tends to promote muscular imbalances between IR and ER in competitive swimmers.

At 1.04 rad s^{-1}, the DS results (Table III) are, to a large extent, similar to those previously described. They show a significant increase in ER strength values for the experimental group, and significant differences when this group is compared to either the training or the control group. Likewise, the strength-training programme produced marked increases in ER/IR ratios for the experimental group (3.8%) and decreases in both the training and control groups (−8.3% and −1.66%, respectively).

Also, regarding the NDS (Table III), with the exception of a slight alteration in the ratio for the training group (0.01%), the pattern of change from baseline to post-test was similar to that recorded for the 1.04 rad s^{-1} protocol, while there were no significant differences between the experimental and training groups.

On the results from both isokinetic strength protocols, our findings agree with previous research that included compensatory training programmes focusing on the shoulder rotator muscles (Kluemper & Hazelrigg, 2006; Malliou, Giannakopoulos, Beneka, Gioftsidou, & Godolias, 2004; Swanik et al., 2002). Significant gains in strength were recorded for recruited muscle groups in the exercises. In some studies (Beneka, Malliou, Giannakopoulos, Kyrialanis, & Godolias, 2002; Malliou et al., 2004; Swanik et al., 2002), reflecting on unilateral ratios, the findings were in contrast to those presented in the present study, with diminishing ratios after interventions. The main difference lies in the type of strength training that was employed, which did not seem to relate to the ER. Therefore, IR strength values were significantly higher when compared to their antagonists. This fact, together with our results, provides strong support for the use of compensatory strength training on the swimmer's shoulder rotators, which should include both ER strengthening as well as shoulder stabilization. In addition, although some evidence exists mentioning that exercises in the prone position allow for greater muscle recruitment of the ER (Marta et al., 2013), the exercises performed while standing demonstrated to be a very effective workout.

Still on unilateral ratios, previous research findings in swimming, tennis, water polo and badminton, point to normative ER/IR ratio values of 66–75% (Cingel et al., 2007; Ellenbecker & Roetert, 2003; Ramsi et al., 2004). The decrease in these values has been linked to instability and imbalance in the glenohumeral joint (Leroux et al., 1994). Taking in account these normative values, our results, on both protocols, did not register below 66% at any point, although they declined in the ratios for the training and control groups from baseline to 16 weeks. This means, according to Leroux et al. (1994), that they should therefore be considered positive since they are not yet within the range associated with muscular imbalance or instability in the shoulder joint. On future research, it would be interesting to analyse the possibility that younger swimmers may have lower ratios than older swimmers, raising the question of whether there is an increase in joint instability and shoulder muscular imbalance as the swimmer's career (and training volume) advances.

Based on these results, swim coaches should use dry land functional strength-training programmes, comparable to those used in this study, focusing specifically on strengthening the ER and stabilizers of the shoulder joint. This kind of functional strength training can help swimmers to reduce the risk of injury by increasing shoulder rotator strength and preventing any shoulder muscle imbalances.

We believe that the main limitation of this study was related to the isokinetic testing position. Swimmers were seated with a single arm elevated in the scapular plane, which is not a swimming-specific position. A prone testing position may be more suitable for swimmers; however, this position was not an option using this assessment tool.

Conclusion

The findings of the present study suggest that the prescribed shoulder-strengthening exercises represent a useful compensatory training option for young competitive swimmers, since there is an increase in absolute strength values for shoulder rotators and greater muscle balance is produced by significantly increasing unilateral ratio values in both limbs. Therefore, swimming coaches should use dry land strength-training programmes, focusing specifically on strengthening the ER and stabilizers of the shoulder joint.

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