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original article

Shoulder rotator isokinetic strength profile in young swimmers

Perfil de força isocinética dos rotadores dos ombros em jovens nadadores

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Abstract – Considering that some studies suggest that shoulder rotators muscle imbalances are related to joint pain and injury, and that there are no normative data for young swimmers, the aim of this study was: i) to describe the muscle balance, fatigue and isokinetic strength profile of the shoulder rotators in young swimmers; ii) to compare the results between swimmers and a group of young non-practitioners; iii) to contribute to the acquisition of normative data of unilateral ratios of shoulder rotators. We evaluated the shoulder rotators concentric strength and unilateral ratios (ratio between torque of external and internal rotators) of 60 swimmers (age: 14.55 ± 0.5 years old; body mass: 61.16 ± 7.08 kg) and 60 non-practitioners (age: 14.62 ± 0.49 years old; body mass: 60.22 ± 10.01 kg). The evaluation was performed in the sitting position (90° abduction and elbow flexion) at 60º.s^{-1} and 180º.s^{-1} angular speeds using an isokinetic dynamometer (Biodex System 3). The results of the fatigue ratios revealed no differences between the groups. Swimmers showed unilateral ratios of 73.39 ± 17.26% in the dominant limb (DL) and 77.89 ± 15,23% in the non-dominant limb (NDL) for assessments at 60º.s-^{1}. At 180º.s^{-1}, ratios were 74.77± 13.99% for DL and 70.11 ± 14.57% for NDL. Swimmers presented greater muscle imbalance, and differed from non-practitioners in the ability to produce power with the internal rotators, which was significantly higher in the former group.

Key words: Muscle strength; Shoulder joint; Shoulder rotators; Swimming.

Resumo – *Considerando que alguns estudos sugerem que desequilíbrios musculares dos rotadores dos ombros estão relacionados com dores e lesões na articulação e que não existem dados normativos para jovens nadadores, o objetivo deste estudo foi: i) caracterizar o equilíbrio e fadiga musculares bem como o perfil de força isocinética dos rotadores dos ombros em nadadores jovens; ii) comparar os resultados entre nadadores com jovens não praticantes; iii) contribuir para a criação de dados normativos de rácios unilaterais dos rotadores do ombro. Foi avaliada a força isocinética com ações concêntricas dos rotadores e respectivos rácios unilaterais (quociente entre torque dos rotadores externos e internos) em 60 nadadores (idade: 14,55 ± 0,5 anos; massa corporal: 61,16 ± 7,08 kg) e 60 não praticantes (idade: 14,62 ± 0,49 anos; massa corporal: 60,22 ± 10,01 kg). Com um dinamômetro isocinético (Biodex System 3), avaliou-se na posição de sentado (90º de abdução e de flexão do cotovelo), às velocidades angulares de 60º.s^{-1} e 180º.s^{-1}. Os resultados dos índices de fadiga não revelaram diferenças entre grupos. Os nadadores apresentaram rácios unilaterais entre os 73,39±17,26% no membro dominante (MD) e 77,89±15,23% no membro não dominante (MND), para avaliações efetuadas a 60º.s^{-1}; a 180º.s^{-1}, obtivemos resultados entre 74,77±13,99% para MD e 70,11±14,57% para MND. Os nadadores apresentaram um maior desequilíbrio muscular, sendo a capacidade de produção de força dos rotadores internos (significativamente superior nos nadadores) o que os distingue do grupo de não praticantes.*

Palavras-chave: *Articulação do ombro; Força muscular; Manguito rotador; Natação.*

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INTRODUCTION

Competitive swimming (CS) is considered a resistance sports modality, in which the practitioners daily perform considerable amount of training. Being a modality of cyclic movements, either alternating or simultaneous, in which the propulsive force is obtained essentially from the action of the upper limbs, it is easy to understand that overload to these structures may occur, in which the shoulder joint complex plays a key role. O'Donnell et al.[1] state that the biomechanical actions inherent to the CS techniques promote muscle imbalances that lead to the overload of the capsular and ligament structures, and contribute to shoulder instability.

Several studies[2-4] have shown the relevance of the coordinated and synchronized action of the muscle groups that comprise the shoulder joint, as well as the importance of the balanced relationship of the shoulder cuff muscles strengths throughout the range of motion. Slight imbalances in the relationship between the shoulder internal (IR) and external rotators (ER) power may lead to joint dysfunction, and cause injury and further functional inactivity[5,6].

Unilateral ratios, defined as the quotient between concentric strength values of ER and IR, are used to describe the proportionality among the muscle groups of the shoulder rotators, which characterize the quality of the muscle balance[7]. Some authors have reported a correlation between pre-seasonal low unilateral ratio values and further injuries among baseball players[8]. Other studies emphasize the importance of resistance tests as a reliable means to access muscle fatigue[9], which are important in the development of training programs. In a study performed with swimmers, the authors correlated the ratio values and fatigue indexes with shoulder pain[9]. In the other hand, they related the joint instability with the impingement syndrome and shoulder pain[10].

For injury prevention, the concept of muscle imbalance suggests the existence of a muscle performance pattern that differs from the normal values[11]. Such evaluation is based in the comparison with normative data. Some studies have shown normative ER/IR ratio values from 66-75%[7,12,13]. Nevertheless, we have no knowledge of normative data for young swimmers, with only one study that evaluated the isokinetic strength among adolescent swimmers[14].

As there seems to exist a correlation between low shoulder unilateral ratios with the occurrence of injuries, and as no data regarding young swimmers are available, the objectives of this study were: i) to describe the balance, muscle fatigue and isokinetic strength profiles of the shoulder rotators, namely the unilateral ratios, of young swimmers, contributing to the acquisition of specific normative data; ii) to compare the results obtained from young swimmers with those from non practitioners.

METHODS

Subjects

The study population consisted of two groups of male adolescents: the study group consisting of 60 swimmers and a control group of 60 non-regular practitioners with similar characteristics (table 1).

Table 1. Baseline characteristics of the study groups

	Swimmers (N=60)	Control (N=60)
Age (years)	14.55 ± 0.5	14.62 ± 0.49
Body mass (kg)	61.16 ± 7.08	60.22 ± 10.01
Height (cm)	170.76 ± 7.5	169.59 ± 6.88
Breadth (cm)	176.43 ± 9.1	174.3 ± 7.85
Trainings/week (sessions)	5.95 ± 0.83	---
Training time/Day (min)	122.58 ± 30.47	---
Training time/Week (min)	803. 5 ± 225.53	---

We established the following entry criteria for the two groups:

1) Swimmers group: a minimum of 8 hours training per week; ages between 14-15 years; no prior shoulder dysfunction.
2) Control group: ages between 14-5 years; not participate in organized sport whatsoever and not involved on informal sports more than twice a week; no prior shoulder dysfunction.

The swimmers group should practice training sessions in the water only, with no complimentary exercises outside the water. All the participants and their respective coaches were instructed about the objectives and possible difficulties in implementing the protocols, after which they signed a consent form. All procedures were approved by the Ethics Committee of Health and Welfare of the University of Evora (Process No. 09002), and were in accordance with the 1975 Helsinki Declaration.

Isokinetic Evaluation

The isokinetic evaluation of the shoulder IR and ER was performed using an isokinetic dynamometer (Biodex System 3 – Biodex Corp., Shirley, NY, USA) in the beginning of the sports season. The swimmers performed the isokinetic tests in a sitting position, with the shoulder at 90º abduction in IR (frontal plan) and 90º elbow flex, a position previously recommended by other investigators[15-17]. The subjects, who were fixed to the seat with belts around the trunk and pelvis in order to avoid compensatory movements, began the exercises by performing about 90° range of motion in ER. The positioning of the subjects and the joint alignment were done according to the instructions set out in the device's operations manual[18].

Regarding the angular speed and the number of repetitions used, taking into account the consulted literature and also that swimming is essentially a sports modality in which the resistance strength and high muscle power are decisive[19], we opted for performing the following protocols for both arms:

- Protocol 1: 3 repetitions (concentric actions) at $60^{o}{\cdot}s^{-1}$. Verbal stimuli coming from the researcher was kept constant along the process.
- Protocol 2: 20 repetitions (concentric actions) at $180^{o}{\cdot}s^{-1}$. At this speed, the verbal stimuli occurred in the 5^{th}, 10^{th} and in the last five repetitions.

Prior to the implementation of the protocols, all the subjects performed 15 minutes of warm-up with joint mobilization and stretching. They were also informed about the tasks to be done, and were allowed to perform two repetitions at each test speed, with the aims of warming-up and also of getting used to the position, the angular speed, and the task to be performed.

All the subjects were evaluated at the $60^{o}.s^{-1}$ angular speed, and then at $180^{o}{\cdot}s^{-1}$, with 2 minutes interval between both. The correction to the gravity effect was performed for all the protocols.

Study variables

- *Peak Torque* (PT) – the highest moment of force applied along the whole range of motion
- *Unilateral ratio* (ER/IR ratio): the quotient between the concentric values of PT of the ER and the IR (equation 1)[12,20]. The result is expressed as a percentage, and characterizes the balance between the muscle groups afore mentioned[7].

$$[(ER/IR)x100] \quad (1)$$

- *Fatigue index*: the fatigue index was calculated using the following equation:

$$[(W1-W2)/W1]x100 \quad (2)$$

Were *W1* is the workload performed in the first third of the repetitions and *W2* the workload performed in the last thirds[21].

Statistical analysis

Data normality was initially tested using the Kolmogorov-Smirnov test, and the homogeneity of variances was tested by the Levene's test. Descriptive statistics was performed for all variables using means and standard deviations. Comparisons between the groups were performed using the *t-student* test for independent samples. The significance level was set at α=0.05. Calculations were performed using the *Statistical Package for the Social Sciences* (SPSS) software, version 17.0.

RESULTS

Table 2 shows the results of the evaluation performed at the angular speed of $60^{o}{\cdot}s^{-1}$. The *p* values refer to the comparative analysis between the groups.

Table 2. Descriptive statistics of the variables and comparisons between the groups for evaluations at 60º·s-1

3 repetitions at 60º·s-1		Swimmers (n=60)	Control (n=60)	
		Mean ± sd	Mean ± sd	p
Dominant limb (DL)	PT-ER (Nm)	26.39 ± 5.66	25.05 ± 7.08	0.334
	PT-IR (Nm)	33.88 ± 8.50	26.99 ± 8.27	0.001
	Ratio ER/IR (%)	77.89 ± 15.23	92.81 ± 13.31	0.000
Non Dominant limb (NDL)	PT-ER (Nm)	24.96 ± 4.74	24. 09 ± 6.10	0.463
	PT-IR (Nm)	34.01 ± 9.33	25.91 ± 6.99	0.000
	Ratio ER/IR (%)	73.39 ± 17.26	92.98 ± 16.38	0.000

PT-ER = Peak Torque of External Rotation; PT-IR = Peak Torque of Internal Rotation; Ratio ER/IR = Unilateral Ratio

The PT values for swimmers were invariably higher in both IR and ER. However, significant statistical differences ($p<0.05$) between the groups were observed only for the values of the IR and ER/IR ratio.

Table 3 shows the results of the protocol at 180º·s^{-1} angular speed. Similar to the results obtained at 60º·s^{-1}, significant statistical differences were only observed in the IR and unilateral ratio.

The results related to fatigue indexes did not show significant differences between the groups.

Table3. Descriptive statistics of the variables and comparisons between the groups for evaluations at 180º·s-1

20 repetitions at 180º·s-1		Swimmers (N=60)	Control (N=60)	
		Mean ± sd	Mean ± sd	p
Dominant limb (DL)	PT-ER (Nm)	23.29 ± 4.15	22.61 ± 5.85	0.544
	PT-IR (Nm)	31.15 ± 7.93	23.02 ± 8.16	0.000
	Ratio ER/IR (%)	74.77 ± 13.99	92.21 ± 18.05	0.000
	FI--ER (%)	1.99 ± 8.54	14.71 ± 10.55	0.889
	FI- IR(%)	1.94 ± 6.73	5.98 ± 19.44	0.756
Non Dominant limb (NDL)	PT-ER (Nm)	22.07 ± 3.87	21.57 ± 4.27	0.521
	PT-IR (Nm)	31.48 ± 8.38	23.85 ± 6.64	0.002
	Ratio ER/IR (%)	70.11 ± 14.57	90.44 ± 19.01	0.000
	FI--ER (%)	15.76 ± 6.74	17.31 ± 8.18	0.337
	FI- IR(%)	5.96 ± 6.14	6.09 ± 15.52	0.960

PT-ER = Peak Torque of External Rotation; PT-IR = Peak Torque of Internal Rotation; Ratio ER/IR: =Unilateral Ratio; FI-ER = Fatigue Index of ER; FI-IR = Fatigue Index of IR

DISCUSSION

The objective of this study was to characterize the muscle balance and isokinetic strength profile of the shoulder rotators in young swimmers, comparing the results with a group of non-practitioners. Swimmers showed greater muscle imbalances when compared with non-practitioners, with the higher IR strength values among the swimmers clearly distinguishing them from the controls.

One of the first conclusions we can draw, which is consensual in other studies in the field[7,22-24], is that the IR ability to produce power is invariably superior to that of their antagonists. The results of the present study show that, for both groups and protocols, the IR values were constantly higher when compared with those of the ER. Actually, these results could be expected, considering that the muscles that perform the internal rotation of the glenohumeral joint are not only more numerous, but also greater and stronger[25].

This fact justifies the use of the ER/IR ratio, and the attempt to consult their normative values[7]. According to the authors afore mentioned, the unilateral ratios distinguish the quality of muscle balance, and are one of the key variables to be investigated in the evaluation of the muscle imbalance of any joint complex.

In this study, the results of the unilateral ratios, both at $60^{o}{\cdot}s^{-1}$ and at $180^{o}{\cdot}s^{-1}$, show significant differences of the DL and the NDL between the groups, such difference being significantly lower in swimmers. Considering the scientific evidences that mention that a decrease in the value of concentric strength of the ER, combined with an increase of the same amount of the IR is a feature of athletes who present with instability of the glenohumeral joint[22,23], contributing to an increased risk for joint injury[12], we can state that the swimmers group have greater muscle imbalance of the shoulder joint and, consequently, higher risk for injury.

In spite of this evidence, and based on the results of other studies that point to normative values of the ER/IR ratios between 66-75%[7,12,13,26], we cannot definitely conclude that swimmers have serious muscle imbalances with high risk for injury. We have no knowledge of the existence of normative values for young swimmers. Nevertheless, some authors who evaluated older athletes obtained similar reference values (66-75%) for swimmers and water polo players[13,26], as well as for badminton and tennis players[7,12].

In the present study, the ER/IR ratio in the group of swimmers ranged from 70.11 ± 14.57% to 77.89 ± 15.23%, values that are close to, but slightly higher, than the normative values previously described. The single study conducted with young swimmers[14] showed unilateral ratio values slightly lower than ours (64.75 ± 6.75% for the DL and 69.45 ± 9.29% for the NDL). It is important to notice, however, that the study included 15 swimmers who were younger (mean 13.3 years), and that the evaluation was performed in the supine position.

We also noticed that ER/IR ratio values found in the swimmers group evaluated at $60^{o}{\cdot}s^{-1}$ (DL: 77.89 ± 15.23%; NDL: 73.39 ± 17.26%) in our study are slightly higher than those reported by Beach et al[9], 70 ± 9% and 71 ± 10% for the DL and the NDL, respectively. However, that study evaluated 28 competitive swimmers of a North-American university team (ages ranging from 16 to 21 years) at the same angular speed ($60^{o}{\cdot}s^{-1}$) and arm positioning, but in prone position.

In the study by Olivier et al.[27] that evaluated 20 high level swimmers (age 29 ± 5 years) and 20 sedentary individuals (age 27 ± 5 years) using an isokinetic dynamometer at the same angular speed ($60^{o}{\cdot}s^{-1}$) but in the supine position, the ER/IR ratio values (53.27-65.90% for swimmers;

73.90-74.73% for controls) were considerably lower for both groups when compared with our findings

The significant differences in the unilateral ratio values between the groups at both angular speeds are corroborated by other authors[20,27], who report that the ER/IR ratio for swimmers are smaller in comparison with non athletes. However, it is important to notice that the differences found in our study are essentially consequent to the differences of the IR strength values in opposition to the ER values, such differences found in both protocols. These results support the hypothesis that, in swimmers, the IR are proportionally stronger when compared with the ER, due to the repeated concentric contractions performed by these muscles during the propulsive phase of the swimming techniques[10], with the ER getting comparatively less strong with the growing age and along the athlete's career[26]. This fact reinforces the importance of performing specific compensatory exercises, which should focus mainly on the ER.

In regard to muscle fatigue, the values found in the swimmers group are similar to those reported by Beach et al[9]. However, contrary to what would be expected, the fatigue indexes are not the feature that distinguishes competitive swimmers from little active individuals. Since there are no normative data for this variable, further studies will be necessary.

This study presents some limitations. First, given that we intended to contribute to the establishment of normative data of the shoulder rotators strength values, we consider that the sample size should have been larger. The second aspect refers to the little specificity of the isokinetic device. Finally, the sitting position with 90° shoulder abduction is not specific for swimmers, for whom the prone position is more adequate. Such position, however, is not provided in the protocols of the device used in this study.

CONCLUSIONS

Swimmers present greater muscle imbalance of the shoulder rotators when compared with little active individuals. What clearly distinguish the swimmers from the sedentary group in the ability to produce power with the shoulder rotators are the values of the internal rotators, which are significantly higher in swimmers. It is thus justified the development of compensatory training for swimmers, with special focus on the reinforcement of the external rotators.

It is our opinion that, in face of the inexistence of other studies in the field, our study can contribute to the establishment of normative data that allow the characterization of the unilateral ratio for young swimmers, which are particularly relevant for clinicians and Coaches in the identification of possible muscle imbalances of the shoulder joint complex.

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