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ORIGINAL RESEARCH

Isokinetic dynamometry on the internal rotator and adductor muscles of the swimmers' shoulders: no differences between asymmetrical and symmetrical swimming strokes

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OBJECTIVE: In this study, we compare muscular strength of the internal rotators and adductors of the shoulder between asymmetrical (backstroke and freestyle) and symmetrical (breaststroke and butterfly) swimming strokes.

METHOD: We evaluated: shoulders of (a) asymmetrical swimmers (aged 21.8 ± 3.8 years), (b) symmetrical swimmers (aged 20.3 ± 4.5 years), (c) recreational swimmers (aged 24.5 ± 4.5 years), and (d) control individuals (aged 25.8 ± 3.5 years). All evaluations were performed on a Biodex® isokinetic dynamometer at velocities of 60° and 300°/second. Adduction and internal rotation movements were evaluated. The variables studied were peak torque corrected for body weight (PTQ/BW), total work (TW) and the agonist/antagonist relationship.

RESULTS: There were no differences in adductor strength between the symmetrical and asymmetrical swimmers regarding PTQ/BW (symmetrical: 114.4 Newto-meter vs. asymmetrical: 109.4 Newton-meter) and TW (symmetrical: 642.9 Joules; asymmetrical: 641.5 Joules). There was no difference in the abduction/adduction relationship between the symmetrical (67.4%) and asymmetrical (68.3%) swimmers. There was no difference in the internal rotator musculature between the symmetrical and asymmetrical swimmers regarding the variables PTQ/BW (symmetrical = 66.4 Newton-meter and asymmetrical = 63.4 Newton-meterm) and TW (symmetrical = 517.4 J and asymmetrical 526.7 J). There was no difference in the ratio of external to internal rotation of the shoulder between the symmetrical (65.7%) and asymmetrical (61.5%) swimmers.

CONCLUSIONS: There were no differences in muscular strength in the adductor and internal rotator muscles of the shoulder between symmetrical and asymmetrical swimming strokes.

KEYWORDS: Shoulder; Swimming; Muscle force; Dynamometry; Physiotherapy; Torque.

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INTRODUCTION

Swimming is a throwing sport in which the arms are thrust out in front of the body in order to overcome water resistance and move the swimmer.[1,2] The adductor and internal rotator muscles of the shoulder are the main means of propulsion in swimming.[3–5] The acts of thrusting, pulling, sweeping in or grabbing are characterized by actions of the propulsion muscles: internal rotators (subscapular and teres major muscles) and adductors (latissimus dorsi and pectoralis major muscles) of the shoulder, especially in subaquatic movements.[6,7,8]

In freestyle and backstroke swimming, the arms move in a rhythmic alternating manner, while in the breaststroke and butterfly, the two arms move simultaneously. In both types of stroke, whether alternating or simultaneous, the movement of swimming is the same and recruits the same muscle groups of the shoulders and arms, but the duration of the stroke and the quantity of movement differ. Do the swimming styles (simultaneous and alternating) recruit the internal rotator and adductor muscle groups in the same way?

The aim of this study was to comparatively evaluate the use of the internal rotator and adductor muscle groups of the shoulder in simultaneous and alternating swimming stroke styles, by means of isokinetic dynamometry. To the best of our knowledge, there is only a single report on shoulder rotational strength in healthy elite athletes in various different sport modalities.[9]

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METHODS

Study location and ethical issues

The study was performed at the Motion Study Laboratory of the Institute of Orthopedics and Traumatology, Hospital das Clínicas, University of São Paulo School of Medicine with approval granted by the Ethics Committee of the University of São Paulo (number 1247-07). All participants signed an informed consent form.

Design. This is a controlled cross-sectional observational study, without intervention.

Participants. Evaluations were conducted on 162 shoulders of 81 individuals of both sexes, aged between 17 and 33 years, consisting of competitive swimmers using all styles, non-competitive swimmers, and non-swimmers, who were distributed as follows:

- Alternating (asymmetrical) stroke group: 46 shoulders of competitive freestyle and backstroke swimmers aged 21.8 ± 3.8 years; weight 71.2 ± 10.0 kg, height 177.6 ± 8.5 cm and BMI 22.3 ± 1.3; weekly distance 42.4 ± 11.3 km, daily distance 7.1 ± 1.9 km and dedication to the style 76.5 ± 14.7 of training time %.
- Simultaneous (symmetrical) stroke group: 44 shoulders of competitive breaststroke and butterfly swimmers aged 20.3 ± 4.5 years; weight 70.5 ± 9.3 kg, height 167.2 ± 37.6 cm and BMI 22.6 ± 1.9; weekly distance 40.7 ± 14.8 km, daily distance 7.1 ± 2.4 km and dedication to the style 55.9 ± 9.1 of training time %.
- Recreational group (RG): 28 shoulders of recreational swimmers aged 24.5 ± 4.5 years; weight 70.8 ± 16.6 kg, height 173.4 ± 9.2 cm and BMI 23.3 ± 3.9; weekly distance 6.1 ± 3.7 km, daily distance 2.0 ± 0.8 km and dedication to the freestyle style (asymmetrical): 70.7 ± 15.4 of training time %.
- Sedentary control group (CG): 42 shoulders of non-swimmers aged 25.8 ± 3.5 years; weight 68.7 ± 11.2 kg, height 171.9 ± 9.3 cm and BMI 23.2 ± 2.6.

Procedures

Physiotherapic Evaluation. All participants answered a questionnaire that sought personal data and information on previous injuries. The swimmers were asked about the specialization and training that they had undergone. Shoulder function was assessed using the functional tests of Neer and Hawkins.[10,11]

Isokinetic Evaluation. To assess muscle force, a Biodex Multi-joint System 3 isokinetic dynamometer was used (Biodex Medical Systems Inc, Shirley, NY, USA), at the Movement Studies Laboratory of the Institute of Orthopedics and Traumatology, Hospital das Clínicas, University of São Paulo School of Medicine.

All the individuals did a warm-up on a stationary bicycle (Moviment® Biocycle 2600), followed by large-amplitude movements of the shoulder joint and stretching based on Perrin's protocol.[12]

Adduction/abduction measurements. The subjects were positioned on a chair, and the shoulder was aligned with the axis of the dynamometer at an inclination of 10°, to evaluate the abduction and adduction movements. Assessments were performed on both shoulders, beginning with the dominant side. The range of motion went from 0° of adduction to 90° of abduction. A gravity correction was made at 50° of abduction. Three repetitions of the movement were made for familiarization, followed by five effective repetitions at a velocity of $60°.sec^{-1}$, with recovery intervals of 30 sec, and 20 repetitions at a velocity of $300°.sec^{-1}$. An interval of 60 sec of rest was allowed before repeating the procedure on the other side.

Internal/external rotation measurements. The dynamometer was positioned laterally in relation to the swimmer, with 30° of internal rotation in the scapular plane and was fixed at an inclination of 50°, while the shoulder was kept slightly flexed in the sagittal plane (20°; neutral rotation). The elbow was positioned in a support, to keep its position flexed at 90°. The total internal and external range of motion was 90°. Assessments were performed on both shoulders, beginning with the dominant side. Three repetitions were performed for familiarization, followed by five repetitions at $60°.sec^{-1}$, with intervals of 60 sec, and 20 repetitions at $300°.sec^{-1}$, to obtain measurements. An interval of 60 sec of rest was allowed before repeating the procedure on the other side. The recovery interval between the abduction/adduction and internal/external rotation movements was 120 sec.

Statistical Analysis

The Anderson-Darling test was performed to investigate whether the isokinetic variables presented normal distribution.[13]

To compare the isokinetic variables of the adductor and internal rotator muscles in the study groups, the nonparametric Kruskal-Wallis test was used. A confidence interval (Q1 to Q3) was used to assess the variation of the median. To identify which group presented the difference, the Mann-Whitney test was used. The significance level used in the tests was $P < 0.05$. All the statistical analyses were performed using the following software: SPSS version 16.0, Minitab 15 and Excel Office 2007.

RESULTS

The groups were matched for age, weight, height and BMI. The variables evaluated were the peak torque corrected according to body weight (PTQ/BW) at the velocity of $60°.sec^{-1}$ and the total work done in the 20 repetitions at the velocity of $300°.sec^{-1}$. The agonist/antagonist relationship of the muscle groups was also analyzed, i.e. the abduction/adduction ratio and the external/internal rotation ratio.

No statistical difference in the parameters evaluated was observed between the dominant and non-dominant shoulders and therefore it was decided to group the shoulders and disregard the dominance within each study group.

The following comparisons were made between the groups related to the adductor muscles (Table 1 and 2) and internal rotation (Table 3 and 4) of the shoulder.

There was no statistical difference between the symmetrical and asymmetrical swimming groups in relation to the PTQ/BW and TW, but the competitive swimmers presented greater muscle force than shown by the recreational and the control groups. The recreational group presented better performance in the adductor muscles compared to the controls.

Regarding the agonist/antagonist relationships of the abductor/adductor and external/internal muscle groups, there was no difference between the asymmetrical and symmetrical swimming groups in relation to the muscle balance of abduction/adduction and external/internal rotation. The recreational group presented a relationship of greater imbalance than shown by the asymmetrical, but not in relation to the symmetrical swimmers.

Table 1 - Groups comparison for the adductor muscles of the shoulder

		Mean (SD)	Median	Q1	Q3	P-value
PTQ/BW (%)	ASG	114.0 (±32.1)	109.4	100.6	124.4	
	SSG	113.4 (±25.5)	114.6	101.8	129.5	<0.001*
	RG	91.4 (±30.4)	88.5	66.6	113.9	
	CG	84.2 (±29.4)	79.5	61.7	100.6	
TW (J)	ASG	703.2 (±511.8)	641.5	385.5	913.2	
	SSG	670.7 (±289.3)	642.9	425.3	901.2	<0.001*
	RG	458.0 (±355.5)	358.4	145.0	806.8	
	CG	287.9 (±312.8)	203.7	25.3	456.0	
AGO/ANTA (%)	ASG	69.8 (±12.0)	68.3	60.6	74.8	
	SSG	66.5 (±10.8)	67.4	57.6	72.1	<0.001*
	RG	74.4 (±26.9)	68.9	63.1	76.5	
	CG	81.3 (±15.5)	79.6	71.3	88.8	

PTQ/BW: peak torque corrected for body weight; TW: total work; AGO/ANTA: the relationship of the agonist and antagonist muscle groups; ASG: alternating stroke group; SSG: simultaneous stroke group; RG: recreational group; CG: sedentary control group; Q: confidence interval (first and third quartiles).
Krusal Wallis test *P < 0.001 ASG and SSG vs. RG and CG.

Table 2 - P-values of the comparison of each group for the adductor muscles of the shoulder

		ASG	SSG	CG
PTQ/BW (%)	SSG	0.505		
	RG	0.002**	0.002**	
	CG	<0.001*	<0.001*	0.224
TW (J)	SSG	0.698		
	RG	0.028**	0.008**	
	CG	<0.001*	<0.001*	0.019**
AGO/ANTA (%)	SSG	0.229		
	RG	0.696	0.214	
	CG	<0.001*	<0.001*	0.006**

PTQ/BW: peak torque corrected according to body weight; TW: total work; AGO/ANTA: the relationship of the agonist and antagonist muscle groups; ASG: alternating stroke group; SSG: simultaneous stroke group; RG: recreational group; CG: sedentary control group.
Mann-Whitney test *P < 0.001 **P < 0.05.

DISCUSSION

In swimming, performance is influenced by the capacity to generate propulsive force and the capacity to minimize the resistance to the body's forward movement within the liquid medium.[8] The type of stroke used could have an influence on the muscle force generated and, therefore, the muscle force could vary according to the swimming style. The simultaneous strokes (butterfly and breaststroke) and the alternating strokes (freestyle and backstroke) might be assumed to act differently on the propulsive musculature of the shoulder and require different types of preparation and training, both to improve performance and to prevent and treat injuries.

Some studies have disregarded the asymmetry of swimming, but because the execution time for the movement is a determinant in each style, the difference in this time between the alternating and simultaneous strokes might influence the generated propulsion force, even considering that the movement of the stroke is very similar in the four styles[5,9].

We did not find any comparative studies in the recent literature on the propulsive muscle force of swimming (adductors and internal rotators of the shoulder) between the alternating stroke styles (freestyle and backstroke) and simultaneous stroke styles (breaststroke and butterfly).

There was no difference in the muscle force of the adductor and internal rotator groups between the symmetrical and asymmetrical swimmers, even with the differences in stroke times.

Swimming practice begins with freestyle, in which swimmers acquire motor learning of the sport movement. The other styles come later. Even when swimmers choose another style, the amount of time spent practicing freestyle

Table 3 - Groups comparison for the internal rotation muscles of the shoulder

		Mean (SD)	Median	Q1	Q3	P-value
PTQ/BW (%)	ASG	62.0 (±17.6)	49.4	75.9	63.4	
	SSG	68.0 (±14.7)	57.8	79.2	66.4	<0.001*
	RG	49.7 (±16.3)	39.6	61.3	46.0	
	CG	47.5 (±12.8)	35.6	58.0	48.2	
TW(J)	ASG	538.0 (±235.8)	319.8	695.1	526.7	
	SSG	552.0 (±226.9)	371.5	723.2	517.4	<0.001*
	RG	242.9 (±139.5)	155.8	296.6	232.0	
	CG	347.5 (±237.0)	144.1	515.3	294.2	
AGO/ANTA (%)	ASG	70.5 (±44.7)	57.3	66.8	61.5	
	SSG	63.2 (±9.4)	56.7	70.8	65.7	<0.001*
	RG	72.2 (±12.7)	62.3	83.0	68.7	
	CG	76.1 (±11.8)	67.7	83.3	73.1	

PTQ/BW: peak torque corrected according to body weight; TW: total work; AGO/ANTA: the relationship of the agonist and antagonist muscle groups; ASG: alternating stroke group; SSG: simultaneous stroke group; RG: recreational group; CG: sedentary control group; Q: confidence interval.
Krusal Wallis test *P < 0.001 between ASG and SSG vs. RG and CG.

Table 4 - P-values of the comparison of each group for the internal rotation muscles of the shoulder

		ASG	SSG	RG
PTQ/BW (%)	SSG	0.105		
	RG	0.007**	<0.001*	
	CG	<0.001*	<0.001*	0.395
TW (J)	SSG	0.765		
	RG	<0.001*	<0.001*	
	CG	<0.001*	<0.001*	0.144
AGO/ANTA (%)	SSG	0.417		
	RG	0.001**	0.007**	
	CG	<0.001*	<0.001*	0.144

PTQ/BW: peak torque corrected according to body weight; TW: total work; AGO/ANTA: the relationship of the agonist and antagonist muscle groups; ASG: alternating stroke group; SSG: simultaneous stroke group; RG: recreational group; CG: sedentary control group.
Mann-Whitney test *$P < 0.001$ **$P < 0.05$.

continues to be high during training, and this factor may be a greater determinant for the muscle force of the adductors and internal rotators of the shoulder than the specialized type of stroke used, if only because the biomechanics of the sport movements are similar.

The performance measured by the total work (TW) of the adductors and internal rotators of the competitive swimmers (symmetrical and asymmetrical swimmers) was greater (55%) than that of the recreational swimmers. These, in turn, showed better performance than shown by the control group, only in relation to adductor activity and not in internal rotator activity. Since the recreational group had a less refined technique for moving through the water, and did not use the three-dimensional axes of the stroke,[8] there was less activity of the internal rotators. These used the adductor musculature as the propulsive muscles, thus showing that their biomechanics was deficient in relation to the competitive swimmers. The smaller muscle force of the internal rotators of the recreational swimmers suggested that their technique was incorrect, thereby compromising their performance, with the possibility of development of imbalances and shoulder joint injuries. The lack of activity of the internal rotators may be related to the lower degree of trunk rotation along the longitudinal axis, thus favoring greater use of the adductors for moving through the water and characterizing a two-dimensional stroke.

The relationship between the agonist and antagonist groups is an appropriate means of assessing the muscle balance of a joint.[14] In the present study, there was less muscular imbalance, physiologically, in the relationship between external and internal rotators in the two groups of swimmers (symmetrical 65.7%; asymmetrical 61.5%). These results differ from those of Rupp et al,[11] who showed a relationship of 80.1% in the left shoulder and 76.2% in the right shoulder, thus suggesting that there was relative weakness in the internal rotators, especially given that their subjects were swimmers. The present study showed that the internal rotators were stronger. It can be said that this relationship would be expected and even desirable in the shoulders of high-performance swimmers. Oliver et al.[5] showed smaller values than those of the present study (61% for the right shoulder and 52% for the left shoulder), which may signify an imbalance caused by relative weakness of the external rotators.

In evaluating the abduction/adduction relationship of the shoulder, McMaster et al.[15] found results that were lower (42%) than those of the present study for asymmetrical (68.3%) and for symmetrical (67.4%) swimmers, which signifies an imbalance due to relative weakness of the abductors. The introduction of resistance exercises into swimmers' physical preparation, in a manner that is more controlled and aimed towards prevention of imbalance and injuries, may explain the differences between the work by MacMaster's et al.[15] and the present study.

Symmetrical swimmers showed relationships between external and internal rotation (65.7) and between abduction and adduction (67.4) that were better balanced, i.e. more physiological, than shown by asymmetrical swimmers, even though there was no statistically significant difference. One of the possible explanations for this finding might be that making the arm recovery movement of the stroke simultaneously is more efficient in regulating the external rotators and abductors.

Preservation of the balance between the propulsive muscles and their antagonists is very important for preventing instability and impact,[16,17] as well as protecting against secondary injuries. The present study demonstrated that muscle evaluations using isokinetic dynamometry does not distinguish between alternating and simultaneous swimming strokes and does not provide support for specific training for any group or style.

Groups of sedentary individuals and recreational swimmers were included in this study in order to determine normal values for shoulder muscle force and balance. This avoided the bias that could have arisen through exclusively evaluating high-performance swimmers who might have had muscle profiles that are very characteristic of the sport.

The weekly and daily training distances in the swimmers' specialty were measured to make correlations with the muscle force of the symmetrical and asymmetrical swimmers. The asymmetrical group had greater dedication to training within the specialty, which was expected. Freestyle was the stroke most used during training in both groups and was obviously used more by the asymmetrical swimmers, because they would not normally be training intensively in the symmetrical styles.

The recreational swimmers were slightly older than the performance swimmers, but this is not believed to have interfered with the results that were found. The difference in age group was small, and the normative data from isokinetic dynamometry has enabled evaluations that have included wider age ranges, given that muscle loss is only seen to be significant from the sixth decade of life onwards,[18] an age group that was not included in the present study.

CONCLUSION

There was no difference in muscular strength in the adductor and internal rotator muscles of the shoulder between simultaneous and alternating swimming strokes.

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CONFLICT OF INTEREST

None.

DINAMOMETRIA ISOCINÉTICA DOS MÚSCULOS ROTADORES INTERNOS E ADUTORES DOS OMBROS DE NADADORES: SEM DIFERENÇAS ENTRE BRAÇADAS DE NADOS ASSIMÉTRICOS E SIMÉTRICOS

RESUMO

OBJETIVO: Neste estudo, comparamos a força muscular dos músculos rotadores internos e dos adutores do ombro entre nadadores especializados em estilos assimétricos (costas e nado livre) e simétricos (nado peito e borboleta).

MÉTODO: Foram avaliados: ombros de (a) nadadores assimétricos (com idade 21,8 ± 3,8 anos), (b) nadadores simétricas (com idade de 20,3 ± 4,5 anos), (c) nadadores recreativos (com idade de 24,5 ± 4,5 anos), e (d) indivíduos do grupo controle (idade 25,8 ± 3,5 anos). As avaliações foram realizadas em um dinamômetro isocinético Biodex® nas velocidades de 60° e 300° / segundo. Foram avaliados adução e movimentos de rotação interna. As variáveis estudadas foram o pico de torque corrigido para peso corporal (PTQ/BW), trabalho total (TT) e a relação agonista/antagonista.

RESULTADOS: Não houve diferenças na força adutora entre os nadadores simétricos e assimétricos em relação PTQ/BW (simétricos: 114,4 newton-metro vs. assimétricos: 109,4 newton-metro) e TW (simétrica: 642,9 Joules; assimétrica: 641,5 Joules). Não houve diferença na relação abdução/adução entre nadadores simétricos (67,4%) e assimétricos (68,3%). Não houve diferença na musculatura rotadora interna entre o nadadores simétricos vs. assimétricos em relação às variáveis PTQ/BW (simétricos = 66,4 Newton-metro e assimétricos = 63,4 Newton-metro) e TW (simétricos = 517,4 J e assimétricos 526,7 J). Não houve diferença na relação de rotação externo para interno do ombro entre nadadores simétricos (65,7%) e assimétricos (61,5%).

CONCLUSÕES: Não houve diferenças na força muscular dos músculos adutores e rotadores internos do ombro entre estilos de natação simétricos e assimétricos.

UNITERMOS: ombro, natação, a força muscular, a dinamometria, Fisioterapia, torque

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