Hand force symmetry during breaststroke swimming

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Abstract

The aim of this study was to analyze the hand force symmetry during the breaststroke and its relationship with swimmers' performance. Seventeen breaststroke and/or medley specialists participated (12 men and 5 women, 19.5 ± 5.2 years and average performance of $73.4 \pm 7\%$ of the 50 m breaststroke world record). Each swimmer performed three repetitions of 25 m breaststroke swimming at maximal speed. Pressure sensors from Aquanex acquisition system were placed in both swimmers' hands and Mean Force (F_{mean}) and Maximal Force (F_{max}) were measured. The symmetry index proposed by Sanders was calculated and the time of a 50-m breaststroke trial at maximum speed (T_{50m}) was used as a performance indicator. The variables were compared between hands using tests for dependent samples, and the relationship between variables were investigated using Spearman correlation test ($p<0.05$). The F_{mean} applied was 47.9 ± 16.7 N and 47.9 ± 14.5 N for right and left hands, respectively. The F_{max} corresponded to 120.7 ± 43.6 N and 112.8 ± 35.7 N for right and left hand, respectively. No significant differences were observed for none of the variables between right and left hands. Analyzing the subjects individually, it was possible to observe asymmetries levels up to 30.6% for F_{mean} and 35.9% for F_{max}, however the relationship between symmetry indexes and the 50 m breaststroke performance was not statistically significant.

Keywords: Swimming; Biomechanics; Performance.

Introduction

The goal of competitive swimmers is to travel the swimming race distance in the shortest time possible, with the highest average speed, considering the traveled distance, as well as the total time to complete the race, always respecting its specific rules[1]. To this goal, it is necessary to improve technical and physical aspects aiming to increase the swimmer's propulsive capacity and reducing the water resistance.

Therefore, it seems obvious that the propulsive force is an important determinant of swimming performance[2], and its assessment may provide indicatives of the effectiveness of the swimming technique[3]. Estimation of propulsive force has been investigated by sports biomechanical analysts throughout the years by several methods, as tethered swimming[2, 4-5], tridimensional video analysis[6], computational fluid dynamics[7] and with pressure sensors attached in swimmer's hands[8-10].

When analyzing propulsive force production, researchers are interested in the incidence of asymmetries between the right and left limbs, and its relationship with the performance[5,11]. Even though a certain level of asymmetry is acceptable/tolerable, due to differences inherent to human body[12], the bilateral difference in force production during swimming activities may be a limiting factor for optimal performance[13]. According to Sanders et al.[14], in order to accomplish a high performance level, both arms and legs have to contribute in an

optimal manner to maximize propulsion and reduce swimming drag.

The studies presented in literature analyzed the propulsive asymmetry during the crawl stroke[5,11,15]. Marinho et al.[7] investigated the relationship between propulsive force and swimming performance of competitive swimmers, however, the authors did not analyze the bilateral symmetry. Data on the difference between limbs, with regards to the force production in symmetrical swimming such as breaststroke, are scarce.

Jaszczak and Zatón[16] pointed out that the symmetry of movements, typical of the breaststroke, makes it an interesting tool in the treatment of postural problems in children's. However, Jaszczak[12] showed asymmetries between the upper limbs during a simulation of the breaststroke swimming in an ergometer. Years later, in studies carried out in the swimming pool with youth and adult amateur swimmers, authors from the same research group also verified the occurrence of force asymmetries in the stroke[9, 16]. We believe it is necessary to investigate if there are asymmetries in real swimming conditions performed by breaststroke specialists, as according to Maglischo[17], swimmers seems to have an arm more effective than the other, which could influence the performance. In this sense, the present study aimed to analyze the hand force symmetry during the breaststroke and its relationship with swimmers' performance.

Method

Subjects

Seventeen subjects (12 men and 5 women), specialists in breaststroke and individual medley races, participated in this study. Swimmers were from teams of the region of Grande Florianopolis, Santa Catarina, and were regularly participating in continental, national and state competitions. All subjects were informed about the aims, procedures and possible risks associated with the present study and gave their informed consent prior to enrolment in the study. The present study was approved by the Ethics Committee of the institution. Subjects' characteristics are depicted in TABLE 1.

TABLE 1 -   Mean (standard deviation) of the swimmers' characteristics from the present study.

*Relationship, in percentage points, between the performance in the 50 m breaststroke at maximum speed and the world's record on the 25 m swimming pool, respecting the men and women categories.

	n	Age (years)	Body mass (kg)	Height (m)	Experience (years)	% World Record*
Men	12	19.1 ± 5.6	69.9 ± 14.1	1.78 ± 0.10	11.7 ± 6.2	72.6 ± 8.2
Women	5	20.6 ± 4.6	63.8 ± 8.7	1.71 ± 0.05	11.6 ± 3.8	75.3 ± 1.9
All	17	19.5 ± 5.2	68.1 ± 12.8	1.76 ± 0.09	11.7± 5.5	73.4 ± 7.0

Instruments and variables analysis

Swimmers' anthropometric measures (body mass and height) were obtained with a digital scale (Techline, model BAL- 150 PA) and a stadiometer with accuracy of 0.01m (Sanny, professional model). Subjects responded to anamneses with information regarding laterality, training duration, frequency and the most relevant performance in swimming competitions.

Dynamometric data were collected using the Aquanex system (Swimming Technology Research, United States of America), composed by two pressure sensors, one A/D converser and a software for data acquisition. The sensors allowed estimating the force applied by the arms during the stroke with an error of 0.2%. The system was connected with a portable computer and the data acquisition frequency was 100 Hz. The following variables were analyzed:

• Mean Force (F_{med}): mean force value, expressed in N, measured in the swimmer's hand during the propulsive phase of the arm stroke.

• Maximum Force (F_{max}): maximum force value, expressed in N, measured in the swimmer's hand

during the propulsive phase of the arm stroke.

• Symmetry index for F_{med} (IS_{med}%): percentage difference between the mean force measured in the swimmer's left and right hand. The symmetry index was calculated as follows[3]:

$$IS_{med}(\%) = \left[\frac{(F_{med}R - F_{med}L)}{\max(R,L)}\right] \times 100$$

Where:

$F_{med}R$: mean force applied by the swimmer's right hand;

$F_{med}L$: mean force applied by the swimmer's left hand;

max(R,L): maximum value obtained for the mean force, irrespectively of the side (right or left).

• Symmetry index for F_{max} (IS_{max}%): percentage difference between the maximum force measured in the swimmer's left and right hand. The symmetry index was calculated as follows[3]:

$$IS_{max}(\%) = \left[\frac{(F_{max}R - F_{max}L)}{\max(R,L)}\right] \times 100$$

Where:

$F_{max}R$: maximum force applied by the swimmer's right hand;

$F_{max}L$: maximum force applied by the swimmer's left hand;

max(R,L): maximum value obtained for the maximum force, irrespectively of the side (right or left).

The total time to complete the breaststroke 50 m test (T_{50m}) at maximum speed was recorded with a digital chronometer (Casio, model HS-3V), with a precision of 0.01s.

Data Collection

Data were acquired in a 28º C heated swimming pool with 25 m width, before the swimmer's regular training session. After the anamneses, each subject warmed up for approximately 10 minutes according to the coaches' instructions. Then, the pressure sensors were positioned between the middle and ring fingers of both hands and their cables were fixed with elastics in the forearms, shoulders and hip. Subjects were allowed to familiarize with the equipment as they were instructed to freely swimming with it before data acquisition.

After this, each swimmer performed three repetitions of 25 m swimming breaststroke at maximum speed, with an interval of five minutes between trials. Then, swimmers performed an active period of recovery, according to the coaches' instructions. Lastly, subjects were instructed to perform a 50-m breaststroke trial at maximum speed in order to obtain the T_{50m}, used in this study as a performance indicator.

Data analyses and processing

Data acquired by anamnesis were digitalized in a Microsoft Office Excel 2010 spreadsheet (Microsoft Inc., United States of America) and were analyzed with using a descriptive statistical procedure (mean, standard deviation and percentage). The analyzis of dynamometric data were performed using Matlab 7.1 environment (Mathworks Inc., United States of America), with a processing routine composed by the following steps: (1) filtering (low-pass 3rd order Butterworth digital filter with 10 Hz cutoff frequency); (2) visual inspection of curves for the right and left hands, separately, in order to manually select six stroke cycles for each attempt (discarding the underwater phase and the first stroke cycle); (3) extraction of the variables of the study and (4) exportation of the variables values of each curve in *.txt format. FIGURE 1 presents an example of force versus time curves of the right and left hands obtained during one 25-m breaststroke trial performed by one of the participants of the study, with the indication of the six stroke cycles analyzed.

For the statistical analyzes, the mean value of 18 stroke cycles (six stroke cycles in each 25 m attempt) was used. Regarding the symmetry index, IS% positive values indicate that the absolute value for the variable (F_{max} or F_{mean}) was greater for the right hand, whereas IS% negative values indicate that the absolute values for the variable (F_{max} or F_{mean}) was greater for the left hand. The mean and standard deviation for IS_{med}% and IS_{max}% were calculated considering the module of individual values.

Data normality was verified by the Shapiro-Wilk test. When the normal distribution was assumed, comparison between the right and left hands was performed using a Student t test; in cases where normal distribution was not assumed, data were compared with the Wilcoxon test. The relationship between independent variables (F_{med}, F_{max}, IS_{med}%

and IS_{max}%) and performance (T_{50m}) was investigated through the Spearman correlation coefficient. All data were analyzed with the SPSS 20.0 for Windows package

software (SPSS Inc., United States of America). The level of significance adopted was $p<0.05$.

The red rectangle indicates the six stroke cycles selected for analysis in this trial, excluding the underwater phase and the first stroke cycle.
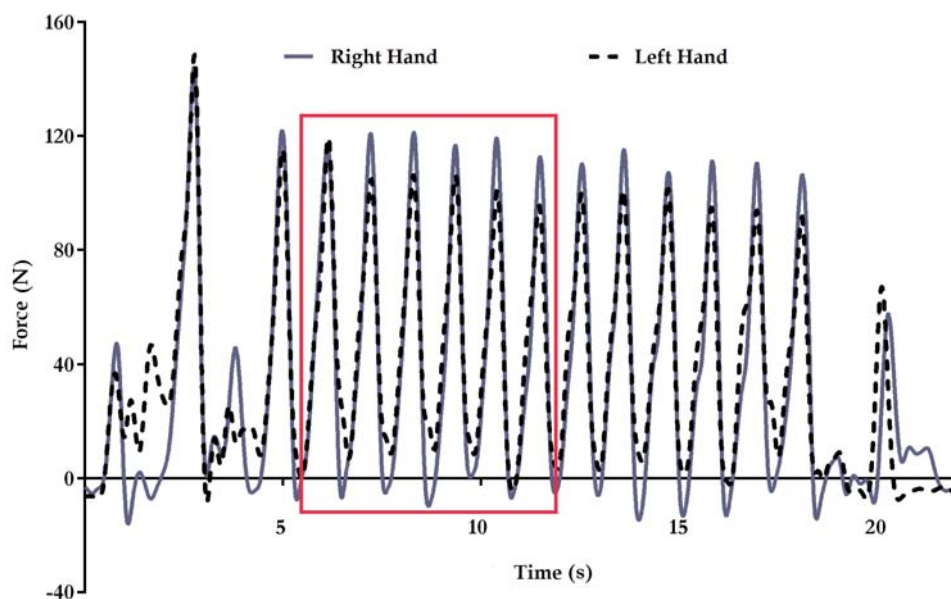

FIGURE 1 - Force versus time curves of right hand (gray solid line) and left hand (dashed black line) obtained during a 25-m breaststroke trial performed by one of the participants of the study.

Results

TABLE 2 shows the mean values, standard deviation and confidence interval (95%) for F_{med} and F_{max}, as well as the mean difference and p-value for right and left hand comparison.

TABLE 2 - Mean ± standard deviation (95% confidence interval) for mean force (F_{med}) and for maximum force (F_{max}), and the results for between right and left hand comparison.

Variables	Right Hand	Left Hand	Mean Difference	p-value
F_{med} (N)	47.9 ± 16.7	47.9 ± 14.5	-0.05	0.967*
	(39.3 – 56.4)	(40.4 – 55.4)	(-2.84 – 2.72)	
F_{max} (N)	120.7 ± 43.6	112.8 ± 35.7	7.9	0.086†
	(98.3 – 143.1)	(94.5 – 131.1)	(-1.26 – 17.1)	

The main results showed no significant statistical differences for the mean force, as well as for the maximum force, between the right and left hands. However, when inspecting data individually (TABLE 3), it was observed that some individuals presented an asymmetry index higher than 20% both for the mean and the maximum forces.

TABLE 3 - Mean ± standard deviation of individual values and symmetry index (IS%) for mean force (F_{med}) and maximum force (F_{max}).

| | F_{med} | | | F_{max} | | |
	Right Hand	Left Hand	IS_{med}%	Right Hand	Left Hand	IS_{max}%
1	46.9 ± 3.8	41.3 ± 9.0	11.9	115.9 ± 6.6	109.6 ± 12.0	5.5
2	69.6 ± 7.1	69.8 ± 5.0	-0.3	152.5 ± 12.9	148.3 ± 6.0	2.7
3	60.7 ± 6.3	64.6 ± 7.9	-6.0	142.7 ± 9.7	136.2 ± 15.5	4.6
4	47.1 ± 8.9	51.8 ± 6.7	-9.0	158.0 ± 12.1	172.4 ± 7.9	-8.3
5	25.9 ± 2.0	28.2 ± 1.9	-8.3	71.9 ± 4.0	72.4 ± (5.0)	-0.7
6	51.9 ± 7.7	48.2 ± 3.2	7.1	133.5 ± 11.7	106.8 ± 4.4	20.0
7	44.7 ± 3.1	44.3 ± 3.5	0.8	89.2 ± 6.7	90.7 ± 9.1	-1.6
8	52.6 ± 9.2	46.3 ± 6.4	11.9	139.9 ± 11.3	107.6 ± 7.6	23.1
9	36.3 ± 6.7	37.5 ± 5.6	-3.0	94.4 ± 8.3	88.1 ± 6.6	6.6
10	42.3 ± 11.0	45.8 ± 9.5	-7.7	106.3 ± 16.3	96.7 ± 16.8	9.1
11	35.4 ± 4.0	43.5 ± 7.0	-18.6	100.9 ± 11.6	94.9 ± 12.4	5.9
12	25.2 ± 1.7	36.3 ± 5.0	-30.6	45.3 ± 4.5	70.6 ± 4.2	-35.9
13	35.8 ± 5.6	30.9 ± 4.7	13.6	84.0 ± 16.7	74.0 ± 6.2	11.9
14	39.9 ± 6.2	40.1 ± 6.0	-0.5	93.7 ± 12.5	105.8 ± 15.3	-11.4
15	84.4 ± 12.8	73.9 ± 10.03	12.3	217.8 ± 22.8	167.8 ± 16.4	22.9
16	76.3 ± 13.4	75.1 ± 10.6	1.5	191.7 ± 23.7	182.6 ± 12.5	4.7
17	38.7 ± 2.9	36.8 ± 3.1	4.7	93.1 ± 10.2	114.3 ± 9.8	18.5

The mean values for IS_{med}% and IS_{max}% were 8.7 ± 7.7% e 11.4 ± 9.6%, respectively. Regarding the swimmers' performance, mean time for the 50 m (T_{50m}) was 36.06 ± 3.44s. TABLE 4 shows the results for the correlation between T_{50m} and the other variables of the study.

TABLE 4 - Spearman coefficient correlation (ρ) obtained from the correlation analysis between the swimmer's performance indicator (T50m) and the other variables of the study.

		ϱ	p-value
F_{med}	Right Hand (N)	-0.363	0.152
	Left Hand (N)	-0.346	0.174
	IS_{med}%	0.424	0.090
F_{max}	Right Hand (N)	-0.287	0.264
	Left Hand (N)	-0.186	0.474
	IS_{max}%	0.159	0.542

Discussion

The present study analyzed the maximum force and the mean force of the right and left hands during the breaststroke using a pressure sensor system. Additionally, swimming performance, measured as the total time to complete one trial of 50m at maximum speed, was correlated with the mean force values and maximum force values applied by each hand, and with the hand force symmetry index, calculated from these values.

The maximum force values for the breaststroke

observed by MOROUÇO et al.[2] are five times greater as compared with those presented in this study (513.0 ± 153.9 N); and the mean force values are more than the double as observed herein (115.6 ± 30.5 N). However, it is important to highlight that those authors measured the force using the tethered swimming method, as such, these values represent the total force produced by the strokes of the arms and legs, without any distinction between the right and left limbs. The analysis of force production by swimmers during breaststroke in ergometers showed maximum force values of 159.9 ± 37.6 N and 113.1 ± 15.5 N for men and women, respectively[12]. According to the authors, the symmetry analysis revealed mean differences of 13.9 ± 4.9 N between hands for men and of 8.7 ± 3.1 N for women, but there is no mention if the difference between limbs was statistically significant.

In the present study it was not possible to observe statistically significant differences in force application between right and left hands during breaststroke swimming. However, individual data presented in TABLE 3 point to a high variability within the group. These variations, which could be due to factors as gender, physical characteristics (e.g. maximal strength and the length of the segments involved in propulsion) and technical aspects (e.g. stroke mechanics and performance level), among others, may have "masked" possible differences of force between right and left hands.

A great variability within group was also observed for the symmetry indexes. Although the average IS% was 8.7% for F_{med} and 11.4% for F_{max}, individual values were up to 30.6% for IS_{med}% and 35.9% for IS_{max}%. In the current literature, asymmetries up to 10% between limbs are considered acceptable for activities such as human walk[18]. These values are also adopted for swimming studies that aim to investigate coordination analysis, force applied in swimming ergometer and tethered swimming[19-22]. In this study, six of the 17 analyzed swimmers presented values higher than 10% for the IS_{med}%, and seven for the IS_{max}%.

The occurrence of force asymmetry has been showed in crawl stoke[4,15,22], and it is generally attributed to the unilateral alternation of arm movements and to the breathing mechanics[14,22]. However, substantial asymmetries between limbs are also found in strokes with bilateral characteristics, such as breaststroke and butterfly, even in elite swimmers[13].

Recently, studies involving breaststroke swimmers

with different technical levels sought to understand the magnitude of asymmetries, its possible causes and also the consequences for performance[9,12, 16,23]. JASZCZAK[12] compared the force asymmetry between crawl stroke and breaststroke performed in a ergometer by swimmers of both genders and with a "moderate" performance level (as defined by the author). The mean values of asymmetry found for the breaststroke was of 8% for women and 9% for men. For the crawl stroke, average values were of 14% and 12% for female and male subjects, respectively. For the male swimmers, there were no significant differences between swimming strokes (crawl or breaststroke). It is important to highlight that there are technical differences between swimming in an ergometer and in a real swimming scenario, and this could cause some confusion in the interpretation of the values, which were probably underestimated for the ergometer.

Aiming to analyze the hand force symmetry during breaststroke in situations with a higher ecological validity, JASZCZAK[9] and JASZCZAK and ZATÓN[16] investigated maximal repetitions of 15 m in a swimming pool, using pressure sensors attached to the swimmers' hands. In both studies, the authors analyzed the effect of the leg kick technique ("correct" - symmetrical movements, "incorrect" - asymmetrical movements) in hand force symmetry, in college students[9] and 11-year old boys[16] with "moderate" performance level, and with no expertise in swimming competition. For both groups, the upper limb symmetry was registered during isolated movement of arms (using a pull-buoy between legs) and during breaststroke (whole stroke). In both groups, swimmers that performed asymmetrical movement of legs also presented an increase of asymmetries in upper limbs, when the isolated upper arm condition was compared to the whole stroke condition: 12% versus 14% for college students[9] and ~25% versus ~30% for 11-year old boys[16]. According to the authors, the results point that the increase of asymmetries in upper limbs may be a compensatory response to asymmetrical movements of the lower limbs. SANDERS[24] corroborates with the previous hypothesis, indicating that in bilateral strokes, differences in force production in the lower limbs could cause body misalignment and, consequently a compensation in the hand's trajectory; this compensation, in turn causes a technical asymmetry that could become a habit, leading the swimmer to produce more force in one side of the body than in another.

Asymmetrical movements of upper and/or lower limbs are not only present in swimmers with low and moderate levels of performance. Sanders et al.[23], in a recent case study with an elite female swimmer specialist in breaststroke, observed asymmetries in the kinematic path of both lower and upper limbs during 100-m trials, which lead to the occurrence of a momentum in the antero-posterior axis (vertical in relation to the bottom of the swimming pool). Sanders et al.[14] point the possibility that the technical asymmetries could reinforce and perpetuate other types of asymmetries, for example, muscular imbalance. In the case analyzed by Sanders et al.[23], the authors attribute part of magnitude of the technical asymmetries to the fact that the muscles from the right side of the swimmer were stronger than the ones from the left side, both for flexion and internal rotation. Consequently, the stroke pull is faster for the right side, producing higher propulsive force, which causes the momentum in the antero-posterior axis.

Sanders et al.[14] state that, although the breaststroke is a bilateral demand, and the activity by itself stimulates symmetry, it is not possible to neglect the effect of other daily and sportive activities of asymmetrical nature. In this context, it is important to highlight that swimmers, in general, train a huge amount of distances swimming crawl stroke, even being specialists in other strokes.

In relation with the asymmetry direction (IS positive or negative, depending on the side that the swimmer applies more force), it seems important to consider aspects like laterality. In the present study, the laterality was determined by questioning the preferential hand of the swimmers for performing daily actions. Fifteen of the 17 swimmers chose the preferential side as the right one. In this way, the individual data (TABLE 2) do not seem to present any relation between the laterality - in the way it was measured - and the direction of asymmetry. It is important to consider that other strategies could be used to the determination of laterality (e.g. the preferential side for breathing in crawl stroke, or the analysis of the unilateral strength of muscles involved in propulsion).

The data found on the present study corroborates with findings in the literature in respect to the presence of asymmetries in breaststroke. Considering the information previously debated, it is possible that the IS% values during the arm stroke might be influenced by some associated factors, such as the kinematical asymmetry of upper and lower limbs, the asymmetry of force production in the lower limbs, and the asymmetries of strength and flexibility of the main muscular groups involved in propulsion.

Since the causes of symmetry were already discussed, it is interesting to analyze its relationship with swimming performance. In bilateral strokes, the asymmetry in force production could cause a rotation in the antrero-posterior axis, increasing active drag[13, 24]. The imbalanced force contribution could also compromise the propulsive efficiency[24]. Although it is expected that these aspects may directly affect performance, a lack of studies regarding this topic is found. It is not clear if the presence of asymmetries of different natures is necessarily related with a decrease in performance[24].

According to Morouço et al.[22], it is not yet defined if the asymmetries of force, velocity, trajectory and coordination reported by the literature for the crawl stroke could alter the optimal function, or simply are inside a normal boundary of variation. In order to contribute with the discussion, the authors analyzed the relationship between the symmetry index of crawl stroke on tethered swimming and the total time in a 50 m performance, in male swimmers of different performance levels. The authors found values of IS% between 3.3% and 48.5%, with the majority of the swimmers presenting values above 10%. Interestingly, the analysis of the relation between force and performance, when controlled by the IS% magnitude, showed that higher values of asymmetry did not lead to worse performances. Based on that, the authors assumed that, until a certain limit, the asymmetry may not be a critical factor to achieve maximal swimming velocities.

On the present study, the analysis of relationship between IS% and swimming performance (T_{50m}) resulted in a moderate, non-statistically significant correlation coefficient for mean force ($\varrho=0.424$, p=0.090), and a weak, non-statistically significant correlation coefficient for maximal force ($\varrho=0.159$, p=0.542). In this way, the upper limb asymmetry seems to not influence the breaststroke 50 m performance, considering the way the variables were measured. It is important to emphasize that, although the asymmetries may increase the active drag and reduce the propulsion, it is possible that the subjects analyzed - aligned with other scientific findings - adopted strategies of compensation, reducing its effects in the global stroke performance. Additionally, it is possible that the 50 m performance is influenced in a greater scale by other factors, such as the leg kick efficiency (most propulsive element in the stroke[17]), the coordination between lower and upper limbs, and the individual capacity of

energy consumption and resistance to fatigue. The force applied by the upper limb, by itself, seems to have low relevance in the 50 m performance, based on the low correlation coefficients presented in TABLE 4.

When the total force produced by the swimmer (using upper and lower limbs propulsion) is considered, its relationship with swimming velocity is substantially stronger (r-0,94)[2]. Also, according with HAVRILUK[10], for all competitive strokes, the technique adopted by the swimmer to reduce the active drag appears to have a better effect on performance, compared with the quantity of force applied. The author also empathize the necessity of analyzing the way the swimmers apply the force during the entire stroke cycle.

According with SANDERS at al.[23], the severity of asymmetries and the impact that they have on performance vary from swimmer to swimmer. More information is needed to assist the observation of the effectiveness of interventions to correct the issue. As reported by the authors, some asymmetries may not affect performance and, in this case, drills performed to correct them may negatively interfere in the training program of the swimmer. In contrast, if asymmetries of force, flexibility or technique would produce a momentum that could cause bad alignment and increased drag, it may be valid to consider strategies to correct them. It is important to consider that it could be necessary to correct asymmetries that although not bring significant reduction in performance, may expose the swimmer to a higher incidence of musculoskeletal issues. The need of force or/

and kinematical compensations in function of asymmetries, combined with the high number of repetitions and the training overload, could lead to organic adaptations, causing muscular imbalance and increasing the risk of injuries[25].

This exploratory study allowed to analyze the hand force symmetry during the breaststroke and, although the aim was not to examine the eventual causes of asymmetries, it sought to contribute in the whole understating of the relation between the asymmetries and swimming performance. The results showed that, although the differences of mean and maximum forces between left and right hands are not statistically significant for the analyzed swimmers, individual asymmetries could reach 35%. However, it seems not to exist a relation between this asymmetry and the total time of a 50 m performance. Some limitations are recognized in regard of the measurement method used on the study for estimation of hand force, since it provides an indirect measure of force, and does not represent propulsive force by its entirety. However, the instrument allowed the swimmers to perform freely during the analysis, increasing the ecological validity in comparison with tethered swimming. Finally, the authors suggest that further studies analyze the relationship between asymmetries in hand force and other performance indicators, such as stroke frequency and stroke length. Additionally, it could be relevant to investigate the relationship between hand force asymmetry and/or swimming technique with other types of asymmetries (e.g. morphological and/or functional).

Resumo

Análise da simetria de força na braçada do nado peito

Este trabalho teve como objetivo analisar a simetria da força aplicada durante a braçada do nado peito e a sua relação com o desempenho de nadadores. Participaram do estudo 17 nadadores especialistas em nado peito e medley (12 homens e 5 mulheres, 19,5 ± 5,2 anos, melhor tempo pessoal correspondente a 73,4 ± 7,0 % do recorde mundial dos 50 m peito). Cada sujeito realizou três repetições de 25 m peito em máxima velocidade. Sensores de pressão do Sistema Aquanex foram posicionados na mão direita e na mão esquerda dos nadadores, possibilitando a aquisição das variáveis Força Média (F_{med}) e Força Máxima (F_{max}). Calculou-se o índice de simetria conforme proposto por Sanders e utilizou-se o tempo de uma execução de 50 m peito em velocidade máxima (T_{50m}) como indicador de desempenho. A comparação das variáveis entre a mão direita e a mão esquerda foi realizada através de testes para amostras dependentes, e a relação entre as variáveis foi investigada através da correlação de Spearman ($p < 0,05$). A F_{med} aplicada foi de 47,9 ± 16,7 N e de 47,9 ± 14,5 N para as mãos direita e esquerda, respectivamente. A F_{max} correspondeu a 120,7 ± 43,6 N e 112,8 ± 35,7 N para as mãos direita e esquerda, respectivamente. Não foram encontradas diferenças significativas quando comparadas as mãos direita e esquerda. Uma análise individual e descritiva das variáveis permitiu observar assimetrias de até 30,6% para a F_{med} e de até 35,9% para a F_{max}. Entretanto, parece não haver relação entre os índices de simetria com o desempenho no nado peito em 50 m.

PALAVRAS-CHAVE: Natação; Biomecânica; Desempenho.

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