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ISOKINETIC SHOULDER EXTENSION TORQUE AND WORK VALUES OF COMPETITIVE SWIMMERS

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SUMMARY
The aim of the present study was to analyze isokinetic torque production during shoulder extension in competitive swimmers. Nine male competitive swimmers were evaluated during concentric shoulder extension at $60°\cdot s^{-1}$ on prone position for both upper limbs. The data suggest that competitive swimmers present asymmetry for peak torque and symmetry for peak torque angle and work during shoulder extensor torque angle curve.

INTRODUCTION
In swimming the goal is to maximize propulsion while reducing the resistance forces. Front crawl is an alternating swimming stroke technique broken into four phases (entry/catch, pull, push and recovery) [1]. Both pull and push phases are considered propulsive and important component of swimming performance.
Shoulder muscles play an important role during propulsive phase [2]. Previous studies have used isokinetic dynamometry to investigate swimmers shoulder dysfunctions [3], but few studies have evaluated shoulder forces related to propulsion and performance [4]. Generally, studies involving isokinetic shoulder evaluation in swimmers have analyzed torque production during internal/external rotation and abduction/adduction regarding its relationship to the propulsion phase during front crawl stroke [3,4,5]. However, the important role of shoulder extension for propulsion during front crawl swimming seems to have been reduced in the previous studies. Thus, the aim of the present study was to analyze isokinetic torque production during shoulder extension in competitive swimmers.

METHODS
Subjects: Nine male competitive swimmers volunteered to participate in this study (mean ± standard deviation for age 17.0 ± 4.9 years old; height 1.67 ± 0.04 m; body mass 64.5 ± 13.16 kg). All were healthy and free injury or symptoms at the time of the experiment. The swimmers were involved in training sessions of 1.5 h on at least five occasions per week for at least a 1-yr period preceding the study. The subjects were fully informed of the risks and discomforts associated with the experimental procedures. All participants signed an Informed Consent Form in agreement with the Committee of Ethics in Research of the institution where this study was conducted.

Protocol: Shoulder extensor torque angle curve was obtained bilaterally during isokinetic contractions by means of an isokinetic dynamometer (Biodex S4, New York, USA). The swimmers were asked to lie in ventral decubitus on the dynamometer with trunk stabilized with straps to avoid undesirable movements. In this position swimmers were able to exert the action with the forearm in a prone position to better simulate front crawl swimming. Dynamometer axis was visually aligned with shoulder axis (inferior to acromion lateral border). Upper limb weigh with shoulder in anatomical position (0°) to gravity correction.
Data collection: Five minutes warm up with shoulder flexion/extension movements using a rod were performed prior the test. Five trials were performed in order to get subjects familiarized with the movement. Swimmers preformed five concentric shoulder flexion/extension repetitions at $60°\cdot s^{-1}$ for both limbs.
Data analyses: The highest point on the torque curve was considerate the peak torque (PT). Peak torque-to-body mass ratio (PT/BM), peak torque angle (PTA) and work-to-body mass ratio (W/BM) for both pull (from 160 to 90°) and push phase (from 89 to 0°) were calculated using the segment of the curve where the angular velocity was constant ($60 \pm 1°\cdot s^{-1}$).
Statistics procedures: Data normality was verified by Shapiro-Wilk test. An independent t-test was used to compare preferred and non-preferred limb (PT, PTA, and W/BM) and paired sample t-test was used to compare pull and push work-to-body mass ratio. Data were analyzed in SPSS version 12.0 for Windows (SPSS Inc., USA). The level of significance was set at 0.05.

RESULTS AND DISCUSSION
Isokinetic extensors torque-angle curve is illustrated in Figure 1. Comparing limbs, preferred presented higher PT/BM ($p=0.023$) compare to non-preferred, but no differences were observed for PTA ($p=0.417$) and W/BM during pull ($p=0.069$) and push phases ($p=0.206$) (Table 1). Differences were observed for W/BM between pull and push phases for both limbs ($p<0.01$).

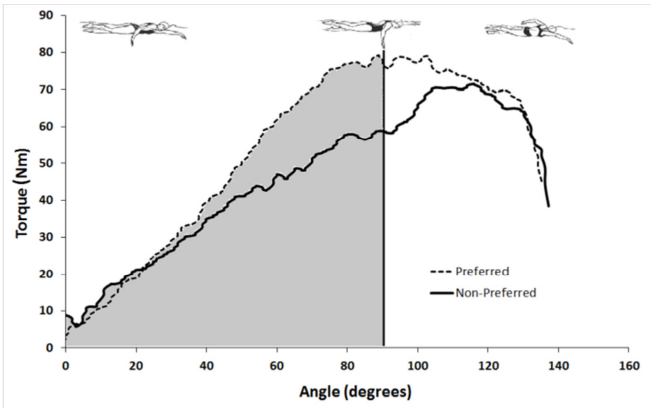

Figure 1: Torque-angle relationship of one representative swimmer during the isokinetic extension test. White area represents the work accomplished during pull phase of the preferred (—) and non-preferred limb (**---**). Gray area represents the work accomplished during push phase of the preferred and non-preferred limb.

To our knowledge, no studies have evaluated isokinetic shoulder extension in prone position to better simulate front crawl swimming. At any rate, Perrin et al. [6] observed greater PT values for the preferred limb during shoulder extension, but no asymmetries for torque acceleration energy, average power, and total work were observed. Upper limb force asymmetries are expected, even in relatively symmetric sports (e.g. artistic gymnastic events as rings, high bar, and parallel bars), once daily life activities seems to be more asymmetrical and useful to choose preferred limb to perform tasks.

Table 1: Mean ± standard deviation (SD) of the peak-to-body mass torque (PT/BM), peak torque angle (PTA), work-to-body mass (W/BM), for preferred (P) and non-preferred (NP) limb, during isokinetic shoulder extension.

	Mean (SD)	
	P	NP
PT/BM (Nm·kg^{-1})	1.16 (0.14)	1.00 (0.12)*
PTA (°)	109.9 (12.9)	104.1 (16.3)
Pull W/BM (J·kg^{-1})	72.36 (9.99) [@]	62.13 (12.13) [#]
PushW/BM (J·kg^{-1})	87.54 (16.88)	78.79 (10.55)

*Significant difference related to preferred limb. [@]Significant difference related to preferred limb in the push phase. [#]Significant difference related to non-preferred limb in thepush phase. $p<0.05$.

It seems to have no agreement about maximum torque production angle for shoulder extensors. Our results indicate that PTA for both limbs occurred in the end of pull phase (110 and 104º, respectively). But during a similar study, authors observed that 66.7% of the swimmers presented PT between 120 and 180º and 30% between 60 and 119° [7]. Furthermore, it has been reported that non-athletes during isokinetic shoulder extension presented PT at 90° [8].

Our results for PTA can be explained by pectoralis major and latissimus dorsi muscles contribution to the movement. Muscle activation analysis during front crawl stroke demonstrated an increase of these powerful extensors muscles activity in the end of pull phase until the beginning of push phase [2,9].

Previous study has shown that swimmers reduce body roll around the longitudinal axis when speed increase due to non-breathing cycles [10]. We suggest that reducing body roll sprint swimmers may give more emphasis to the shoulder extensor muscles during the underwater phase (i.e. pull and push).

The present study shows that even presenting PT over pull phase the great contribution of the total propulsion (i.e. work accomplish) comes from push phase in both limbs (Table 1). This information provides a biomechanical framework to guide strength training to improve propulsion force during front crawl stroke, especially at pull phase.

CONCLUSIONS

The data suggest that competitive swimmers present asymmetry for peak torque and symmetry for peak torque angle and work during shoulder extensor torque angle curve.

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