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Non-linear properties of front crawl swimming propulsive forces: a pilot study

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INTRODUCTION

The complex patterns of the human aquatic locomotion have already demonstrated non-linear properties. So far, this non-linear approach was just conducted using kinematic data. It remains unclear if other performance-related parameters, such as the propulsive force, show similar patterns. The aim of this study was to assess the non-linear properties of the propulsive forces in three different front crawl conditions comparing outputs from both dominant and non-dominant limbs.

METHODS

Eleven male swimmers were recruited for this study (15.87 ± 3.08 years old, 63.15 ± 12.99 kg). All subjects had at least two years of experience in competing at regional and/or national level. Every subject performed 4 maximal bouts of 25m at three different conditions of the front crawl stroke: i) full body stroke (sensors in the hands, FBH); ii) full body stroke (sensors in the feet, FBF); iii) arms' stroke-pull only (sensors in the hands, AS) and; iv) leg kicking only (sensors in the feet, LK). A differential pressure system (Aquanex System, DU2V, STR, EUA) with two sensors was used. Fractal Dimension and Sample Entropy were the non-linear parameters computed according to Higuchi (1988) and Richman and Moorman (2000) procedures, respectively. A paired sample T-test and a two-way repeated measures ANOVA with Bonferroni post-hoc correction were performed ($p \leq 0.05$).

RESULTS

Paired samples T-test showed no difference between dominant and non-dominant limbs in every condition and variable (table 1). Two-way repeated measures ANOVA showed no main effects of condition or limb in SampEn. However, it showed significant and strong main effect of condition in FD ($F3=40.012$; $p<0.001$; $\eta_p^2=0.784$) (table 2).

Table 1
Sample entropy and Fractal dimension values obtained in each condition for both dominant and non-dominant limb.

	Full Body Hand Mean ± 1 SD (95CI)	Full Body Feet Mean ± 1 SD (95CI)	Arm stroke Mean ± 1 SD (95CI)	Leg kicking Mean ± 1 SD (95CI)
	Sample Entropy (SampEn, dimensionless)			
Dominant limb	0.388 ± 0.083 0.324 – 0.452	0.307 ± 0.176 0.172 – 0.442	0.354 ± 0.108 0.271 – 0.437	0.251 ± 0.261 0.05 – 0.451
Non Dominant Limb	0.351 ± 0.099 0.275 – 0.427	0.283 ± 0.156 0.171 – 0.395	0.316 ± 0.084 0.252 – 0.381	0.286 ± 0.31 0.048 – 0.524
	Fractal Dimension (FD, dimensionless)			
Dominant limb	1.936 ± 0.01 1.929 – 1.942	1.96 ± 0.014 1.951 – 1.968	1.942 ± 0.008 1.937 – 1.947	1.97 ± 0.009 1.964 – 1.976
Non Dominant Limb	1.929 ± 0.018 1.918 – 1.940	1.954 ± 0.013 1.946 – 1.963	1.94 ± 0.012 1.933 – 1.948	1.967 ± 0.011 1.961 – 1.974

Table 2
Main effects and interactions between the conditions and limbs.

	df	F-ratio	p-value	η_p^2
	Sample Entropy (SampEn)			
Condition	3	0.820	0.495	0.093
Limb	1	1.546	0.249	0.162
Condition * Limb	3	2.571	0.078	0.243
	Fractal Dimension (FD)			
Condition	3	40.012	<0.001	0.784
Limb	1	2.849	0.12	0.206
Condition * Limb	3	0.456	0.715	0.04

DISCUSSION

The propulsive force of the front crawl stroke generated by the upper and lower limbs, in both full body and segmental strokes presented non-linear properties.

Post-hoc Bonferroni correction showed that FD presented no difference between FBH and AS. However, both of them are statistically less complex than both FBF and LK. LK on the other hand, is significantly the most complex condition of all. Under the light of the non-linear pedagogy, it is important for the coach to know that the complexity of the force pattern depends on the segments that are in action, so he can manipulate one of the key factors that underpin performance, in order to provide an effective training program.

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