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COMPARISON OF CLASSICAL KINEMATICS, VARIABILITY AND NONLINEAR PARAMETERS FOR THE FOUR COMPETITIVE SWIMMING STROKES

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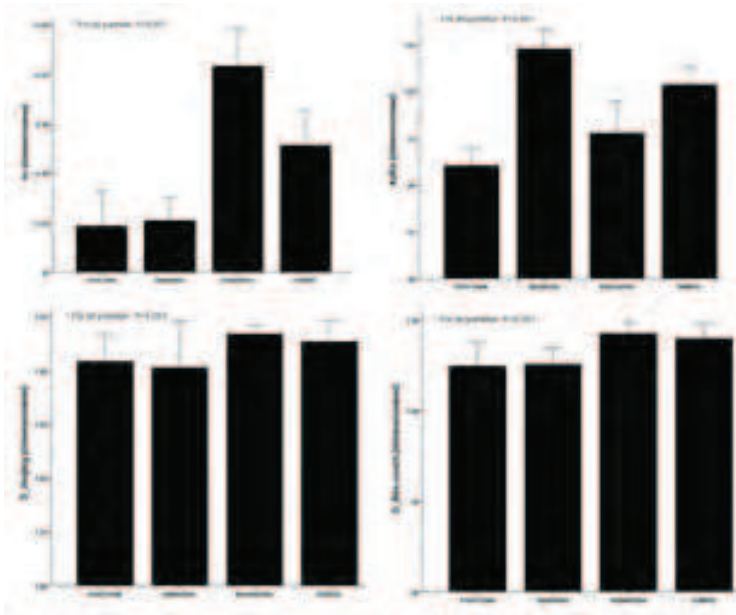
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Introduction and Objectives: The aim of this research was to compare classical kinematic and nonlinear parameters in the four competitive swimming strokes.

Methods: Twenty-one national level swimmers (11 boys and 10 girls; 13.61±1.3-y) performed a set of 4×25 m swims from a push-off start with the front-crawl, backstroke, breaststroke and butterfly stroke in random order. A speedo-meter (Swimspotec, Hildesheim, Germany) was attached to the subjects' hip (f=50Hz) to determine instantaneous velocity. Data were exported to a signal processing software (AcqKnowledge, Santa Barbara, USA). Velocity fluctuation (dv) was selected as a classical kinematic parameter and based on previous studies, is also considered an energy cost estimator [1]. For the non-linear analysis, ApEn was calculated for at least 700 pairs of speed-time, an embedding dimension of m=2 and the maximum tolerance value of r=0.1 [2]. The D was calculated by the Higuchi's method (D_Huijing) from the speed-time pairs and complemented with the Box-count method (D_Box-count) [3]. Repeated measures (within-subjects ANOVA) analysis was performed (P≤0.05).

Results: Fractal properties were 1.80±0.86 - 1.93±0.02 for D_Huijing and 1.24±0.07 - 1.42±0.03 for D_Box-count (Fig 1). There were significant variations among the four swimming strokes for dv [F(1,21)=620.99; P<0.001], ApEn [F(1,21)=296.50; P<0.001], D_Huijing [F(1,21)=87.86; P<0.001] and D_Box-count [F(1,21)=207.81; P<0.001]. Post-hoc testing showed that all possible pairwise combinations were significantly different (P<0.001). Overall, the lowest values were observed for front-crawl; followed by the backstroke, butterfly stroke and breaststroke (Fig 1). Conversely, within-subject testing controlling the effect of velocity (ANCOVA) did not demonstrated significant interactions for the dv [F(1,20)=0.12; P=0.91], D_Huijing [F(1,20)=0.001; P=0.97] and D_Box-count [F(1,20)=0.05; P=0.83] but did for the ApEn [F(1,20)=4.96; P=0.04].

Figure:



Conclusion: Human swimming with all four competitive strokes showed fractal properties ($1 \leq D \leq 2$). More predictable swimming patterns (i.e. ApEn) have a lower level of complexity (D) and this might have an effect on the energy cost of swimming based on the observed dv. Figure 1: Comparison of the classical and nonlinear parameters between the swim strokes (mean \pm 2SD).

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