Fractal analysis of human aquatic locomotion: an exploratory and descriptive study

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Introduction

Fractal analysis has recently been applied to study a wide range of objects/systems in Biology and Medicine to assess non-linear phenomena.

Human swimming is a non-linear behavior and as much as we are aware, no fractal research was conducted in such locomotion technique.

The aim was to carry out an exploratory and descriptive study to investigate whether human swimming performance can be evaluated using fractal properties.

Methods

Subjects: Eighty-two male swimmers with varying competitive levels (from the local level up to World-ranked athletes).

Experimental Design: Each swimmer undertook a set of maximal 3x25 m at front-crawl with push-off starts.

A speedo-meter cable (Swim speedo-meter, Swimsportec, Hildesheim, Germany) was attached to the subjects' hip (f=50 Hz) (Fig 1).

Data were exported to a signal processing software (AcqKnowledge v.3.5, Biopac Systems, Santa Barbara, USA) and filtered with a 5 Hz cut-off low-pass 4th order Butterworth.

The stroke cycles were normalized to time, since fractal analysis is sensitive to the duration of the observation.

Fractal dimension (D, dimensionless) was calculated with the box-counting method from the speed-time graphs.

D is an index to characterize fractal patterns or sets and quantify their complexity as a ratio of the change in detail to the change in scale.

Descriptive statistics (mean, one standard deviation, median, quartiles) were considered for further analysis.

Results

Overall, the fractal dimension was lower than that reported for human gait on land (table 1) .

This might be related to the lower range of speeds reached in human swimming in comparison to walking, running or sprinting.

Some of the swimmers reached *D* values close to what is reported for human gait though.

One might consider that those are the less expert swimmers.

Highly-expert swimmers (e.g. World-ranked athletes) avoid significant changes in their speed, having a more "smooth" and uniform motion, as it increases their efficiency, and thus decreases their energy cost.

Table 1: Descriptive statistics of the fractal dimension (D) in human swimming.

	Avg	1SD	Me	Min	Q1	Q2	Q3	Max
D [dimensionless]	1.079	0.053	1.068	1.010	1.040	1.068	1.109	1.250

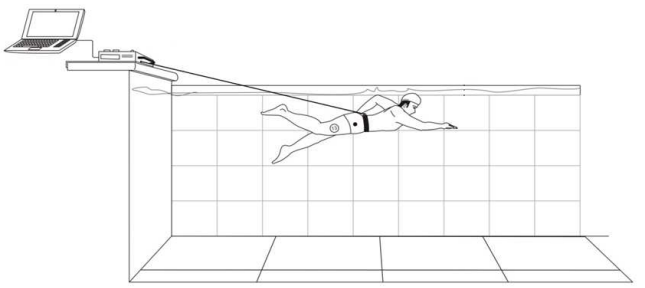

Figure 1: Apparatus set-up.

Conclusions

It can be concluded that human swimming has fractal properties. Swimmers' and their techniques can be analyzed by non-linear parameters.