USING METHODS OF NON-LINEAR DYNAMICS TO LOAD-STRESS-TESTS IN A SWIMMING FLUME

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INTRODUCTION

It is generally known that two types of approaches may be distinguished in movement science: structural and phenomenological approaches (BEEK / PEPER / STEGEMANN (1995)). Structural models of human movement are typically (neuro)physiological models which attempt to explain different aspects of motor behavior on the basis of (neuro)physiological mechanisms for the generation of movement. While the aim of phenomenological models is to describe the functional properties without addressing the structural basis of these properties. The non-linear theories of dynamic systems constitute a special subclass of phenomenological models of movement coordinaton.

The follow properties are characteristic for the dynamical system theory:

- the basis of movement coordination is the physical self-organization which can adapt in a flexible manner to changing internal and external conditions,
- existence of general principles of movement coordination which are relatively independent of the structural and material properties of the system's components,
- it is possible to describe the total system in terms of one or a few order parameters,
- the dynamics of these models capture the qualitative changes of the order parameter(s) (called phase transitions) due to the systematic manupulation of a control parameter.

The dynamical system theory is an interdisciplinary theory in comparision with other sciences: biomechanics, psychology, anatomy, physiology. This theory is able to describe the movement coordination by means of general laws of interactions between information, force/energy and matter.

The object of this paper is the application of methods of non-linear dynamics on breaststroke swimming in load-stress-tests. The obtained results were compared with results from traditional methods of time series analysis.

METHODS

Corresponding to the dynamic-pattern-theory of human movement coordination (JEKA / KELSO (1989)) the identification of one or a few order parameter(s) is important. With help of these parameters it is possible to represent the state of the system with an attractor. The construction of the substitute-phase-space-diagram is realized by time shifting of the time series of the order parameter (O_{n+1} over O_n). For this, it is necessary to determine the embedded dimension m and the time delay τ. For the fundamental answer to the question about the possibility of embedding and the reconstruction of the phase space the Waberproduct-analysis can be used (LIEBERT, 1991). This procedure allows the determination of m and τ from the time series.

Dimensions are used for analysis of the reconstructed attractor. Various notions of dimension allow one to quantify the number of generalized degrees of freedom that are relevant to the dynamics. The dimension of a chaotic or strange attractor is a fractured number. The fractal dimension characterized the fractal geometry of the attractor. But then the correlation dimension considers the density of distribution of attractor points. A popular numerical method to calculate this dimension is given by GRASSBERGER / PROCACCIA (1983).
The experimental investigations were accomplished exemplarily for breaststroke swimming as a single case study. Two female members (BOR and WOL) of a sports club (age: 14 years) were available as subjects. A 3-step-load-test was carried out in a swimming flume (s. fig. 1). The tests were held at the beginning and in the middle of a training phase.

fig. 1: Test configuration on the basis of the best time for a distance of 200 m

step	percentage of load	duration of load	intesity of load	break
1	85 %	2 min	1 x	4 min
2	90 %	2 min	1 x	4 min
3	95 %	2 min	1 x	4 min

For the futher calculations only step 3 (95 % of the best performance) was considered. After several years of research the fundamental quantities of the breaststroke were found by means of simple ANOVA-technique: horizontal hip velocity and cycle length. On grounds of proved stationarity of the first quantity in the time course the horicontal hip velocity was defined as the order parameter. From the time series of this parameter the statistical values, the autocorrelation function, the Waberproduct and the both dimensions were calculated.

RESULTS

The time course of the horizontal hip velocity (fig. 2) shows in no case of the investigations a trend that makes it is possible to assume stationarity. The accompanying autocorrelation function (fig. 3) for 1200 data and 200 lags is drawn to zero. This is evidence for a stochastic or a chaotic process.
On closer examination of the time series it can be find out that the second test is characterized by stronger irregularity than the first test. The results of the descriptive statistics do not show this. However the fractal and correlation dimensions are higher in the second test than in the first test. With help of the Waberproduct-analysis the embedded dimensions for the fractal dimension $m = 4$ and for the correlation dimension $m = 5$ were calculated. The particular time delays τ were for this determined. The calculation of the dimensions (fig. 4) followed by means of these parameters. The increase in dimensions indicates an increase in available movement parameters. With that the effect of the training phase was a higher variability of movement at the end of the test. In most cases the variability at the beginning of the test was lower in comparison with the end of the test. A practicable reason for this phenomenon is a worse sporting technique of the sportswomen under high load.

fig. 2: Time course of horizontal hip velocity (WOL, test 1, beginning of the test)

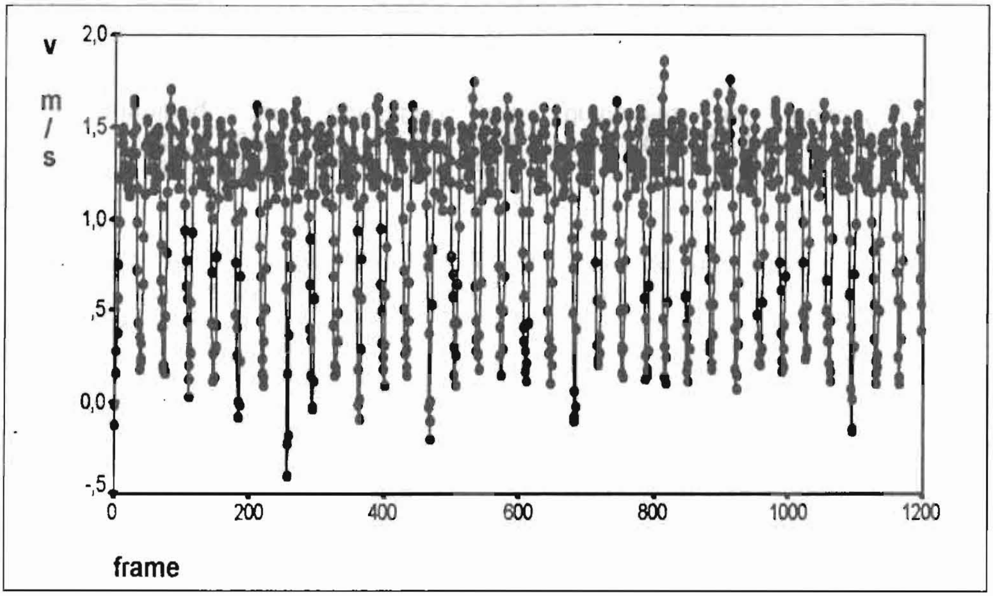

fig. 3: Autocorrelation function (s. fig. 2)

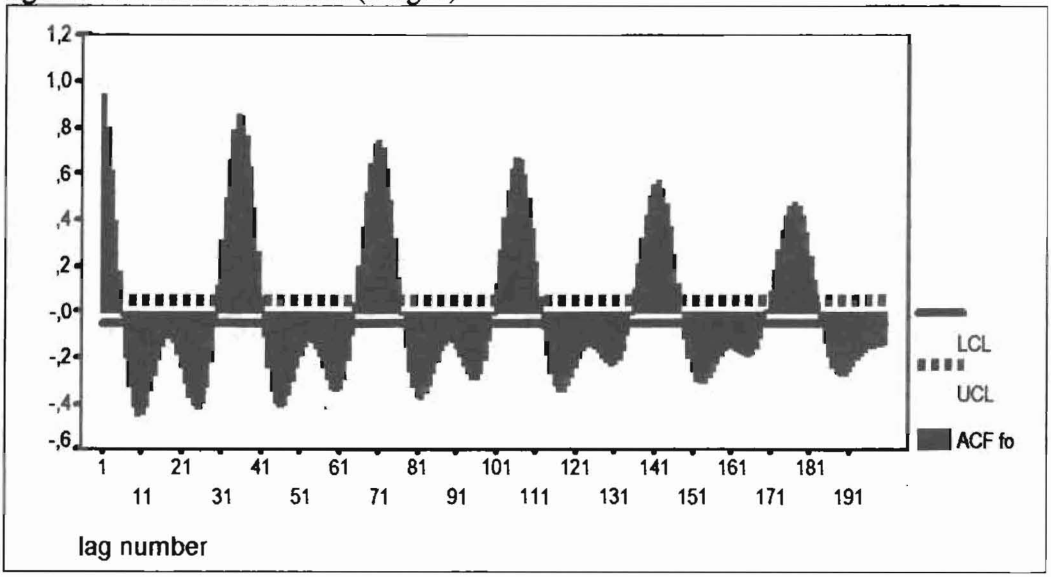

fig. 4: Fractal (Fdim) and correlation (Cdim) dimensions for the sportswomen WOL and BOR

	WOL				BOR			
	test 1		test 2		test 1		test 2	
	beginning	end	beginning	end	beginning	end	beginning	end
Fdim	1.49	1.41	1.83	1.80	1.55	1.49	1.62	1.62
Cdim	3.28	3.30	3.00	3.46	3.11	3.04	2.67	3.26

CONCLUSIONS

The order parameter horicontal hip velocity describes the movement coordination in breaststroke swimming. By means of Waberproduct-analysis it was proved that it is possible to create a phase space for a strange attractor. Therefore, the coordination of breaststroke is 'chaotic'. The determined dimensions show an increase in variability with higher load and after training. For the assessment of the variability it is necessary to take the sporting technique into consideration. Conventional methods of statistics (time series, autocorrelation function, descriptive statistics) for this are used.

According to this the methods of the non-linear dynamics are very suitable for determinations of variability of motor control on the basis of only one movement parameter.

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