STRENGTH ENDURANCE DIAGNOSIS OF THE UPPER LIMBS

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INTRODUCTION: Recently the performance factor of special strength abilities has gained in importance for endurance athletes (Wilke/Madsen 1988; Polunin/Snesarev 1990; Verchoshanskij 1992; Reiß 1995). The diagnosis of strength or power endurance is always done using increasing resistance (e.g., carrying additional loads, running uphill, shifting gears in cycling). Thus in each case athletes must generate a higher energy output per repetition in relation to the original movement. As a consequence the duration of the active part of the movement (force production) is prolonged. The purpose of this strength and power diagnosis is to measure the athlete's response to these conditions. In our paper we describe variations of biomechanical parameters in swimming.
Based on experience in diagnosis with an arm pulling apparatus in skiing and swimming, we developed a rope-pulling ergometer for the upper limbs to measure force and power in several endurance sports, and it has been adapted to the special conditions in swimming.

METHODS: The arm pulling ergometer is the official diagnosis equipment of the German Skiing Association, the German Swimming Association and the German Triathlon Association. Within the diagnostic protocol athletes perform two tests of speed strength and strength endurance. Additionally, the arm pulling ergometer may be used for measurement in training.

Figure 1: Equipment for investigations in swimming

Several working conditions, for instance arm movement in skiing and swimming or canoeing may be reproduced with the help of the ergometer, as well as different postures of the athletes and different amounts of resistance.
The resistance units for the left and right arm may be adjusted separately. Resistance was produced by an eddy-current brake. During tests the force-time-

curves of the left and right arms are presented on-line. Additionally, the parameters pulling frequency, test duration, heart rate, pulling distance, work and power of each pull are shown.
The athletes performed 10 maximum power repetitions against a defined resistance. After a short rest an endurance test of one or two minutes' duration with alternate (free style) or simulated (butterfly) arm movement was performed. 41 top level swimmers served as subjects in the study.
The total power (total work/test time) and the intracyclical parameters work and power for the interval of force production were calculated. Additionally, maximum velocity and relation of active pulling time and rest were computed.

RESULTS: The force-path-curves show differences between athletes. We found the same form of the curve and typical deviations as described by Counsilmann (1994). There is a strong agreement between the technical attributes of the dry land swimming movement and the movement in water, for instance in the swimming flume.

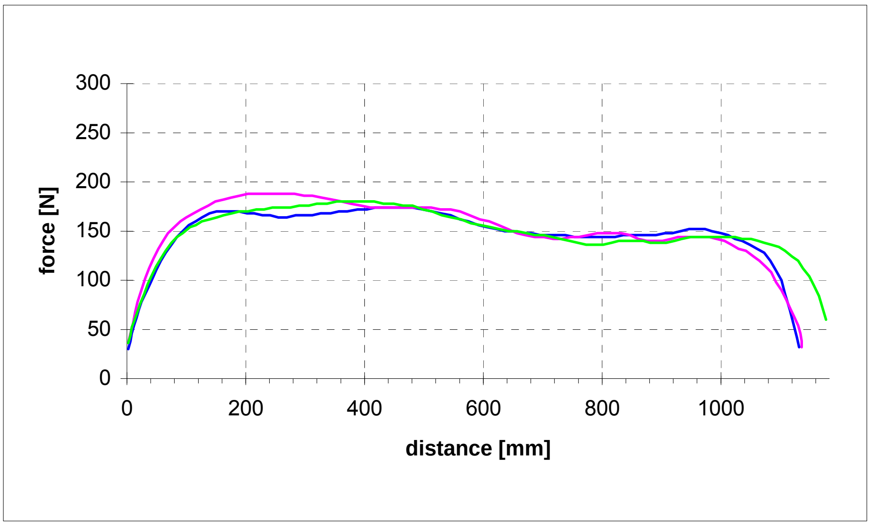

Figure 2: Force-path-curve of three consecutive pulls

We found different values of work and power for the individual subjects. The total power exerted by the athletes in the endurance test ranged from 200 to 320 W. This corresponds to a body mass-related power of a maximum of 3.5 W/kg.
In the same test triathletes reach power values of about 200 W. That is less than half of the values in a comparable cycling ergometer test for the lower extremities. But during the active part of the arm stroke movement (power per repetition) higher mechanical power values were measured; in the 10 repetitions-maximum test they amounted to 500 W and during endurance test to about 400 W.
Table 1 gives an overview of the mean values for men and women. In the endurance test athletes reach only 80 to 90 % of the maximum intracyclical power values, but more than 90 % of the maximum velocity. The duration of the active part of the movement is prolonged. The structure of the cycle differs between athletes (Table 2).

Table 1: Comparison of parameters measured during maximum power repetitions (max) and endurance test (endurance) in men and women

Mean values Men		total power [W]	fre-quency [1/min.]	intracyclic parameters work [Nm]	power [W]	time [s]	vmax [m/s]	active part [%]
Alternated N=15	max		44		313	0,61	3,88	45
	endu-rance	434	46	326	253	0,65	3,51	49
Simulated N=13	max		42		340	0,61	3,79	42
	endu-rance	375	45	365	294	0,64	3,52	48

Mean values Women		total power [W]	fre-quency [1/min.]	intracyclic parameters work [Nm]	power [W]	time [s]	vmax [m/s]	active part [%]
Alternated N=12	max		41		161	0,69	3,06	47
	endu-rance	225	44	197	146	0,73	2,78	52
Simulated N=16	max		43		201	0,64	3,14	46
	endu-rance	249	44	171	171	0,68	2,94	50

Table 2: Individual parameters of the intracyclical structure (total work, work per repetition, total power, intracyclical power in endurance test and maximum power repetitions)

Ath-Lete	work [Nm] total	work [Nm] repet.	frequency [1/min.]	power [W] total	power [W] endurance	power [W] max	pulling time [s]	rest time [s]
	simulated arm movement, 1 minute							
A	19286	470	45	321	388	429	0.61	0.72
B	18408	484	41	314	441	492	0.55	0.90
C	17920	448	44	299	407	516	0.55	0.81
D	15369	427	39	256	381	434	0.56	0.98
E	14872	363	46	248	283	304	0.64	0.68
	simulated arm movement, 2 minutes							
F	34531	397	45	291	292	309	0.68	0.64
G	32962	407	42	275	323	397	0.63	0.80
H	31377	353	47	261	261	343	0.68	0.60
I	25113	322	41	209	208	273	0.78	0.68
J	23201	280	43	193	193	267	0.73	0.67

With the same frequency athlete G performed an intracyclical relation of pulling and rest time of 1:1.3 vs. athlete H of 1:0.9. All power parameters of athlete G were much higher. On the other hand, athletes D and E performed almost the same total power. Because of the shorter active time of athlete D, he attained higher intracyclical power in spite of lower frequency. In our opinion, the relation between active stroke and rest within one repetition is of great importance. This feature essentially influences adaptation processes in training.

Figure 3 shows the tendency between intracyclical power reached on the rope pulling ergometer and stroke index in semi-tethered freestyle sprint swimming (11.5 m). The stroke index was calculated from the product of quadratic swimming velocity and the stroke distance. It is likely that there is a relatively strong relation between the dry land and swimming power tests.

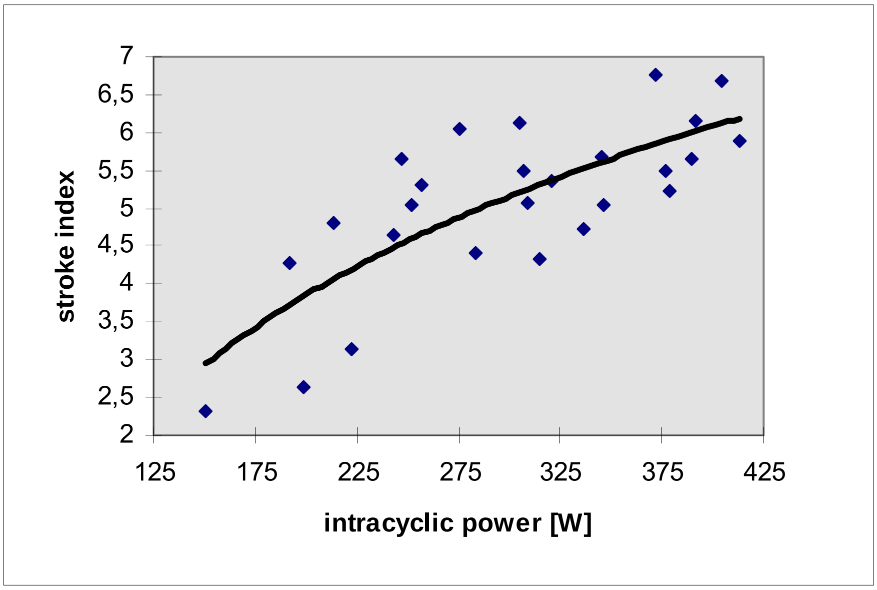

Figure 3: Relation between intracyclical power on the rope pulling ergometer and stroke index (v^2 x s) in semi-tethered freestyle sprint swimming

CONCLUSIONS: The pulling ergometer is a diagnostic apparatus with the help of which it is possible to make differentiated statements on the performance requirements of the upper limbs in swimming and on their changes as a result of training. Proceeding from these findings a portable training apparatus has been developed for training at home and in training camps.

REFERENCES:

Counsilman, J. E., Counsliman, B. E. (1994). The New Science of Swimming. Englewood Cliffs, N.J.: Prentice-Hall.

Reiß, M. (1995). Effektives Kraftausdauertraining in den leichtathletischen Ausdauerdisziplinen. Leipzig: IAT.

Polunin, A. I., Snesarev, N. K. (1990). Metodiceskie osobennosti podgotovki vysokokvalificirovannych begunov na dlinnye distancij. Moskva: Sovetskij sport.

Vajcechovskij, S. M. (1993). Sistema podgotovki plovcov k olimpijskim igram. In Sovremennyj olimpijskij sport. Kiev: KDIFK.

Verchoshanskij, J. (1992). Ein neues Trainingssystem für zyklische Sportarten. Münster: Phillipka.

Wilke, K., Madsen, O. (1988). Das Training des jugendlichen Schwimmers. Schorndorf: Hofmann.