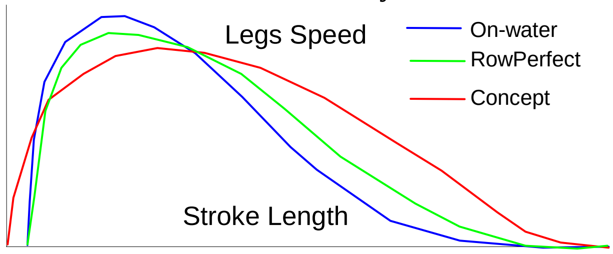
Q & A

Q: We received a number of questions about differences and similarities of ergo and on-water rowing. These are some of them: What are the main differences between on-ergo and on-water rowing technique? How do they affect each other? How to use an ergo better for selection of the rowers? What is the biomechanical difference between stationary Concept-II and mobile RowPerfect ergos?

A: We already published a comparison of biomechanical features of rowing on-ergo and on-water (RBN 2003/10). Here we will try to give a more practical explanation of the facts.

It is obvious that rough mistakes in a rower's technique, such as "bum shooting" or early body opening at catch should be seen on both ergo and on-water. It is also obvious, that an ergo can not reproduce arms and shoulders movement, vertical movement of the handle, feathering and squaring of the blade. Below are six main biomechanical differences between these two sorts of exercises:

1. Stroke rate on-water is always 10-15% higher than on stationary ergo, because the recovery phase is longer, which is affected by higher inertia forces. Mobile ergo eliminates this difference.
2. Rowers usually execute 3-5% longer stroke on stationary ergo, which occurs by means of 8-10% longer leg drive. The reason is the rower's inertia, which helps to bend knees passively at catch. This factor can increase risk of injuries. Also, it is doubtful that the longer drive can be translated into a boat, which requires active flexibility at catch and faster leg drive. Mobile ergo eliminates this difference as well.
3. Handle speed curve is more rectangular on-ergo and has a more peaky shape on-water. This difference affects the rower's feeling of the handle acceleration and is related to the difference in gearing ratio. This difference is NOT eliminated on a mobile ergo.
4. Difference in magnitude and ratio of the stretcher and handle forces: on-water foot-stretcher's force is 30% higher than that of handle force, whilst on ergo they are nearly equal. This difference is NOT eliminated on a mobile ergo.
5. Difference in the timing of the stretcher and handle forces. Mobile ergo eliminates this difference.
6. There are differences in power production of the body segments. Legs execute more work on stationary ergo, but in slower static motion. On water legs work much faster at catch, when the force is not very high and, therefore execute less power. In this aspect a mobile ergo stands somewhere between a stationary one and on-water:



In general, there is about 60-80% similarity between ergo and on-water rowing, which depends on the type of ergo. Currently commercially available rowing machines can not simulate interaction of the rower with the handle and the stretcher and temporal structure of the drive in the boat (micro-phases, RBN 2004/1,2). This is key point, something that rowers call "boat feeling" and define as whether the boat is "going" or "not going".

Rowing on-water and on-ergo are two different sorts of exercises. Ergo should be considered as a cross-training in rowing. Obviously, ergo is much closer to rowing than running, cycling or weight-lifting, but it is still not rowing. This should be remembered when the ergo is used for testing and selection purposes. A good rower should achieve certain result on an ergo, which shows his/her sufficient physiological work-capacity. Other exercises (running, weights) can be used (and were used) for this purpose as well.

Higher results in cycling or weights can make an athlete a better cyclist or weightlifter, but can make him/her a poorer rower. Similarly, higher than certain standards performance on an ergo can make a faster "ergoer", but slower rower, i.e. on-water and on-ergo performance can have a negative correlation. A number of illustrations of this fact can be seen. One of the most known is a competition of Australian and UK men's pairs during the last Olympic cycle, where the Australians showed 10-12s slower results on-ergo, but beat the English pair on-water.

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Facts. Did You Know That…

✓ …analysis of the stroke rate during the Olympic Games-2004 in Athens was conducted recently in similar way, as it was done for OG-2000 and WC-2002 (RBN 1,2/2003). The measurements were done for medal winners only using official video footage. It was measured around 70% of the total number of strokes. The data was filtered and compared with official split and final times.

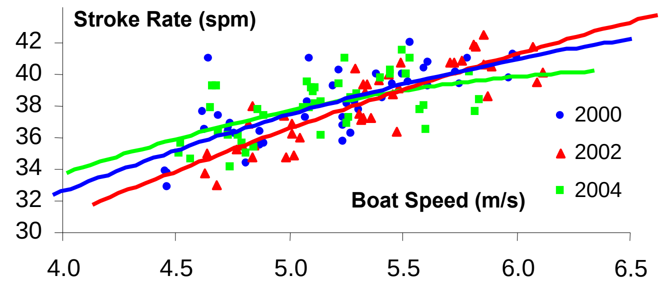
✓ …average stroke rate of the medal winners in the last Olympics was 37.86spm. The same parameter in the Olympics-2000 was 38.07spm, and in the Worlds-2002 it was 38.19spm. So, we can see small decrease in the average stroke rate;

✓ … since 2000-2 the average stroke rate increased in small boats: singles, doubles and pairs, except LW2x. Medal winners in nig boats (quads, fours and eights) had a lower stroke rate.

Average stroke rate over 2000m in medalists of OG-2000, WC-2002 and OG-2004.

	W1x	M1x	W2-	M2-	W2x	M2x	M4-
2000	33.5	35.9	38.4	38.8	35.8	38.0	40.1
2002	33.9	36.4	36.2	38.6	35.7	38.3	41.7
2004	35.0	36.7	37.6	39.1	36.3	38.3	39.8
	LW2x	**LM2x**	**LM4-**	**W4x**	**M4x**	**W8+**	**M8+**
2000	36.8	38.9	40.5	36.2	40.2	39.3	40.7
2002	35.7	38.6	40.8	38.4	40.3	39.7	40.4
2004	35.9	38.9	40.4	37.5	37.4	38.2	38.8

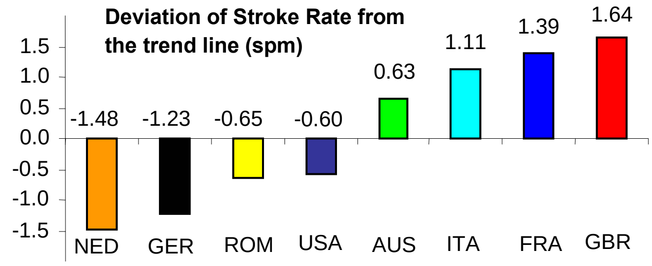
✓ …the previous fact affected the trend line of the Rate/Speed dependence, which became higher for low speeds (small boats) and lower for high speed (big boats):



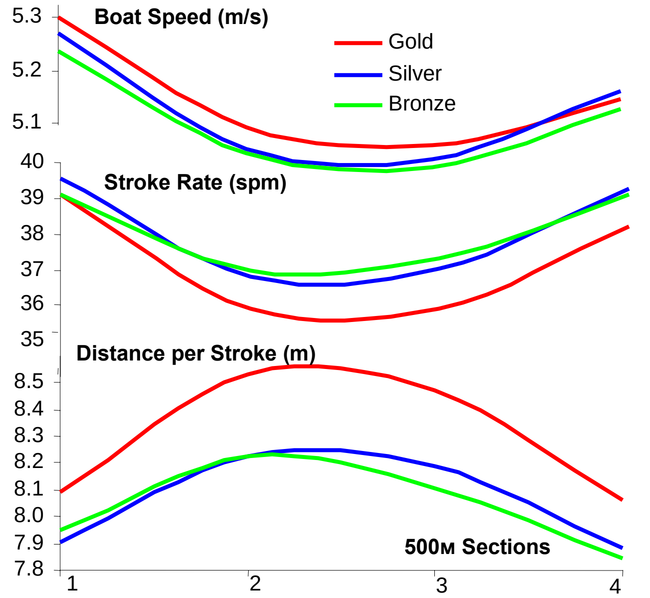
✓ …the winners had higher variation (ratio of the standard deviation to the average over four sections of the race) of the stroke rate (5.1%), than silver (4.7%) and bronze medalists (4.0%). This tells us that the winners can spurt at high rate at the start and finish of the race, but they have lower rate at cruising speed;

✓ …on average, the winners had about 1spm lower stroke rate (37.3) than silver (38.3) and bronze medalists (38.2). This difference was the most significant in winners in LM2x (3.8spm lower than 2nd place and 2.6 spm lower than 3rd place), W2- (2.5 and 1.4) and W2x (1.7 and 4.4);

✓ …crews from the main rowing countries performed differently in regards of stroke rate: NED, GER, ROM and USA usually have a stroke rate below the trend line, with longer DPS. GBR, FRA, ITA and AUS emphasized a higher stroke rate and a shorter DPS.



✓ …below are the graphs of the boat speed, rate and DPS averaged in medal winners for each of four sections of the race:



It is obvious, that the winners had significantly longer DPS, especially in the middle of the race. You can find details of the stroke rate analysis for each medal winner in the Appendix 1.

References

1. Kleshnev V. 2001. Stroke Rate vs. Distance in Rowing during the Sydney Olympics. Australian Rowing. 25(2), 18-21.

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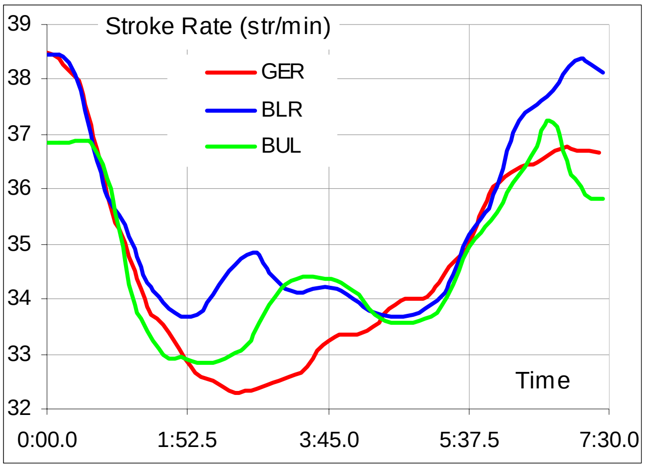
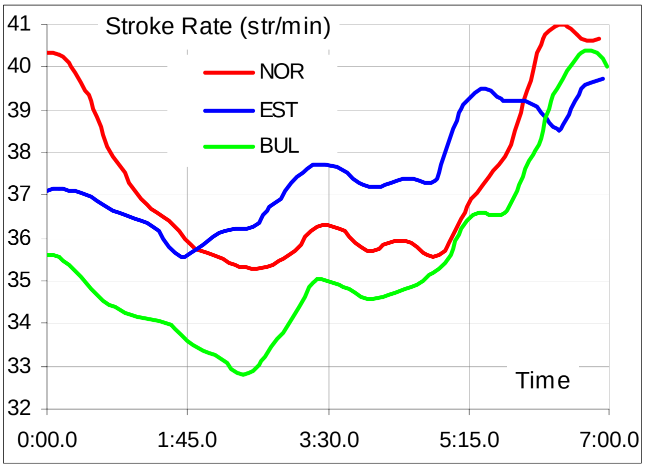
Appendix 1 to the Rowing Biomechanics Newsletter 2(5), February 2005.

Boat speed, stroke rate and distance per stroke in the medalists of the Olympic Games -2004 in Athens.

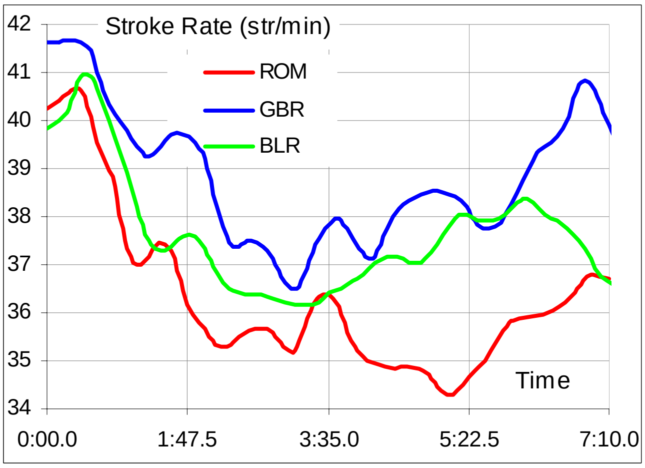
W1x		Speed over the 500m section (m:s)				
	Crew	1	2	3	4	**2000**
1	GER	1:50.62	1:51.00	1:48.81	1:47.69	**7:18.12**
2	BLR	1:49.62	1:52.69	1:51.43	1:48.30	**7:22.04**
3	BUL	1:49.26	1:53.40	1:50.65	1:49.79	**7:23.10**
		Stroke Rate (str/min)				
1	GER	35.8	32.6	33.8	36.4	**34.6**
2	BLR	36.2	34.4	34.1	37.5	**35.5**
3	BUL	35.6	33.7	33.9	36.3	**34.9**
		Distance per Stroke (m)				
1	GER	7.58	8.29	8.15	7.66	**7.91**
2	BLR	7.57	7.75	7.90	7.39	**7.64**
3	BUL	7.72	7.84	7.99	7.53	**7.77**



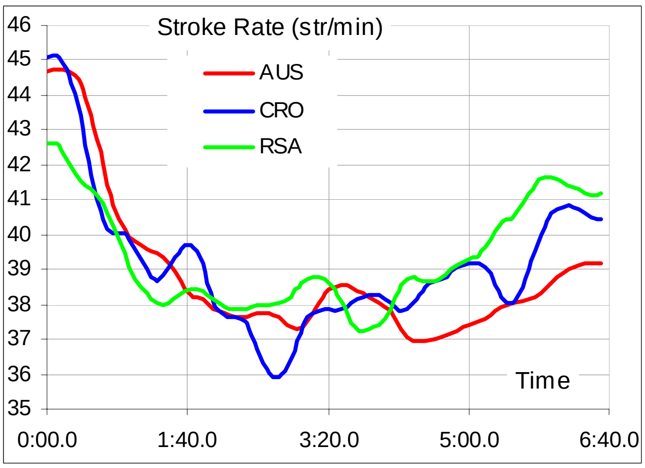
M1x		Speed over the 500m section (m:s)				
	Crew	1	2	3	4	**2000**
1	NOR	1:41.77	1:43.63	1:43.02	1:40.88	**6:49.30**
2	EST	1:42.64	1:43.44	1:41.92	1:43.42	**6:51.42**
3	BUL	1:42.41	1:44.00	1:43.59	1:42.80	**6:52.80**
		Stroke Rate (str/min)				
1	NOR	38.0	35.7	35.9	39.5	**37.3**
2	EST	36.5	36.7	37.5	39.2	**37.5**
3	BUL	34.6	33.7	35.1	38.2	**35.4**
		Distance per Stroke (m)				
1	NOR	7.75	8.12	8.11	7.52	**7.86**
2	EST	8.02	7.90	7.85	7.40	**7.79**
3	BUL	8.48	8.57	8.25	7.63	**8.21**



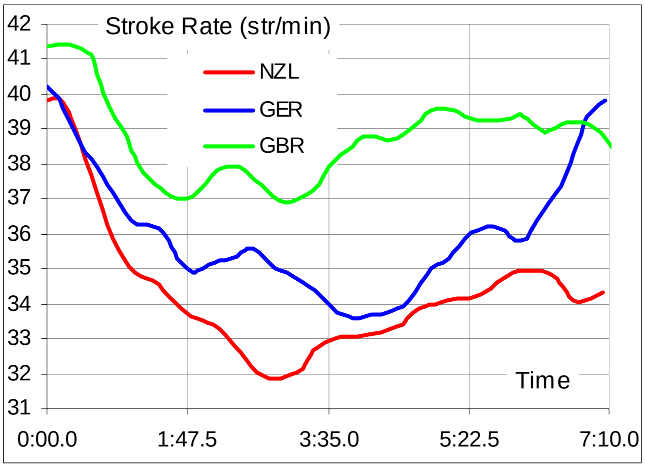
W2-		Speed over the 500m section (m:s)				
	Crew	1	2	3	4	**2000**
1	ROM	1:44.03	1:45.60	1:48.46	1:48.46	**7:06.55**
2	GBR	1:44.53	1:48.45	1:49.99	1:45.69	**7:08.66**
3	BLR	1:44.21	1:47.67	1:50.18	1:47.80	**7:09.86**
		Stroke Rate (str/min)				
1	ROM	38.5	35.6	35.0	36.1	**36.3**
2	GBR	40.3	37.6	37.8	39.5	**38.8**
3	BLR	39.2	36.6	37.2	37.7	**37.7**
		Distance per Stroke (m)				
1	ROM	7.49	7.99	7.90	7.66	**7.75**
2	GBR	7.13	7.35	7.22	7.19	**7.22**
3	BLR	7.35	7.61	7.31	7.38	**7.41**



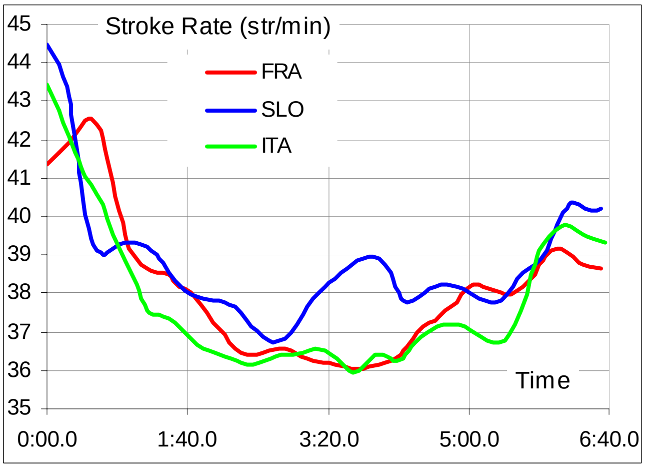
M2-		Speed over the 500m section (m:s)				
	Crew	1	2	3	4	**2000**
1	AUS	1:34.68	1:39.37	1:39.03	1:37.68	**6:30.76**
2	CRO	1:35.57	1:40.09	1:39.69	1:37.29	**6:32.64**
3	RSA	1:36.93	1:40.06	1:39.75	1:36.66	**6:33.40**
		Stroke Rate (str/min)				
1	AUS	41.8	37.8	37.7	38.5	**38.9**
2	CRO	41.1	37.4	38.3	39.6	**39.1**
3	RSA	40.2	38.2	38.4	40.8	**39.4**
		Distance per Stroke (m)				
1	AUS	7.58	7.99	8.04	7.98	**7.89**
2	CRO	7.64	8.02	7.86	7.79	**7.82**
3	RSA	7.70	7.85	7.84	7.61	**7.75**



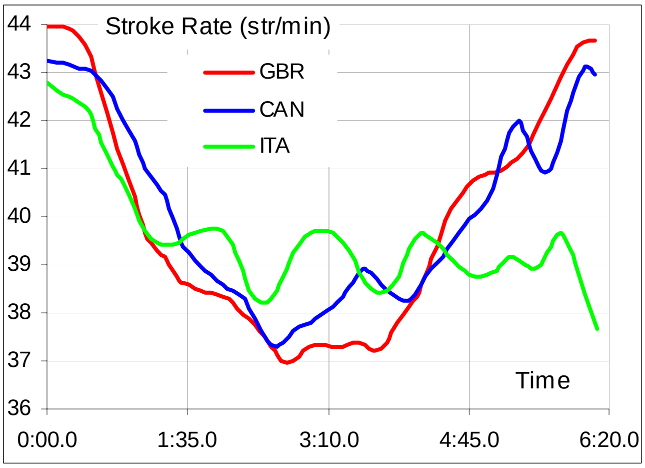
W2x	Crew	Speed over the 500m section (m:s)				
		1	2	3	4	**2000**
1	NZL	1:40.89	1:46.17	1:46.72	1:48.01	**7:01.79**
2	GER	1:42.58	1:46.79	1:48.46	1:44.95	**7:02.78**
3	GBR	1:43.09	1:49.06	1:47.92	1:47.51	**7:07.58**
		Stroke Rate (str/min)				
1	NZL	36.4	32.9	33.4	34.4	**34.3**
2	GER	37.4	35.1	34.3	37.2	**36.0**
3	GBR	39.1	37.5	39.0	39.2	**38.7**
		Distance per Stroke (m)				
1	NZL	8.16	8.59	8.41	8.08	**8.30**
2	GER	7.82	8.01	8.06	7.68	**7.88**
3	GBR	7.44	7.34	7.13	7.12	**7.25**



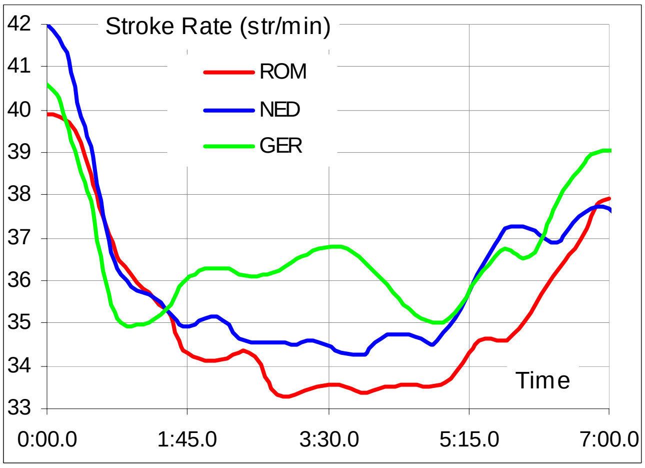
M2x	Crew	Speed over the 500m section (m:s)				
		1	2	3	4	**2000**
1	FRA	1:33.63	1:38.83	1:39.85	1:36.69	**6:29.00**
2	SLO	1:33.99	1:38.75	1:39.90	1:39.08	**6:31.72**
3	ITA	1:32.58	1:38.16	1:41.20	1:40.99	**6:32.93**
		Stroke Rate (str/min)				
1	FRA	40.8	36.7	36.6	38.6	**38.1**
2	SLO	40.2	37.4	38.3	39.1	**38.7**
3	ITA	39.7	36.4	36.4	38.4	**37.7**
		Distance per Stroke (m)				
1	FRA	7.85	8.28	8.21	8.05	**8.09**
2	SLO	7.95	8.12	7.84	7.75	**7.91**
3	ITA	8.17	8.39	8.14	7.74	**8.10**



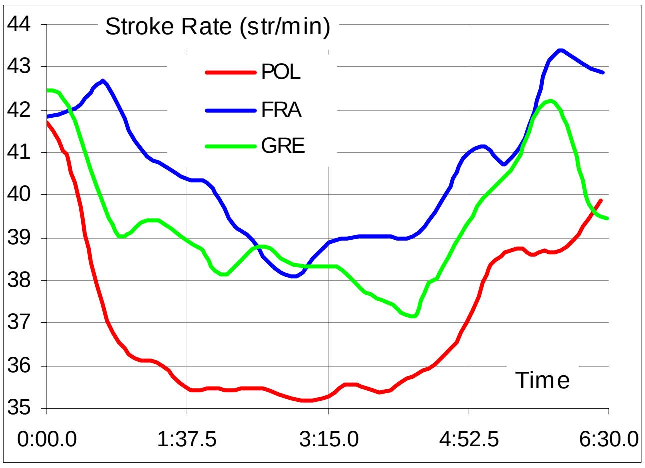
M4-	Crew	Speed over the 500m section (m:s)				
		1	2	3	4	**2000**
1	GBR	1:28.00	1:33.68	1:35.04	1:30.26	**6:06.98**
2	CAN	1:28.41	1:33.71	1:34.09	1:30.85	**6:07.06**
3	ITA	1:31.00	1:33.35	1:33.05	1:33.01	**6:10.41**
		Stroke Rate (str/min)				
1	GBR	41.6	37.6	37.9	42.1	**39.8**
2	CAN	42.1	38.0	38.7	41.5	**40.1**
3	ITA	40.9	39.1	39.2	39.0	**39.5**
		Distance per Stroke (m)				
1	GBR	8.19	8.51	8.32	7.90	**8.21**
2	CAN	8.07	8.43	8.23	7.95	**8.16**
3	ITA	8.05	8.22	8.23	8.27	**8.19**



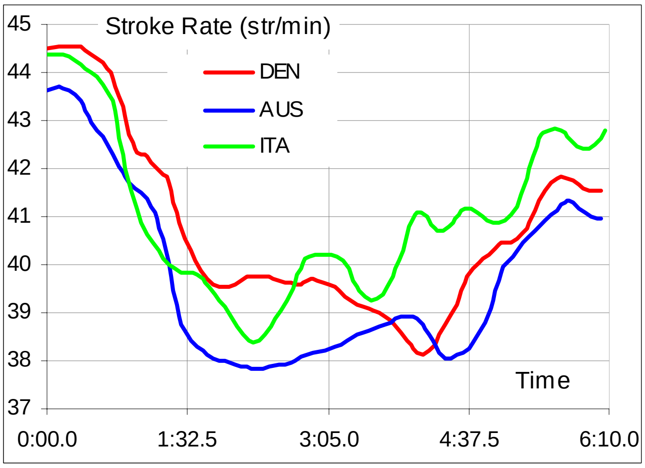
LW2x	Crew	Speed over the 500m section (m:s)				
		1	2	3	4	**2000**
1	ROM	1:43.27	1:44.57	1:45.00	1:43.21	**6:56.05**
2	NED	1:41.84	1:45.36	1:47.86	1:42.27	**6:57.33**
3	GER	1:44.11	1:45.04	1:47.31	1:42.08	**6:58.54**
		Stroke Rate (str/min)				
1	ROM	37.3	33.8	33.6	35.9	**35.1**
2	NED	37.8	34.7	34.7	37.2	**36.1**
3	GER	36.8	36.4	35.8	37.4	**36.6**
		Distance per Stroke (m)				
1	ROM	7.78	8.50	8.51	8.10	**8.21**
2	NED	7.79	8.21	8.02	7.89	**7.97**
3	GER	7.82	7.85	7.82	7.86	**7.83**



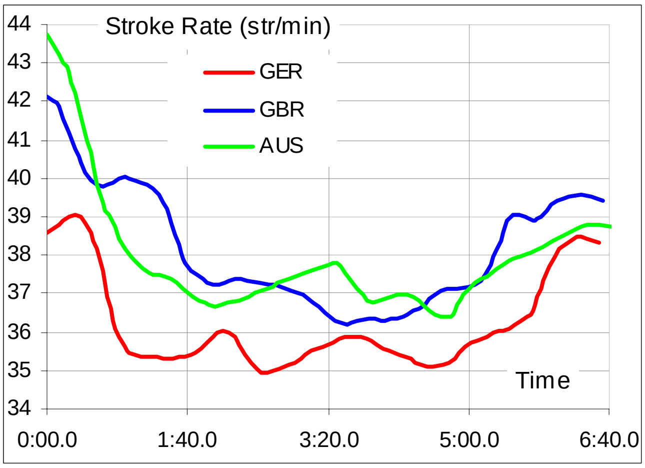
LM2x		Speed over the 500m section (m:s)				
	Crew	1	2	3	4	2000
1	POL	1:31.63	1:34.69	1:35.57	1:39.04	**6:20.93**
2	FRA	1:32.42	1:35.98	1:37.23	1:35.83	**6:21.46**
3	GRE	1:32.80	1:36.58	1:37.71	1:36.14	**6:23.23**
		Stroke Rate (str/min)				
1	POL	37.5	35.4	35.6	38.6	**36.8**
2	FRA	41.8	39.1	39.4	42.1	**40.6**
3	GRE	40.1	38.5	37.8	41.2	**39.4**
		Distance per Stroke (m)				
1	POL	8.73	8.95	8.82	7.85	**8.57**
2	FRA	7.76	8.00	7.84	7.44	**7.75**
3	GRE	8.06	8.08	8.12	7.57	**7.95**



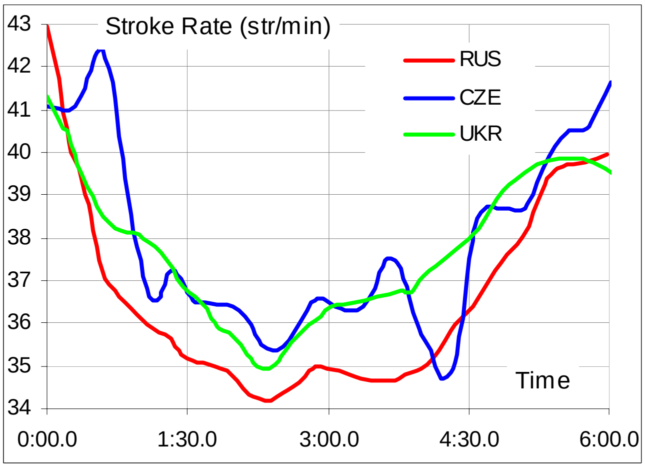
LM4-		Speed over the 500m section (m:s)				
	Crew	1	2	3	4	2000
1	DEN	1:26.41	1:31.09	1:33.39	1:30.50	**6:01.39**
2	AUS	1:28.06	1:31.40	1:32.25	1:31.08	**6:02.79**
3	ITA	1:27.52	1:31.62	1:32.27	1:32.33	**6:03.74**
		Stroke Rate (str/min)				
1	DEN	43.2	39.8	38.9	41.0	**40.7**
2	AUS	41.8	38.0	38.6	40.5	**39.7**
3	ITA	42.1	39.2	40.3	42.0	**40.9**
		Distance per Stroke (m)				
1	DEN	8.03	8.28	8.27	8.08	**8.15**
2	AUS	8.16	8.64	8.43	8.13	**8.33**
3	ITA	8.13	8.34	8.07	7.74	**8.06**



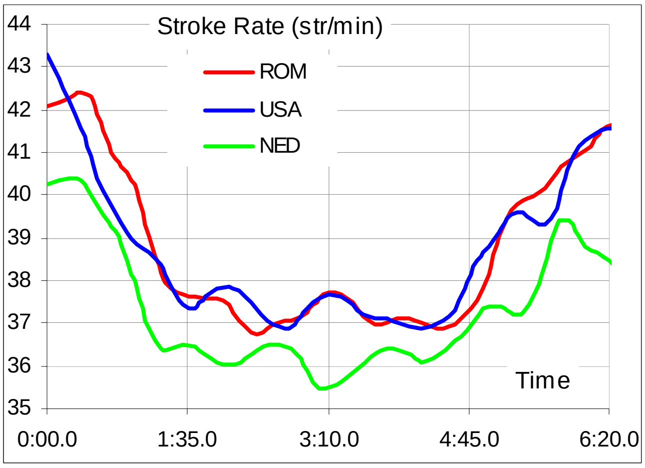
W4x		Speed over the 500m section (m:s)				
	Crew	1	2	3	4	2000
1	GER	1:34.63	1:37.58	1:38.58	1:38.50	**6:29.29**
2	GBR	1:35.81	1:39.13	1:38.84	1:37.48	**6:31.26**
3	AUS	1:35.16	1:38.97	1:40.73	1:39.87	**6:34.73**
		Stroke Rate (str/min)				
1	GER	37.0	35.5	35.6	37.1	**36.3**
2	GBR	40.1	37.2	36.6	38.9	**38.2**
3	AUS	39.5	37.0	36.9	38.2	**37.9**
		Distance per Stroke (m)				
1	GER	8.57	8.66	8.56	8.21	**8.49**
2	GBR	7.81	8.13	8.30	7.91	**8.03**
3	AUS	7.97	8.19	8.06	7.87	**8.02**



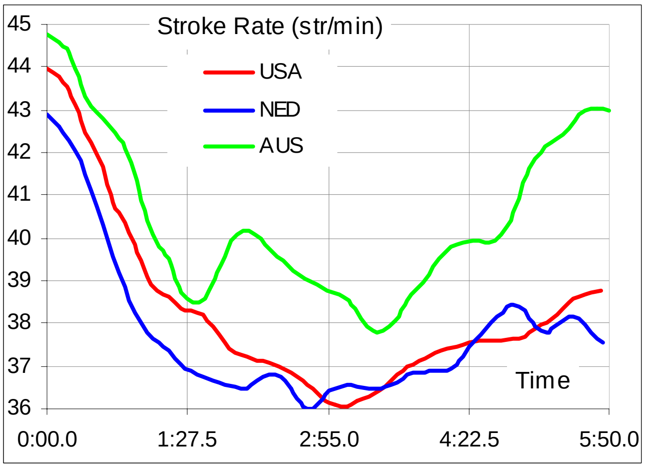
M4x		Speed over the section (m:s)				
	Crew	1	2	3	4	2000
1	RUS	1:25.79	1:31.15	1:30.48	1:29.43	**5:56.85**
2	CZE	1:25.49	1:31.16	1:31.87	1:28.91	**5:57.43**
3	UKR	1:28.23	1:31.73	1:32.14	1:26.77	**5:58.87**
		Stroke Rate (str/min)				
1	RUS	37.8	34.7	35.0	38.6	**36.5**
2	CZE	39.6	36.1	36.3	39.8	**37.9**
3	UKR	38.9	35.7	37.1	39.2	**37.7**
		Distance per Stroke (m)				
1	RUS	9.26	9.50	9.47	8.69	**9.21**
2	CZE	8.87	9.10	8.99	8.49	**8.85**
3	UKR	8.75	9.17	8.78	8.82	**8.87**



W8+	Crew	Speed over the 500m section (m:s)				
		1	2	3	4	**2000**
1	ROM	1:32.49	1:36.67	1:36.26	1:32.28	**6:17.70**
2	USA	1:32.24	1:36.66	1:37.35	1:33.31	**6:19.56**
3	NED	1:34.53	1:36.55	1:36.74	1:32.03	**6:19.85**
		Stroke Rate (str/min)				
1	ROM	40.5	37.2	37.1	40.1	**38.7**
2	USA	40.0	37.4	37.2	40.1	**38.7**
3	NED	38.5	36.1	36.3	38.2	**37.3**
		Distance per Stroke (m)				
1	ROM	8.01	8.33	8.40	8.10	**8.20**
2	USA	8.14	8.30	8.28	8.01	**8.17**
3	NED	8.23	8.61	8.54	8.53	**8.47**



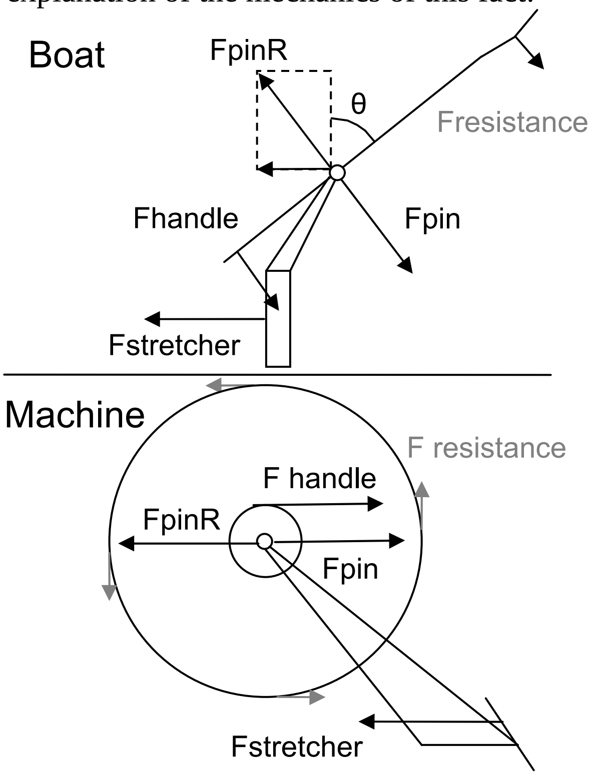
M8+	Crew	Speed over the 500m section (m:s)				
		1	2	3	4	**2000**
1	USA	1:21.95	1:26.23	1:28.77	1:25.53	**5:42.48**
2	NED	1:23.58	1:28.86	1:26.72	1:24.59	**5:43.75**
3	AUS	1:22.86	1:28.58	1:28.29	1:25.65	**5:45.38**
		Stroke Rate (str/min)				
1	USA	41.1	37.4	36.7	38.0	**38.3**
2	NED	39.4	36.5	36.7	38.0	**37.7**
3	AUS	42.1	39.4	38.7	41.6	**40.4**
		Distance per Stroke (m)				
1	USA	8.92	9.31	9.20	9.23	**9.15**
2	NED	9.11	9.26	9.42	9.33	**9.27**
3	AUS	8.61	8.61	8.78	8.42	**8.59**



Facts. Did You Know That…

✓ …a comparison of on-water rowing with Rowperfect and Concept2 machines was done recently. Biomechanical parameters were measured in five female rowers during two 90s pieces: at training stroke rate around 20 spm and at racing rate around 32 spm. Average curves and derivative values are presented in Appendix 1.

Maximal force applied to the handle on both rowing machines was 27-30% higher at the training stroke rate (Rowperfect-Concept2, respectively) and 34-40% higher at racing stroke rate. Average force on machines was 22-19% and 25-26% higher, respectively. This confirms our previous considerations (RBN 2005/1). Below is an explanation of the mechanics of this fact:



In the boat, the handle force ***Fhandle*** equal to the pin force ***Fpin*** multiplied by the gearing ratio:

Fhandle = Fpin (Rout / Roar)

where ***Rout*** is the actual outboard, ***Roar*** is the actual oar length. The pin reaction force ***FpinR*** relates to the stretcher force ***Fstretcher*** as:

$$FpinR = -(Fstretcher + m_b a_b) / \cos\theta$$

where $m_b a_b$ is inertia force of the boat shell (relatively small), θ is the oar angle. So:

$$Fhandle = (Fstretcher + Finert.) (Rout / Roar) / \cos\theta$$

In simple terms, if the rower applies a certain force to the stretcher, then the corresponding handle force depends on gearing ratio and oar angle.

On the machines, the handle and the pin reaction forces create a couple, i.e. they have the same magnitude and opposite direction: ***Fhandle = -FpinR*** The difference between the pin and stretcher forces is equal to the inertia force of the mobile unit on Rowperfect ($m_u a_u$, smaller) or the rowers mass on Concept2 ($m_r a_r$, larger):

Fhandle = Fstretcher + ma

So, if the rower applies a certain force to the stretcher of the machine, then he/she has to apply a similar force to its handle.

In our case the approximate gearing ratio in the single was 2.00m/2.88m = 0.695, which explains 30% difference in the maximal forces. In the boat the handle/stretcher forces ratio depends on the oar angle. For example, at 50° in catch it is 0.695/cos(50°) = 1.08, i.e. the handle and stretcher forces are nearly equal. This explains the smaller difference in the handle force at the catch and finish between on-water and on-machines rowing. It affects the difference in average forces, which is lower, than the difference in the maximal forces.

The gearing ratio in the boat varies during the drive, because it depends on the oar angle. In both machines it is constant. This explains difference in the handle velocities profiles. This difference significantly affects the rower's perceptions.

Rowers executed 11-12% longer stroke on-water than on both machines, which mainly occurred by means of 30% longer arms pull. This can be explained by curvilinear geometry of the movement of the arms in the boat and the linear handle path on machines.

Faster increase of the handle force and leg speed in the boat and on the RowPerfect can be explained by the different magnitude of inertial forces caused by interaction of the rower with mobile or stationary point of support. For the same reason, leg drive was 4-6% longer on Concept2.

The RowPerfect machine accurately simulates negative acceleration of the boat shell at the catch. During the drive, acceleration of the single was significantly (20-30%) higher than acceleration of the mobile unit of the RowPerfect. The latter exceeded the boat acceleration during recovery phase. This also can affect rower's sensations.

Acknowledgment. This study was supported by Australian Institute of Sport. Many thanks to Bruce Grainger for help with editing this issue.

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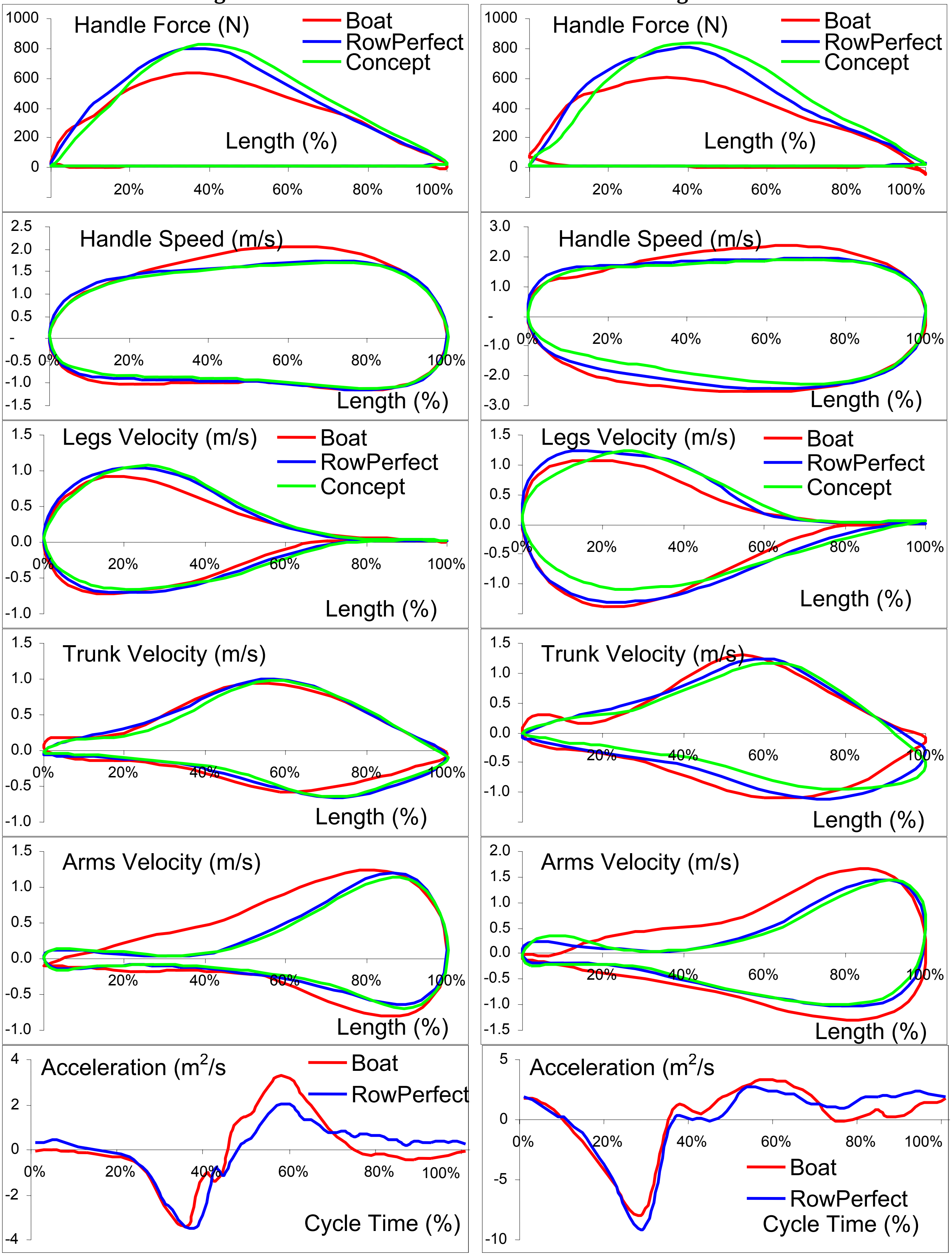
Appendix 1 to the Rowing Biomechanics Newsletter 3(5), March 2005.

Average biomechanical parameters in five female rowers during rowing in single scull, on Rowperfect and Concept2 rowing machines.

Training rate | **Racing rate**



Derivative numerical values of rowing at training and racing stroke rates

	Parameters	Boat		RowPerfect		Concept2	
	Rate	Training	Racing	Training	Racing	Training	Racing
1	Average Rate (str/min)	20.1	32.3	22.3	35.2	20.7	32.1
2	Rowing Power (W)	247	391	247	401	237	375
3	Drive Time (s)	1.26	1.00	1.13	0.92	1.21	0.97
4	Rhythm (%)	42.0%	54.0%	42.0%	53.9%	41.7%	51.9%
5	Drive Length (m)	1.60	1.59	1.42	1.43	1.44	1.41
6	Maximal Force (N)	634	602	803	806	826	840
7	Average Force (N)	331	342	404	427	394	430
8	Ratio Aver/Max Forces (%)	52.3%	56.9%	50.4%	53.0%	47.7%	51.2%
9	Position of Max. Force (%)	37.6%	34.7%	36.3%	40.5%	37.2%	40.8%
10	Catch Slip (m)	0.04	0.04	0.07	0.09	0.12	0.13
11	Release Slip (m)	0.22	0.20	0.24	0.25	0.22	0.21
12	Max.Handle Velocity (m/s)	2.06	2.36	1.73	1.94	1.70	1.89
13	Average Velocity (m/s)	1.28	1.59	1.26	1.55	1.19	1.45
14	Position of Max.Velocity (%)	59.4%	65.2%	73.5%	71.4%	76.4%	74.1%
15	Min. Acceleration (m/s^2):	-3.35	-7.92	-3.46	-9.13	0	0
16	Max. Acceleration (m/s^2):	3.23	3.39	2.01	2.78	0	0
17	Legs Travel (m)	0.52	0.51	0.52	0.52	0.55	0.53
18	Trunk Travel (m)	0.50	0.48	0.48	0.48	0.47	0.46
19	Arms Travel (m)	0.61	0.62	0.43	0.43	0.44	0.43

Ideas. What if…

✓ …we put a rowing boat on hydrofoils?! Khaled Sanad, Head men's rowing coach .of Colgate University, USA kindly sent us information about using a hydrofoil in canoeing. He said that a single canoe with the hydrofoil can go as fast as rowing eight! (i.e. about 30% faster)

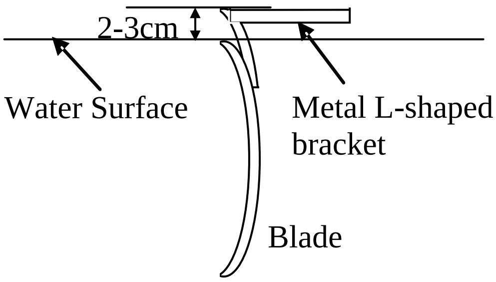
Rowing in a boat with hydrofoils can be used as a speed drill (RBN 2001/4), instead of towing with speed boat. This sort of speed drill can be used more easily, more often and in locations, where speed boats are not allowed (race courses). Ideally, using a hydrofoil would be as easy as using a brake (eg a bungee). Rowers could quickly attach a pair of temporary hydrofoils in the middle of a training session, do their speed work, and then detach them and row normally.

Obviously, there are a lot of question marks and practical problems to be solved. The main problem is a difference in the height of the boat relative to the water. Rowing is much more sensitive to this parameter than canoeing. However, the height can be set a little lower for this drill and the difference can be acceptable for good rowing.

We estimate that a men's' eight could achieve 8m/s speed (4:10 per 2000m) with hydrofoils. Also, the hydrofoil will force rowing power to be higher than a certain threshold. Below the threshold the boat would run much slower in water-displacement mode and the hydrofoil would work as a brake. This could create very interesting training methods with variable force/velocity emphasis.

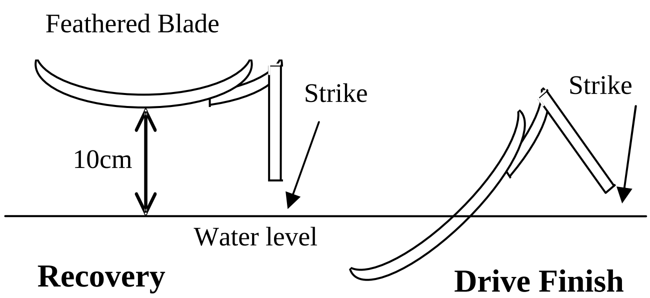
✓ …there is another gadget from Khaled Sanad, which he picked up from Steve Tucker the L2x. The gadget can be made from a piece of light L-shaped bracket attached to the blade as shown below.

The main purpose of the gadget is controlling of the depth of the blade during the drive. Rowers have to pull the blade through the water keeping the L-shaped bracket out of water. Otherwise, they'll have problems with extracting the blade out of water.



Also, Khaled wrote: "When you row with the metal L's, they will teach you to carry your blades higher on the recovery. This higher carry will help you later on when you row in rough water because the higher carry will allow your blades to more easily clear the wave caps.

Another advantage of rowing with the metal L's is that they will teach you to extract your blade on the square and not wash-out at the finish. If you try to feather the blade before it is completely clear of the water, the metal-L will catch the surface of the water as the blade is rotated. It will be caught on the surface and you'll feel it in the handle. It will make rowing miserable and force you to learn to extract the blades on the square and then feather in order to row comfortably."



The L-shaped brackets can be made out of 1-2mm thin aluminum sheet. Cut a strap about 20-30cm long and 15cm wide; bend it square along the centerline; shape one side with pliers and attach it to the blade with double-sided tape.

Contact us if you require further information about either of these two gadgets. We would greatly appreciate your feedback about:

- Have you used these or other gadgets? How?
- What benefits or drawback did you find with these or other gadgets?
- What other problems in rowing technique are important and require a closer look?

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Q & A

? Q. Quite often rowers and coaches ask: What are the ratios of the boat speed in various boat types? Evaluation of the performance in the events of a rowing program is important for selection of the squad and combination of the crews.

✓ A: The common practice is developing "prognostic times" or "Gold Standards" for every boat type. The performance of each crew can be evaluated as a percentage of the "prognostic speed".

The most obvious solution is using the World records (www.worldrowing.com) as "prognostics" However, the best times can be achieved only with the combination of very fast weather conditions and very good athletes in perfect shape, which is very rare. These single data points do not necessarily correlate with the whole population of rowers and distribution of the speed in various boat types can be skewed.

If we need a larger sample, we can use an average time of the winners over the years. The second row in the Table 1 represents filtered average times of the Worlds' and Olympics' champions between 1993-2004 (the best and worst times rejected).

Table 1. "Prognostic" times in the boat types: 1st row is the World best times, 2nd row is the winners' average of WCh and OG, 3rd row is the average trend for 2008, 4th row is the best case trend for 2008, 5th row is Australian "prognostic times"

W1x	M1x	W2-	M2-	W2x	M2x	M4-
7:07.7	6:36.3	6:53.8	6:14.3	6:38.8	6:04.4	5:41.3
7:22.5	6:45.2	7:05.3	6:24.6	6:51.2	6:14.3	5:54.4
7:13.2	6:38.3	6:58.8	6:19.4	6:43.3	6:09.4	5:44.1
7:09.8	6:31.5	6:51.7	6:15.9	6:40.7	6:03.3	5:38.8
7:08.0	6:31.0	6:51.0	6:13.0	6:37.0	6:00.0	5:41.0
LW2x	**LM2x**	**LM4-**	**W4x**	**M4x**	**W8+**	**M8+**
6:49.9	6:10.8	5:45.6	6:10.8	5:37.7	5:56.6	5:19.9
7:04.5	6:23.0	6:02.5	6:25.1	5:51.6	6:17.6	5:38.6
6:56.6	6:15.2	5:55.5	6:20.7	5:47.8	6:10.5	5:33.6
6:53.3	6:09.3	5:46.6	6:14.6	5:39.4	6:02.6	5:25.9
6:43.0	6:06.0	5:45.0	6:05.0	5:33.0	5:53.0	5:19.0

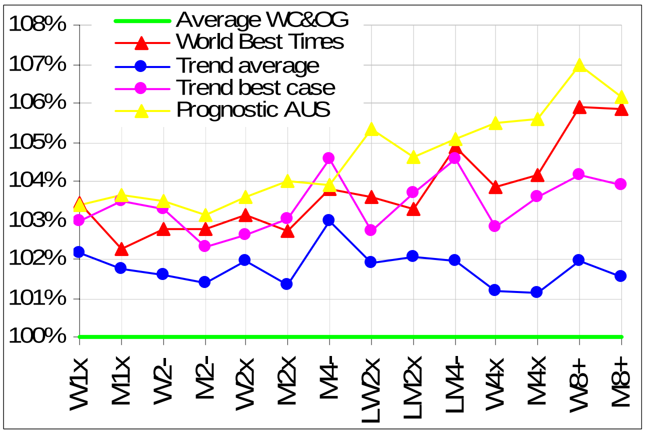
Another approach is analysis of the trends in the boat speeds over the years. We already published them in RBN 9/2002. Since that time we have two more points on the graphs, but the trends are still quite unreliable owing to very high variation of the boat speed caused by various weather conditions. The data has to be filtered by means of rejecting certain number of slowest times. We have derived two values of the prognostic speed for 2008: the best case scenario and average of all linear trends based on 4-12 data points. The slope of the trend lines in the Table 2 (below) reflects the growth of the boat speed per year:

W1x	M1x	W2-	M2-	W2x	M2x	M4-
0.52%	0.55%	0.42%	0.25%	0.50%	0.26%	1.01%

LW2x	LM2x	LM4-	W4x	M4x	W8+	M8+
0.35%	0.50%	0.32%	-0.20%	-0.42%	-0.06%	-0.25%

Moreover, coaches develop their own "Gold standards" using their knowledge and expertise. Quite often they keep the methods "in house" and the only references were found on the Australian site www.rowingqld.asn.au/Documents/Prognostics, and the same data on the Irish site http://208.56.168.207.

If we take the winners' average speed as 100%, then the following chart reflects the speed of various boats in each "prognostic" system.

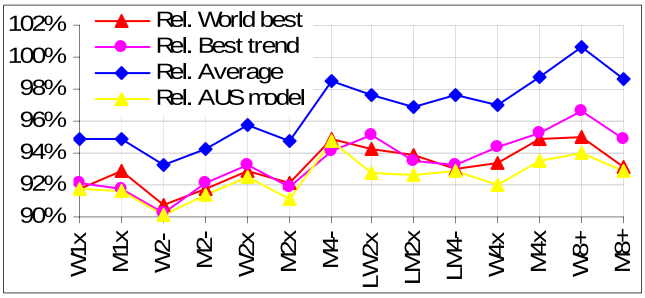


Australian standards look very close to the best case trend in small boats, and in LM4-. All "prognostics", except average trend, show significantly higher speeds in the bigger boats. This can be explained by less competition in big boats, which increases the gap between average winners' times and the best times.

What "prognostic times" do you use in your work? We would greatly appreciate your feedback with regards to this important matter.

News

The first stage of World Cup-2005 was conducted with great success on Dorney Lake near Eton, UK. The chart below represents evaluation of the winners' speed using different "prognostic" models:



We can observe that the small boats were relatively slower, which can be related to a very strong side wind during the finals of the regatta.

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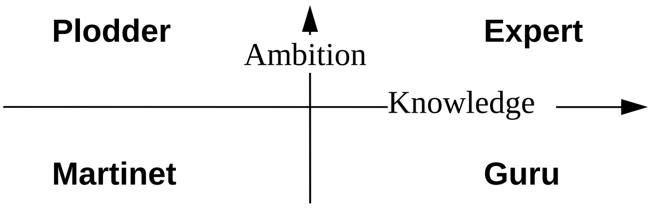
Q & A

? Q. "I'm a rowing coach and very keen to use biomechanics and other sport sciences in my work. What is the best way to do it? How do other coaches use science?" This is a typical question, which we receive from a number of coaches.

✓ A: To answer this question we need to analyse how different coaches utilise sport science. Then we can build a model of the most efficient coach-scientist interaction. To simplify things, let's make a simple chart, where the X axis is a coach's knowledge in sport science/biomechanics and the Y axis is ambition to use science in training process:



Using this simple model, we can define four types of coaches. Let's call them provisionally: Martinet (negative knowledge and ambition), Plodder (negative knowledge, positive ambition), Guru (positive knowledge, negative ambition) and Expert (positive knowledge and ambition).

Martinet. This is a type of old-fashioned coach who believes that sports scientists are very smart people, who manage to get their salary by doing nothing, but creating hassle for coaches. Martinet's favourite slogan is: "I (my crew) achieved (in far past) great successes without your bloody biomechanics!" This coach believes that the most important things in sport are aggression, bravery and discipline and that he is usually very good in inculcating them.

If Martinet is forced to use biomechanics, he says: "OK, I don't understand what your numbers and figures mean (and don't want to understand them). Just tell me what we should do to win a gold medal?" After the scientist explained the points to be improved, this coach would usually say: "That is exactly what I say every training session!" Martinet can be quite successful if he can recruit great athletes. However the performance is usually unstable and results are unreliable.

Plodder. This coach is very keen to use sport science and quite often uses it more than necessary. Plodder works really hard himself and forces the scientist to work hard and produce a huge amount of information, which has little or no use at all. Quite often this coach lacks knowledge not only of biomechanics, but also of basic school science; e.g. he/she has difficulty in understanding the difference between force and power, kg and Newton units, etc. Plodder always changes testing protocols and conditions which make the data incomparable. This coach likes to modify equipment and boat setup without sensible reasons, select a better shape of the blade, etc.

The Plodder was usually a good athlete himself in the past. This coach has dominating practical perspective on rowing technique, which was derived from his/her own experience. The Plodder is usually a good psychologist and can communicate effectively with athletes and motivate them for hard work.

Guru. This coach usually has a sports science background and even a degree in it. However, he prefers to work behind closed doors and does not allow anybody to see his training methods. When, the scientist delivers the data, Guru usually says: "Thanks. (quite often omitted). See you later!" He is usually reluctant to accept any idea, which conflicts with his own and doesn't want to learn from others. This prevents the development of his coaching technology and makes it out-of-date after a while. Guru is usually reactive. He doesn't tell the scientist what he wants or how to modify measurements, but quite often criticises the biomechanical equipment and data. Data inaccuracy is his favourite soapbox. Owing to his low ambition and motivation, Guru can experience problems in communicating with and in motivating athletes.

Expert. This is the best combination of a good knowledge of sports science with a high ambition to use it. Expert is always open to new ideas and very keen to learn, even if he has already achieved great success. However, he/she analyses every new idea and discusses it with the scientist; i.e. the idea is broken down into logical parts which should be checked to see if they are consistent with existing, verified concepts. Expert is usually proactive. He knows perfectly what sort of information is needed for a certain coaching task and tells the scientist exactly what he wants.

The most important quality of Expert is an ability to develop new training methods based on scientific information and ideas received from the scientist. Though new methods can be erroneous sometimes (but doing nothing is the only way to avoid mistakes), an adequate error analysis would improve them and finally produce the most efficient system. It is impossible to implement this system without scientific support, which becomes an integral part of it. The sport scientist becomes a partner in the creative process of achieving top performance.

Conclusion. It is obvious that it is better to have good knowledge and high ambition, but it is also important to estimate them adequately. For example, good results can be achieved when Guru works together with Plodder as a team. In this case, Guru compensates for the low knowledge of Plodder and, in return, receives high ambition and motivation.

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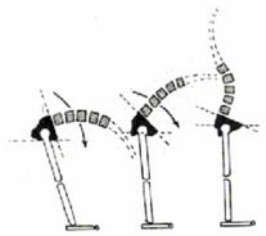
Q & A

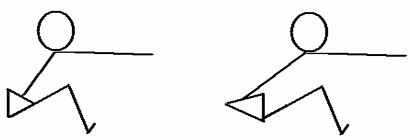
? Dr. Alison McGregor of Imperial College in London is the leading world expert in spine and pelvic biomechanics. We have asked her to explain mechanics of back pain and injury prevention in rowing:

✓ In terms of biomechanics the spine has a very complex design that allows it to offer protection to the spinal cord, transfer weight between the limbs and permit mobility. Perhaps the last two are of more relevance to injury and the sport of rowing, with an annual incidence of between 32-75%.

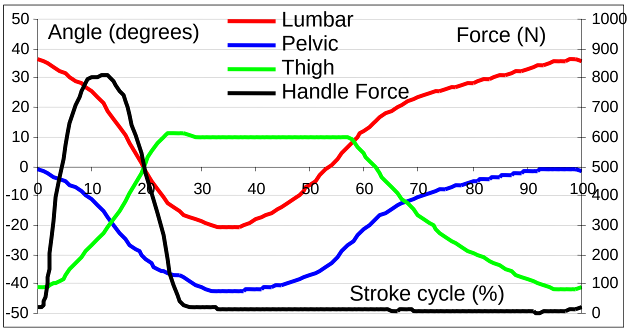
Structurally we divided the spine into regions, sacral (the pelvis), lumbar (the lower back), thoracic (the chest) and cervical (the neck), however, these regions are all connected and all relate to each other. This is particularly relevant when we consider the back as often we only think of the lumbar spine and neglect the pelvis which it sits on. When we move the spine and pelvis move together in synchrony creating what we shall refer to as lumbo-pelvic rhythm. When we bend forwards the pelvis usually starts the movement followed shortly afterwards by movement of the lumbar spine this is simplified below.



Of course rowing is very similar to touching your toes, and like bending forward it comprises of this lumbo-pelvic motion. However, most people don't look at what the pelvis is doing and just focus on the lumbar spine. Have you ever noticed how some people keep the back straight right from where their bottom contacts the seat whilst others drop their pelvis back and hinge at the junction between their pelvis and lumbar spine? The pictorial below tries to demonstrate this.

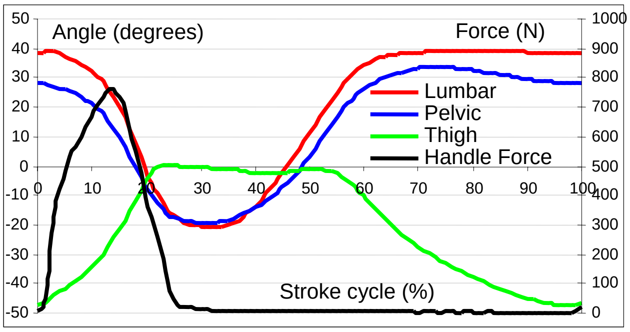


We have been measuring this motion in great detail using motion analysis techniques. Consider the two graphs below, where the stroke cycle is presented as the catch being at 0% and 100% being the return to this catch position. In this first graph, in green we see the knees starting in a flexed position at the catch, extending through the drive and returning to the flexed position during the recovery. We also see the motion of the pelvis in blue and the lumbar spine in red. Clearly there is much more movement in this person in the lumbar spine with some but limited movement in the pelvis overall though the lumbar spine is moving three times more than the pelvic.



1

Compare this with the next graph: -



2

Here we see that the lumbar spine and pelvis move almost in synchrony some that ratio of lumbar to pelvic motion is much closer to one. This position and the maintenance of this healthy relationship between the pelvis and spine we think relieves the loading on the junction between the lumbar spine and pelvis and protects the spine. Incidentally this is the region of the spine most frequently injured in rowers.

From our studies we have seen that certain things can affect this lumbar-pelvic motion pattern including fatigue, rating, rowing level, and strength which we will talk about in another newsletter.

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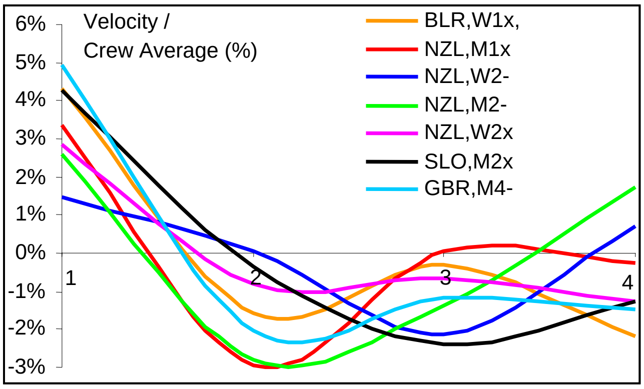
News

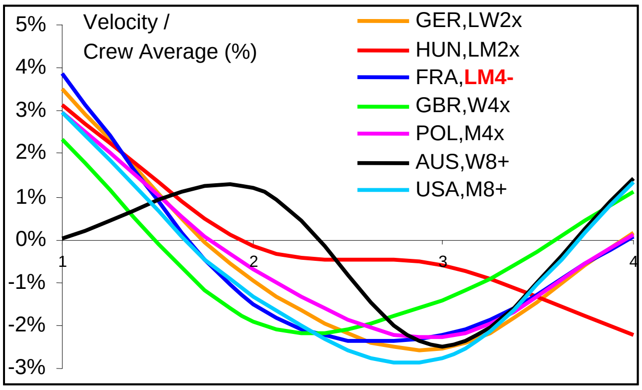
The 2005 World Rowing Championship have just finished in Gifu, Japan. Congratulations to all the winners! The most successful nations in Olympic boat types were: NZL (4 gold), GBR (2 gold), GER (1 gold, 1 silver, 2 bronze), AUS and USA (both 1 gold, 1 silver, 1 bronze).

Some very fast times were shown during the latest Worlds, but they were caused by water flow in the river. Therefore, we didn't consider the absolute boat speed, but analysed the race strategy and tactics (as we usually do) and trends in margins in recent years.

Facts. Did you know that...

✓ …the average race strategy of the winners of the 2005 Worlds was: 3.0%, -0.6%, -1.9%, -0.3%. The two charts below show the strategy of each winning crew:





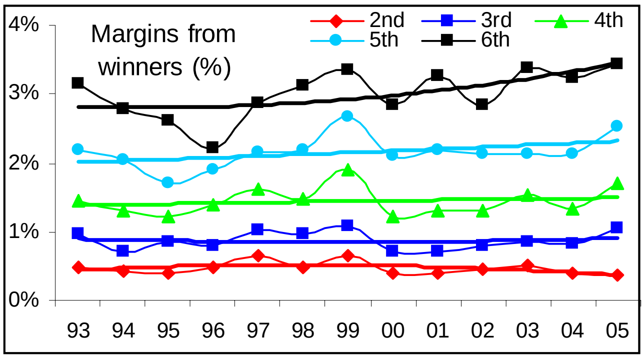
Most of the winners made their first 500m 2-4% faster than their average speed over 2000m. The exceptions were W2- (1.5%), M4- (5.0%) and W8+ (0.0%).

✓ …analysis of the race tactics shows where the winners gain their advantage RELATIVE to other competitors. This time we made a comparison not with average speed of the race, but with the speed of the CLOSEST competitors. The table below shows a count of each of 12 tactics amongst the finalists.

2005	Place						
Tactics	1st	2nd	3rd	4th	5th	6th	Total
1-2	3	1					4
1-3	1				1	2	4
1-4	5	1	6	1	1	4	18
2-1	1	1	1		1		4
2-3		2	1	1	1		5
2-4	1	1	1		1	1	5
3-1		2	1	3	1		7
3-2		1	1			1	3
3-4	1			1	1	5	8
4-1	1	3	1	5	2	1	13
4-2	1	1	1	1	1		5
4-3		1	1	2	4		8
Total	14	14	14	14	14	14	84

Once again we can see that the most of the winners (9 out of 14) concentrate their efforts on the first section of the race. Three out of five other tactics were used by winners from New Zealand.

✓ …despite the commonly held view, there was no significant narrowing of the margins between medal winners found during the last 13 years. We found only a tiny (-0.01% per year) reduction of the margins between winners and silver medalists in Olympic boats. The margins between winners and bronze medalists didn't change at all, and the margins between winners and all other finalists increased: 4th place by 0.01% per year, 5th place by 0.03% and 6th place by 0.05%. The chart below shows average margins in the 14 Olympic boats and their trends:



It is interesting to see the variations in phase with Olympic years. The average margins during the last three Olympiads were significantly narrower than in the years between:

Margins:	2nd	3rd	4th	5th	6th
Olympics	0.43%	0.77%	1.31%	2.04%	2.76%
Worlds	0.49%	0.90%	1.48%	2.19%	3.08%

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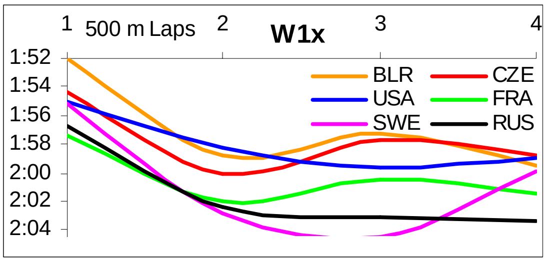
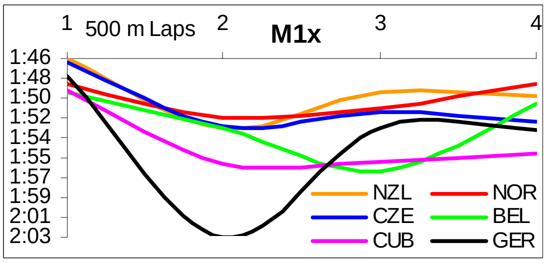
Appendix 1 of the Rowing Biomechanics Newsletter 8(5), August 2005.
Race strategy and tactics in Finals A during 2005 World Championship in Gifu (Japan).

W1x



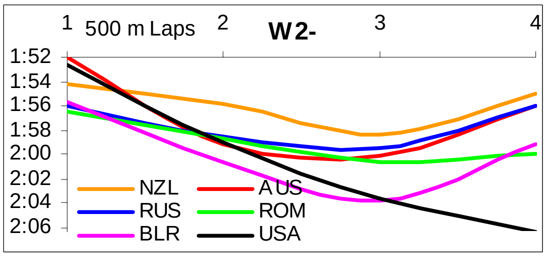
		Strategy				Var.	Tactics
1	BLR	4.3%	-1.6%	-0.3%	-2.2%	2.9%	1-4
2	CZE	2.9%	-1.9%	0.0%	-0.9%	2.1%	3-2
3	USA	2.5%	-0.2%	-1.4%	-0.8%	1.7%	2-3
4	FRA	2.5%	-1.4%	-0.1%	-0.9%	1.7%	3-1
5	SWE	4.6%	-1.8%	-3.1%	0.6%	3.4%	4-3
6	RUS	4.0%	-0.8%	-1.4%	-1.6%	2.7%	3-4

M1x



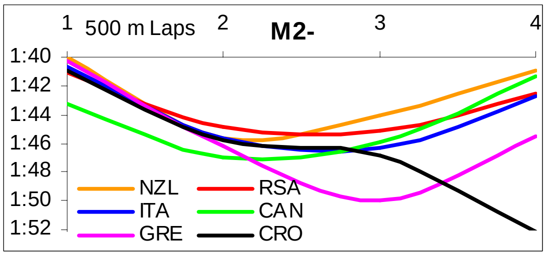
		Strategy				Var.	Tactics
1	NZL	3.3%	-3.0%	0.1%	-0.2%	2.6%	1-4
2	NOR	1.3%	-1.8%	-0.8%	1.4%	1.6%	4-1
3	CZE	4.1%	-1.8%	-0.6%	-1.5%	2.7%	1-4
4	BEL	2.9%	-0.3%	-4.1%	1.9%	3.1%	4-3
5	CUB	4.8%	-1.9%	-1.6%	-1.0%	3.1%	2-4
6	GER	6.2%	-7.7%	1.4%	1.1%	5.8%	3-2

W2-



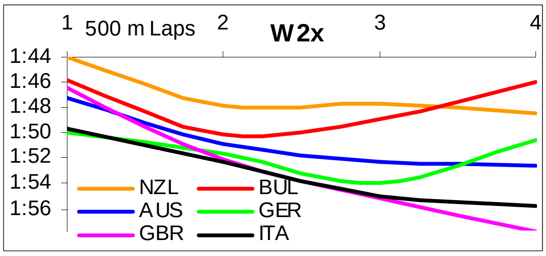
		Strategy				Var.	Tactics
1	NZL	1.5%	0.0%	-2.1%	0.7%	1.5%	2-1
2	AUS	4.3%	-2.0%	-2.8%	0.8%	3.2%	1-2
3	RUS	1.3%	-0.9%	-1.6%	1.2%	1.5%	4-1
4	ROM	2.1%	0.2%	-1.4%	-0.8%	1.5%	3-4
5	BLR	3.5%	-0.7%	-3.2%	0.6%	2.8%	4-2
6	USA	6.9%	1.2%	-2.6%	-4.7%	5.1%	1-4

M2-



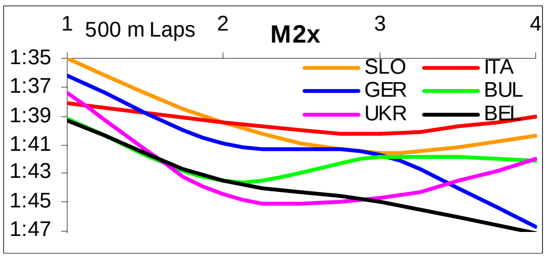
		Strategy				Var.	Tactics
1	NZL	2.6%	-2.8%	-1.4%	1.7%	2.5%	4-2
2	RSA	2.2%	-1.3%	-1.7%	0.9%	1.9%	2-1
3	ITA	3.1%	-1.7%	-2.3%	1.1%	2.5%	1-4
4	CAN	1.1%	-2.5%	-1.4%	3.0%	2.5%	4-1
5	GRE	5.1%	-0.7%	-4.1%	0.0%	3.8%	1-3
6	CRO	5.4%	0.6%	-0.4%	-5.0%	4.3%	3-4

W2x



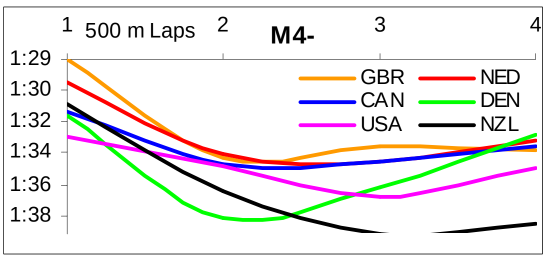
		Strategy				Var.	Tactics
1	NZL	2.9%	-0.8%	-0.7%	-1.3%	1.9%	2-4
2	BUL	1.7%	-2.1%	-1.1%	1.6%	1.9%	4-2
3	AUS	3.3%	-0.1%	-1.4%	-1.6%	2.2%	1-4
4	GER	1.4%	-0.1%	-2.1%	0.8%	1.5%	4-1
5	GBR	6.0%	0.7%	-2.0%	-4.2%	4.4%	1-4
6	ITA	3.2%	0.8%	-1.6%	-2.2%	2.5%	4-1

M2x



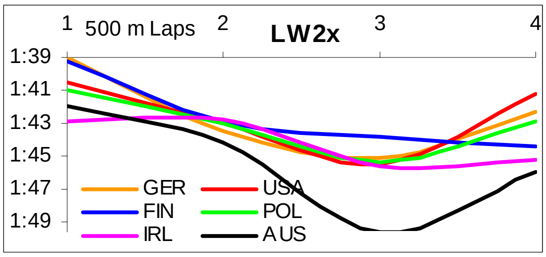
		Strategy				Var.	Tactics
1	SLO	4.3%	-0.4%	-2.4%	-1.2%	2.9%	1-4
2	ITA	1.1%	-0.3%	-1.0%	0.2%	0.9%	4-1
3	GER	5.3%	0.4%	-0.3%	-4.9%	4.2%	1-4
4	BUL	2.5%	-1.7%	-0.1%	-0.5%	1.8%	4-1
5	UKR	4.7%	-2.2%	-2.4%	0.2%	3.3%	4-3
6	BEL	4.3%	0.2%	-1.1%	-3.1%	3.2%	2-4

M4-



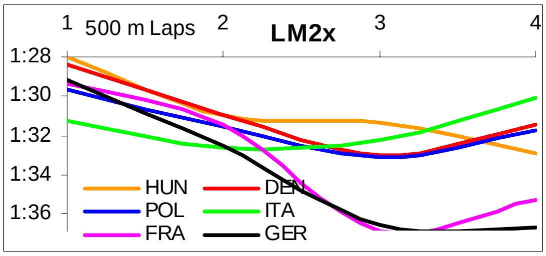
		Strategy				Var.	Tactics
1	GBR	5.0%	-2.0%	-1.2%	-1.5%	3.3%	1-4
2	NED	3.7%	-1.3%	-1.8%	-0.5%	2.5%	2-3
3	CAN	2.4%	-1.3%	-1.0%	0.0%	1.7%	2-1
4	DEN	3.4%	-3.5%	-1.5%	1.9%	3.1%	4-2
5	USA	2.1%	0.0%	-2.0%	-0.1%	1.7%	2-1
6	NZL	5.9%	-0.2%	-2.9%	-2.3%	4.0%	1-4

LW2x



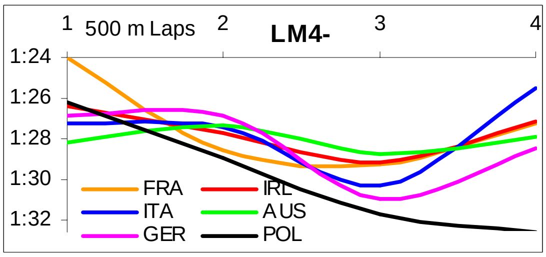
		Strategy				Var.	Tactics
1	GER	3.5%	-1.0%	-2.5%	0.2%	2.6%	1-4
2	USA	2.0%	-0.4%	-2.8%	1.3%	2.1%	4-1
3	FIN	3.4%	-0.3%	-1.2%	-1.8%	2.3%	1-4
4	POL	2.0%	0.1%	-2.2%	0.2%	1.7%	4-3
5	IRL	1.2%	1.3%	-1.4%	-1.1%	1.4%	3-1
6	AUS	3.5%	1.2%	-3.8%	-0.5%	3.1%	1-3

LM2x



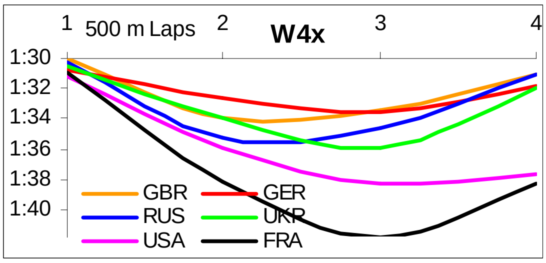
		Strategy				Var.	Tactics
1	HUN	3.2%	-0.2%	-0.6%	-2.2%	2.3%	3-4
2	DEN	2.9%	0.0%	-2.2%	-0.6%	2.1%	4-3
3	POL	2.0%	0.0%	-1.7%	-0.3%	1.5%	2-4
4	ITA	0.3%	-1.2%	-0.7%	1.6%	1.2%	4-1
5	FRA	4.3%	1.9%	-3.7%	-2.1%	3.6%	2-3
6	GER	5.0%	1.3%	-2.9%	-3.0%	3.8%	3-4

LM4-



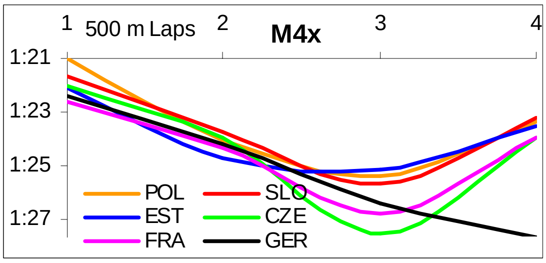
		Strategy				Var.	Tactics
1	FRA	3.9%	-1.5%	-2.3%	0.1%	2.7%	1-2
2	IRL	1.4%	-0.1%	-1.8%	0.5%	1.3%	3-1
3	ITA	0.5%	0.2%	-2.9%	2.4%	2.2%	4-3
4	AUS	-0.2%	0.8%	-0.8%	0.2%	0.7%	3-1
5	GER	1.7%	1.7%	-3.0%	-0.2%	2.2%	4-3
6	POL	4.2%	1.0%	-2.0%	-2.9%	3.3%	1-4

W4x



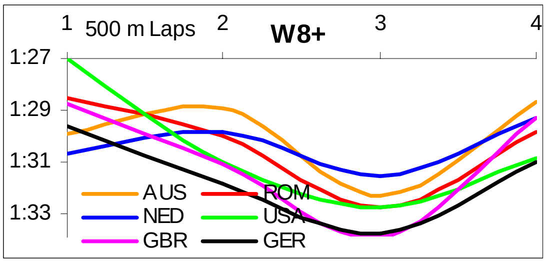
		Strategy				Var.	Tactics
1	GBR	2.3%	-1.9%	-1.4%	1.1%	2.0%	1-2
2	GER	1.6%	-0.4%	-1.5%	0.4%	1.3%	2-4
3	RUS	2.8%	-2.5%	-1.9%	1.9%	2.7%	4-2
4	UKR	2.8%	-1.0%	-2.9%	1.3%	2.5%	4-1
5	USA	5.0%	-0.2%	-2.6%	-1.8%	3.4%	3-4
6	FRA	6.9%	-0.9%	-4.4%	-0.9%	4.8%	1-3

M4x



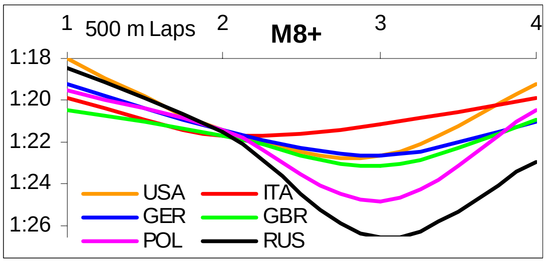
		Strategy				Var.	Tactics
1	POL	3.0%	-0.7%	-2.3%	0.1%	2.2%	1-2
2	SLO	2.3%	-0.2%	-2.4%	0.4%	2.0%	2-3
3	EST	2.1%	-1.0%	-1.5%	0.4%	1.6%	3-2
4	CZE	2.8%	0.5%	-3.6%	0.5%	2.7%	2-3
5	FRA	2.1%	0.1%	-2.7%	0.6%	2.0%	4-1
6	GER	3.3%	1.2%	-1.4%	-2.8%	2.7%	3-4

W8+



		Strategy				Var.	Tactics
1	AUS	0.0%	1.2%	-2.5%	1.4%	1.8%	4-1
2	ROM	2.0%	0.3%	-2.7%	0.5%	1.9%	1-4
3	NED	-0.4%	0.6%	-1.3%	1.2%	1.1%	3-1
4	USA	3.9%	-0.6%	-2.5%	-0.5%	2.7%	1-4
5	GBR	2.2%	-0.3%	-3.4%	1.6%	2.5%	4-3
6	GER	2.2%	-0.3%	-2.4%	0.6%	1.9%	3-4

M8+



		Strategy				Var.	Tactics
1	USA	3.0%	-1.3%	-2.8%	1.4%	2.6%	1-3
2	ITA	0.9%	-1.2%	-0.6%	0.9%	1.1%	3-1
3	GER	2.3%	-0.4%	-1.9%	0.0%	1.7%	1-4
4	GBR	1.3%	-0.2%	-1.9%	0.8%	1.4%	3-1
5	POL	2.5%	0.2%	-3.8%	1.3%	2.8%	4-1
6	RUS	4.9%	1.0%	-4.8%	-0.7%	4.0%	1-4

Q & A

? ***Dr.*** *Volker Nolte of University of Western Ontario is the best known expert in rowing biomechanics in the world. We have asked him the question:* ***"What should rowers and coaches do to maintain better boat balance?"*** *Dr. Nolte kindly agreed to answer the question and you can see his reply below.*

A.: The system consisting of rower(s), boat and oars is free to rotate around the longitudinal axis of the boat and the effort to control this movement (to maintain a postural balance) is important for the performance of the crew. This increases in difficulty when the boat is moving around its longitudinal axis. When a boat rolls, the crew members will adjust their body positions in an attempt to balance it. In addition, the oar and blade are often used for stability.

Since the centre of gravity (CG) of the system rower/boat lies quite a distance above the centre of buoyancy (CB) of the boat, rowers struggle with their balance in the boat. Of course, beginners experience more of a challenge from the balance than skilled rowers, but even a world class crew will show significant movements around the boat's longitudinal axis. (Fig. 2):

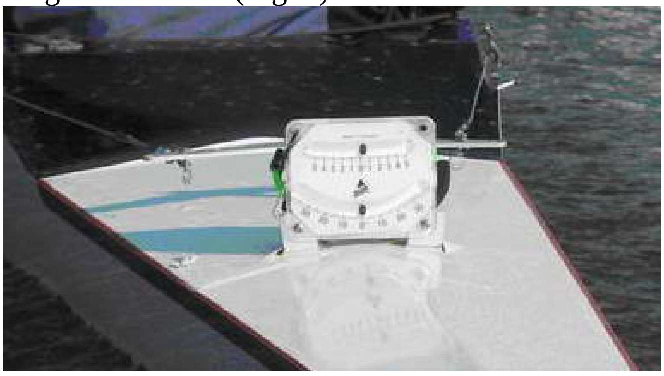


Fig. 1: Pitch-meter mounted on stern deck to measure balance.

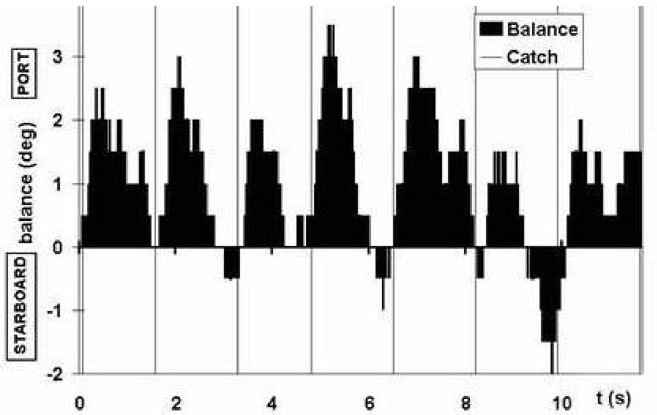


Fig.2: Balance measurements from a National team eight during normal training

To put the measured rolling angles in perspective, one must realise that if a sweep boat is 1 deg out of balance, the rowers on one side of the boat carry the hands at the end of the oars about 5 cm higher than the rowers on the other side. These are very significant differences to the optimal height the rowers carry their hands in a balanced boat. Coaches and athletes spend considerable time to rig the height of the oarlocks properly with millimeters accuracy.

In addition, the rowers sit on seats that are connected with the boat. This means, any rolling of the boat is directly transferred to the seats. The rowers then shift their body through movements in the lower back to regain balance. This can lead to extended loads in the spine, which can lead to back injuries, especially when rowers apply force on the oar in the moment the boat is out of balance. A rolling boat can therefore lead to injuries.

One goal in technique training is learning to keep the boat in balance. However, it is literally impossible even for the best crew to accomplish this task so that the boat would not roll at all. Every crew will have some kind of rolling motion. In the best case, it would be a minimal oscillation around the 0° balance point.

Why is it so difficult to keep the boat balanced?

It needs only very small forces to roll a boat. Two simple tests should illustrate this:

- Imagine a single rower sits in their boat that does not move. The rower holds one handle between the thumb and the pointer finger, when the other handle is been left alone. In this position, the rower can move the handle up and down with literally no effort that would create large rolling movements of the boat.
- Another example: an eight crew balances the boat with the blades off the water and the rowers' eyes closed. If the coxswain moves one arm out to the side, the boat will roll over to this side.

Therefore, a change in hand height during the recovery, a small shift of the upper body by a few millimeters, the swaying of the legs during recovery, or a light touch on the rudder will influence the balance of the boat.

Rowers obviously learn to compensate for all kinds of lateral movements happening in a boat and these counteracting movements eventually happen subconsciously with experienced rowers. Beginners tend to overcompensate in their attempt to balance, upsetting the boat even more. A highly skilled crew reacts with very small and coordinated movements.

How can you learn balance?

We know from new motor control studies that rowers have to experience the whole variety of rolling movements, if they want to balance a boat. They need to feel the forces on the seat, handle and footstretcher when the boat is in certain positions. They need to find out, what they can do to bring the boat back to a level position. And finally, the fine art of rowing means that rowers learn to anticipate any rolling motions.

You could never learn balancing a boat in a stabilised boat (like half-crew-rowing). On the contrary, a rower needs to experience many different rolling positions. Therefore, the best boat to learn balance is the racing single, the most unstable boat.

Rowers also need to do balance drills. Let them experience the largest rolling movements by pushing the one side of handles down to the gunwales when the other side moves the hands up as high as they can without flipping the boat. Then roll the boat to the other side and eventually flop back and forth realising how easy it is to do this. If the environment is safe, let the rowers stand up in the boat and ask them to let the oars go.

Other good balance drills are:

- Pause every other stroke at a certain point of the recovery,
- One-hand-only rowing,
- Wide grip rowing etc.

Do not shy away from any new ideas – the wider the variety of the drills, the better for learning! You can do even fun and challenging stuff, like putting the handles in the water at the catch…

Finally, make sure the boat is well rigged. A poorly rigged boat will not allow the rower to experience the proper forces necessary to balance the boat or to bring it back in a balanced position.

Fig.3: Balance drill: Standing up in the boat

Fig.4: Fun balance drill: Clean your handles at the catch

Literature

1. McLaughlin, S. (2004), A Comparison of two Methods for Teaching Beginners the Sport of Rowing. Masters Thesis, University of Western Ontario.

2. Nolte, V., McLaughlin, S. The balance of crew rowing boats. In: Malaysian Journal of Sport Science and Recreation. Vol. 1 (1), 51-64, 2005

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News

We previously discussed relationships between boat speed, stroke rate and DPS: in RBN 2001/04 and 2004/03 in step test; in 2003/01 and 2005/02 race analysis was focused. Recently, we have developed a new method of assessment of these variables, which can be considered as a real breakthrough in this area. The method can be widely used in practice and bridges a gap between performance analysis and rowing biomechanics/technique. Below is the description of the new method.

It is obvious that the distance per stroke, *DPS*, decreases as the stroke rate, *R*, increases at constant speed, *V*, because the duration of the stroke cycle, *T*, becomes shorter:

$$DPS = V * T = 60\ V / R \qquad (1)$$

To maintain *DPS* at a higher stroke rate, we need to increase speed proportionally, which never happens in practice. So, let us ask: **What do we need to preserve as the stroke rate increases?**

From pure common sense, the main objective is to sustain the application of force, *F*, of stroke length, *L*, and of mechanical efficiency, *E*. **The effective work per stroke,** *WPSe*, integrates all these parameters and is used as the key variable of the method:

$$WPSe \sim F * L * E \qquad (2)$$

The hydrodynamic drag resistance force, *Fd*, speed, *V*, and power, *P*, generated by the athlete, are related as follows:

$$Fd = k * V^2 \qquad (3)$$

$$P = V * Fd = k * V^3 \qquad (4)$$

where *k* is some non-dimensionless factor depending on the boat type, displacement, weather conditions and blade efficiency.

WPSe can be expressed in terms of power, *P*, stroke cycle time, *T*, speed, *V*, and stroke rate, *R*, *thus*:

$$WPSe = P\ T = P\ (60 / R) = 60k\ (V^3 / R) \qquad (5)$$

If the two values of *WPSe* are equal ($WPSe_0 = WPSe_1$) for the two sections of the race with different stroke rates (R_0 and R_1), then using equation 5 we can derive the ratio of the boat speeds (V_0 and V_1) for these sections as follows:

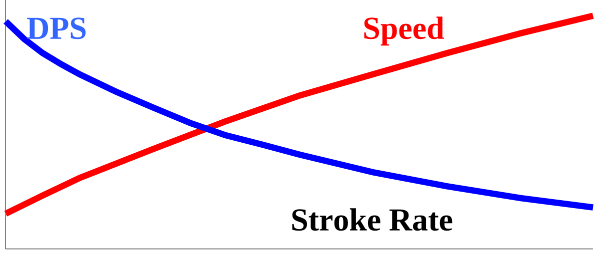
$$V_1 / V_0 = (R_1 / R_0)^{1/3} \qquad (6)$$

Correspondingly, the ratio of *DPS* values is:

$$DPS_1 / DPS_0 = (R_0 / R_1)^{2/3} \qquad (7)$$

To use equations 6 and 7, we don't need to know factor *k*, because we assume that it is the same for the two sections. However, remember that this is applicable only for the same boat, rowers and weather conditions, which is a limitation of the method.

The chart below illustrates the equations 6 and 7 and represents dependencies of the boat speed and DPS on the stroke rate at **constant effective work per stroke**:



The most practically convenient implication of the method is the definition of "prognostic" or "model" values of speed *Vm* and distance per stroke *DPSm*, which can be achieved at the constant effective work per stroke *WPSe*:

$$Vm = V_0\ (R_1 / R_0)^{1/3} \qquad (8)$$

$$DPSm = DPS_0\ (R_0 / R_1)^{2/3} \qquad (9)$$

An important question is what values we use for the base values of V_0 and DPS_0. The possible solutions are:

1. Average of all samples taken;
2. Minimal or maximal values of V and DPS;
3. Values obtained at the lowest stroke rate.

Obviously, the first option should be used for race analysis, because it represents the average speed and rate over the whole race. In a step test, we can use option 1 as well, but option 3 also makes sense.

Finally, ratios of the real values *Vi* and *DPSi*, for each race section, to the "model" values were used for evaluation of the effective work per stroke:

$$eVi\ (\%) = Vi / Vm \qquad (10)$$

$$eDPSi\ (\%) = DPSi / DPSm \qquad (11)$$

This method…

- …can be successfully used for race analysis in cyclic water sports (rowing, swimming, canoeing);
- …can be employed for evaluation of the strength- and speed-endurance using step-test in cyclic water sports;
- …does not require sophisticated equipment (except for a stop watch or StrokeCoach ®) and can be used in every day training.

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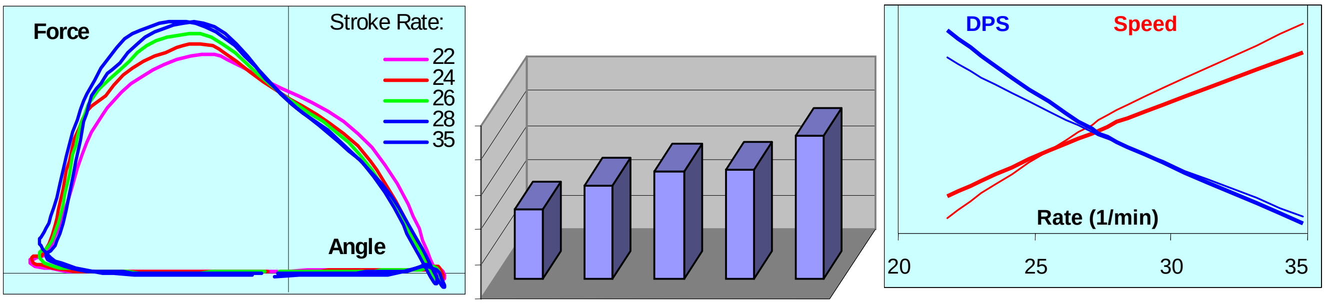
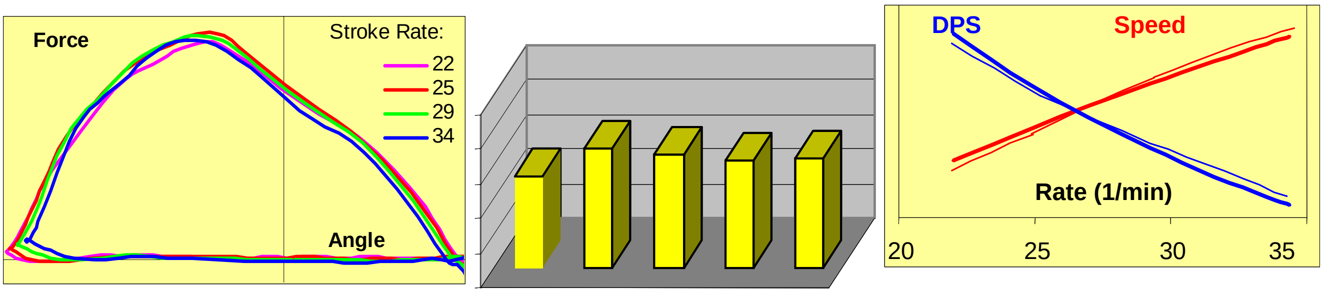
Appendix 1 of the Rowing Biomechanics Newsletter 10(5), October 2005.
Validation of the analysis method based on the effective work per stroke.

Three rowing crews performed the step test on water. Each row of charts below represents one crew.
Left column: Force curves at different stroke rate;
Centre column: Measured mechanical work per stroke;
Right column: real (thin line) and "model" (thick line) dependencies of the boat speed and DPS on the stroke rate



1



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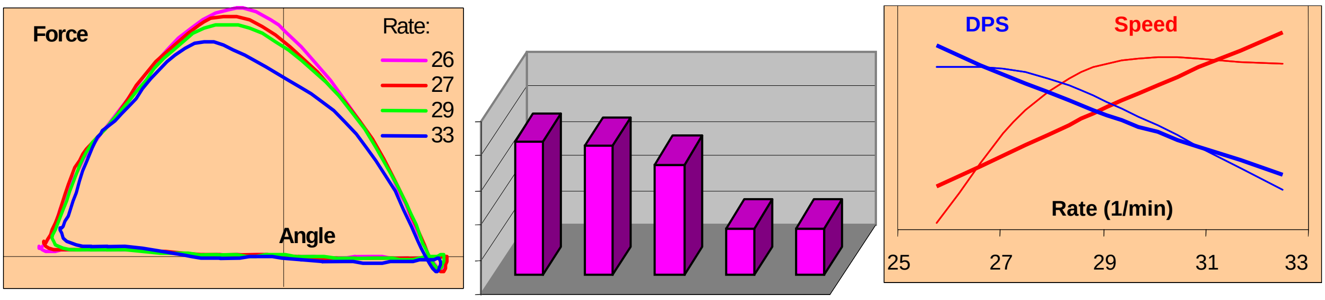
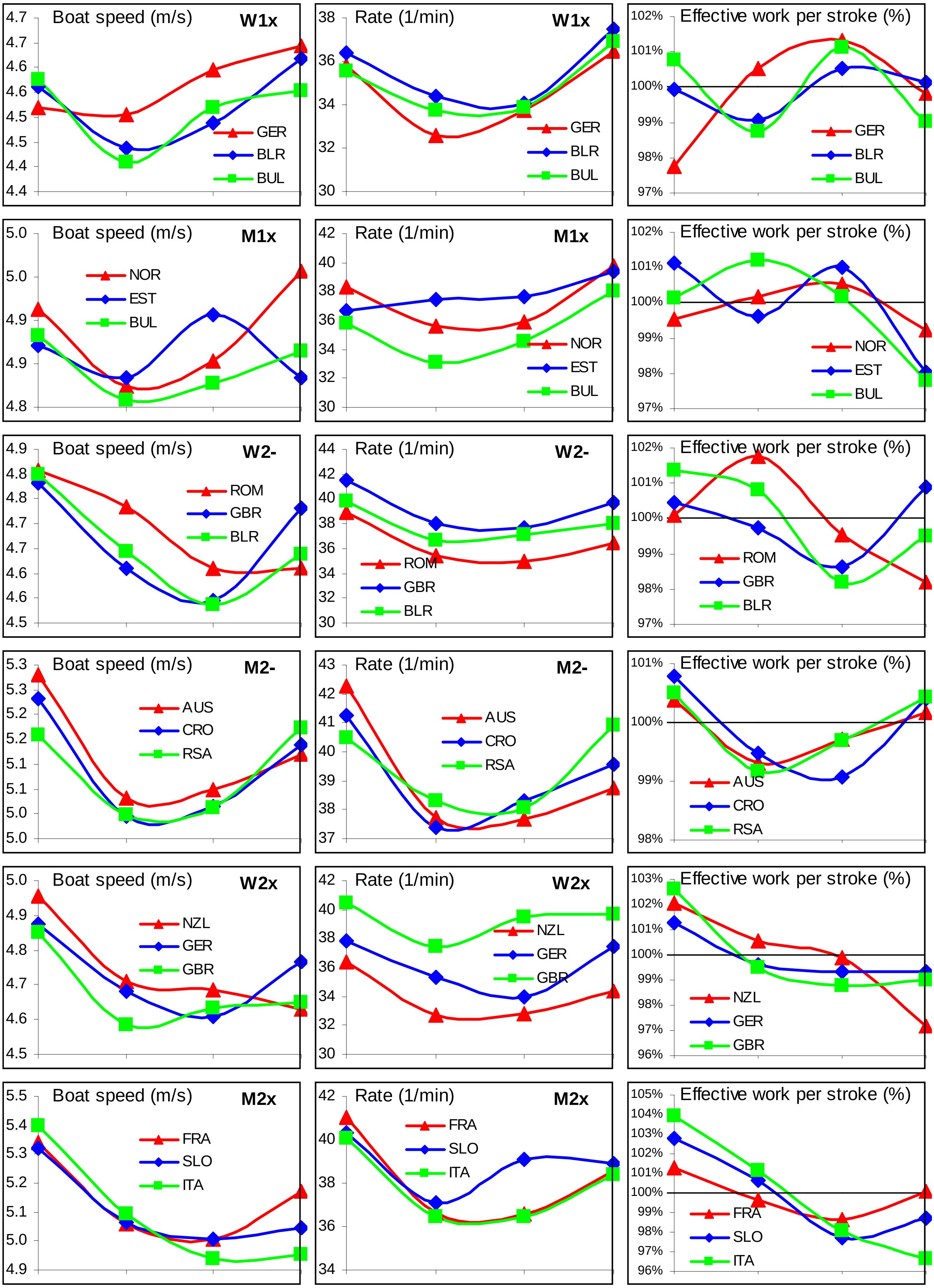


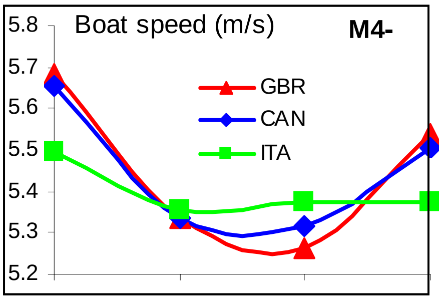
3

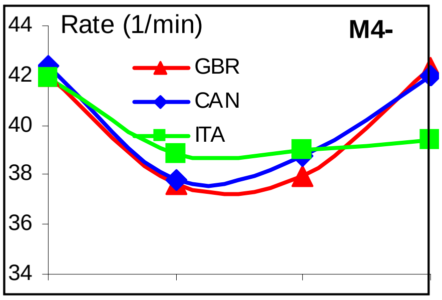
1. The first crew increases force and maintain length at higher stroke rates => mechanical work per stroke became higher => measured trends of the boat speed and DPS overtake "model" lines at higher rates.
2. The second crew maintain both force and length at higher stroke rates => mechanical work per stroke is nearly constant => measured trends of the boat speed and DPS follow "model" lines.
3. The third crew decreases both force and length at higher stroke rates => mechanical work per stroke became lower => measured trends of the boat speed and DPS go below "model" lines at higher rates.

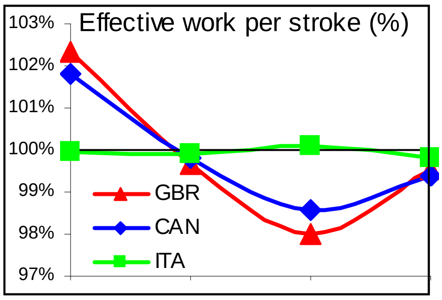
Appendix 2 the Rowing Biomechanics Newsletter 10(5), October 2005.

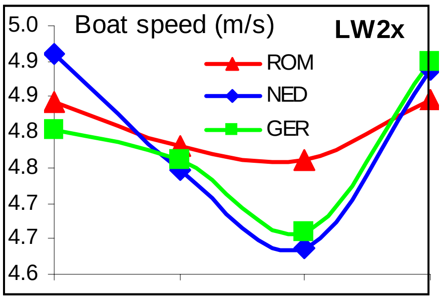
Analysis of effective work per stroke in the rowing medallists of Olympics-2004 in Athens.

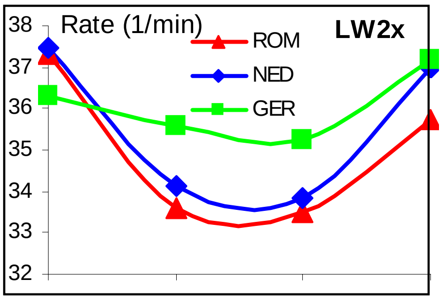


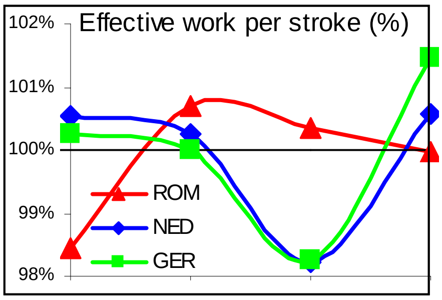

Boat speed (m/s)
M4-
GBR
CAN
ITA
5.8
5.7
5.6
5.5
5.4
5.3
5.2

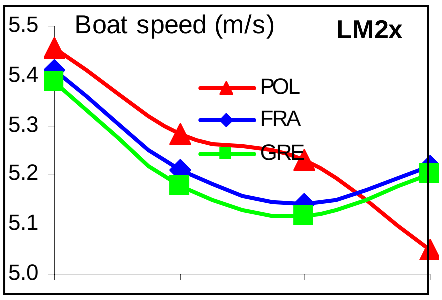

Rate (1/min)
M4-
GBR
CAN
ITA
44
42
40
38
36
34

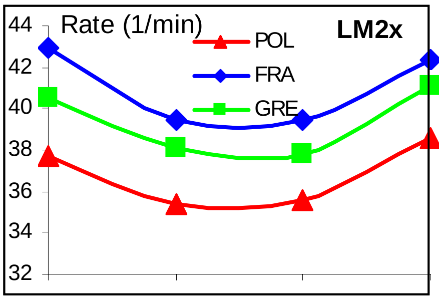

Effective work per stroke (%)
GBR
CAN
ITA
103%
102%
101%
100%
99%
98%
97%

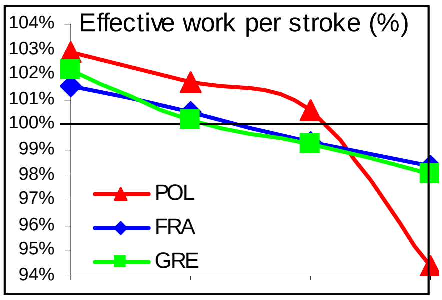

Boat speed (m/s)
LW2x
ROM
NED
GER
5.0
4.9
4.9
4.8
4.8
4.7
4.7
4.6

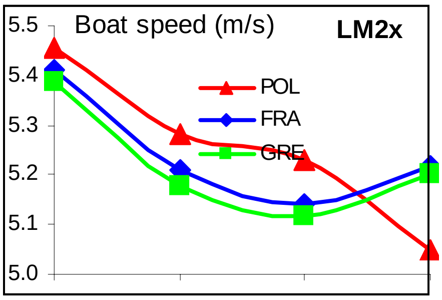

Rate (1/min)
LW2x
ROM
NED
GER
38
37
36
35
34
33
32

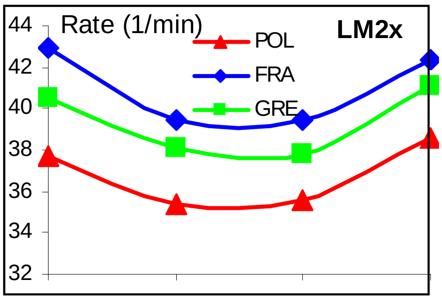

Effective work per stroke (%)
ROM
NED
GER
102%
101%
100%
99%
98%

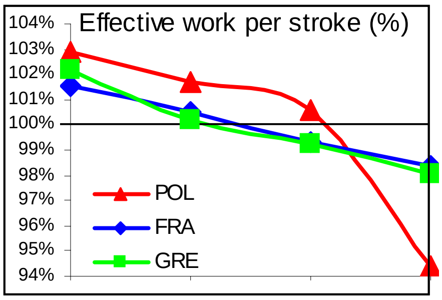

Boat speed (m/s)
LM2x
POL
FRA
GRE
5.5
5.4
5.3
5.2
5.1
5.0

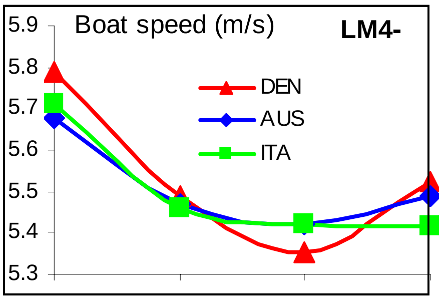

Rate (1/min)
LM2x
POL
FRA
GRE
44
42
40
38
36
34
32

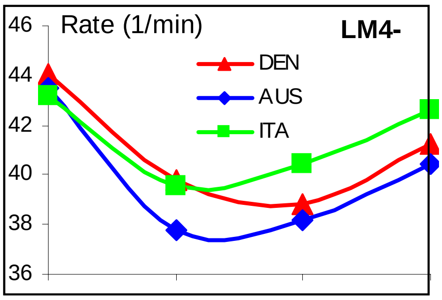

Effective work per stroke (%)
POL
FRA
GRE
104%
103%
102%
101%
100%
99%
98%
97%
96%
95%
94%

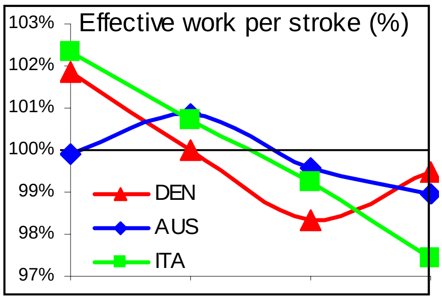

Boat speed (m/s)
LM2x
POL
FRA
GRE
5.5
5.4
5.3
5.2
5.1
5.0

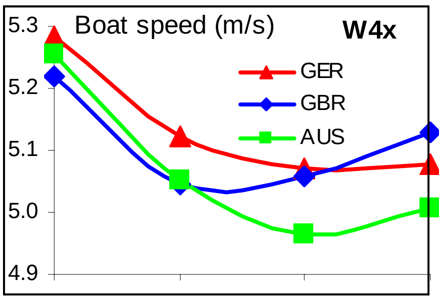

Rate (1/min)
LM2x
POL
FRA
GRE
44
42
40
38
36
34
32

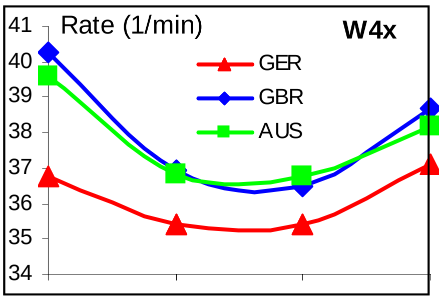

Effective work per stroke (%)
POL
FRA
GRE
104%
103%
102%
101%
100%
99%
98%
97%
96%
95%
94%

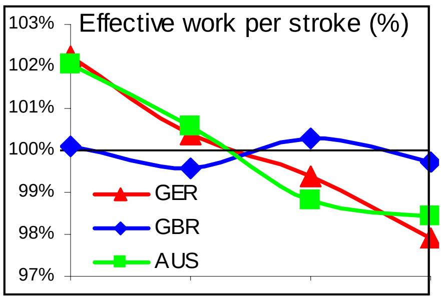

Boat speed (m/s)
LM4-
DEN
AUS
ITA
5.9
5.8
5.7
5.6
5.5
5.4
5.3

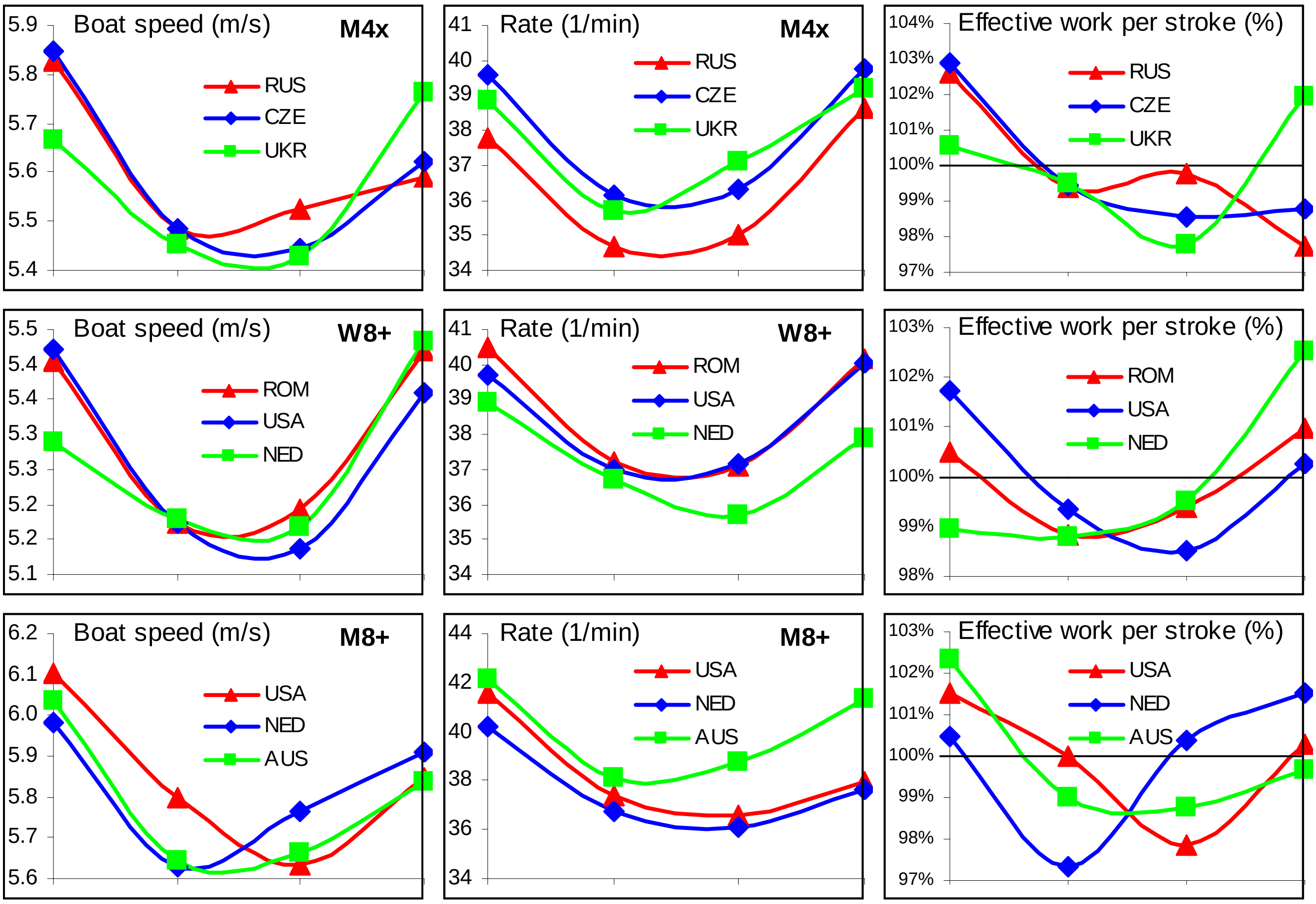

Rate (1/min)
LM4-
DEN
AUS
ITA
46
44
42
40
38
36


Effective work per stroke (%)
DEN
AUS
ITA
103%
102%
101%
100%
99%
98%
97%

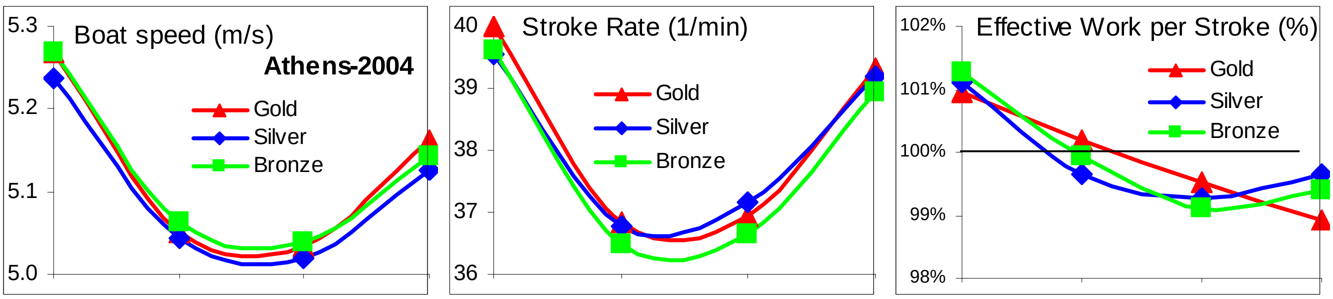

Boat speed (m/s)
W4x
GER
GBR
AUS
5.3
5.2
5.1
5.0
4.9


Rate (1/min)
W4x
GER
GBR
AUS
41
40
39
38
37
36
35
34


Effective work per stroke (%)
GER
GBR
AUS
103%
102%
101%
100%
99%
98%
97%



Average data in 14 Olympic boats:



Q & A

Q.: During the last World Rowing Forum (www.worldrowing.com/news/fullstory.sps?iNewsid=272187&itype) British National coach Miles Forbes-Thomas asked us a question with the following meaning: "Can we use hydro-dynamical drag factors of the various boat types for defining their relative speeds and Gold Standard Times?"

A.: First, let us mention two serious limitations of this analysis method:

1. There is no such a thing as generic drag factor for certain boat type, because different boat brands have different dimensions and other parameters (riggers, surface finish, etc.).

2. The method assumes constant rowing power production, which is obviously not the case in different rowers' categories (man vs. women, heavyweight vs. lightweight, sweep vs. sculling) and may vary even in the same category with different boat size (single-double-quad).

For these reasons, we didn't use the drag factors in the Forum presentation. However, now we've decided to investigate it further. We took boat dimensions from www.empacher.com because this brand was the most popular in elite rowing. Matthew Findlay, an Eng.D. scholar at Southampton Uni., made calculations of the **drag factor k1 using computational fluid dynamics (CFD), 1st and 2nd rows in the tables below**.

Also, we derived **drag factor k2 based on statistics of our biomechanical measurements during 7 years in AIS, Canberra: 3rd and 4th rows** (total sample size 1102 points).

The next six rows in the tables represent ratios of the boat speeds based on prognostic times:

5th row - Average of the winners of Worlds and Olympics during 1993-2005;

6th row - World Best Times;

7th row – Australian Gold Times (1);

8th row – Dr. Peter Schwanitz prognosis (2);

9th –Our moderate trends (RBN 2005/5);

10th– The best case trends (RBN 2005/5).

	W1x	W2-	W2x	W4x	W8+
k1	1.000	0.749	0.748	0.662	0.624
2	100.0%	110.1%	110.2%	114.8%	117.0%
k2	1.000	0.693	0.692	0.530	0.425
4	100.0%	113.0%	113.1%	123.6%	133.0%
5	100.0%	104.0%	107.6%	114.9%	117.2%
6	100.0%	103.4%	107.3%	115.3%	120.0%
7	100.0%	104.1%	107.8%	117.2%	121.2%
8	100.0%	103.4%	107.1%	113.4%	118.4%
9	100.0%	105.6%	109.2%	117.7%	121.6%
10	100.0%	104.4%	108.7%	116.1%	120.0%

The similar ratios of the speed in men's boat types, assuming M1x is 100%:

	M2-	M2x	M4-	M4x	M8+
k1	0.744	0.743	0.667	0.664	0.615
2	110.4%	110.4%	114.5%	114.6%	117.6%
k2	0.711	0.778	0.514	0.619	0.480
4	112.0%	108.7%	124.8%	117.3%	127.7%
5	105.4%	108.2%	114.4%	115.2%	119.7%
6	105.9%	108.8%	116.1%	117.4%	123.9%
7	104.8%	108.6%	114.7%	117.4%	122.6%
8	106.6%	109.3%	115.5%	115.5%	120.9%
9	104.5%	107.7%	114.8%	116.6%	120.9%
10	105.0%	107.9%	115.7%	116.5%	120.8%

The calculations were done assuming equal power production in open men's (or women's) boat types and using equation: $V = (P / k)^{1/3}$ Therefore, we do not compare lightweight categories here.

In the big boats, 4x, 4- and 8+, computational values are very close to average of the winners of Worlds and Olympics over the last 13 years. It is interesting that computational ratios are similar (117.0%-117.6%) between 1x and 8+ in both men and women, but the observed ratios show 2-3% faster speed in M8+ compared with W8+ This could tell us that W8+ has more reserve to increase the speed. (It is unlikely that W8+ will use this reserve owing to less competition at International regattas). In pairs and doubles, computational boat speed must be much higher that we observe now. We can only speculate now why it happened.

Considering boat speed ratios based on our biomechanical measurements, we can say that only the ratio of speeds between M1x and M2- is very close to the ratio observed at the Worlds and found in the best times. For other big and medium boats this data says that they must be much faster than singles. This, probably, can be explained by specifics of the sample tested: singles have shown much better performance than crew boats.

In conclusion, prognostic times based on boat hydrodynamics have significant limitations and not applicable for comparison between rower's categories. They require further investigations, which may involve measurements of the real drag factors and/or more accurate modelling.

References

1. Australian "Gold Standard Times" on www.rowingqld.asn.au/Documents/Prognostics

2. Schwanitz. P. 2005. Vollzogener Entwicklungstrend und mogliche Prognose 2005-2008. Rudersport, 16, p.526-527

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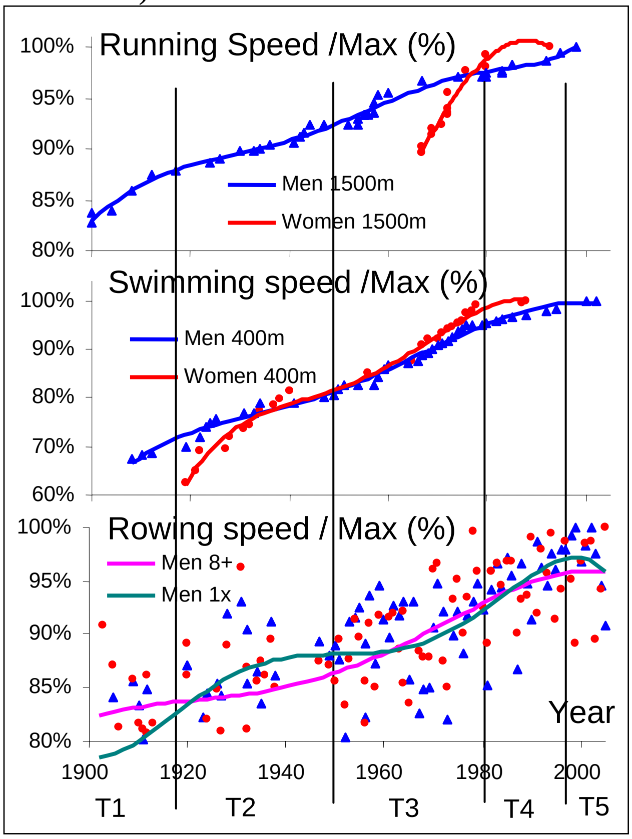
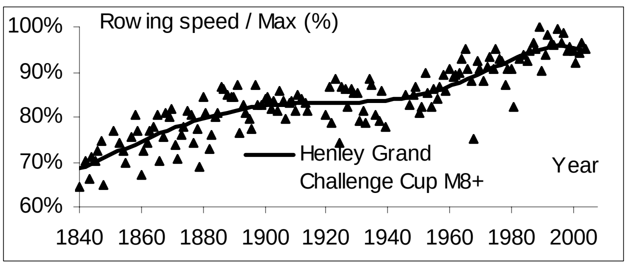
Long term trends of performance

✓ This is a brief summary of one of the topics presented on the World Rowing Forum (http://www.worldrowing.com/news/fullstory.sps?iNewsid=272187&itype=&iCategoryID=0). Long term performance in rowing is difficult to analyse, because it is significantly affected by weather conditions. Therefore, we analysed long term 1900-2005 trends of world records in similar endurance events, such as 1500m running (1) and 400m freestyle swimming (2) and compared them with the world winners times in rowing (the data iscourtesy of Milan Bacanovic):



It is quite obvious that the trend lines in all analysed sports have quite similar patterns. We can define five common periods:

T1 before 1920. Fast growth of performance 1-1.5% per year, which can be explained by **initial development** of sporting technique and training methods. It is interesting that the trend in M8+ is already quite flat during this period and initial development occurred before 1900, which can be seen from the records of the Royal Henley Regatta (http://www.hrr.co.uk/archive/records.htm, digitised by Nick Caplan):

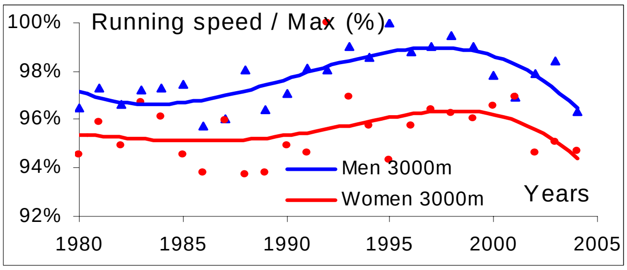


T2 1920 – 1950. Slow growth (0.5% per year) caused by two World Wars, amateur status of the athletes and lower competition due to separation of the East and West sport systems.

T3 1950 – 1980. Very fast growth of performance 1-2% a year. Eastern block joined Olympic sport in 1952. Sport became a political factor and professional activity, which boomed development of training volume, methods and use of drags in sport. This performance growth was even faster in women, because it coincided with initial development in some women's events.

T4 1980 – 1996. Slower growth 0.5-0.8% a year. Training volume approached its biological limit; effective training methods became widely known, improvement of the drag control. Rowing performance continue to grow relatively faster (1.5% a year) than in athletics and swimming. We can speculate that the reasons were equipment development (plastic boats and oars replaced wooden ones, big blade, etc.) and active FISA position in wider promoting of rowing and popularisation of modern training technologies.

T5 1996 – now. Stable period and even decreasing of performance, which can be seen in the latest trends of the yearly world best times in athletics (http://www.gbrathletics.com):



We can speculate that the reasons could be further development of doping control methods (such as blood doping test) and sociological factors. Professors Nevill and Whyte (1) recon that "many of the established …endurance running world records are nearing their limits. …the athletic and scientific community may continue to explore greater performance gains through use of pharmacology and the evolving science of gene doping" We hope that the room for improvement in rowing is a bit wider than in athletics, and its significant part can be fulfilled by biomechanics.

Literature

1. Nevill A., Whyte G. 2005. Are there limits to running world records? Med.Sci.Sports Exerc. 37, No.10, pp.1785-1788.
2. Volkov N., Popov O. 1999. Current development of sport records. RGUFK, Moscow, p.82

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