



BioRow

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Innovative Leadership in Rowing and Sport -
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Learning from Racing



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Contents

- Trends of boat speed;
- "Gold Standard" times;
- Race strategy and tactics;
- Modelling of the boat speed, stroke rate and distance per stroke;
- Analysis from 2011 international races.


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Factors affecting performance in sport:

- Training volume and professionalism;
- Training methods;
- Technique development;
- Equipment development;
- Doping control;

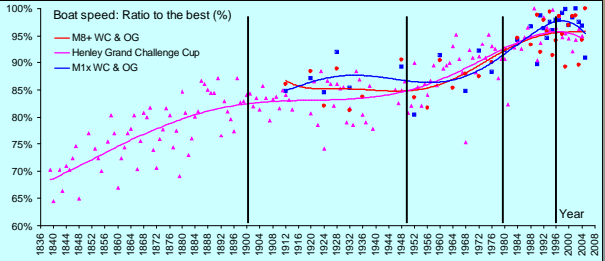
Rowing specific factors:

- Weather conditions;
- Synchronisation in the crew.



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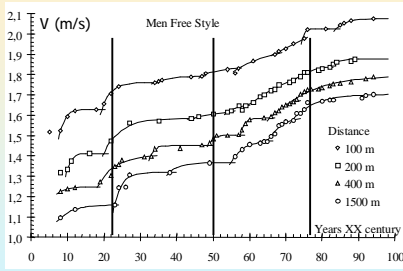
Long term trends of the boat speed in rowing



- Before 1900 – growth => equipment and technique;
- 1900 – 1950 – stable period;
- 1950 – 1980 – fast growth => training methods and volume;
- 1980 – 1996 - fast growth => equipment & training methods;
- 1996 – now – decreasing => doping control.

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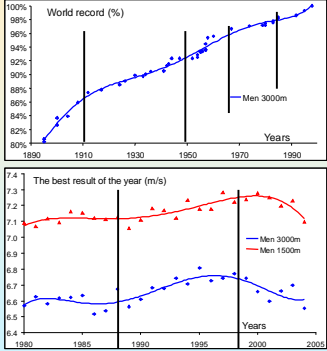
Trends of world records in swimming (by Volkov & Popov 1999)



- Before 1920 – fast growth;
- 1920 – 1950 – nearly stable period;
- 1950 – 1978 – fast growth => training volume, methods & technique;
- 1978 – now – slower growth.

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Trends of performance in athletics / running.

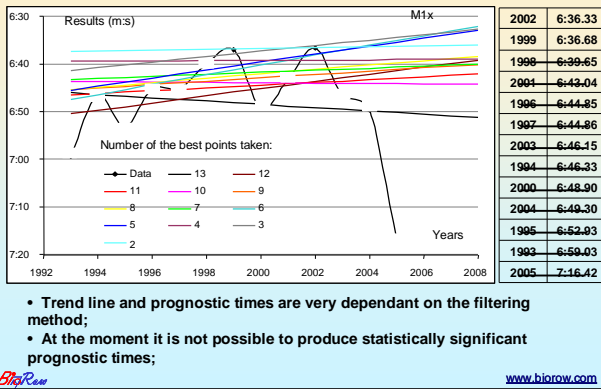


- Before 1910 – fast growth;
- 1910 – 1950 – slow growth;
- 1950 – 1965 – fast growth => training methods;
- 1965 – 1985 – slower growth;
- 1985 – 1995 – fast growth => drugs?
- 1995 – now – decreasing => doping control.

▫ Not all races were won with world record.

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Validity of the trends of boat speed

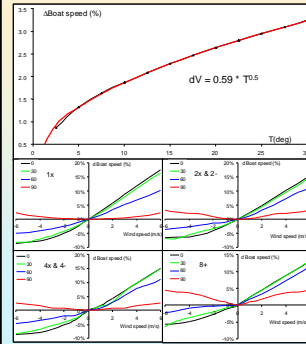


- Trend line and prognostic times are very dependant on the filtering method;
- At the moment it is not possible to produce statistically significant prognostic times;

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Influence of the weather conditions (Filter K.B. 2000)



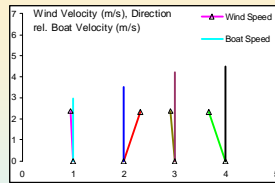
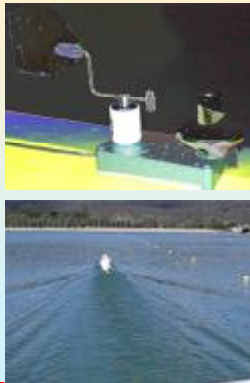
- Water temperature:
 - Around 2.5% decreasing of the boat speed from 25deg down to 4deg;
- Wind speed:
 - Around two times less increase of the boat speed at tail wind than decrease at head wind;
 - Cross wind affect crew boat more than singles.



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Wind gauge or "Rowing Simulator ☺" ?

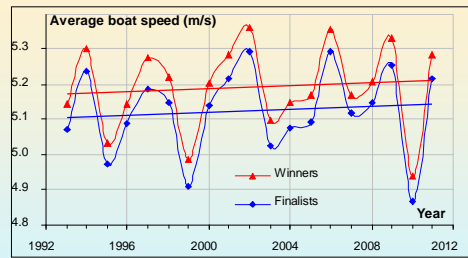


- Wind Gauge and a chart of wind/boat speeds;
- "Rowing Simulator ☺"

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Trends of the boat speed in winners and finalists in Olympic events



- Both trends of winners and finalists show long-term growth of performance about 0.2% per year;
- Weather affects 90% of variation of the boat speed;
- Human factors affect the rest 10% of variation of the boat speed.

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Results of 2011 World Championship in Bled

N	Boat	Day	Gold Standard	Winner's Time	%%	Average Rate
1	M2-	3	06:14.3	6:14.77	99.87%	39.4
2	W2-	1	06:52.9	6:58.16	98.74%	39.7
3	W2x	3	06:39.5	6:44.73	98.71%	36.6
4	M1x	3	06:32.5	6:39.56	98.23%	35.4
5	M4x	3	05:33.2	5:39.31	98.20%	38.1
6	M2x	2	06:02.1	6:10.76	97.66%	37.4
7	LM4-	2	05:46.2	5:55.10	97.49%	38.9
8	W4x	1	06:06.5	6:18.37	97.39%	35.4
9	W8+	2	05:53.1	6:03.65	97.10%	37.4
10	LW2x	4	06:47.0	6:59.80	96.95%	36.1
11	M8+	1	05:18.6	5:28.81	96.89%	38.7
12	W1x	4	07:11.5	7:26.64	96.61%	32.3
13	M4-	4	05:41.0	5:55.18	96.01%	38.0
14	LM2x	4	06:07.2	6:18.67	94.79%	38.9

- The four-day format of the final races in Bled and changing weather conditions make it difficult to compare the boat speed in various events;
- Both M2- and W2- has shown the highest stroke rate 39+ str/min and the highest ratio to the Gold Standard time.

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Results of 2011 World Championship in Bled

N	Country	Places						Entries	Medals	Points	Licenses	
		1st	2nd	3rd	4th	5th	6th					7th
1	GBR	3	3	4			1	2	14	10	66	13
2	NZL	4	1	3			1		12	8	55	11
3	AUS	2	1	2	3	1		1	11	5	48	10
4	GER	2	2		2	1	2	1	14	4	44	11
5	CAN	2	1			1		1	10	3	21	7
6	ITA	1	2				1	1	9	3	19	6
7	USA	1	1		2				14	2	22	8
8	GRE	1	1		1				4	2	18	4
9	CZE	1	1				1		10	2	16	4
10	BLR		1						5	1	6	2
11	FRA			1				1	9	1	6	3
12	CRO			1					4	1	5	1
13	CHN				3	1	2	1	14	0	20	8
14	POL				1	2		1	10	0	11	4
15	UKR				1	1	2	6	0	8	4	4
16	NED					1	2	6	0	7	4	4

- The best three countries Great Britain, New Zealand and Australia won 20 out of 42 medals in Olympic events (47.6%).

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Conclusions on the "Gold Medal Times":

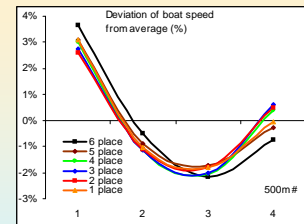
- First of all, use your common sense! Think about the main purpose of using "Gold Medal Times";
- Currently, the average prognostic growth of the boat speed is around 0.5-0.8% per year, which is significantly slower than during 1950-1990 (2.0-2.5% average growth);
- The various boat types have quite different trends of the boat speed;
- Continuous weather monitoring during major regattas can significantly improve estimation and prognosis of the boat speed.

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Race strategy in Gold vs. Silver and Bronze

- Winners are relatively faster at the 1st section of the race, than silver and bronze medallists;
- 2nd, 3rd and 4th place-takers usually have faster final section of the race.



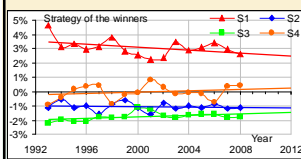
Place	1 st 500m	2 nd 500m	3 rd 500m	4 th 500m	Variation
1 st	3.09%	-1.04%	-1.80%	-0.05%	2.15%
2 nd	2.61%	-1.11%	-1.80%	0.49%	1.96%
3 rd	2.75%	-1.13%	-2.01%	0.60%	2.10%
4 th	3.01%	-1.12%	-2.05%	0.39%	2.21%
5 th	3.09%	-0.89%	-1.71%	-0.28%	2.11%
6 th	3.67%	-0.48%	-2.15%	-0.74%	2.51%
General	3.03%	-0.96%	-1.92%	0.07%	2.15%

Average data over 11 years (1993-2004).

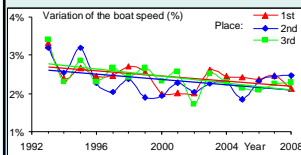
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Trends of the race strategy over the last 16 years



- The race strategy changes over the years.

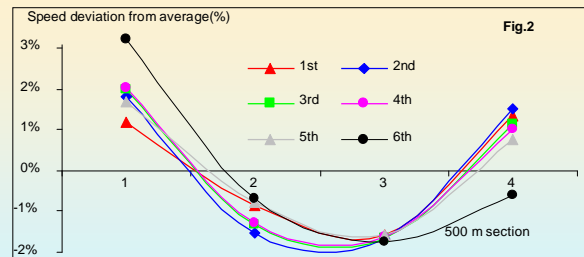


- Distribution of the boat speed is becoming more and more even;
- Prognostic race strategy of the winners for 2008 is: +2.5%, -1.1%, -1.4%, +0.2%

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Race strategy of finalists during 2011 Worlds in Bled



- Winners in Olympic events have shown relatively slower speed over the first 500m than all other finalists;
- This trend is opposite to what was found in previous World regattas.

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Matrix of race tactics

All 12 tactics are shown in a matrix where:

- Each column represents the same fastest piece (from 1 to 4);
- Each row represents slowest piece;
- Percentage shows number of cases in Finals A over the last 11 years.

	4 th 1500-Finish n=26	3 rd 1000-1500m n=19	2 nd 500-1000m n=13	1 st Start-500m n=26
4 th 1500-Finish n=26	1-4 14.1%	2-4 10.2%	3-4 6.3%	X
3 rd 1000-1500m n=19	1-3 7.9%	2-3 3.5%	X	4-3 6.6%
2 nd 500-1000m n=13	1-2 5.6%	X	3-2 3.9%	4-2 10.8%
1 st Start-500m n=26	X	2-1 6.1%	3-1 8.5%	4-1 16.0%
	1 st Start-500m n=26	2 nd 500-1000m n=16	3 rd 1000-1500m n=13	4 th 1500-Finish n=29

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Analysis of the place takers distribution

- The most popular tactics in winners was "1-4" (17.1%);
- The most popular tactics in silver and bronze medallists was "4-1";
- This corresponds with the race strategy distribution;

Tactic	Place					
	1	2	3	4	5	6
1-2	3.6%	4.3%	6.4%	11.4%	5.0%	2.9%
1-3	6.4%	6.4%	9.3%	9.3%	10.7%	5.1%
1-4	17.1%	5.7%	5.0%	6.4%	20.0%	34.3%
2-1	2.9%	6.4%	9.3%	3.6%	7.9%	6.6%
2-3	2.1%	4.3%	2.9%	2.9%	2.1%	6.6%
2-4	9.3%	5.7%	5.0%	7.1%	13.6%	20.4%
3-1	7.9%	12.1%	7.1%	9.3%	9.3%	5.1%
3-2	7.9%	2.1%	3.6%	3.6%	5.0%	1.5%
3-4	14.3%	5.7%	4.3%	5.0%	6.4%	2.2%
4-1	14.3%	26.4%	23.6%	18.6%	9.3%	3.6%
4-2	10.0%	15.7%	12.1%	13.6%	5.7%	7.3%
4-3	4.3%	5.0%	11.4%	9.3%	5.0%	4.4%

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Recommendations:

Choose the race strategy with faster start section if you are going to win (or die);

Choose the race strategy with faster finish and more even distribution of efforts if you want to maximise your result.



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Modelling of the boat speed, stroke rate and distance per stroke

In swimming, there was used an index of speed/stroke distance relationship (Keskinen 1989, Mason, 1996-2000)

$$K (m^2/s) = V * D = D^2 * R / 60 = 60 V^2 / R$$

where V is swimming velocity, D is distance per stroke, R is stroke rate.

This controversial index have no mechanical meaning. It always decreases at higher stroke rate.

In 1999, in collaboration with swimming coach Genady Touretsky we developed a method for evaluation of the speed, stroke rate and distance per stroke (DPS) based on the second order polynomial equation

$$V = aR^2 + bR + c.$$

The method was adapted for rowing and successfully used by successful rowing coach Paul Thompson in Australia and UK



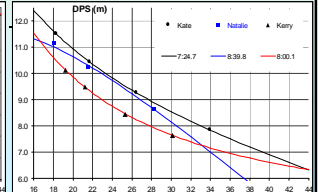
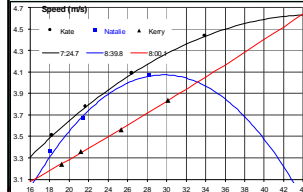
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Modelling of Distance per Stroke															
Input 1 Alex Popov				Input 2 Michael Klim				Input 3 David Jenkins							
Rate	Time (min)	Speed (m/s)	% of Goal	Time (min)	Speed (m/s)	% of Goal	Time (min)	Speed (m/s)	% of Goal	Time (min)	Speed (m/s)				
20	33.06	1.27	61.3%	3.81	9.2	38.24	1.14	56.5%	3.43	10.2	35.43	1.21	62.3%	3.64	8.6
22	31.21	1.36	65.7%	3.71	9.4	34.04	1.23	60.9%	3.36	10.4	32.89	1.28	65.8%	3.50	10.0
24	29.68	1.45	69.8%	3.61	9.7	32.23	1.31	65.0%	3.29	10.6	31.56	1.35	69.2%	3.37	10.4
26	28.41	1.53	73.7%	3.52	9.9	30.72	1.39	68.9%	3.22	10.9	30.41	1.41	72.4%	3.25	10.8
28	27.34	1.60	77.3%	3.43	10.2	29.45	1.47	72.8%	3.15	11.1	29.40	1.47	75.5%	3.15	11.1
30	26.43	1.67	80.7%	3.34	10.5	28.37	1.54	76.0%	3.08	11.4	28.52	1.53	78.4%	3.05	11.5
32	25.66	1.73	83.8%	3.25	10.8	27.45	1.60	79.3%	3.01	11.9	27.74	1.58	81.1%	2.98	11.8
34	25.00	1.78	86.6%	3.16	11.1	26.66	1.66	82.2%	2.93	11.8	27.06	1.63	83.7%	2.88	12.2
36	24.44	1.85	89.1%	3.08	11.4	25.97	1.72	85.0%	2.86	12.2	26.45	1.68	86.1%	2.80	12.5
38	23.97	1.89	91.4%	2.99	11.7	25.39	1.77	87.5%	2.79	12.6	25.91	1.72	88.4%	2.72	12.9
40	23.57	1.93	93.4%	2.90	12.1	24.88	1.82	89.8%	2.72	12.8	25.44	1.76	90.5%	2.65	13.2
42	23.23	1.97	95.2%	2.82	12.4	24.45	1.86	91.9%	2.65	13.2	25.01	1.80	92.5%	2.57	13.6
44	22.96	2.00	96.7%	2.73	12.8	24.08	1.89	93.7%	2.58	13.6	24.64	1.84	94.3%	2.51	14.0
46	22.74	2.03	97.9%	2.64	13.2	23.78	1.93	95.3%	2.51	13.9	24.31	1.87	95.0%	2.44	14.4
48	22.57	2.05	98.9%	2.56	13.7	23.52	1.96	96.8%	2.44	14.3	24.03	1.90	97.5%	2.37	14.7
50	22.45	2.06	99.6%	2.47	14.1	23.31	1.98	97.8%	2.37	14.7	23.78	1.92	98.8%	2.31	15.2
52	22.38	2.07	100.0%	2.39	14.7	23.15	2.00	98.7%	2.30	15.2	23.56	1.95	100.0%	2.25	15.6
54	22.35	2.07	100.2%	2.30	15.2	23.03	2.01	99.4%	2.23	15.7	23.38	1.97	101.0%	2.19	16.0
56	22.37	2.07	100.1%	2.22	15.8	22.95	2.02	99.8%	2.16	16.2	23.22	1.98	101.9%	2.13	16.5
58	22.43	2.06	99.7%	2.14	16.4	22.92	2.02	100.0%	2.09	16.7	23.10	2.00	102.6%	2.07	16.9



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Modelling of Distance per Stroke																		
Kato						Natalie						Kerry						
Rate	Time (min)	Speed (m/s)	% of Goal	Time (min)	Speed (m/s)	% of Goal	Time (min)	Speed (m/s)	% of Goal	Time (min)	Speed (m/s)	% of Goal	Time (min)	Speed (m/s)	% of Goal	Time (min)	Speed (m/s)	% of Goal
16	23.11	3.31	73.6%	12.41	40.3	20.425	3.02	78.5%	11.33	44.1	24.24	3.08	73.9%	11.54	43.3			
18	22.36	3.48	77.4%	11.61	43.1	21.313	3.31	85.9%	11.02	45.4	23.72	3.18	76.4%	10.60	47.2			
20	21.72	3.64	81.0%	10.93	45.7	22.210	3.55	92.2%	10.64	47.0	23.22	3.29	78.9%	9.96	50.7			
22	21.18	3.79	84.3%	10.35	48.3	23.137	3.74	97.2%	10.20	49.0	22.75	3.39	81.4%	9.25	54.1			
24	20.72	3.93	87.4%	9.83	50.9	23.085	3.89	101.1%	9.73	51.4	22.50	3.50	84.0%	8.74	57.2			
26	20.33	4.06	90.2%	9.36	53.4	23.051	4.00	103.9%	9.22	54.2	21.87	3.61	86.5%	8.32	60.1			
28	19.99	4.17	92.7%	8.93	56.0	23.033	4.08	105.4%	8.69	57.5	21.48	3.71	88.2%	7.90	62.8			
30	19.71	4.27	94.5%	8.54	58.6	23.028	4.07	105.8%	8.14	61.4	21.07	3.83	91.8%	7.45	65.4			
32	19.47	4.36	96.9%	8.17	61.2	23.037	4.04	105.1%	7.58	66.0	20.70	3.94	94.5%	7.38	67.7			
34	19.28	4.43	98.6%	7.82	63.9	23.060	3.97	103.1%	7.00	71.4	20.34	4.05	97.2%	7.15	69.9			
36	19.12	4.50	100.0%	7.50	66.7	23.099	3.85	100.0%	6.41	76.0	20.00	4.17	100.0%	6.94	72.0			
38	18.99	4.55	101.1%	7.18	69.6	23.157	3.68	95.7%	5.82	86.0	19.66	4.28	102.8%	6.76	74.0			
40	18.90	4.59	102.0%	6.88	72.6	23.239	3.47	90.3%	5.21	96.0	19.37	4.40	105.6%	6.60	75.8			
42	18.83	4.62	102.6%	6.59	75.9	23.353	3.22	83.7%	4.60	100.7	19.07	4.52	108.5%	6.45	77.5			
44	18.80	4.63	103.0%	6.32	79.2	23.513	2.92	75.9%	3.98	105.6	18.78	4.64	111.3%	6.32	79.1			



What do we need to preserve at increasing of the stroke rate?

Distance per stroke (D) decreases at increasing of the stroke rate, because time of the stroke cycle became shorter

$$D = V * T = 60 V / R$$

The main target is maintaining of force application (F), stroke length (L) and technique efficiency (E)

Effective work per stroke (We) integrates all above parameters:

$$We = F * L * E$$



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The method development, Step 1

Hydrodynamic drag resistance force (Fd), speed (V) and power (P) generated by athlete are related:

$$Fd = k * V^2; \quad P = V * Fd; \quad P = k * V^3$$

where k is some non-dimensional factor

Effective work per stroke (We) can be expressed through power (P) and cycle time (T), and then through speed (V) and stroke rate (R):



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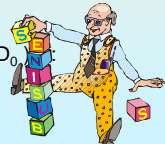
The method development, Step 2

- ü If effective work per stroke is maintained ($We_1 = We_0$) at two race sections with different stroke rate (R_1 and R_0), then ratio of the speeds (V_1 and V_0) at these sections is:

$$\frac{V_1}{V_0} = \sqrt[3]{\frac{R_1}{R_0}}$$

- ü Ratio of the distances per stroke (D_1 and D_0)

$$\frac{D_1}{D_0} = \sqrt[3]{\frac{R_0}{R_1}}$$



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The method development, Step 3

- ü The most practically convenient implication of the method is defining of "prognostic" or "model" values of speed (V_m) and distance per stroke (D_m), which would be achieved at the same effective work per stroke

$$V_m = V_0 (R_1 / R_0)^{1/3}$$

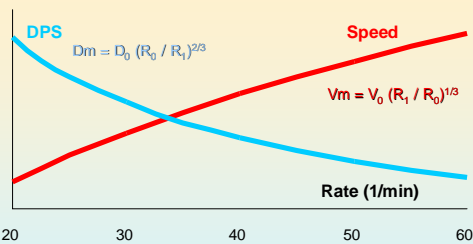
$$D_m = D_0 (R_0 / R_1)^{2/3}$$

- ü Average values of speed and rate over whole race or test were used as the base values V_0 and R_0
- ü Ratios of the real values V and D at each section to the "model" values were used for evaluation of the effective work per stroke

$$E_v (\%) = V_1 / V_m \quad E_D (\%) = D_1 / D_m$$

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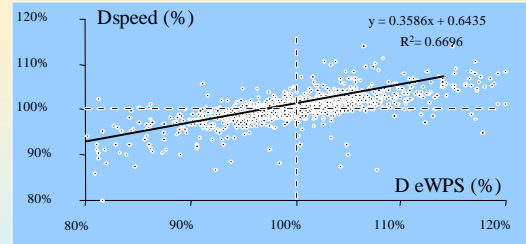
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Dependence of the speed and distance per stroke on stroke rate at the constant effective work per stroke: "model" curves

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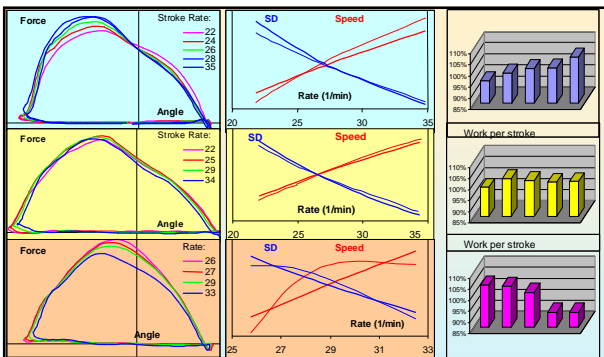
www.biorow.com



Statistical validation of the method in rowing: Correlation of the deviations of real speed from "model" with measured eWPS from the average in rowing crew (294 crews, 1444 samples)

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The method verification in rowing: Force curve, real (thin line) and "model" (thick line) dependencies of V and SD on SR , effective work per stroke during step test in three rowing crews

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The Kleshnev's method of $V/SR/SD$ analysis. Summary:

1. Acquire speed and stroke rate data in sections of the race or incremental test;
2. Calculate SD and average values;
3. Calculate "model" values of speed and SD using equations:

$$V_m = V_0 (R_1 / R_0)^{1/3} \quad D_m = D_0 (R_0 / R_1)^{2/3}$$
4. Calculate ratios of the measured values to the "model" values
5. Enjoy your analysis!

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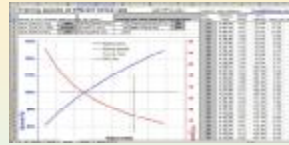
The presented method...

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

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Training times at different stroke rates based on constant eWPS



[www.http://biorow.com/Downloads.htm](http://www.biorow.com/Downloads.htm)
Speed(Rate)-eWPS 12.xls

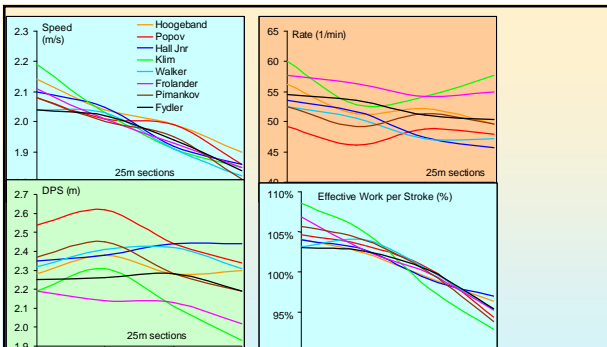


[www.http://biorow.com/RigChart.aspx](http://www.biorow.com/RigChart.aspx)

- ü Based on MS Excel spreadsheet;
- ü Inputs: Target race distance, time and stroke rate, training stroke rates;
- ü Additional inputs: "Extra eWPS" (for power strokes), wind speed & direction, water temperature, current speed.
- ü Outputs: Training times at various stroke rates, %% to the target speed, DPS (distance per stroke, N of strokes per training piece.
- ü Rigging chart produces similar results in interactive mode.

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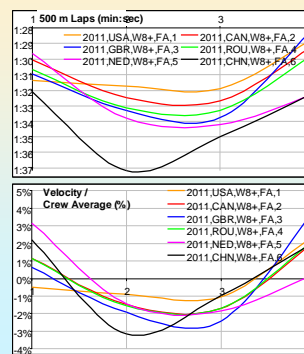


Analysis of Effective Work per Stroke in men's 100 free style final of Sydney-2000 Olympic Games



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Analysis of race strategy in W8+ final of 2011 Worlds in Bled



Country	Velocity / Average (%)				Variation (%)
	1	2	3	4	
USA	-0.5%	-0.9%	-1.1%	2.5%	1.67%
CAN	1.2%	-1.5%	-1.7%	2.2%	1.93%
GBR	0.6%	-1.9%	-2.4%	4.0%	2.93%
ROU	1.1%	-1.6%	-1.7%	2.2%	1.97%
NED	3.2%	-1.4%	-1.9%	0.3%	2.28%
CHN	2.2%	-3.2%	-1.0%	2.1%	2.59%

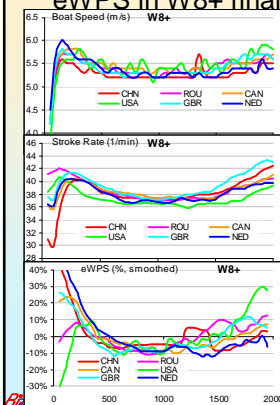
- ü The winner US W8+ has shown relatively the slowest start 500m and the lowest variation of the boat speed during the race.



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Analysis of the boat speed, stroke rate and eWPS in W8+ final of 2011 Worlds in Bled



Official GPS data was used from FISA site www.worldrowing.com

Country	CHN	ROU	CAN	USA	GBR	NED
Aver.SR	38.4	38.7	38.5	37.3	39.4	38.1

- ü The winner US W8+ has shown the lowest average stroke rate over 2000m race 37.3 str/min,
- ü The winner had the lowest rate over the 1st and last 500m;
- ü The winner had relatively the highest eWPS at the finish of the race.

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Thanks for your attention!

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