News

☺ Analysis of the stroke rates during the last World Championship in Seville was conducted recently. The measurements were done using broadcasted footage, therefore only some parts of the race were available (about 40% of the total number of strokes was measured). The data was captured in PC real time, filtered and compared with official splits and final times. These are some results of the analysis.

Facts. Did You Know That…

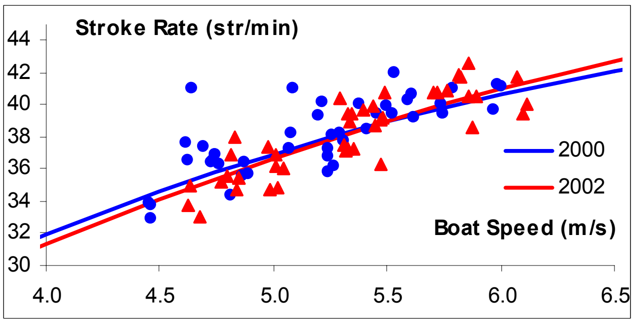
✓ …average stroke rate of the medal winners in 14 Olympic boat types over the last Worlds was 38.19 str/min. The same parameter over the Sydney Olympics in 2000 was 38.07 str/min (1). So, we can see 0.12 str/min increase during the last two years;

✓ …stroke rates in the majority of the boat types hadn't changed much. The largest increases of the stroke rate were in W4x (very low in 2000) and M4- (now the highest value of all boat types). Significantly decreased of the stroke rates occurred in W2- (very high in 2000) and LW2x.

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

Boat	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
Diff.	0.5	0.5	-2.1	-0.2	-0.2	0.3	1.6
Boat	**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
Diff.	-1.1	-0.3	0.3	2.1	0.1	0.3	-0.3

✓ …regression lines of the Rate/Speed dependence were similar in 2000 and 2002. This means that a higher boat speed in larger boats corresponds to a higher stroke rate:



Also, individual values are closer to the regression line in 2002 (r = 0.85), than in 2000 (r = 0.75). This means that now there are fewer crews with very high or very low stroke rates. The majority of the crews choose a common trend line.

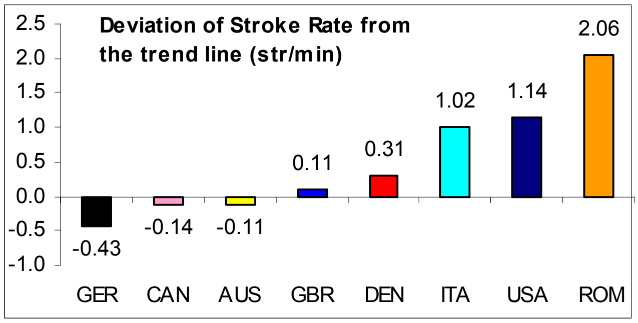
✓ …having equated Rate/Speed dependence and trends of boat speed over the years (RBN 9/2), we can produce "**prognostic**" **times and stroke rates** over 2000m in different boat types **for 2003**:

Boat	W1x	M1x	W2-	M2-	W2x	M2x	M4-
Time	7:10.2	6:36.6	6:55.6	6:14.2	6:37.7	6:07.7	5:42.3
Rate	34.9	36.9	35.7	38.2	36.8	38.7	40.3
Boat	**LW2x**	**LM2x**	**LM4-**	**W4x**	**M4x**	**W8+**	**M8+**
Time	6:54.4	6:12.6	5:48.5	6:14.0	5:41.0	6:04.0	5:27.1
Rate	35.8	38.3	39.9	38.3	40.4	38.9	41.4

"Prognostic" here means the most statistically likely time and stroke rate of the Worlds-2003 winners.

✓ …analysis of the stroke rate in different medal-winners didn't show statistically significant difference between them.

✓ …crews from the main rowing countries perform differently in terms of rate/distance-per-stroke (DPS) ratio. GER, CAN and AUS usually have a stroke rate below the trend line, with longer DPS. ITA, USA and ROM, especially, emphasized a higher stroke rate by means of a shorter DPS.



Outstandingly low stroke rate and long DPS among the winners were shown in M2x (HUN, -2.46) and W1x (BUL, -1.98). On the opposite corner were found W2- (ROM, +2.12) and W8+ (USA, +1.82). So, once again (1), scullers tend to row with a longer DPS and sweep rowers use higher rate.

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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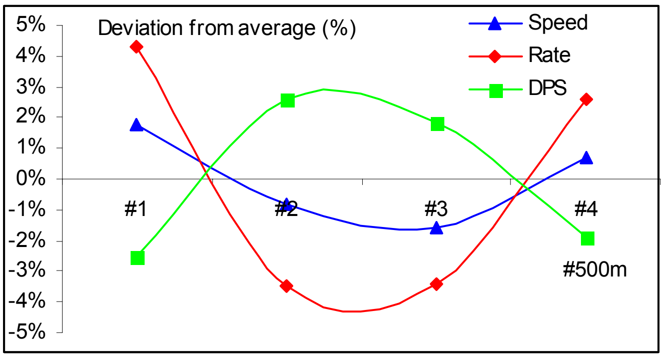
News

☺ We continue the analysis of the stroke rate during Worlds-2002 on the basis of measurements, which were done using video footage (RBN 1/2003).

Facts. Did You Know That…

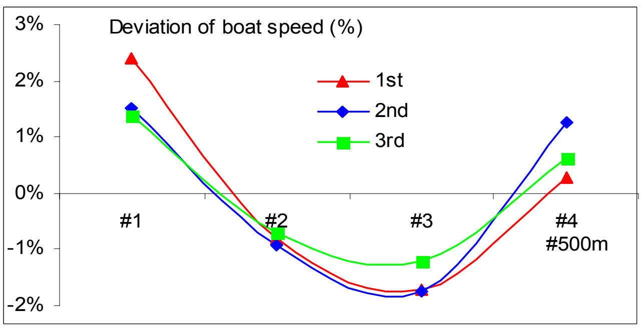
✓ …analysis of stroke rate distribution during each 500m section of the race shows that it's similar to distribution of the boat speed (RBN 10/2002). However, the magnitude of the stroke rate deviation was larger. Being 4.3% higher than average over the 1st 500m, -3.5% and -3.4% lower in the middle of the race and 2.6% higher at finish.

Average deviations of race parameters in medalists of 14 Olympic boats during Worlds 2002



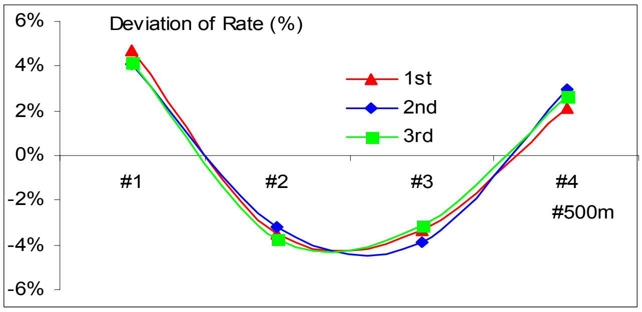
✓ …distance-per-stroke (DPS) had an opposite distribution over the race: A 2.5% shorter DPS was observed over the initial 500m, 2.6% and 1.8% longer during mid race, whilst 1.8% shorter at finish. This means that rowers sacrifice DPS in favor of stroke rate to achieve higher speeds at the start and finish sections of a race, but use longer DPS at cruising speed during the middle of a race;

✓ …there was no statistically significant difference found between the medalists in distribution of the stroke rate and DPS during the race. Though, the difference in boat speed distribution was quite significant (1, RBN 10/2002) as the comparison of the average graphs below indicates:



a

Curves of the stroke rate and DPS distributions were much closer to each other. Due to their very high variation between medalists (Appendix 1) we couldn't statistically verify the average difference. We can only state that, on average, winners had a tendency to have a slightly higher stroke rate and DPS at the start, which gives them a significant difference in speed. Looking at the graphs you can speculate yourself about other sections of the race



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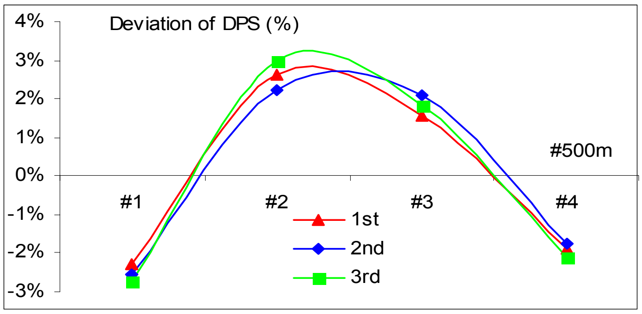
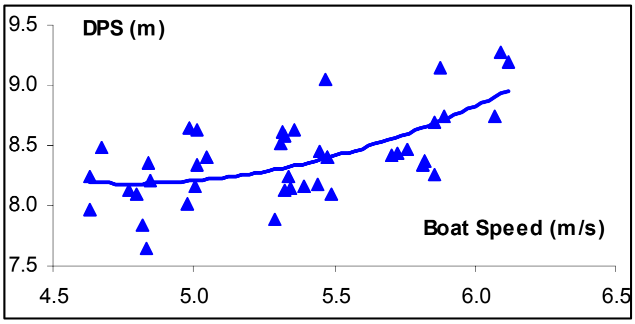


c

✓ …faster boats usually have longer DPS, but correlation (r=0.60) was lower than between stroke rate and speed (r=0.85):



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

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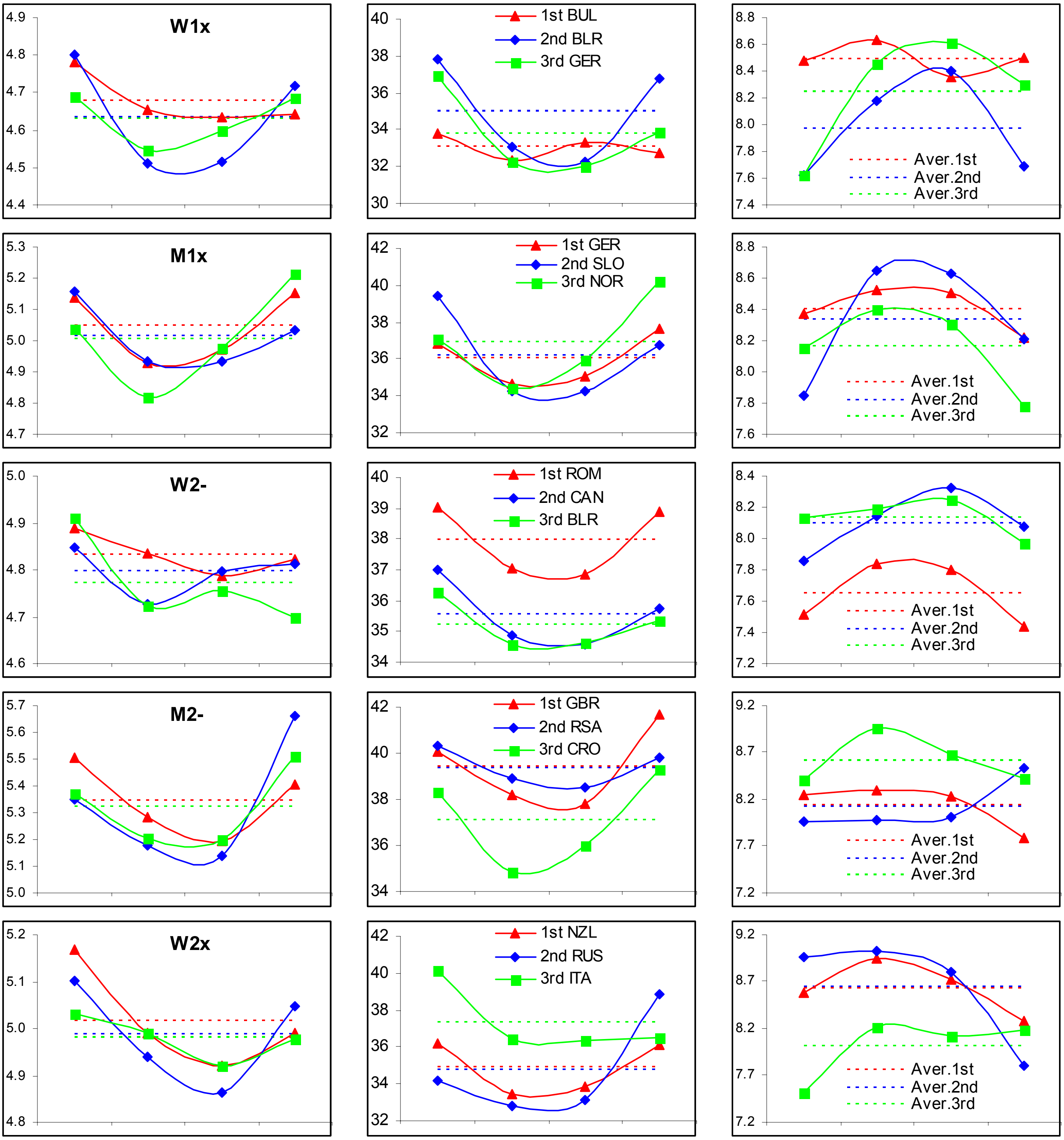
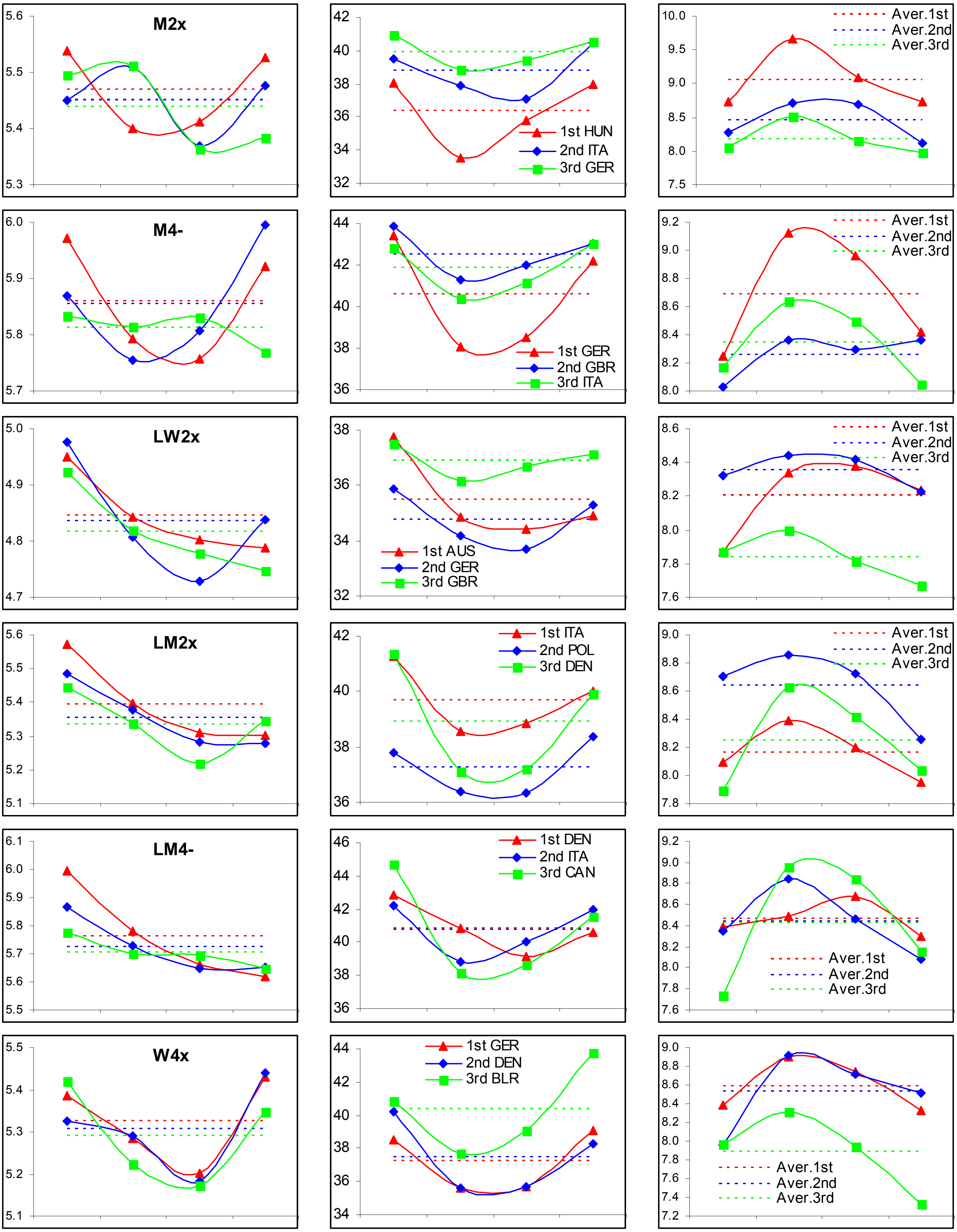
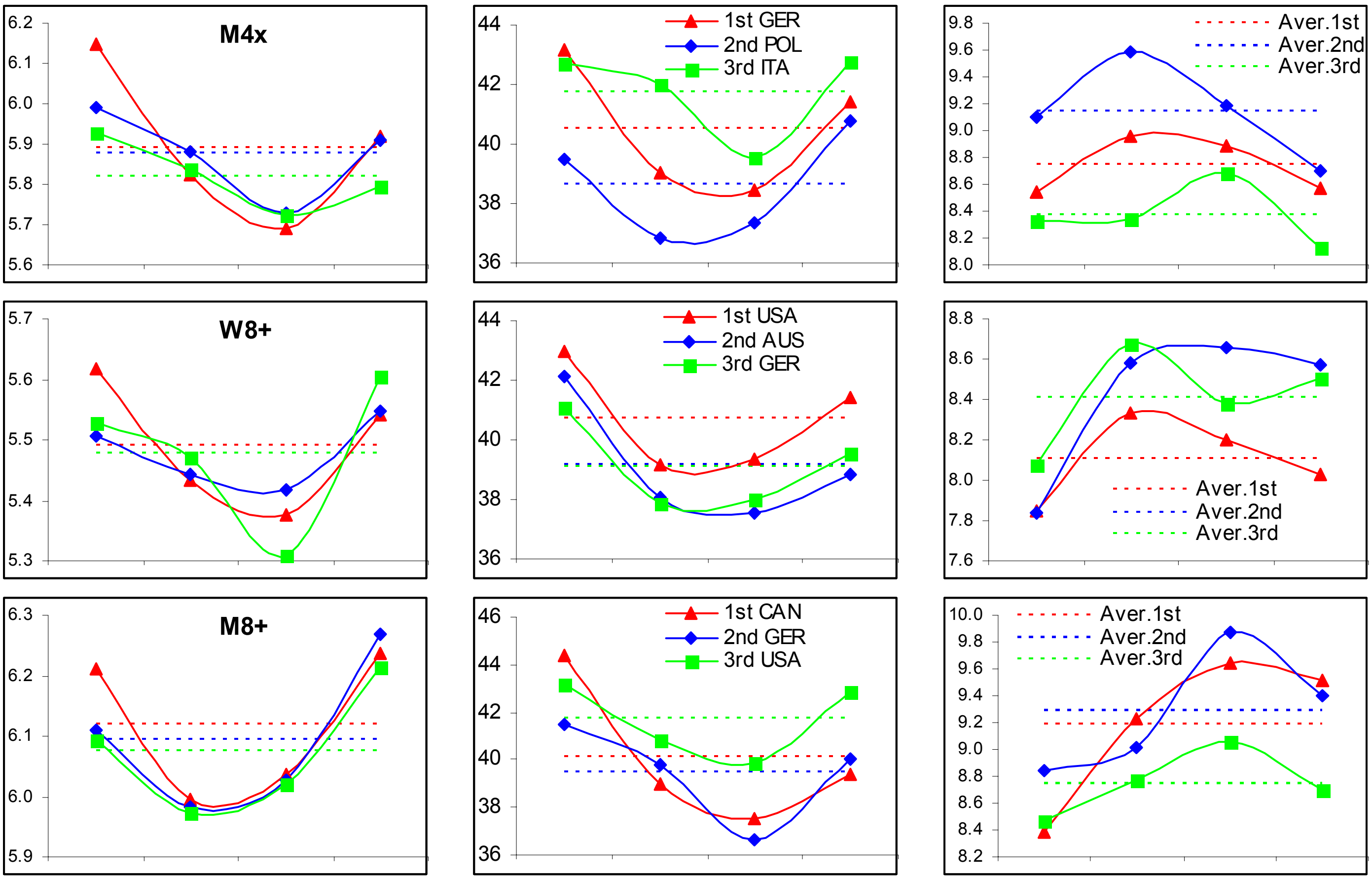
Appendix 1 to the Rowing Biomechanics Newsletter 2(3), February 2002.

Distribution of the boat speed, stroke rate and distance-per-stroke over 500m sections in the medalists of the World Championship 2002 in Seville.

Boat Speed (m/s) | **Stroke Rate (str/min)** | **DPS (m)**




M2x
1st HUN
2nd ITA
3rd GER
Aver.1st
Aver.2nd
Aver.3rd
M4-
1st GER
2nd GBR
3rd ITA
Aver.1st
Aver.2nd
Aver.3rd
LW2x
1st AUS
2nd GER
3rd GBR
Aver.1st
Aver.2nd
Aver.3rd
LM2x
1st ITA
2nd POL
3rd DEN
Aver.1st
Aver.2nd
Aver.3rd
LM4-
1st DEN
2nd ITA
3rd CAN
Aver.1st
Aver.2nd
Aver.3rd
W4x
1st GER
2nd DEN
3rd BLR
Aver.1st
Aver.2nd
Aver.3rd



M4x
1st GER
2nd POL
3rd ITA
Aver.1st
Aver.2nd
Aver.3rd
W8+
1st USA
2nd AUS
3rd GER
Aver.1st
Aver.2nd
Aver.3rd
M8+
1st CAN
2nd GER
3rd USA
Aver.1st
Aver.2nd
Aver.3rd

No.3 Volume 3 Rowing Biomechanics Newsletter March 2003

News

☺ Biomechanical testing was conducted on Kenyan single-sculler Ibrahim Githaiga, who came to AIS as a part of Olympic Solidarity program supported by ASC, AIS, FISA and the AOC.

Kenyan coach Gitau Kariega and AIS rowing head coach Reinhold Batschi, who supervise the rower, were pleased to find some good aspects about Ibrahim's technique and also areas, where it can be improved.

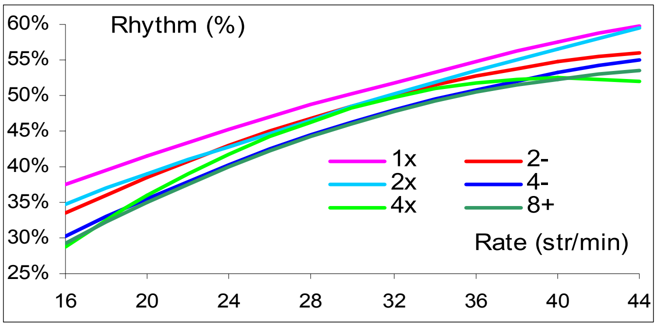
☺ In this Newsletter we begin a new section Q&A (questions and answers). Thanks to feedback from coaches we received some interesting questions. All questions and comments are published here with consent of the author.

Q&A.

Ian Taylor from Melbourne asked a series of good questions. This is one of them:

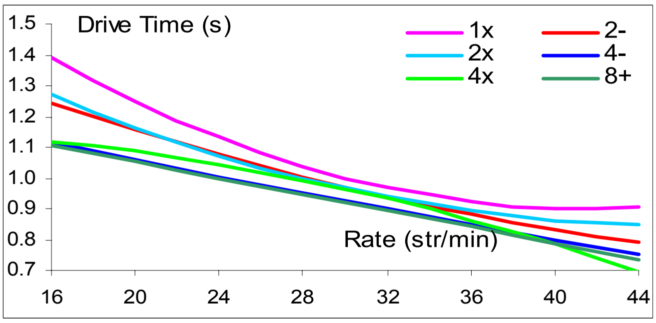
○ Q: What sorts of ratios of blade water time to recovery time are achieved at higher rates? 2:1 (0.5s to 1s).

✓ A: The standard measure of the rhythm in all sports is the ratio of the drive time to the total cycle time. Below is a graph of the rhythm in different boat types at different stroke rates:



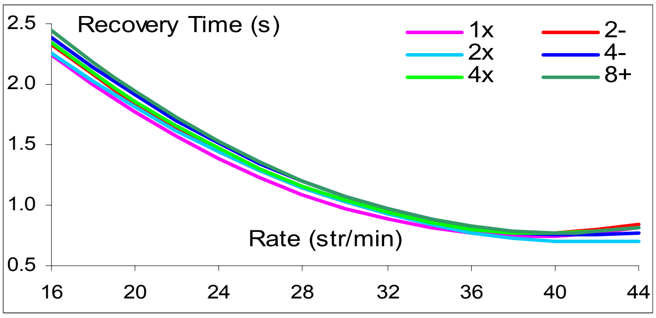
In rowing the rhythm varies from 30-40% at low rate up to 50-60% at the race rate. (from 0.5:1 to 1.4:1 in terms of drive-to-recovery ratio). Correlations between the rhythm and the stroke rate are high (between r = 0.91 in singles and r = 0.96 in eight).

✓ Considering drive time (**DT**) at different stroke rates, significant differences between boat types can be observed:



DT varies from 1.4s at low rates down to 0.9s at high rates in singles and from 1.1s down to 0.75s in big boats. This can be explained by significant differences in boat speed that makes it easier to pull faster at higher boat speed. Correlation between **DT** and the stroke rate is negative and also quite significant (from r =-0.89 in 4- to r = -0.95 in 8+). Please, remember that we define **DT** as an interval between moments of changing direction of the oar movements at the catch and release. Actual time of the blade in the water is about 10-15% shorter and depends on how we define it (blade touching water, or center of the blade is below the water level or blade is fully covered).

✓ On-contrary, the curves of the recovery time (**RT**) predictions are quite close in different boats:



The curves show that rowers increase the stroke rate mainly by means of shortening **RT** (r = -97), but they limited to do it until stroke rate around 40, when **RT** became as short as 0.70-0.75s. If they want to increase the rate higher than they have to shorten **DT**.

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News

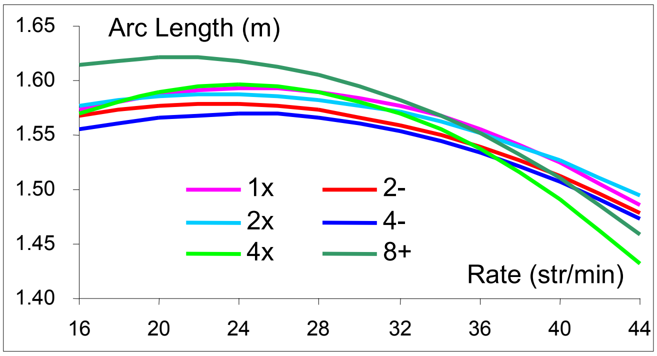
☺ RBN is now turning two years old now. Upon request you can obtain the collection of previous 24 Newsletters by e-mail (2mb).

Q&A.

These are answers to another two good questions asked by Ian Taylor of Melbourne:

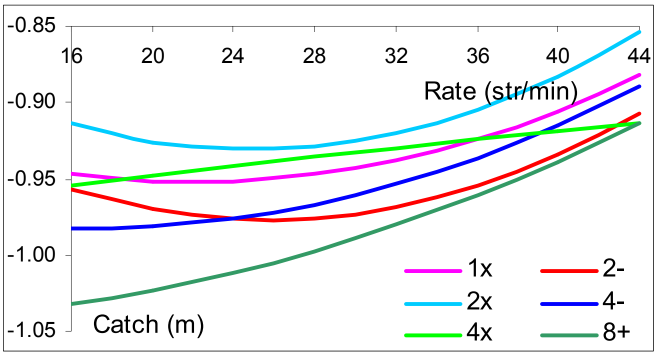
○ **Q**: How much stroke length reduction occurs at higher rates?

✓ **A**: To be able to compare sweep and sculling boats, we took length of the arc, which draw the middle of the handle. Then we built prognostic lines of dependence of the arch length on the stroke rate. Here they are for each boat type:

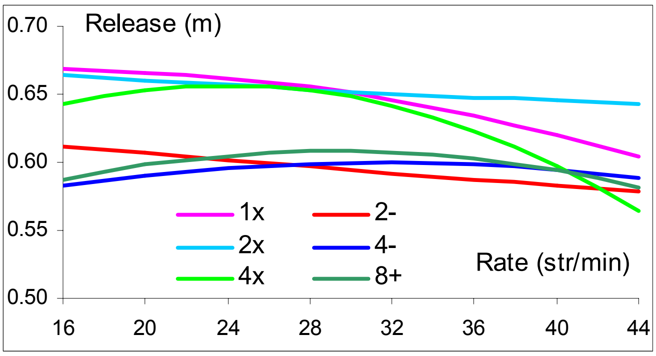


You can see that in all boats the maximal stroke length occurred around 24 str/min. The length is 2-3cm shorter at low rates and much shorter at high rates. It is interesting that **reduction of the stroke length is more significant in bigger boats**. In 4x and 8+ it was 10-11cm shorter at the stroke rate 40 relative to 24 str/min, but in other boats it was only 6-7cm shorter at the same rate.

✓ It could be interesting to find out where shortening of the stroke length happens: at catch or at finish? Below are similar prognostic lines for both:

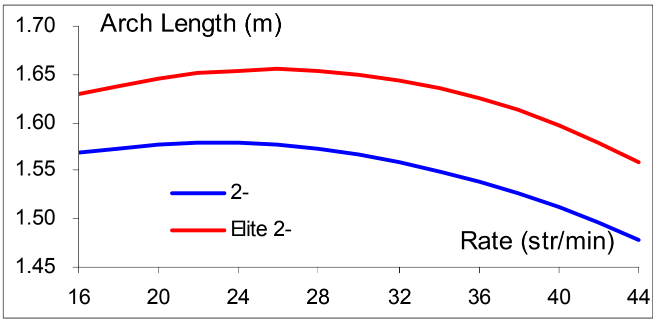


You can see that shortening at catch was a bit more significant in sweep boats (6-10 cm between 24 and 40), than in sculling (4-6 cm).



The opposite trends were found in release length. The shortening was noticeable in sculling (4-6cm) and was nearly zero in sweep boats. **Decreasing of the stroke length at higher ratings occurs mainly at catch in sweep boats and at both ends in sculling.**

✓ Another interesting point, is guessing if better rowers have less shortening of the stroke length at higher rates. When average data of two elite 2- was compared with the rest of the pair's sample, no difference was found in the shape of prognostic lines. However, the only difference was that elite rowers had 10-12 cm longer length at any rate.



Analysis of catch and release angles also didn't show any significant difference between elite and average rowers.

○ **Q**: What is the best way to record a rower's stroke length? (note – no access to mechanical devices that you guys have).

✓ **A**: In RBN 11/2001 an easy method was given to check the stroke length. Use that wire markers in conjunction with video from the bridge to produce more accurate measurements. Also, John Driessen of Tasmania produces a good and simple mechanical protractor, which can mark an angle with a pencil.

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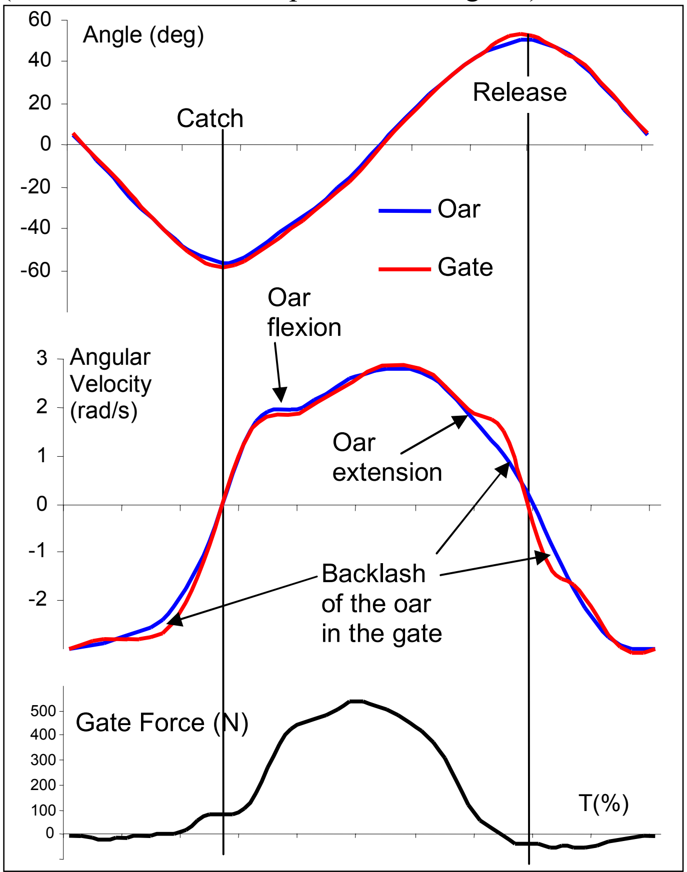
Facts. Did you know that...

✓ …oar and gate angles can be quite different? A brief simultaneous measurement of these two angles was conducted last year. Here are the results (M1x, rate 33.5, Concept-II oars and gates):



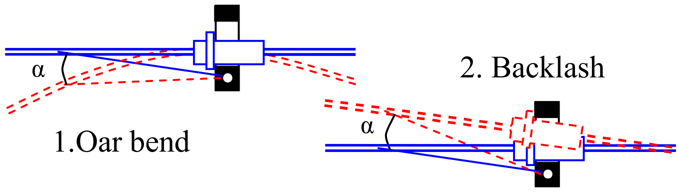
	Gate Angles (deg)			Oar Angles (deg)		
	Catch	Release	Total	Catch	Release	Total
Right	-57.5	53.9	111.4	-56.3	50.3	106.6
Left	-59.9	54.9	114.8	-59.0	52.1	111.1

The total angle measured at the gate was 4-5^o longer than the total oar angle. This occurred mainly by means of release angles, which were 3-4^o longer at the gate. At lower ratings the gap was less (2-3^o).

Calibration errors are unlikely to be the cause as both angles were calibrated twice with the same method. Both left and right sides showed similar results.

Two reasons of this phenomenon can be speculated:

1. A bend of the oar shaft. When force increases at the first half of the drive, angular velocity of the oar is slightly higher. At the second half of the drive the oar extends, its rotation appears to be slower than the gate rotation. Oar bend probably is the reason of small difference in catch angle and has no affect on finish angle, because the force at this point is minor.
2. Backlash of the oar sleeve in the gate is probably the main contributor to the difference in angle readings. It depends on geometry of the gate, sleeve and button, plus coordination of feathering along with horizontal and vertical movements of the oar. It is difficult to predict the amount of backlash that varies with different rowers.



Ideas. What if…

○ Which angle should be measured in rowing biomechanics? This question corresponds closely to another one: should force be measured at the gate or at the oar? There is no simple answer to these questions and it depends on what, actually, needs to be measured.

✓ If the target is geometry and kinetics of rower's movement, then oar angle and force are the best choice. The main advantage of this method is accurate determination of the handle position and power produced by rower. However, the force applied to the pin can not be derived precisely, by not knowing exact points of the forces application at the blade and handle, therefore, actual leverage of the oar is unknown.

✓ If boat kinetics and propulsive forces need to be measured, then gate angle and force are more useful for defining force components at the pin. However, the rower's power can be estimated quite roughly from the reason mentioned above: unknown actual leverage of the oar.

○ Is backlash of the oar in the gate a real problem for rowers? Does it decrease the length of the drive and efficiency? We would answer to these questions negatively, providing the backlash is reasonable. There is, practically, no backlash at catch and during the drive, because applied forces firm press the sleeve to the gate. The backslash at release occurs, when blade is already out of water and there is minimal force applied to it.

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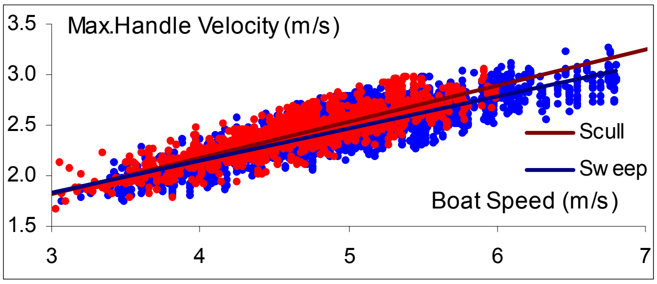
Facts. Did you know that...

✓ …handle velocity has a strong positive correlation (r=0.88) with boat speed? Below are scatter graph and regression lines of maximal handle velocity ***Vh.max*** relative to average boat speed ***Vb.aver*** in sweep and sculling boats:



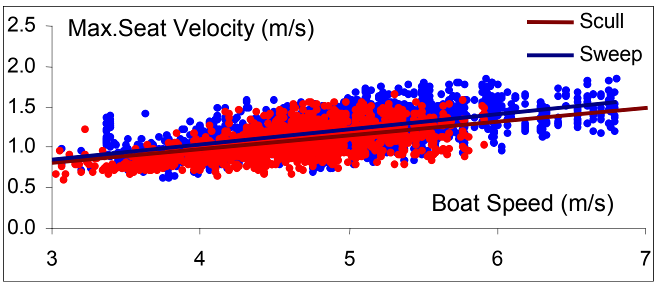
Equations of the regressions are:

Vh.max = *0.32* ***Vb.aver*** + *0.87* for sweep rowing,

Vh.max = *0.36* ***Vb.aver*** + *0.75* for sculling.

It is interesting that the gain *0.32-0.36* in these equations should be equal to the gearing ratio (inboard to outboard ratio) and an offset *0.87-0.75* should be equal to velocity of the blade slippage relative to the water. However, they differ because of the following factors: boat velocity at the time of ***Vh.max*** is lower than average; centers of force at the blade and/or handle differ from the middle points; blade slippage is different at different boat speeds (and force at the blade).

✓ …maximal seat velocity has moderate correlation (r=0.61) with ***Vb.aver***? Therefore, it correlates also with ***Vh.max*** (r=0.65). **On average, max. seat velocity equals half of max. handle velocity and a quarter of average boat speed.** Below are regression and normative data for max. seat velocity.

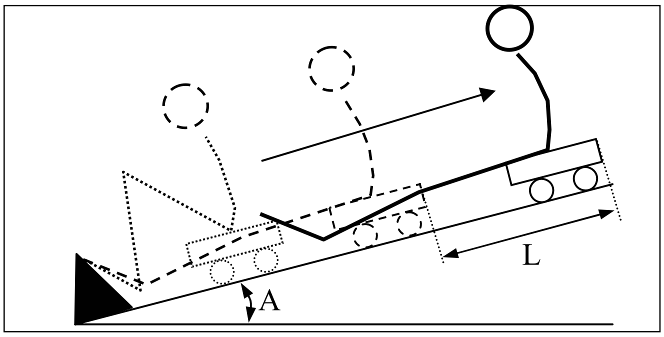


Max. Seat Velocity (m/s) at different average boat speed:

Boat Speed (m/s)	3.0	3.5	4.0	4.5	5.0	5.5	6.0
Very Low	0.51	0.57	0.64	0.73	0.83	0.94	1.06
Low	0.67	0.73	0.81	0.89	0.99	1.10	1.22
Average	0.88	0.96	1.04	1.13	1.23	1.33	1.43
High	0.99	1.06	1.13	1.22	1.31	1.42	1.54
Very High	1.16	1.22	1.29	1.38	1.48	1.58	1.70

Ideas. What if…

○ …you use quite a simple device for testing and training maximal legs speed? The device consists of a seat and slides mounted on a slope of a variable angle. The slope has a foot-stretcher. It is also possible to put another foot-stretcher shaped carriage on the slides to support the rower's heels.



The distance of free travel L (m) is proportional to the slope angle ***A*** and the seat speed (in fact, a speed of rower's center of mass) at the take off (assuming zero friction in the seat):

Slope Angle	Seat Speed at take off (m/s)						
	0.6	0.8	1.0	1.2	1.4	1.6	1.8
5°	***0.35***	***0.47***	***0.58***	***0.70***	***0.82***	***0.94***	***1.05***
10°	***0.18***	***0.23***	***0.29***	***0.35***	***0.41***	***0.47***	***0.53***
20°	***0.09***	***0.12***	***0.15***	***0.18***	***0.21***	***0.24***	***0.27***
30°	***0.06***	***0.08***	***0.10***	***0.12***	***0.14***	***0.16***	***0.18***

You can mount a straw or a door-bell button on the slope to check the desired distance. Angle ***A*** and the seat speed also affect the ***stroke rate (str/min)*** (assuming 0.5m legs drive):

Slope Angle	Seat Speed at take off (m/s)						
	0.6	0.8	1.0	1.2	1.4	1.6	1.8
5°	***29***	***19***	***14***	***10***	***8***	***7***	***5***
10°	***37***	***26***	***19***	***15***	***12***	***10***	***8***
20°	***42***	***30***	***23***	***18***	***15***	***13***	***11***
30°	***45***	***32***	***25***	***20***	***17***	***14***	***12***

You can emphasize legs power production by adding extra weights on the slide, which needs a back support in this case. It is important to accelerate legs quickly after the catch and achieve the maximal speed at 15-25cm of the drive. Therefore, it makes sense to limit legs drive to a half by, say, putting a spring link between the seat and heels (or an extra supporting carriage).

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Back to basics

📖 The **RACE STRATEGY** is defined as the total distribution of crew effort during a race. It can be expressed as a sequence of four numbers representing the ratio (%) of boat speed during each 500m section to the average boat speed over 2000m for the crew. See RBN 10/2001, 10/2002 and (1) for more details on the race strategy.

📖 **RACE TACTICS** are defined as a distribution of crew efforts relative to other competitors in the race, and can be determined using two methods:

- Relative to the average speed of all competitors in the race, where ratios of individual boat speed to the average of the race are produced for each section;
- Relative to the closest competitor. Five pairs of place-takers were defined (1^{st}-2^{nd}, 2^{nd}-3^{rd}, …5^{th}-6^{th}) and ratios of their boat speed were produced for each section of the race.

In both methods, sequential numbers of the fastest and slowest section relative to other competitors were defined. Twelve possible combinations were composed, called "matrix of race tactics" (1). For example, tactic "1-4" means the first 500m section of the race was the most successful and the last section was the slowest relative to other competitors.

We analyzed race tactics of 14 Olympic boat types during the last 10 years. Some results are below.

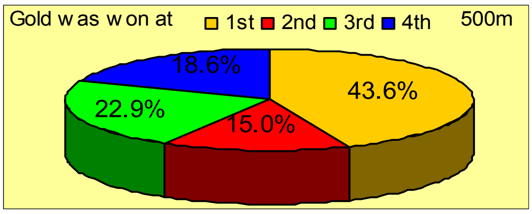
Facts. Did you know that...

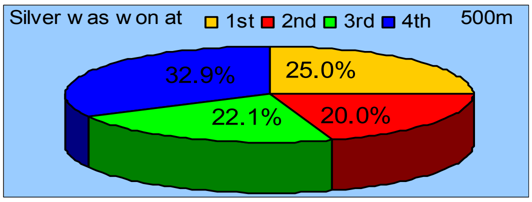
✓ …the most popular race tactics found were 4-1 (135 of 837 cases, 16.1%) and 1-4 (14.6%).

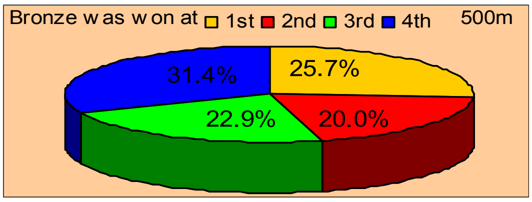
Tactics	Place						Total
	1^{st}	2^{nd}	3^{rd}	4^{th}	5^{th}	6^{th}	
1-2	4	6	10	17	8	4	49
1-3	8	9	12	12	14	7	62
1-4	24	8	7	9	27	47	122
2-1	4	9	14	5	11	9	52
2-3	4	6	4	4	3	9	30
2-4	14	8	6	10	20	28	86
3-1	11	16	10	13	12	7	69
3-2	11	3	5	4	8	2	33
3-4	19	9	6	7	9	3	53
4-1	20	38	33	26	13	5	135
4-2	15	21	17	20	8	10	91
4-3	6	7	16	13	7	6	55

It is interesting that the tactic 1-4 was the most popular in 1st (24 of 140 cases, 17.1%), 5^{th} (19.3%) and 6^{th} (34.3%) place. In contrast, the 4-1 tactic was the most popular in silver (27.1%) and bronze (23.6%) medalists. In other words, **if a crew put all efforts in the first 500m of the race, then the tactic would be "win or die". If a crew saves energy for the last 500m, then they have more chances to win a medal, but fewer chances to win a gold medal**.

✓ …this finding was confirmed by the analysis in the pairs of competitors. In 61 cases (43.6%) the winners took the maximal advantage over the silver medalists during the first 500m section of the race:







In contrast, nearly one third of silver and bronze medalists had beaten their competitors at the final 500m section of the race.

✓ …the majority of German (33.6%), British (30.2%) and Romanian (31.7%) crews emphasized the first section of the race. 38.6% of Australians, 38.7% of Americans and 59.2% of French crews put all efforts into the final section. Italians (32.2%) and Canadians (30.4%) emphasized the second section. This correlates with the percentage of gold medals won by these countries (RBN 8/2001).

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📖 1. Kleshnev V. 2001. Racing strategy in Rowing during Sydney Olympics. Australian Rowing. 24(1), 20-23.

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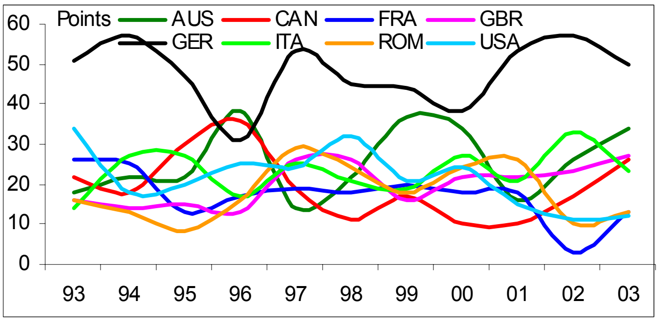
News

☺ Australian crews won two gold, three silver and one bronze medal at the 2003 World Rowing Championships. Well done! Congratulations to the athletes and coaches!

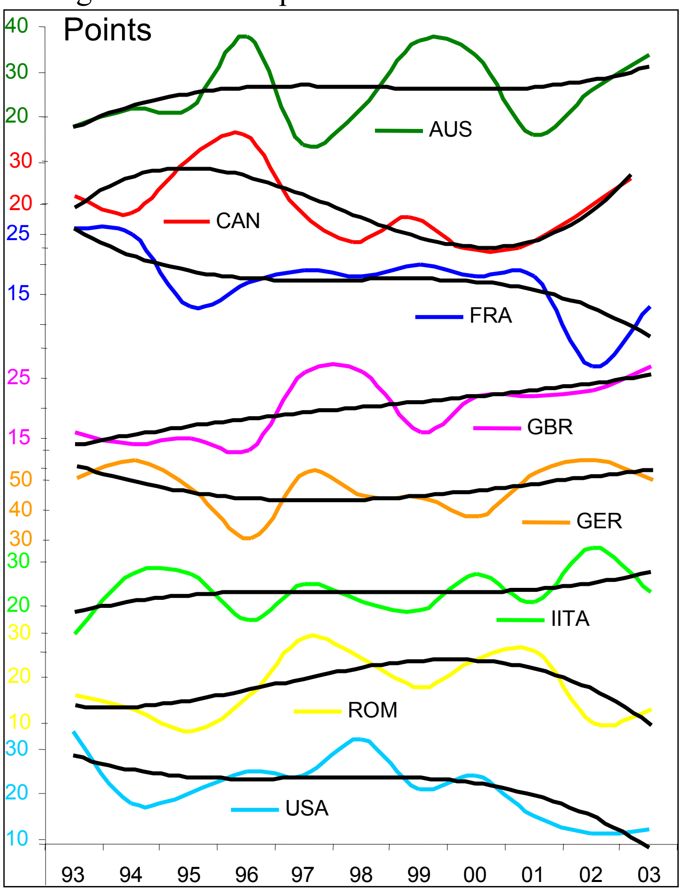
Facts. Did you know that...

✓ ...Australia was second after Germany in Olympic boat events in 2003. We compared performance of the best eight rowing nations in A finals since 1993:



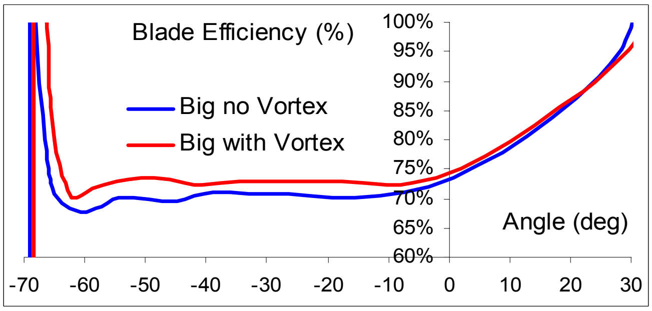
Four-year cycles can be clearly seen in the performances of AUS and GER. The best AUS performances occurred in Olympic years, whilst GER performed better between Olympics.

✓ ...performance trends for the best eight rowing nations were quite different:



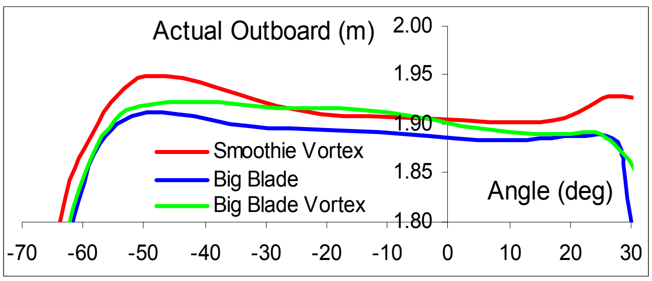
The AUS trend has a positive overall nature, with GBR and ITA. FRA and USA have overall negative trends. CAN had a trough from 1997-2000 and steadily improved performance more recently. In contrast, for the same period ROM had a peak, but decreased performance more recently. GER had the most stable performance during this period.

✓ ...research of blade efficiency was conducted recently. Thanks to Stuart Wilson of Sykes Racing Boats for their kind assistance. We made sculling oar shafts with removable spoons and compared smoothie-vortex against big-no-vortex and big-vortex blades. As was expected, application of the Vortex strips improved blade efficiency of the big blade in the first half of the drive:



In the second half of the drive efficiencies were very close and no-vortex blade was even better at the very end of the drive. Overall improvement of the blade efficiency with Vortex was 1.9%. We did not find significant difference in efficiency between the smoothie and the big blade.

Application of the Vortex shifts the centre of pressure towards the outer edge of the blade, equivalent to increasing the outboard lever of the oar:



Longer outboard equates to lower blade force at the same handle force. This decreases water pressure and reduces slippage of the blade causing increased propulsive power and blade efficiency.

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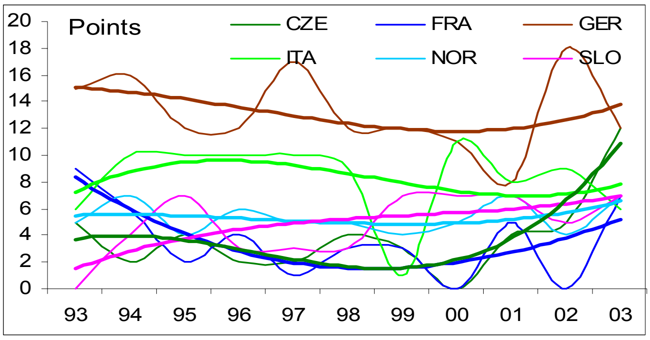
Facts. Did you know that...

✓ …We received positive feedback on the last Newsletter with the trends of performance over the last 11 years. There are some more points and trends in five rowers' categories:

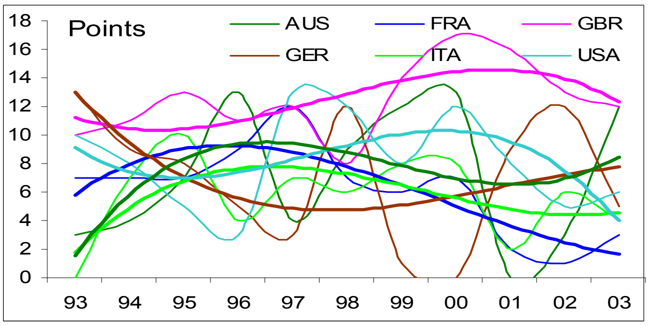
Men's Sculling (M1x, M2x and M4x)

#	Country	Number of places during 93-03						Points
		1st	2nd	3rd	4th	5th	6th	
1	GER	10	8	7	1	1	2	145
2	ITA	6	2	5	4	2	2	90
3	NOR	3	5	3	0	0	1	59
4	SLO	3	2	2	4	1	0	53
5	CZE	0	2	4	3	4	0	43
6	FRA	2	1	2	2	3	1	40
7	SUI	1	4	0	0	4	2	37
8	AUS	0	0	3	5	2	1	32



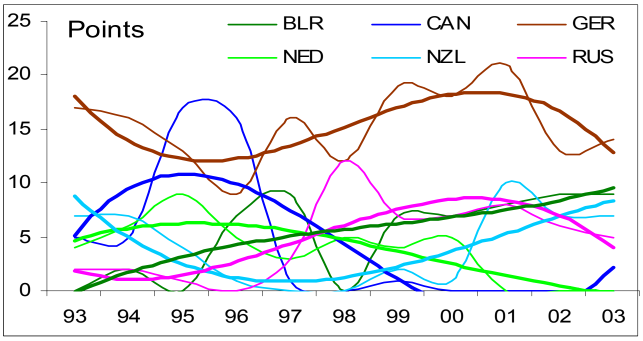
Men's Sweep (M2-, M4- and M8+)

#	Country	Number of places during 93-03						Points
		1st	2nd	3rd	4th	5th	6th	
1	GBR	12	4	3	3	4	4	137
2	AUS	3	5	4	4	2	2	80
3	GER	4	6	2	1	1	6	77
4	USA	4	2	5	3	3	0	73
5	FRA	3	5	2	2	3	2	68
6	ITA	2	2	3	4	5	4	62
7	ROM	1	2	3	2	3	1	42
8	CAN	3	0	0	4	0	2	35



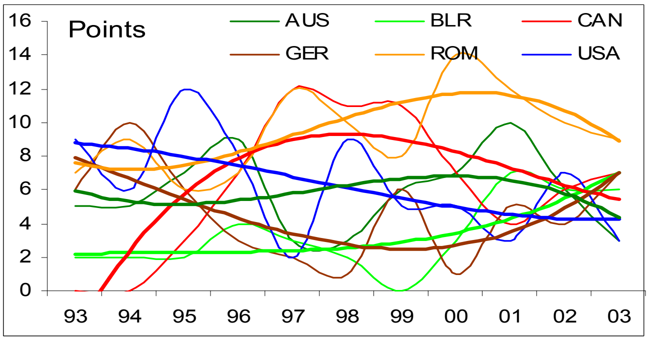
Women's Sculling (W1x, W2x and W4x)

#	Country	Number of places during 93-03						Points
		1st	2nd	3rd	4th	5th	6th	
1	GER	15	7	4	2	3	0	168
2	BLR	4	2	4	0	2	0	58
3	RUS	1	3	3	4	2	3	53
4	NED	1	3	3	4	0	2	48
5	NZL	4	2	1	0	1	2	46
6	CAN	2	5	1	0	0	2	45
7	DEN	1	3	2	2	2	3	43
8	CHN	1	3	0	2	5	2	40



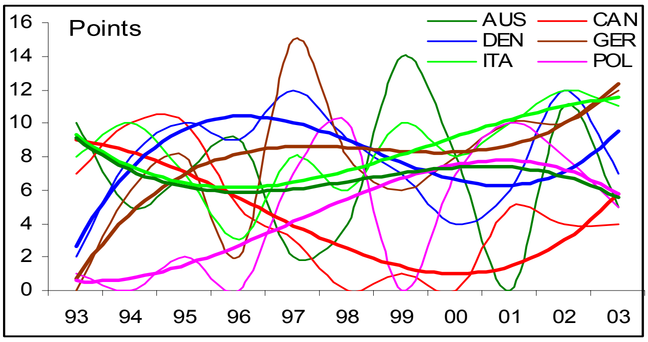
Women's Sweep (W2- and W8+)

#	Country	Number of places during 93-03						Points
		1st	2nd	3rd	4th	5th	6th	
1	ROM	9	5	2	2	0	2	104
2	USA	2	6	3	2	1	5	69
3	CAN	3	3	5	2	2	2	68
4	AUS	3	3	2	4	3	2	64
5	GER	2	1	3	4	2	4	51
6	BLR	0	2	2	2	6	1	37
7	GBR	1	1	1	1	3	1	26
8	NED	1	1	1	2	0	2	24



Lightweight (LW2x, LM2x and LM4-)

#	Country	Number of places during 93-03						Points
		1st	2nd	3rd	4th	5th	6th	
1	ITA	6	4	3	5	1	2	93
2	DEN	7	4	2	0	3	3	86
3	GER	3	3	6	5	5	0	85
4	AUS	2	5	5	4	1	2	75
5	POL	3	4	0	2	1	1	50
6	CAN	3	1	1	4	3	1	49
7	FRA	1	2	4	3	2	3	49
8	USA	2	2	3	2	2	2	48



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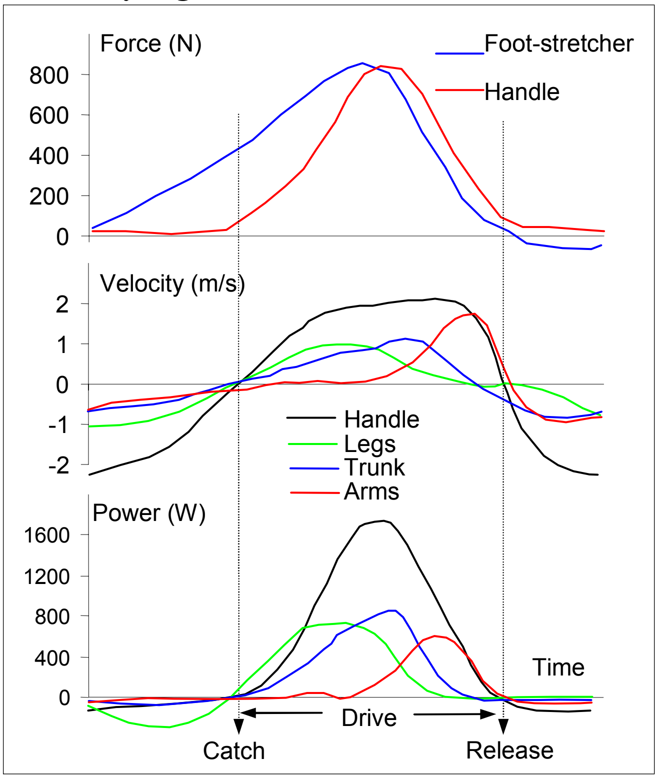
Facts. Did you know that...

✓ …when comparing stationary ergo rowing to on-water, the biomechanics of the action differ some what?

Force, velocity and power during rowing on stationary ergo.



As mentioned in RBN 4/2001, the on-water foot-stretcher's peak force is ~30% higher than that of handle force, whilst on ergo they are nearly equal. This is more info revealed. A rower performed a 6 min test on a Concept-II stationary ergo and in a single scull recorded the following differences:

✓ …foot-stretcher force develop much earlier on an ergo. The increase starts after the mid phase of recovery. This is a consequence of higher inertia forces, which the rower has to overcome to change direction of body mass movement. During on-water rowing these forces develop almost simultaneously;

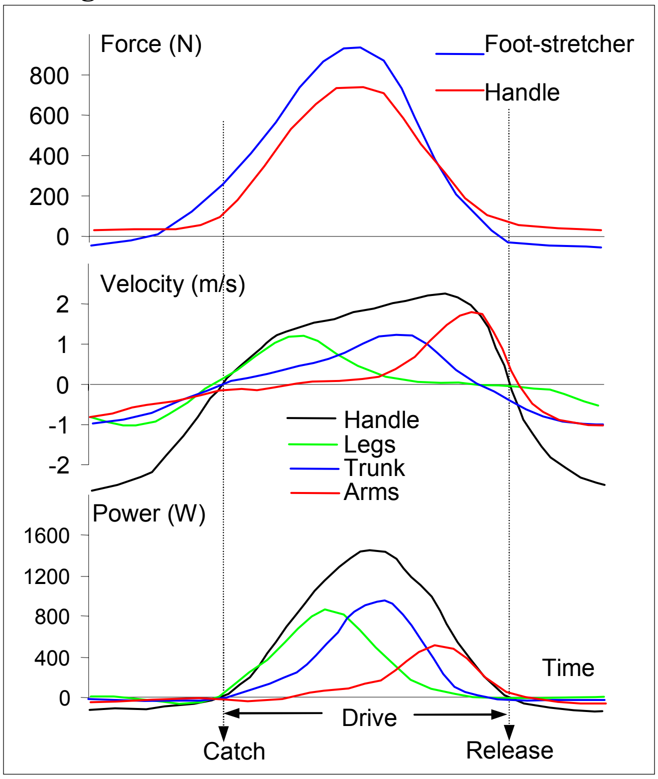
✓ …handle force on the ergo has a higher peak and develops later. On water, it's more a rectangular aspect and can be increased quicker;

✓ …ergo handle velocity longer increase after catch, but remains almost constant through the middle of the drive. On water, there is shorter increase at the catch and more acceleration during the drive;

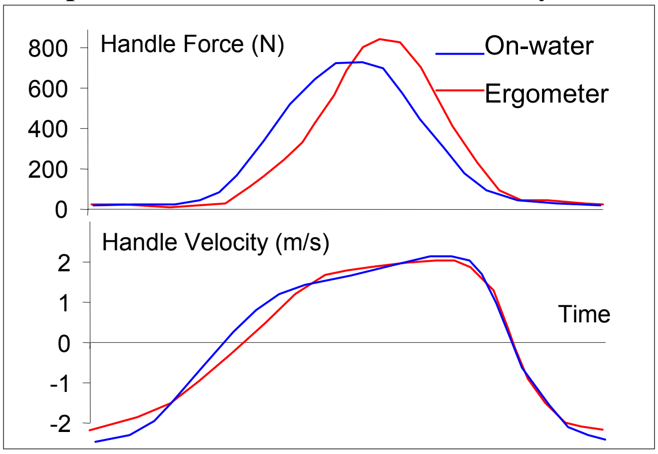
✓ maximal legs velocity is higher on-water. In conjunction with higher foot-stretcher force this leads to higher proportion of the legs power, which is 37%:41%:22% (legs:trunk:arms) on stationary ergo, and 45%:37%:18% during on-water rowing.

✓ …a good thing about the ergo is that they allow to achieve 3-5% longer stroke and better legs compression;

Force, velocity and power during on-water rowing.



Comparison of handle force and velocity curves



In concluding, a comparison of various rowers' profiles show that the power production differs between ergo and on-water. Rowers with fast legs produce more power on-water, while athletes with slower legs and stronger upper body have relatively higher ergo scores.

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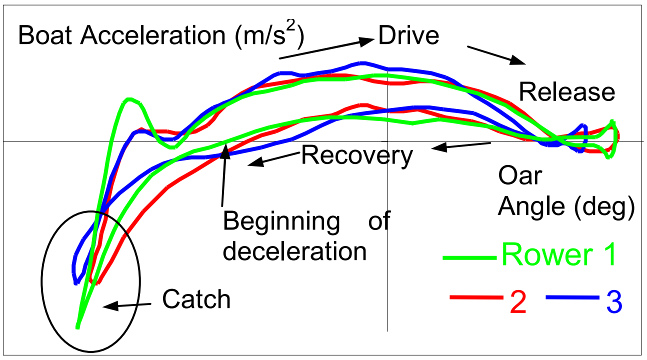
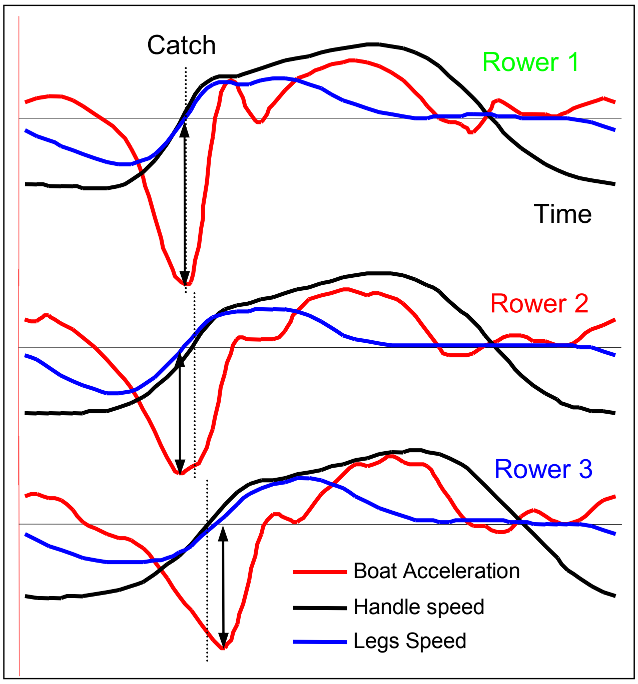
Facts. Did you know that...

✓ …boat acceleration can be used as useful diagnostic tool for defining various aspects of rowing technique? Discussed below are some of the features of the boat acceleration (**BA**) curve in conjunction with oar angle, force curve and segments work.

✓ … shape of the **BA** at catch is determined by coordination of the handle and legs movement? When plotted relative to horizontal oar angle, optimal shape of **BA** curve resembles a sharp wedge (Rower 1). If it is wide (Rower 2), minimal **BA** occurs before catch (change of the oar movement direction). This happens when legs start the drive earlier than the handle ("bum shooting").

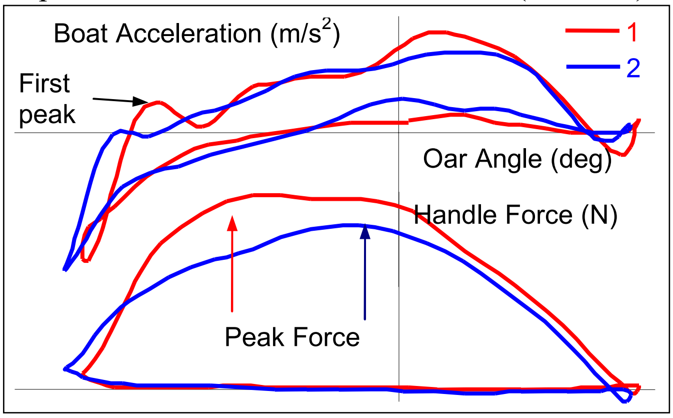




If **BA** curve makes a loop (3), then minimal **BA** is later then the catch. In this case, a rower starts the handle drive with the trunk rotation, while seat is still moving towards the stern.

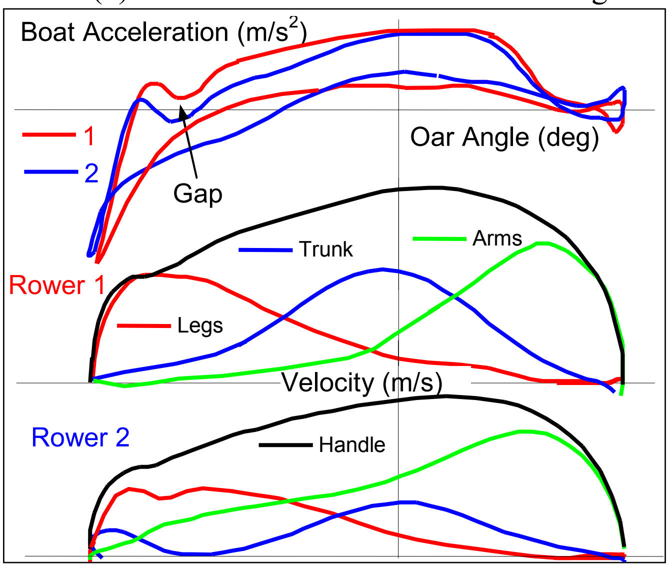
Point where **BA** crosses the X-axis during recovery defines the beginning of boat deceleration, i.e. pushing off foot-stretcher before catch. This happens later with good rowers (1) and then **BA** drops down quickly. Some rowers (3) try to pull foot-stretcher before catch that makes **BA** curve nearly horizontal.

✓ …so called "first peak" of **BA** during the drive is not as bad as some coaches think? It can be found in all crews with a fast increase of the force at catch (Rower 1). On contrary, the first peak was not found in crews with the force emphasis at the second half of the drive (Rower 2).



✓ …a gap after the first peak depends on coordination of legs and trunk, and on their movement patterns? The smaller gap and higher BA during the first half of the drive means that segments speed curves are smooth and the curves are well overlapped (Rower 1).

The **BA** gap can drop below zero (boat deceleration) if legs or trunk have double-peaked curves (2) or trunk "disconnected" from the legs.



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📖 1. Kleshnev V. 2002. Moving the rowers: biomechanical background. Australian-rowing. 25(1), 16-19

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☺ Dear rowing coaches, rowers and all rowing people! ☺ We wish you a Merry Christmas and Happy New 2004 Year!

Facts. Did you know that...

✓ …variation of the boat speed during the race affects performance in rowing? In the last Worlds the most even distribution of efforts was found in W8+AUS and GER (0.01 and 0.03s losses) and the highest variation of the boat speed was found in M4xGER and W2-USA (1.23 and 1.32s losses). The average losses were 0.52±0.38s. Let us explain how we obtained these values.

The data was taken from official 500m splits and 2000m time. Boat speeds V_1-V_4 were produced for each section and on average over the race V_{2000} (e.g. M1x final A):

#	Country	V_1	V_2	V_3	V_4	V_{2000}	Stdev (s)	Var (%)
1	NOR	5.07	4.77	4.92	4.95	4.92	0.12	2.49%
2	GER	5.16	4.77	4.85	4.86	4.91	0.17	3.50%
3	SLO	5.01	4.81	4.90	4.88	4.90	0.08	1.69%
4	CZE	4.98	4.73	4.81	4.77	4.82	0.11	2.32%
5	AUS	5.04	4.69	4.75	4.70	4.79	0.16	3.39%
6	AUT	4.95	4.61	4.61	4.66	4.70	0.16	3.50%

The last two columns in this table are the standard deviation ***Stdev*** of four boat speeds over each 500m and variation ***Var*** of the boat speed, which is ratio of ***Stdev*** to V_{2000}.

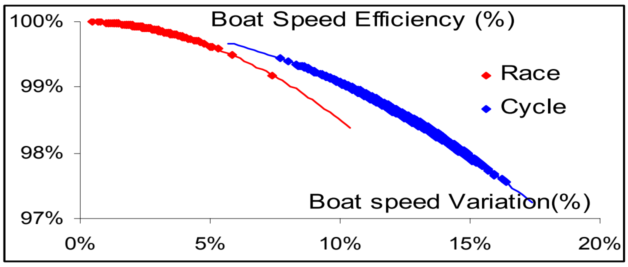
Having boat speed V, the propulsive power P over each 500m can be estimated using the formula $P = k\ V^3$, where k is a drag factor, which depends on boat type and weather (3.22 on average for 1x). The average of these four values is power production over 2000m:

Power (W)					V_{ideal} (m/s)	T_{ideal} (m:s.0)	Loss (s)	Speed Effic.
P_1	P_2	P_3	P_4	P_{2000}.				
419	349	383	391	386	4.93	6:45.77	0.38	99.91%
443	349	368	371	383	4.92	6:46.73	0.74	99.82%
404	358	379	374	379	4.90	6:48.14	0.17	99.96%
398	340	358	350	362	4.82	6:54.53	0.33	99.92%
411	333	345	335	356	4.80	6:56.69	0.71	99.83%
391	316	315	326	337	4.71	7:04.53	0.77	99.82%

Using reverse formula $V = \sqrt[3]{P\ /\ k}$, we can derive ideal boat speed V_{ideal} and time T_{ideal}, which can be achieved with absolute even distribution of given power over the race. The difference of this time and the official race time is the loss in seconds, and ratio of corresponding boat speeds is boat Speed Efficiency in %: $Ev = V_{2000} / V_{ideal}$.

The Speed Efficiency ***Ev*** can be derived from the standard mechanical efficiency ***Ep*** (which is the ratio of the real and ideal powers) using the formula $Ev = \sqrt[3]{Ep}$. Efficiency does not depend on drag factor and absolute boat speed, but losses do: the slower the speed the higher the losses. The loss L (s) can be derived from the boat speed V and its efficiency Ev: $L = 2000/V - 2000/(V/Ev)$.

✓ … losses caused by variation of the boat speed during the stroke cycle are more significant? They are in the range 3-13s and equal to 6.8±1.8s on average for both training and race speeds. Boat speed variation has moderate positive correlation with the stroke rate (r=0.34) and efficiency has negative correlation (r= -0.39), but the losses do not depend on the stroke rate. Speed efficiency and its variation are very well correlated: the higher the variation, the lower efficiency:



They can be easily converted into one another using the formulae $Ev = 1 - 1.5*Var^2$ for the race and $Ev = 1 - 0.9*Var^2$ in stroke cycle.

Ideas. What if...

? …we try to minimize losses caused by boat speed variation? Analysis of the winning race strategy (RBN 10/2002) has shown that most of the winners have to sacrifice even distribution of efforts in favor of faster boat speed over the first 500m. Example above shows us that the bronze medalist had 0.57s lower losses than silver one, but this was not enough to overtake him.

On the contrary, in-cycle speed efficiency varies quite significantly and depends on technique used by the crew. Three techniques were shown in the previous RBN 11/2003, the first example. The rower 1 with better technique had speed efficiency 98.09% and the rower 3 had only 97.78%, which is equal to 1.6s higher losses over 2000m.

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