Q&A

There were discussions on rowing forums about setting the drag factor (DF) on ergs and about differences and similarities of a new Concept2 Dynamic erg (DIR) with its static and on-slides analogies. To provide an objective analysis of mechanical conditions and the rower's feelings, we used a concept of "Handle Drag Factor" (***HDF***), which can be derived similarly to the boat drag factor:

$$HDF = P / V_{h.av}^3 = P / (L / T_d)^3 \qquad (1)$$

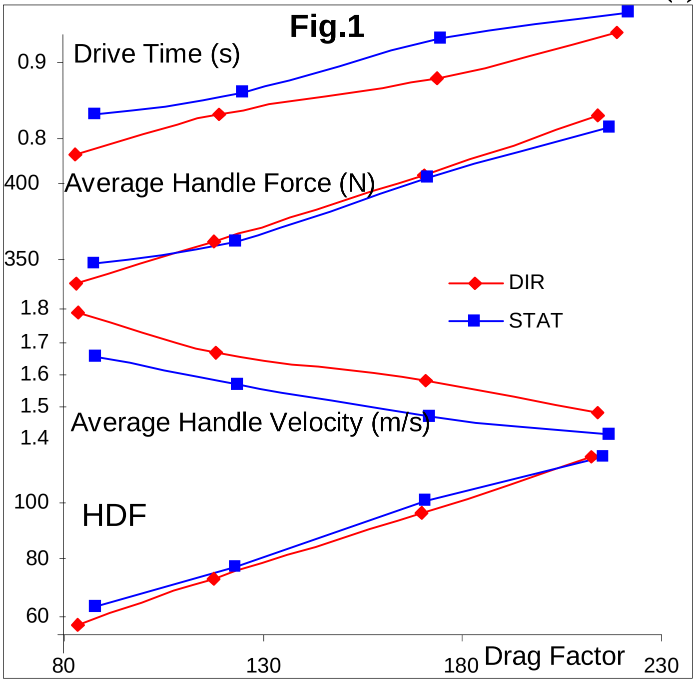
where P is rowing power, $V_{h.av}$ is average handle velocity during the drive, which equal to a ratio of the drive length L and time T_d.

For analysis we used the data of the previous measurements in a boat and on various types of ergs (RBN 2010/10). Also, additional measurements were conducted on DIR and on static erg model D with various Drag Factors (DF). Four 1 min samples were collected at shutter settings 1, 4, 7 and 10 and DF was recorded. The target was set to maintain an average racing intensity. The measured stroke length and average force application was very similar on both ergs.

When DF increases, the drive time also increases on both ergs, force application grows and average handle velocity slows (Fig.1, Appendix 1.). However, drive time was shorter and handle speed was higher on DIR than on the static erg at all DF settings. Very high correlation (r=0.998) was found between calculated ***HDF*** and ***DF*** recorded from the erg monitor, which confirms validity of the measurements and allows us to determine the equations:

$$DF = 2.34 * HDF - 51.0 \quad \text{for DIR} \qquad (2)$$

$$DF = 2.48 * HDF - 69.1 \quad \text{for Static} \qquad (3)$$



On average, ***HDF*** was 5% lower on DIR than on static erg at the same DF settings, which could be explained by lower inertia forces.

To compare mechanical conditions of rowing on both ergs with on-water rowing, we derived ***DF***s, which correspond to various boat types (Table 1) using the following method. Race times were taken and average boat speed was derived in the six men's events as an average of the winners' times of the Worlds and Olympics from 1993-2009. This corresponds to rowing in some average conditions, not in strong tail wind, which usually corresponds to the World Best times. Rigging dimensions were taken based on results of rigging surveys and gearing ratios **G** were calculated using actual inboard and outboard lengths (RBN 2006/11). The maximal blade ***Vb.max*** velocity relative to the boat was calculated as a sum of the boat velocity and blade slippage through the water at perpendicular oar position to the boat (RBN 2007/12). The values of the slippage velocity are higher in rowing than in sculling, which reflects bigger total blade area and higher blade efficiency in sculling (RBN 2010/08). The maximal handle velocity ***Vh.max*** was derived as:

$$Vh.max = Vb.max * G \qquad (4)$$

To produce an average handle velocity ***Vh.av*** during the drive we derived its ratio ***R*** to ***Vh.max*** using our database (n=5522) and found it has very low variation across boat types (***R*** = 0.667±0.03). So,

$$Vh.av = 0.667 * Vh.max \qquad (5)$$

The value of rowing power was taken as 550W as an average across all boat types, which corresponds to the model of the World record times (RBN 2007/08). ***HDF*** was derived using equation 1 and corresponding ***DF***s were derived for DIR and the static erg using equations 2 and 3. Finally, the damper settings ***S*** were derived using a common equation for both ergs:

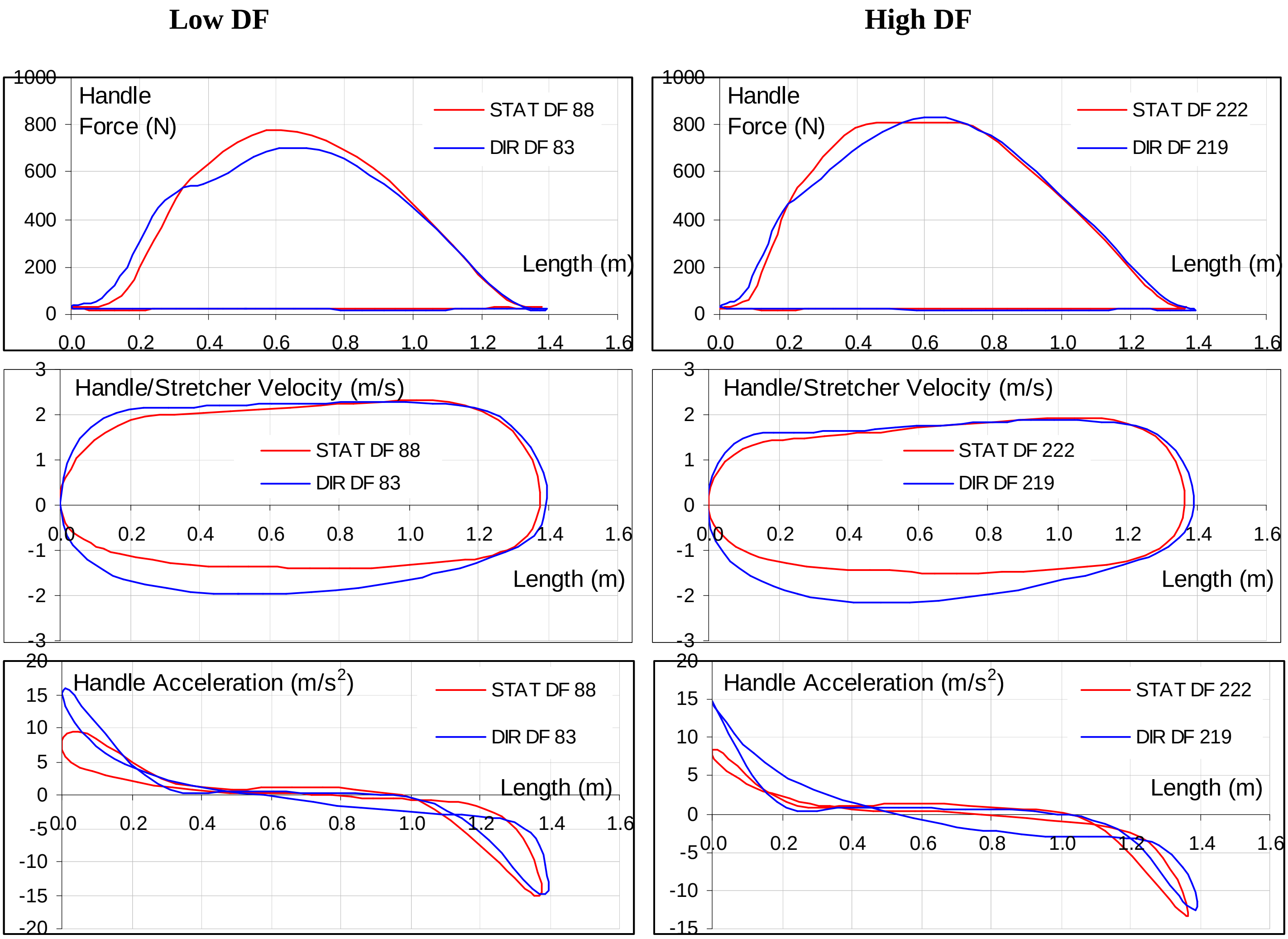
$$S = 0.065 * DF - 4.32 \qquad (6)$$

Table 1	**1x**	**2x**	**4x**	**2-**	**4-**	**8+**
Race Time (m:s)	6:47.0	6:16.1	5:49.7	6:26.3	5:55.1	5:35.5
Boat Speed (m/s)	4.91	5.32	5.72	5.18	5.63	5.96
Inboard (m)	0.89	0.88	0.87	1.16	1.15	1.14
Oar Length (m)	2.89	2.90	2.91	3.75	3.76	3.77
Actual Inboard (m)	0.85	0.84	0.83	1.03	1.02	1.01
Act. Outboard (m)	1.76	1.78	1.80	2.30	2.32	2.34
Gearing Ratio ***G***	2.06	2.11	2.16	2.23	2.27	2.31
Blade Slip (m/s)	1.00	1.00	1.00	1.20	1.20	1.20
Vblade max (m/s)	5.91	6.32	6.72	6.38	6.83	7.16
Vhand. max (m/s)	2.86	2.99	3.11	2.86	3.01	3.10
Vh average (m/s)	1.91	1.99	2.07	1.91	2.01	2.07
Power (W)	550	550	550	550	550	550
HDF	79	69	62	79	68	62
DF DIR	**133**	**111**	**94**	**134**	**108**	**95**
DF Static	**127**	**103**	**84**	**127**	**100**	**86**
Damper DIR	**4.4**	**2.9**	**1.8**	**4.4**	**2.7**	**1.9**
Damper Static	**4.0**	**2.4**	**1.2**	**4.0**	**2.2**	**1.3**

Conclusion: **setting damper on the static erg to 1 corresponds to rowing in 8+ and 4x, to 2-2.5 – in 4- and 2x, to 4 – in 2- and 1x. On DIR the damper should be opened a half unit more.** Check DF from the monitor and adjust it to the values in Table 1 for more accurate settings.

Appendix 1.

Comparison of mechanical variables of the static and dynamic ergs at various settings of the Drag Factor (DF).



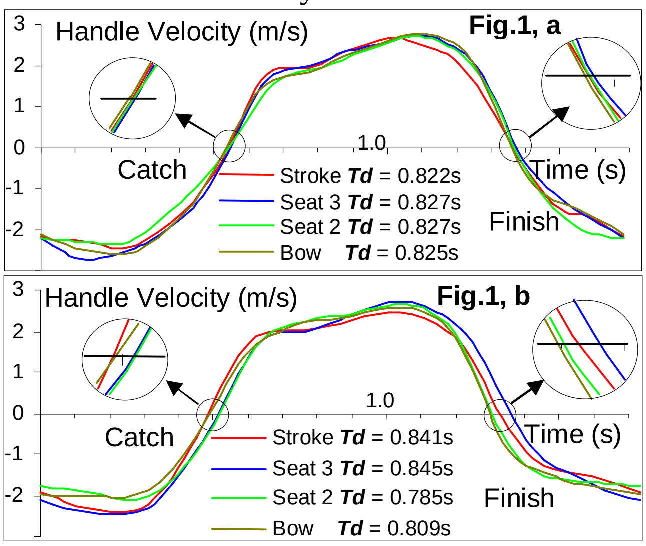
Q&A

Q: Often we receive questions from coaches with the following sense: "How should I change rigging to make rowing angles the same in my crew, if the rowers have different height and physique?"

A: For a number of reasons, time synchronisation of rowers' movements and force application at the catch and finish is the most imperative condition of effective rowing. There are no direct biomechanical reasons, why rowing angles and drive length must be the same in all crew members. However, the spatial variables are closely related to timing and, therefore, important for synchronisation.

The rowers in a crew are mechanically connected to each other through the stretcher and boat hull. It could be illustrated using a concept of "the trampoline effect" (RBN 2006/07), which explains the summation of accelerations the boat and rower's mass. Imagine two jumpers hit the same trampoline board at different times: when it recoils to accelerate the first jumper, the second one arrives. Acceleration of the board would be stopped by impact of the second jumper and the first one couldn't jump high. The second jumper would receive a jolt from the board, which moves fast towards his feet and could be injured. Therefore, rowers have to move and apply forces synchronously, otherwise effectiveness of the crew would be diminished.

The simplest method to measure synchronisation is to check the time of catch and finish, when the oar changes direction of movement. This could be done with frame-by-frame video analysis (high speed video is recommended for accuracy) or with biomechanical equipment (telemetry system). With the last method, the handle velocity could be derived from measured oar angle and known actual inboard. Fig.1 shows patterns of the handle velocity in two men's fours:



- The first crew (a) of World medallists level has very good synchronisation at the catch (max. time difference ΔT=12 ms) and finish (ΔT=13 ms).
- The second crew (b) of a club level has poor synchronisation in both the catch (ΔT= 34ms) and finish (ΔT= 61ms).

How could synchronisation in a crew be improved? **Synchronisation at the catch depends completely on the skills of every crew member**, which usually improves with experience of rowing together. Uniformity of the rhythm of movement of each rower during recovery is important. Every rower in a crew should pay special attention to the forces on the stretcher, which forms a specific "feeling" of the boat and other crew mates. Using drills could accelerate improvement (1).

Synchronisation at the finish depends on one at catch and duration of the drive time ***Td***. Theoretically, ***Td*** depends on the following factors:

- Longer angles, less force, deeper blade path, heavier gearing increase duration of the drive time;
- Shorter angles, more force, shallower blade path, lighter gearing make the drive time shorter.

To analyse effect of above factors, it doesn't make sense to use absolute values, because they are affected significantly by the variation in various boats and rower's categories. Therefore, we analysed deviations of each variable from the average in a crew in the same data sample. It was found that the total oar angle and arc length has significant correlation (r=0.59) with the drive time within a crew. Force application and blade depth has shown very small and statistically insignificant correlations (r=-0.09) with deviation of the drive time in a crew. This means that drive time is defined mainly by its length.

The drive time ***Td*** can be related to the length of the arc ***L*** and average handle velocity ***Vh.av.*** as:

$$Td = L \,/\, Vh.av. \qquad (1)$$

The instantaneous handle velocity ***Vh*** depends on the gearing (ratio of the actual outboard ***Lout*** to inboard ***Lin***), boat velocity ***Vb***, oar angle ***θ*** and velocity of blade slippage ***Vbl*** in the water.

$$Vh = (Lout \,/\, Lin)\,(Vb \cos(\theta) + Vbl) \qquad (2)$$

Combining equations 1 and 2 and assuming the same boat speed ***Vb*** and very similar blade slippage ***Vbl*** in a crew, we can conclude: **To achieve the same drive time, difference in the drive length can be compensated by reversely proportional difference in gearing ratio.** E.g., 1% shorter drive length (about 1deg or 1.5cm), could be compensated by 1% heavier gearing ratio (about 2cm longer outboard or 1cm shorter inboard) and vice versa. However, it could be better to work on rowers' technique to achieve similar time and length of the drive.

References

1. Williams R. 2011. All together now. Rowing & regatta. #50, March 2011, 34-35

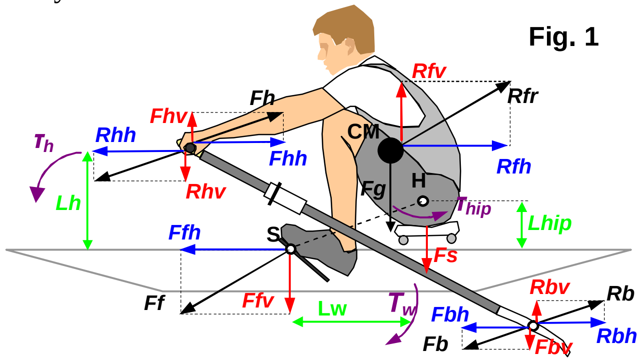
Rowing Biomechanics Newsletter celebrates its 10th birthday! Thanks to all readers for their interest and positive feedback!

Q&A

Q: There was a discussion among rowing coaches and scientists about lift force at the seat: does it really lift the whole rower-boat system and decreases water displacement; or is it just transfer of weight from the seat onto the stretcher?

A: There are five factors affecting force at the seat:

F1. "Static Lift". It is a simple distribution of weight between the seat and stretcher, when the line of gravity force ***Fg*** from rower's CM passes between them (Fig. 1). At catch, about 30% of the rower's weight is statically placed on the stretcher and only 70% is left on the seat, which can be easily checked with bathroom scales on the seat.



A rower usually pushes the stretcher at an angle to the horizon, which is caused by two factors:

F2. "Legs Lift". Hip joint ***H*** is located above the point of force application at the stretcher ***S***, so the line of leg (knee) extension force is not horizontal. This creates downward component ***Ffv*** and upward reaction force ***Rfv***, which lifts the rower.

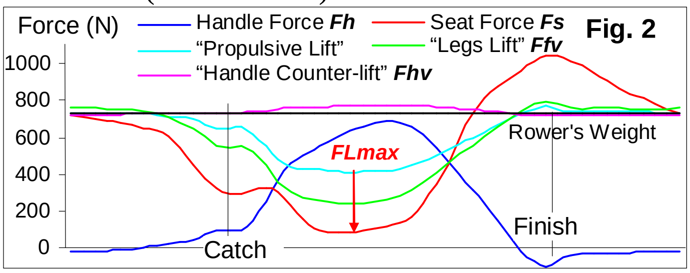
F3. "Hips Torque Lift". When gluts muscles are activated, it creates a torque τ_{hip} around the hip joint, which increases the vertical component of the stretcher force ***Ffv*** and reduces the seat force ***Fs***.

However, reduction of the seat force related to the factors F1, F2 and F3 does not decrease water displacement of the whole rower-boat system, because upward force ***Rfv*** is internal one and balanced by force ***Ffv*** on the stretcher, which pushes the boat down. The higher this couple of forces, the more rower's weight is transferred from the seat onto the stretcher, which creates nodding oscillations of the hull: its pitch increases at the catch (bow goes up, stern down) and decreases at the finish.

F4. "Propulsive Lift". In a horizontal dimension, a rower applies oppositely directed forces to the handle ***Fhh*** and stretcher ***Ffh***, which are distanced vertically by the height of the handle relative to the stretcher ***Lh***. This creates a couple of forces, a torque τ_h around point ***S***, which decreases the oppositely directed torque τ_w of the rower's weight. This could be considered as a lift force ***Flift*** , which reduces force on the seat ***Fs***. The handle force ***Fhh*** is transferred through the oar to the blade force ***Fbh***, which is balances by an external reaction ***Rbh*** and has no counterpart inside the rower-boat system. Therefore, ***Fhh*** really decreases water displacement of the system and drag resistance. On an erg, the handle force is balanced by a reaction of the frame, which is an internal force, so, the total weight of the system is not changed.

F5. "Blade Pitch Lift". In fact, the handle ***Fh*** and blade ***Fb*** forces are directed at some angle to the horizon (RBN 2010/09), equal to the blade pitch angle. To create vertical blade force ***Fbv***, the rower applies upward handle force ***Fhv***, which creates downward "Handle Pitch Counter-lift" ***Rhv*** and increases force on the seat ***Fs***. This internal force ***Rhv*** is partly balanced by the force at the gate, so only ***Rbv*** is external and it pushes the whole system up and reduces water displacement.

Let's try to estimate the shares of each five factors. Fig. 2 shows data of a lightweight Olympic medallist in a single at 32 str/min (RBN 2002/05):



Handle ***Fh*** and seat ***Fs*** forces were measured directly. "Propulsive Lift" ***Flift*** (F4) is presented as a difference from rower's weight and was calculated using the distance ***Lw*** derived from measured data of seat and trunk position:

$$Flift = Fh\ Lh \,/\, Lw \quad (1)$$

"The Legs Lift" (F2) was calculated using hip coordinates derived from seat position data. It was presented as an offset from ***Flift***, so these two lines represent shares in the total lift force.

"Static Lift" (F1) and "Hip Torque Lift" (F3) are quite difficult to estimate. We assume that they represent the residual between red ***Fs*** and green ***Ffv*** lines (Fig.2). At finish, these two factors change sign and push the seat down.

At the moment of maximal weight reduction ***FLmax***, only about 80N of force is left on the seat. <u>About 320 N or 50% of the total lift force 640N is "Propulsive Lift", which decreases water displacement and reduces drag resistance. Another 25% is contributed by "Legs Lift". The residual 25% is related to the "Static Lift" and "Hip Torque Lift".</u> The effect of "Blade Pitch Lift" (F5) is quite small: at peak force application ***Fbv*** is only about 20N (6% of "Propulsive Lift") and "Handle Pitch Counter-lift" ***Rhv*** at the rower's side is about 50N.

<u>**More horizontal stretcher force application reduces water displacement and the boat "nodding", and, hence, decreases of drag resistance and improves performance.**</u> To achieve it:

- Use only knee extensors muscles at catch without activating gluts and opening the trunk;
- Place the stretches higher and steeper, but this could reduce the length of the drive;
- Use a more vertical trunk position at the catch (Adam style, RBN 2006/03), but this could reduce power.

New Research

Recently, we conducted a study with the following hypothesis: **can shorter rowers really benefit from using shorter oars?** Four lightweight single scullers (height 1.68-1.84m, weight 55-73kg) performed four trials each with various rigs (Oar Length/Inboard/Span): Rig1 289/89/159 cm, Rig2 279/86/153, Rig3 269/82.5/147 and Rig4 259/79/141, so the actual gearing ratio (RBN 2006/11) was kept roughly constant at 2.07-2.08. Each trial was 1 km long and the stroke rate increased every 250m (20, 24, 28 and 32 str/min). WinTech Club Racer boat and four sets of Concept2 Smoothie2 Vortex sculls were used together with BioRowTel system (1) to collect the following data:

§ Boat velocity, acceleration, tilt and pitch,
§ Horizontal and vertical oar angles,
§ Forces at the handle and gate (normal and axial),
§ Positions of the seat and trunk,
§ Wind speed and direction.

As it was expected, using shorter sculls enables bigger angles: shortening the inboard by 10cm increased the total angle by 12deg, when the handle arc length shortened by 3 cm. Tables 1 and 2 present average data for all athletes.

Table 1	Drive Time (s)	Catch (deg)	Finish (deg)	Total Angle (deg)	Arc Length (m)
Rig 1	1.093	-64.4	44.2	108.7	1.612
Rig 2	1.118	-64.7	47.3	111.9	1.602
Rig 3	1.145	-70.7	44.9	115.6	1.584
Rig 4	1.198	-73.6	47.3	120.9	1.582

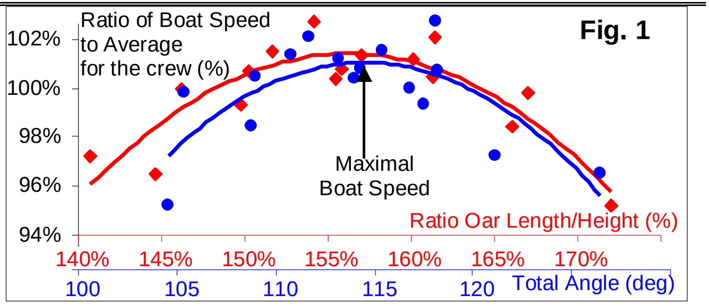
Increase of the angles happened mainly by means of longer catch angles (9 deg on average), where values of more than 80 deg were recorded in the tallest sculler. Longer catch angles increased actual gearing ratio (RBN 2007/03), gave 10% longer drive time and similar slower average handle velocity (Table 2).

Table 2	Aver. Handle Velocity (m/s)	Average Force (N)	Rowing Power (W)	Boat Speed (m/s)	Blade Efficiency (%)
Rig 1	1.49	285.2	249.7	3.85	74.3%
Rig 2	1.44	272.1	233.8	3.79	75.3%
Rig 3	1.39	278.0	233.1	3.80	75.5%
Rig 4	1.33	275.6	223.2	3.73	76.3%

The average forces were quite similar in all rigging settings (3% difference), but slower handle velocity caused a proportionally 10% lower power production. This resulted in a 3.5% slower boat speed, even though the blade efficiency was 2% higher at the shortest rigging.

To find out the optimal rig, the boat speed was corrected using wind speed and direction data (RBN 2009/12) and a prognostic boat speed for absolutely calm conditions was derived. Ratios of prognostic speed in each trial to the average for this sculler in all four trials were derived. Then, two methods could be used:

1. A ratio of the oar length to the athlete's height was related to the boat speed and second order polynomial trend was added (Fig 1, red line). It was found that the maximal boat speed can be achieved at 157% of this ratio.

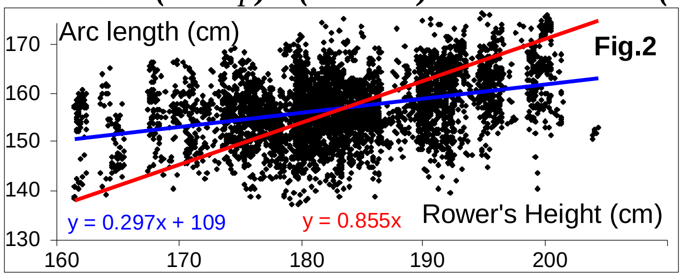


This method leads to very radical rigging dimensions:

Rower's Height (cm)	160	170	180	190	200
Oar Length (cm)	250	265	281	296	312
Inboard (cm)	77	82	86	91	96
Span (cm)	137	146	156	165	175

2. Using similar analysis, it was found that the maximal boat speed was achieved at the total oar angle ***A*** = 114 deg. Using our database (n=4600), ratio of the arc length ***Larc*** to rowers' height was calculated with a linear trend (Fig.2, blue line) and then actual inboard ***Linb.a*** was derived using an equation:

$$Linb.a = (180 / p) * (Larc / A) \qquad (1)$$



Oar length and span were derived using above gearing ratio leading to more realistic dimensions:

Rower's Height (cm)	**160**	**170**	**180**	**190**	**200**
Arc Length (cm)	**157**	**160**	**163**	**166**	**169**
Oar Length (cm)	**272**	**277**	**281**	**286**	**291**
Inboard (cm)	**83.0**	**84.5**	**86.0**	**87.5**	**89.0**
Span (cm)	**149**	**152**	**155**	**158**	**161**

The used linear trend ***y=0.297x+109*** means that every 1cm of extra rower's height increases the arc only by about 0.3cm and the arc has a length 109 m at zero rower's height. If we assume zero arc length at zero height and use the equation ***y=0.855x*** (Fig.2 red line), then the rigging will be similar to radical method 1.

Conclusions:

§ **Total angle of 114 deg (catch 68-70 deg, finish 44-46 deg) appears to be the optimal for achieving the maximal boat speed in sculling.**
§ **Rigging dimensions should be adjusted based on the rower's height and actual length of the arc to obtain the optimal rowing angles (2).**

Acknowledgments: Thanks to Terry O'Neill of Concept2 UK and WinTech Racing boats for kind support of this study and to Stephen Aitken of Brunel University for assistance.

References

1. BioRowTel system www.biorow.com/PS_tel.htm
2. Rigging Chart http://www.biorow.com/RigChart.aspx

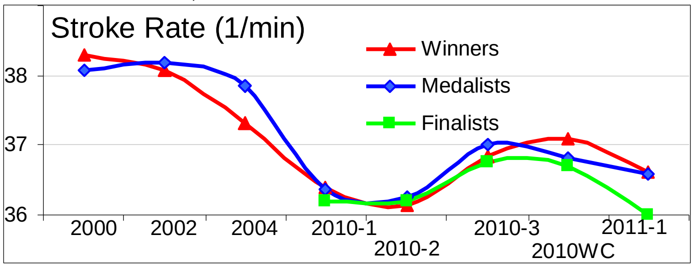
GPS boat speed and stroke rate

Last year GPS data on boat speed and stroke rate became available from FISA website www.worldrowing.com. The data for the World Cups and Championship regattas is presented in 50m splits. To check the accuracy of the data, we have derived an average speed over the whole race using GPS data and compared it with the speed obtained from official results. It was found that the accuracy significantly improved in this year World Cup in Munich: the percentage of correct rankings (GPS based ranking corresponds with official one) data increased up to 60.3% and average deviation of the GPS speed from the official results decreased down to 1.67%:

	2010 Cup1	2010 Cup2	2010 Cup3	2010 WCh	2011 Cup1
N GPS data in FA	82	83	84	84	78
Correct ranking	22	29	24	46	47
Correct ranking (%)	26.8%	34.9%	28.6%	54.8%	60.3%
Average speed deviation (%)	2.60%	3.74%	1.71%	1.99%	1.67%

The accuracy could be improved even more if GPS speed would be represented with two or more decimals. There are still some concerns about the accuracy of GPS stroke rate data, especially in small boats (see Attachments 1 and 2), where the data in side lanes looks quite untrustworthy. Therefore, we took for further analysis only the data of the medallists, which usually go on the middle lanes.

In RBN 2005/02 we already discussed average stroke rate in medallists of the main World regattas in 2000, 2002 and 2004, which was obtained for three medallists in every boat type from video footage. To check the possible effect of different methods of measurement, we took the stroke rate from a video of M8+ and W8+ during Worlds-2010 in Karapiro, compared it with GPS data and found that the average difference in stroke rate in three medallists was 0.2 str/min. This allows us to compare the data obtained using both methods. The chart below shows the average stroke rate in 14 Olympic boat types in the winners, medallists and finalists of World regattas (see Appendix 3 for more details):



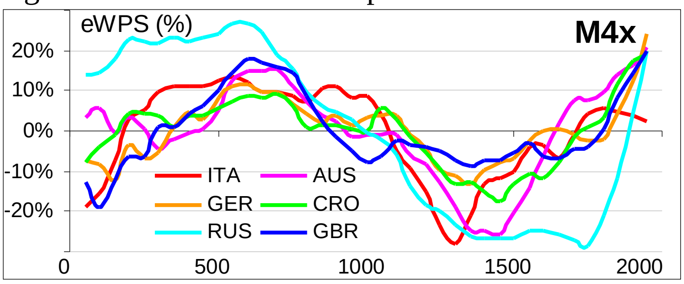
<u>The average stroke rate decreased by about one stroke per minute during the last decade</u>: it was around 38 str/min in 2000-2002 and around 37 str/min in Worlds Championship-2010 and World Cup-2010 in Lucerne. In other World Cups the stroke rate was 0.5-1 str/min lower. No significant difference in stroke rate between various place takers was found.

To analyse the stroke rate in various boat types and its variation during the race, we took the data of three medallists during the last five World regattas of 2010-11 and derived an average stroke rate over the whole race, its standard deviation (±SD) based on 20 50m splits, minimal and maximal values and their difference (range). In the following table the data is ranked based on average stroke rate:

Boat	Average	±SD	Min	Max	Range
W1x	34.6	2.4	31.4	40.9	9.5
W2x	34.8	2.4	32.3	41.4	9.1
LW2x	35.1	2.2	32.5	41.0	8.5
M1x	35.3	2.3	32.1	41.2	9.1
W4x	35.7	2.4	32.5	41.4	9.0
W2-	36.2	2.0	34.2	41.5	7.4
M4x	36.7	2.2	34.5	41.8	7.3
M2x	36.9	2.1	34.5	41.7	7.1
W8+	37.2	1.8	35.2	41.5	6.3
LM2x	37.4	2.1	35.0	42.3	7.3
M2-	38.0	2.0	35.8	42.8	7.0
LM4-	38.2	2.4	35.3	43.1	7.8
M4-	38.3	2.1	36.1	43.0	6.9
M8+	38.4	1.9	36.3	42.5	6.2

Women's sculling boats use the lowest average stroke rate 34-35 str/min and men's sweep boats use the highest stroke rate 38-39 str/min. The larger the boat, the lower variation (±SD) and the range of the stroke rate during the race: in the singles, differences between minimal and maximal stroke rates were more than 9 str/min, but in the eights they were only about 6 str/min. Rowers in all boat types could produce quite a similar maximal stroke rate 41-42 str/min at the start and spurts, but the cruising stroke rate (minimal) was significantly lower in small boats: around 32 str/min, compared to 35-36 str/min in the big boats.

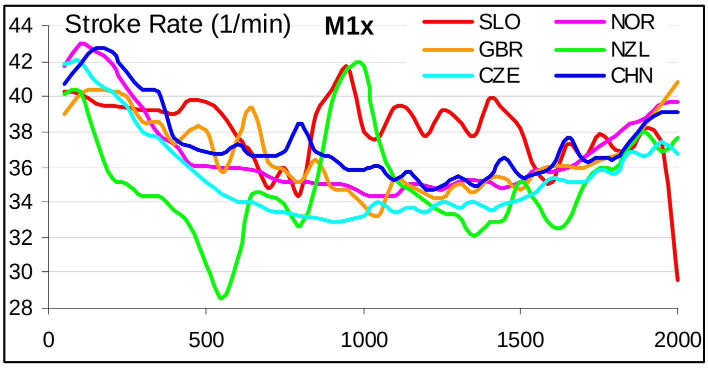
Available GPS data allows to derive information about relative effective work per stroke (eWPS), using our method proposed in RBN 2005/10. As an illustration, we show below a chart of eWPS in M4x race during the Worlds-2010 in Karapiro.

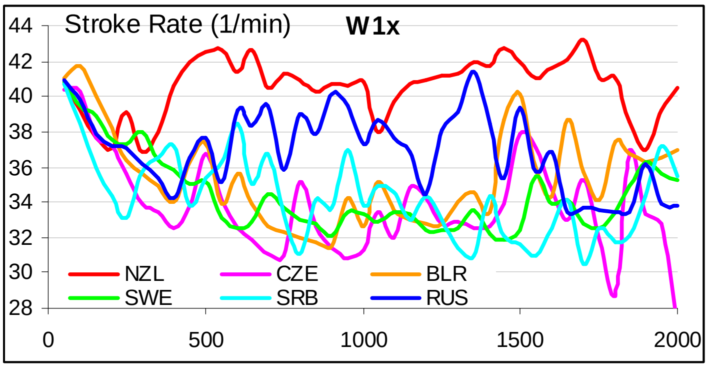


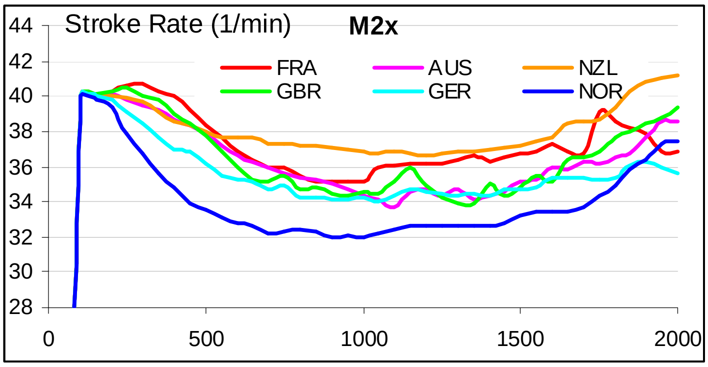
The winners CRO had the most consistent eWPS, i.e. efforts distribution, during the race (SD=8.6%) compared to the last place RUS (SD=20.4%), which applied too high efforts during the first half (high speed at low rate) and couldn't maintain it at finish.

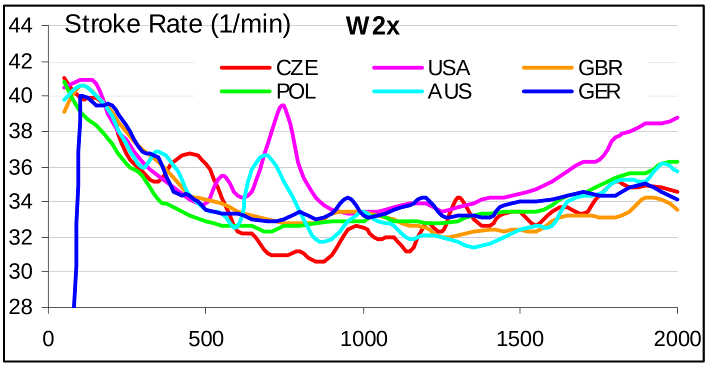
Appendix 1 to Rowing Biomechanics Newsletter 122 (2011 May)

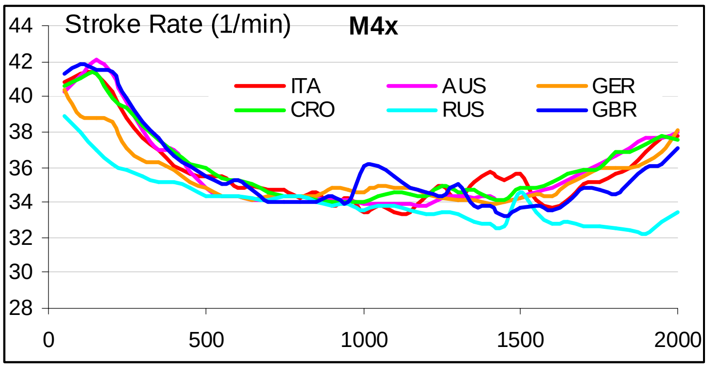
Graphical presentation of GPS stroke rate data during World Championship – 2010 in Karapiro

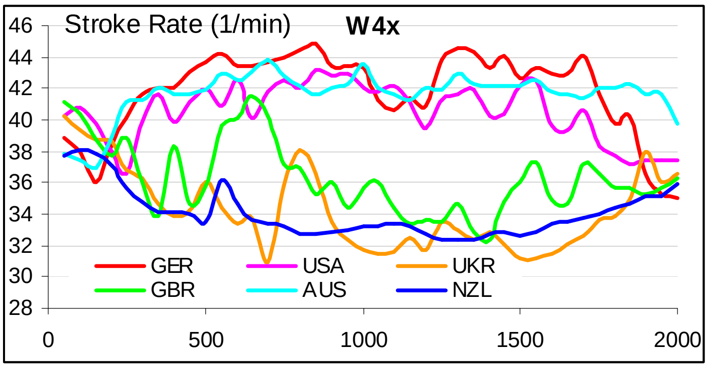


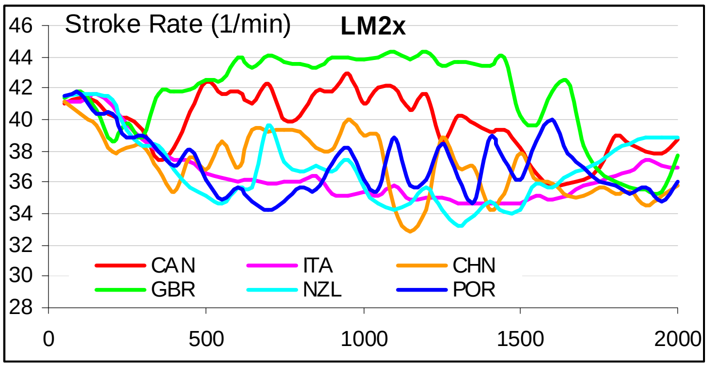


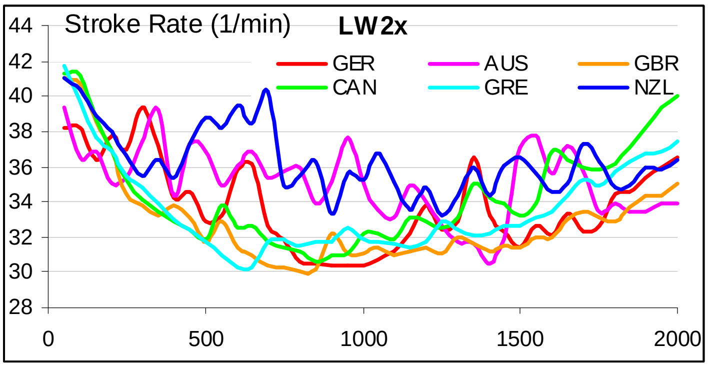


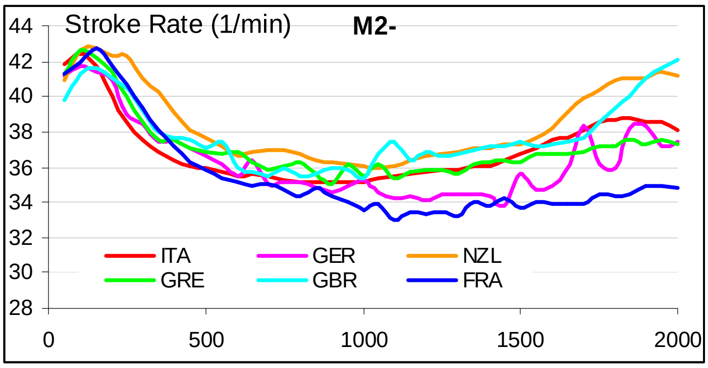


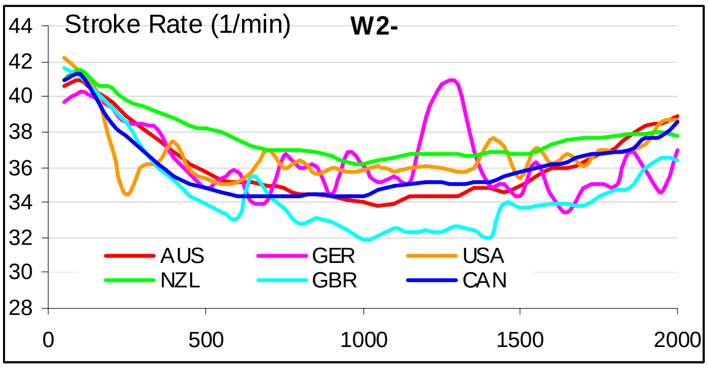


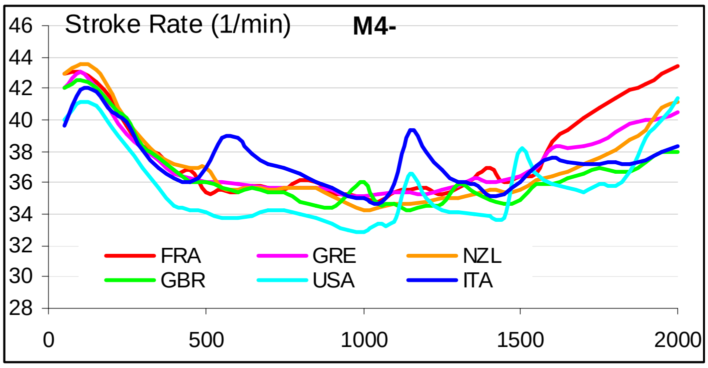


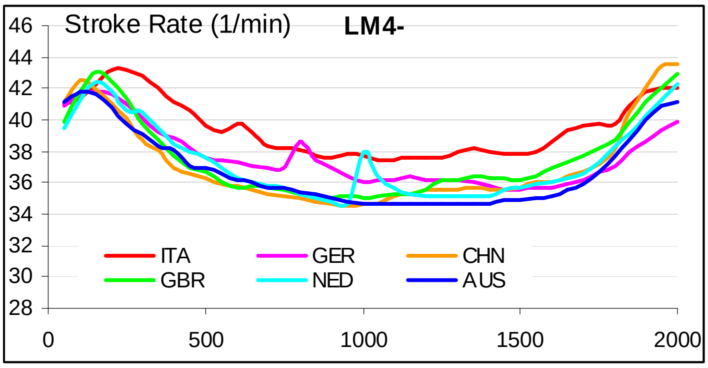


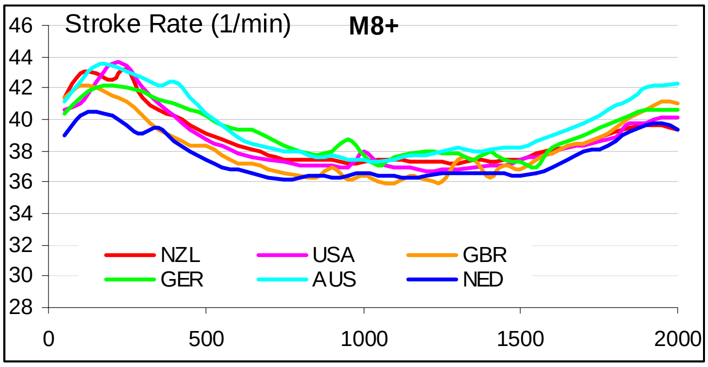


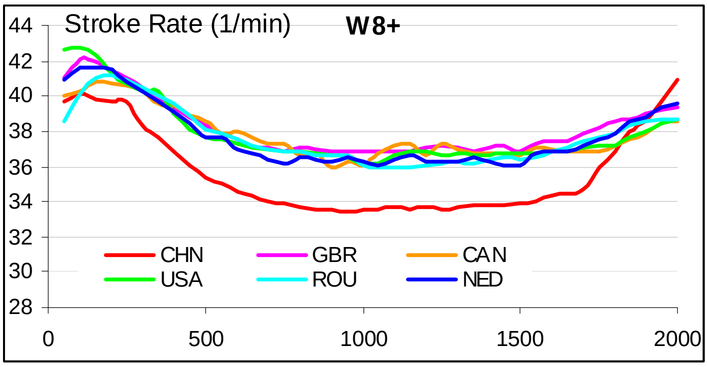






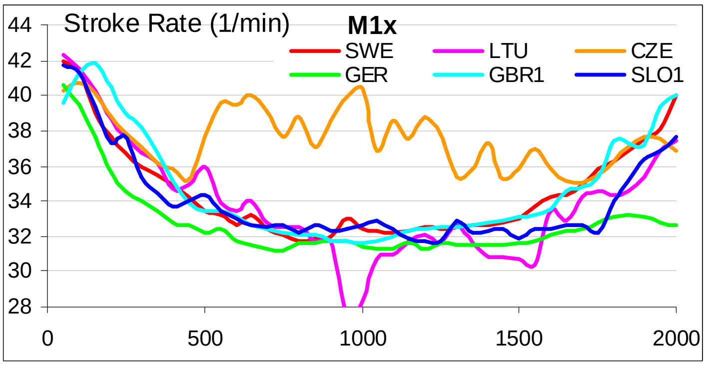


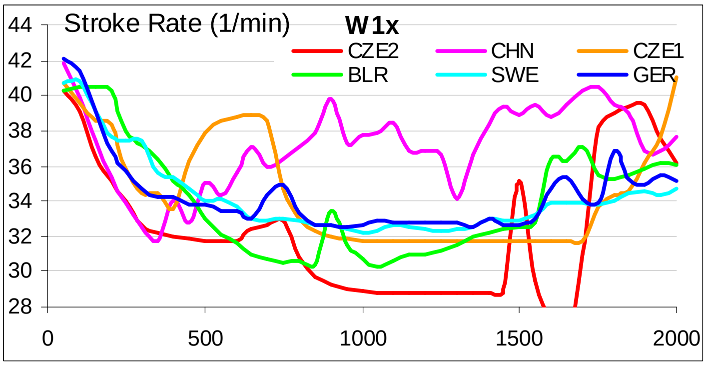


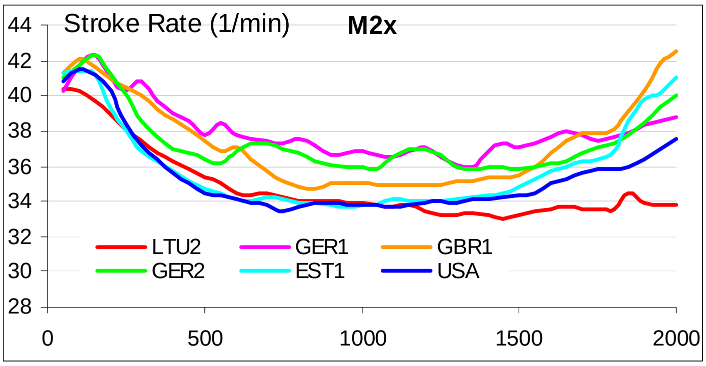


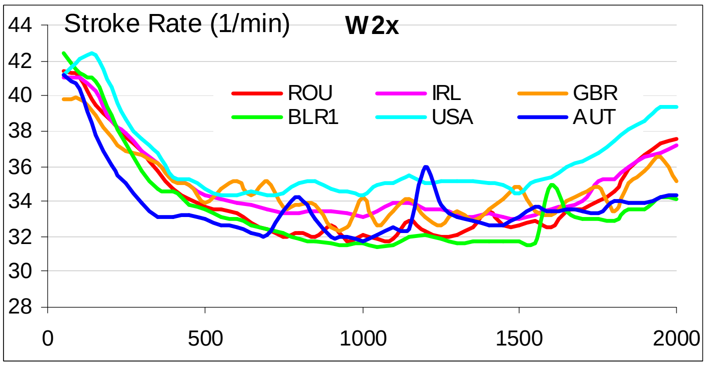
Appendix 2 to Rowing Biomechanics Newsletter 122 (2011 May)

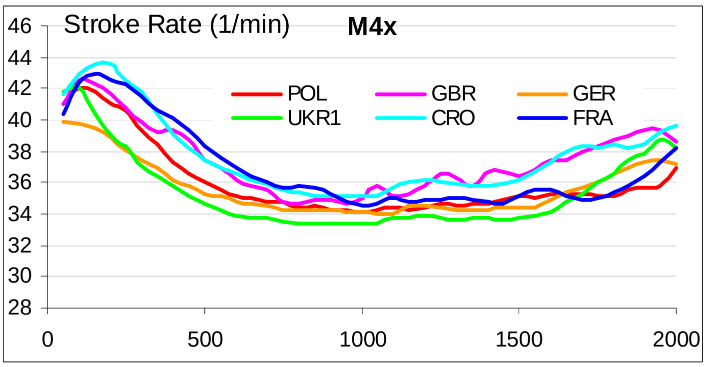
Graphical presentation of GPS stroke rate data during World Cup-1 2011 in Munich

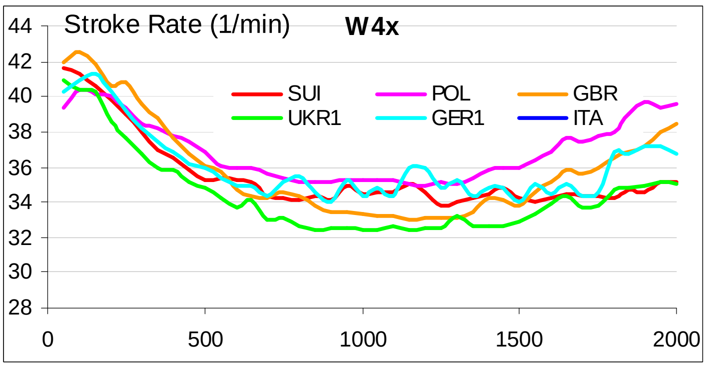


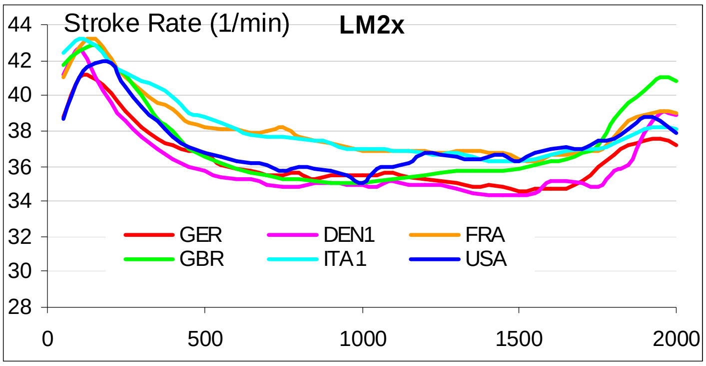


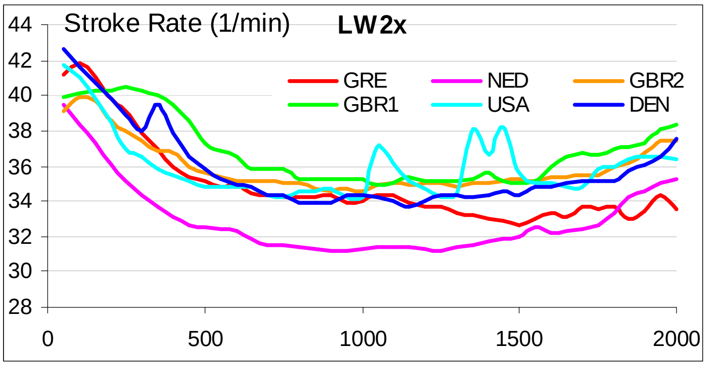


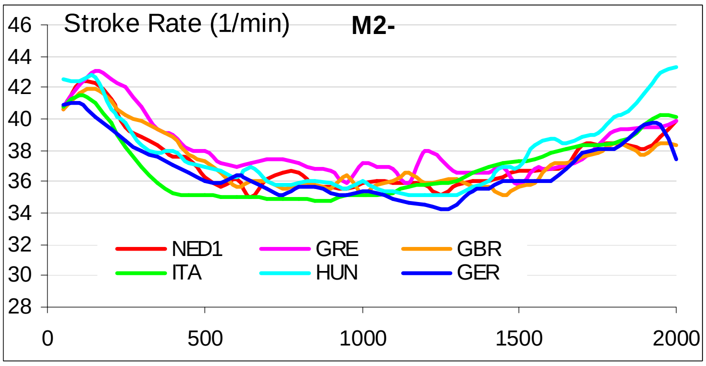


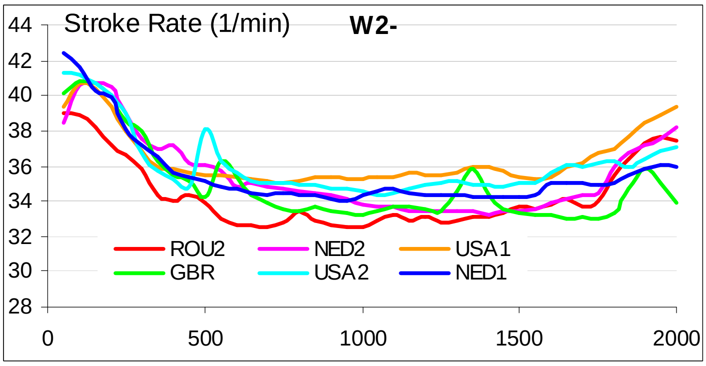


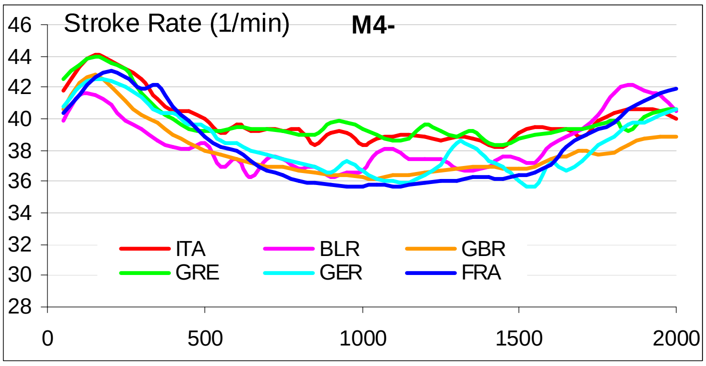


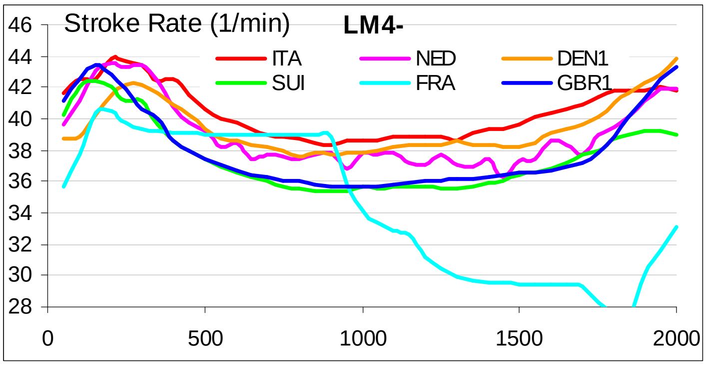


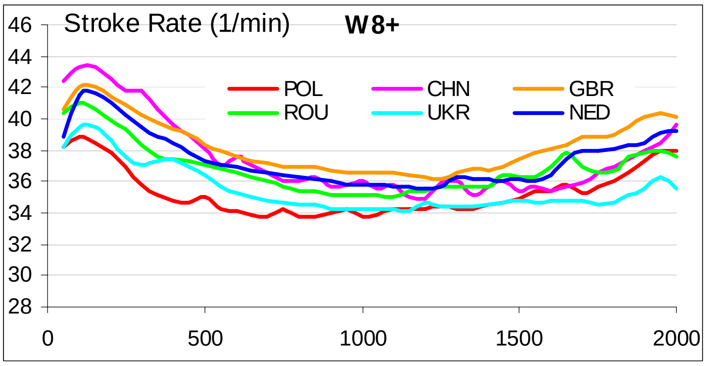












M8+ data was missing

Appendix 3 to Rowing Biomechanics Newsletter 122 (2011 May)

Stroke Rate in various boat classes during 2000-2011 period. Description of the regattas:
2000 – Olympic Games – 2000 in Sydney
2002 – World Championship – 2002 in Seville
2004 - Olympic Games – 2004 in Athens
2010-1 – World Cup 1 in 2010 in Bled, Slovenia
2010-2 – World Cup 2 in 2010 in Munich
2010-3 – World Cup 3 in 2010 in Lucerne
2010W – World Championship – 2010 in Karapiro, New Zealand
2011-1 – World Cup 1 in 2011 in Munich

Winners	2000	2002	2004	2010-1	2010-2	2010-3	2010W	2011-1	**Average**
LM2x	37.2	39.7	36.8	37.0	36.9	38.2	41.5	36.4	**38.0**
LM4-	42.0	40.9	41.0	39.3	37.9	37.8	37.6	39.4	**38.4**
LW2x	36.6	35.5	35.0	35.9	35.5	34.6	34.4	36.9	**35.5**
M1x	35.6	36.1	37.4	35.3	34.7	35.4	35.5	37.6	**35.7**
M2-	41.0	39.4	39.1	37.9	37.4	38.4	38.5	37.3	**37.9**
M2x	37.7	36.3	38.2	36.3	36.6	36.2	38.2	38.0	**37.1**
M4-	39.2	40.6	39.9	38.4	38.1	37.6	37.9	38.0	**38.0**
M4x	41.0	40.5	36.5	37.2	37.3	37.8	36.0	35.7	**36.8**
M8+	41.1	40.1	38.4	37.5	37.7	39.0	39.2	37.7	**38.2**
W1x	33.7	33.1	34.6	31.7	33.6	33.4	34.4	34.0	**33.4**
W2-	41.0	37.9	36.4	36.1	37.1	38.6	37.8	34.9	**36.9**
W2x	34.3	34.9	34.1	34.1	35.3	35.5	34.1	34.8	**34.7**
W4x	36.2	37.3	36.2	35.5	32.6	36.3	36.3	34.4	**35.0**
W8+	39.4	40.7	38.7	37.4	35.4	36.6	37.9	37.4	**36.9**
Average	**38.3**	**38.1**	**37.3**	**36.4**	**36.1**	**36.8**	**37.1**	**36.6**	**36.6**

The data marked in red was missing and inserted from the same boat type in similar regatta to maintain the average.

Medalists	2000	2002	2004	2010-1	2010-2	2010-3	2010W	2011-1	**Average**
LM2x	38.9	38.6	38.9	37.1	37.0	37.6	38.3	36.9	**37.4**
LM4-	40.5	40.8	40.4	38.7	38.5	39.0	37.2	37.3	**38.2**
LW2x	36.8	35.7	35.9	35.7	34.0	35.5	34.0	36.3	**35.1**
M1x	35.9	36.4	36.7	35.1	34.6	36.1	35.8	35.0	**35.3**
M2-	38.8	38.6	39.1	38.1	38.2	38.2	37.8	37.5	**38.0**
M2x	38.0	38.3	38.3	36.1	36.4	36.9	37.4	37.6	**36.9**
M4-	40.1	41.7	39.8	38.0	38.4	38.9	37.5	38.8	**38.3**
M4x	40.2	40.3	37.4	36.5	37.0	37.7	35.9	36.3	**36.7**
M8+	40.7	40.4	38.8	38.1	38.0	39.0	39.1	38.0	**38.4**
W1x	33.5	33.9	35.0	34.2	33.6	33.1	36.8	35.2	**34.6**
W2-	38.4	36.2	37.6	36.0	35.9	37.0	36.4	35.6	**36.2**
W2x	35.8	35.7	36.3	34.1	35.0	35.7	34.3	34.9	**34.8**
W4x	36.2	38.4	37.5	34.9	34.8	35.6	37.5	35.5	**35.7**
W8+	39.3	39.7	38.2	36.6	36.2	37.8	37.8	37.5	**37.2**
Average	**38.1**	**38.2**	**37.9**	**36.4**	**36.3**	**37.0**	**36.8**	**36.6**	**36.6**

Q&A

Q: Ralph Earle, President of the Honolulu Rowing Club, HI, US is asking: “In the January 2011 Newsletter you derive drag factors for ergs to match the perceived feel of various boat types on the water. That suggests that the OTW (on the water) equivalent DFs are dependent on boat speed, so I am writing to ask: Do you have formulae which take that into account?

For example, I row a 2x; your newsletter suggests an equivalent DF=103. The erg I use currently has DF ~110, but it feels noticeably "lighter" than when I'm rowing OTW @2:10/500m.”

A: The following five factors affect the “lightness” or “heaviness” of rowing feelings:

1. Drag resistance force applied to a boat hull or to the flywheel of an erg.
2. Inertia forces, which are created at acceleration of rower-boat or rower-erg masses.
3. Gearing ratio, which affects transfer of above forces to the handle.
4. Blade slippage in the water, which is not presented on an erg.
5. Elastic force of a return cord on an erg, which is quite small and not presented in a boat.

Handle Drag Factor ***HDF*** (RBN 2011/01) represents a cumulative effect of all above factors, which work together and define rowing mechanics and rower’s feelings. It will take many equations to estimate them separately, which will complicate the picture and not really necessary here. Instead, we will try to illustrate how main variables of rowing may affect rower’s feelings.

Effect of the drag resistance is obvious: on water, head wind, cold water, small boats and water brakes make rowing heavier. Weather conditions always change, so, on an erg, it is difficult to simulate a specific boat type with a damper.

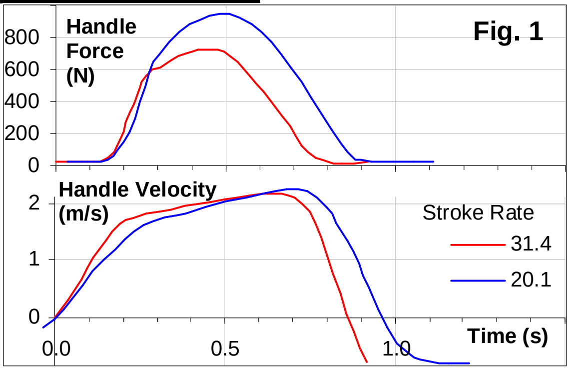
Gearing works differently: in a boat it vary during the drive (heavier at the catch and finish, lighter at the middle, RBN 2007/03), but it is constant on erg. Therefore, if a rower used to apply peak force at catch, it feels heavier on water than on erg and vice versa.

Effect of Stroke Rate (SR) vs. Work per Stroke (WPS). ***WPS*** is a product of the Stroke Length ***SL*** and Force ***F***. It is possible to achieve the same power ***P*** and speed using various combinations of ***SR, SL*** and ***F***:

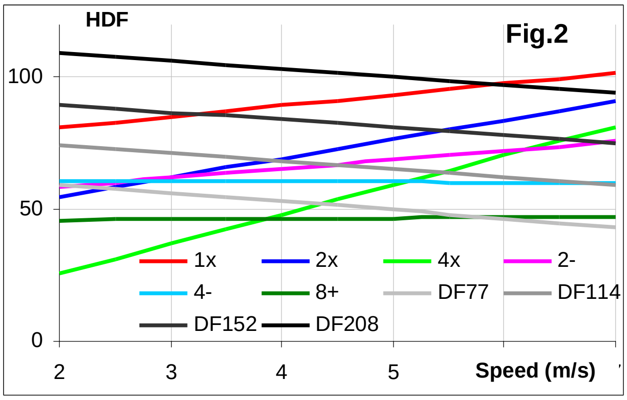
$$P = 60\ WPS / SR = 60\ F\ SL / SR \qquad (1)$$

To achieve the same power at lower stroke rate, a rower has to pull harder and longer, which feels heavier. Also, at lower rate, the recovery time is longer and the rower-boat system or the flywheel on erg decelerates more, so the rower has to start from lower velocity at the catch, which adds even more “heaviness”.

Fig. 1 shows curves of the handle force and velocity, obtained on Concept2 erg model D at the same DF= 118, speed (1:46.6 /500m) and power (288W), but at very different stroke rates 31.4 and 20.1 str/min. In the second sample, the stroke length was 11cm (8%) longer and average forces 110N (26%) higher. HDF values were 71.6 and 79.3 correspondingly, which is closer to a double in the first case and to a single in the second case (RBN 2011/01). This means: **<u>rowing at lower stroke rates with longer length and higher force makes feelings “heavier” at the same boat or erg speed and vice versa</u>**.



Above data shows that rower’s feelings are related to the rhythm (share of the drive time in the total stroke cycle time), which is very closely correlated with the stroke rate (RBN 2003/03) and, hence, with speed. We analysed dependence of HDF on the speed on a static C2 erg at four DF settings (77, 114, 152 and 208) and on water using our database (Fig.2).



It was found that HDF decreases at higher speed on erg, but it increases in sculling boats and 2-, and remains nearly constant in big sweep boats. We don’t know the reasons yet, and only speculate that they could explain higher racing stroke rate usually used in big sweep boats. The correlations between speed and HDF were quite low (the highest r=0.33 in 4x), that means HDF was quite consistent across various speeds.

Concluding: **<u>rower’s feelings depends on many factors: stroke rate, rhythm, power, speed. Some factors are on-water specific: whether, boat type and variable gearing, other erg specific: erg type and DF. HDF factor can be used for general estimation of rower’s feelings, providing similarity of other variables.</u>**

Asymmetry in sculling

Asymmetry in sculling is defined by the overlap of the scull handles, which is commonly set to 18-22 cm (Fig.1). Overlap itself is defined by the inboard length and necessity to scull long angles 100-120deg. At inboard 88cm, span 160cm and overlap 20 cm (+4cm of swivel width), the distance between handles is about 100cm at catch angle 70deg and 30cm at finish angle 44deg. If the overlap would be set to zero, then above distances would be 20cm wider, which is too wide for a normal sculler.

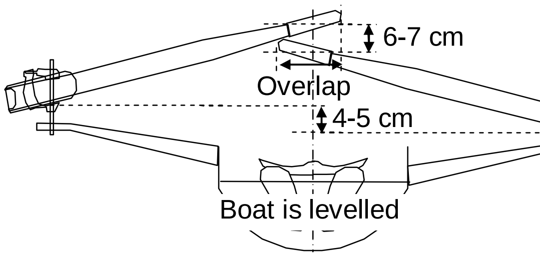


Fig. 1

If a sculler pulls the handles symmetrically in the horizontal plane, then vertical distance between them at the middle of the drive must be 6-7 cm. To achieve this, difference in height of the gates must be set at 4-5 cm, if a boat is kept level and blades move at the same depth in the water. At the finish, however, a sculler must pull the handles the same 6-7 cm apart, which is very difficult in terms of balance and could negatively affect an athlete's posture.

The usual difference in height of the gates is set to 1-2 cm, which allows pulling the handles at the finish to more or less the same height. Therefore, at the middle of the drive, a sculler has to separate the handles in the horizontal plane (pull one handle in front of another) and/or tilt the boat and/or move the blades at different depth in the water. Usually, a combination of all these options is used (Fig. 2, 3).

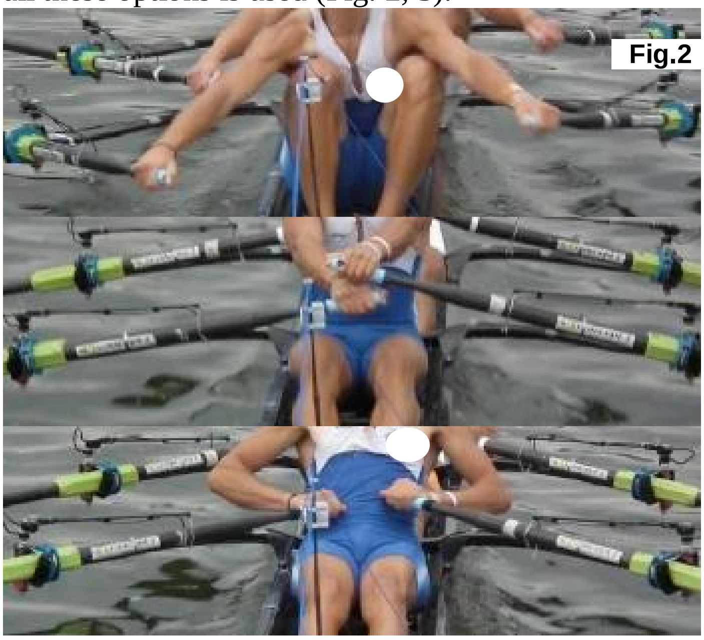


Fig.2

As the most common sculling style is "left handle above right", the right handle is usually pulled in front of the left. Fig. 3 shows typical data of a single sculler at stroke rate 28 str/min.

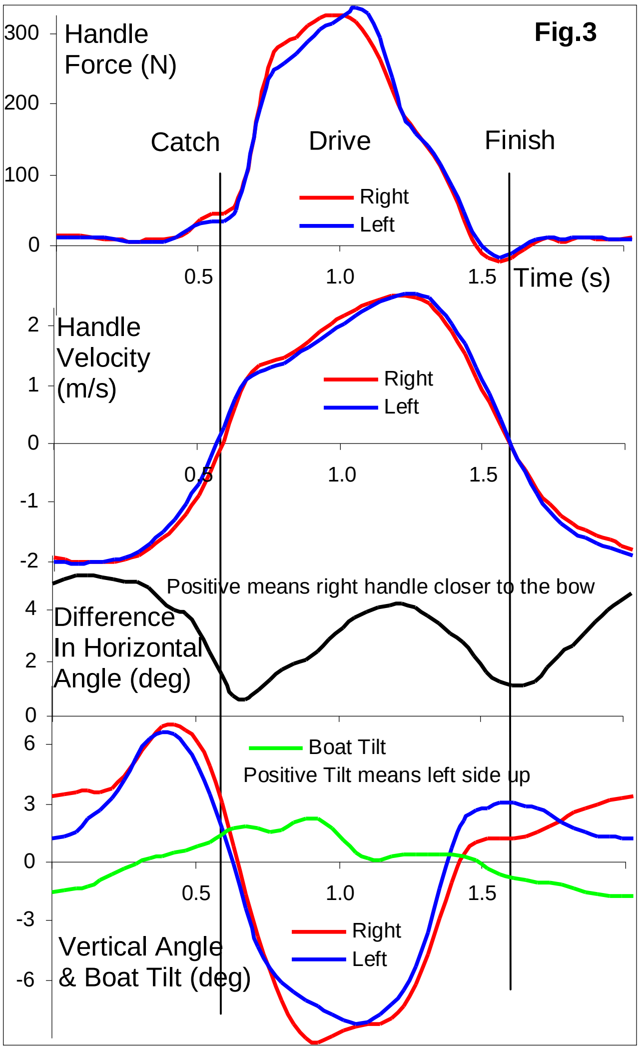


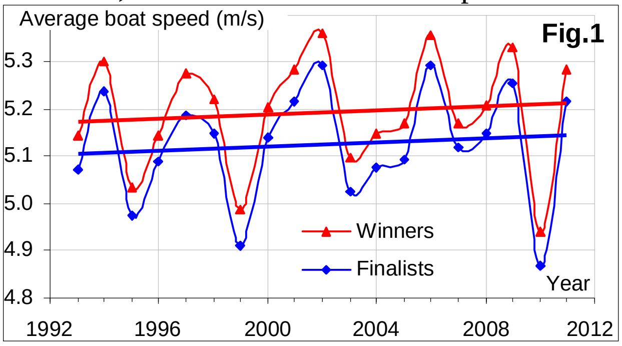
Fig.3

Left catch angle is about 1 deg longer and this difference in the angles increases up to 4 deg at the middle of the drive, then decreases again down to 1 deg at finish. To do this, the sculler must apply forces asymmetrically: right handle force increases faster at catch, which creates higher velocity and allows the right handle to take position in front. At about 30 deg oar angle, the left force increases and became higher than the right one, which allows the left handle to catch up the right one at the finish of the drive. This asymmetry in forces creates a small (0.5-1 deg) wiggle of the hull during the drive, which increases the drag resistance losses. In fact, this particular sculler put right blade deeper at catch, which makes forces asymmetry worse. During the first half of the drive, the boat also tilts about 2 deg right side down. At the finish, the tilt decreases down to zero, which helps to keep the balance

How can an athlete minimize losses caused by asymmetry in sculling? **Pull the handles with even forces to reduce the boat wiggle. Don't worry too much about the boat tilt at catch and middle of the drive. Try setting the overlap to 18 cm and the difference in height of gates to 1.5-2 cm.**

News

- The latest World rowing championship 2011 in Bled, Slovenia was the fifth fastest after Eton-2006, Seville-2002, Poznan-2009 and Indianapolis-1994:



The trend lines of speeds of both winners and finalists in Olympic events go nearly parallel and show **a long-term growth of performance about 0.2% per year**.

- 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. The fastest speeds were shown during the first three days of finals A. One more time we must notice exceptionally fast speed of New Zealand men's pair.

Table 1

N	Boat	Day	G.St	Winner	%%	Av.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	06:08.5	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

- Accuracy of GPS speed data was higher than before (RBN 2011/05): the deviation of the average speed based on GPS from the official results was 1.18% on average and correct ranking was observed in 43 cases out of 84 finalists in Olympic events (51.2%).

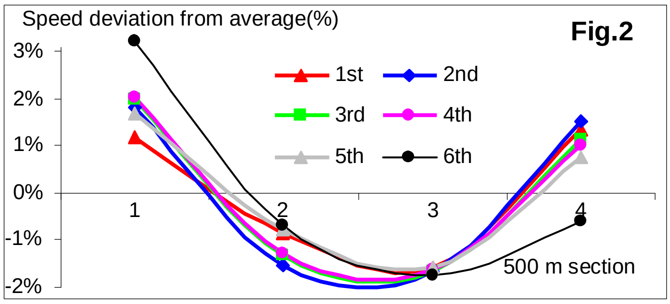
The average stoke rate based on GPS was 37.3 str/min for winners, 37.2 for medallists and 36.9 for finalists in Olympic events, which is 0.3-0.5 str/min higher than in Worlds-2010 in Karapiro. This difference could be related to the possibility of higher boat speed because of better weather conditions. It is interesting that the highest average stroke rate over the race was found in W2- NZL 39.7 str/min (Table 1).

- **The margin between the world's leading rowing nations and the rest of the rowing world is increasing.** During the 2010 Worlds in Karapiro the best three countries (Great Britain, New Zealand and Australia) won 20 out of 42 medals in Olympic events (47.6%), while this year these **three Commonwealth nations managed to win 23 medals (54.8%)**. Obviously, this success is attributed to their effective national team systems and massive commitments to rowing science.

Table 2

N	Country	Number of places 1	2	3	4	5	6	7	Entries	Medals	Points	Licenses
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
16	NED					1	2		6	0	7	4
17	ROU				1	1			5	0	7	2
18	DEN					2			6	0	6	3
19	SWE					2			4	0	6	2
20	RUS					1			5	0	3	2

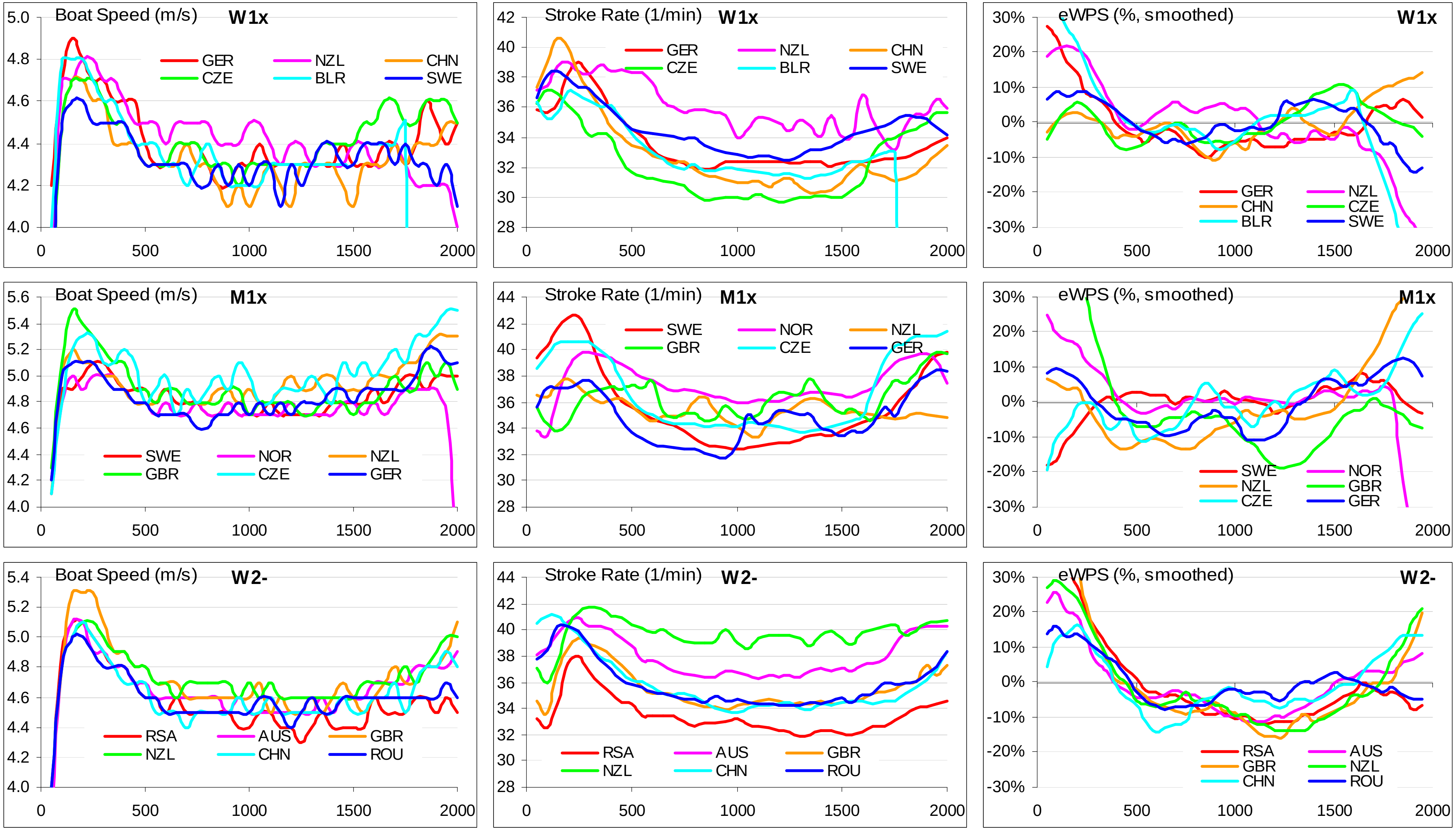
- When analysing race strategies, on average **winners in Olympic events have shown relatively slower speed over the first 500m than all other finalists**:

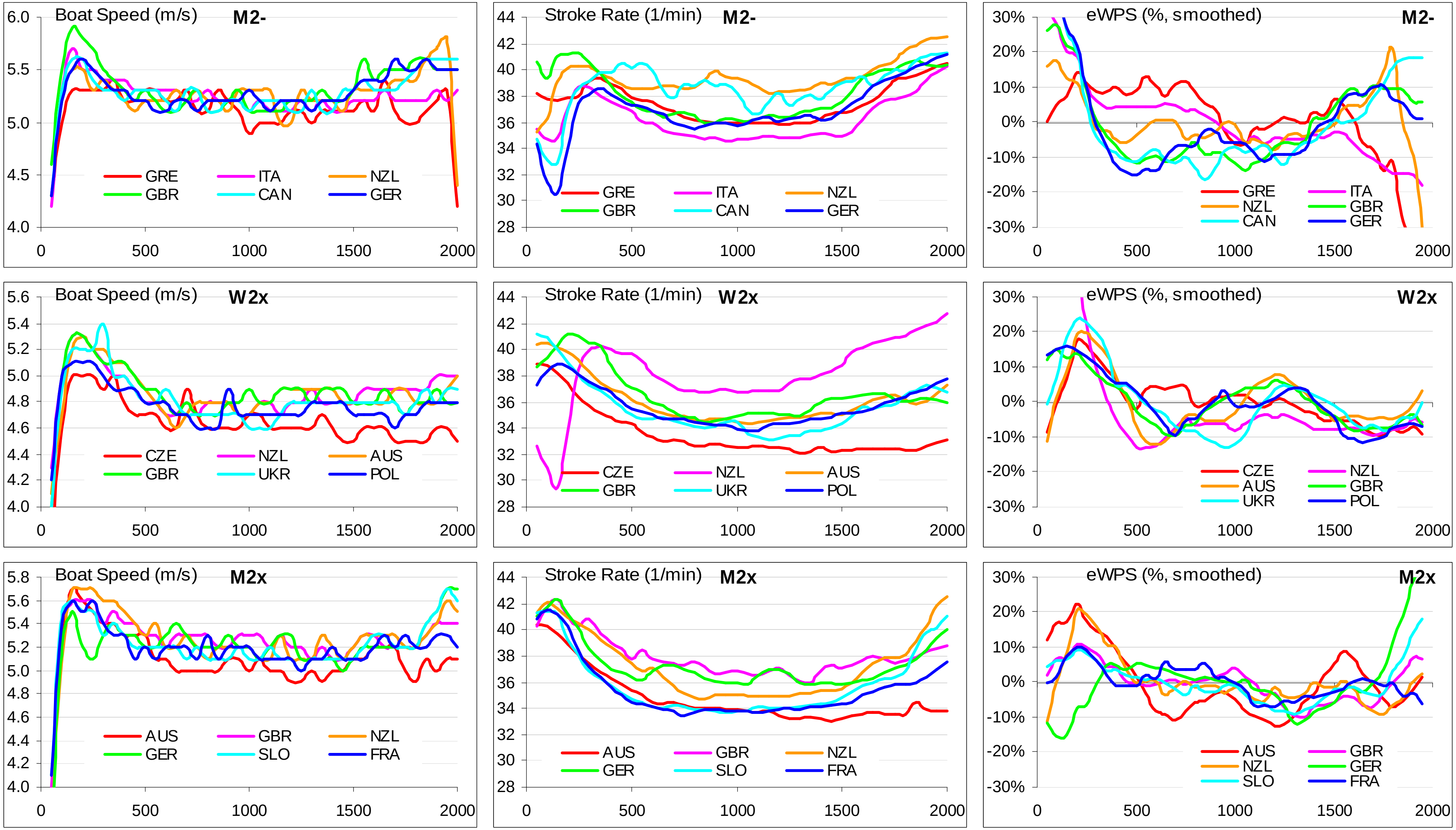


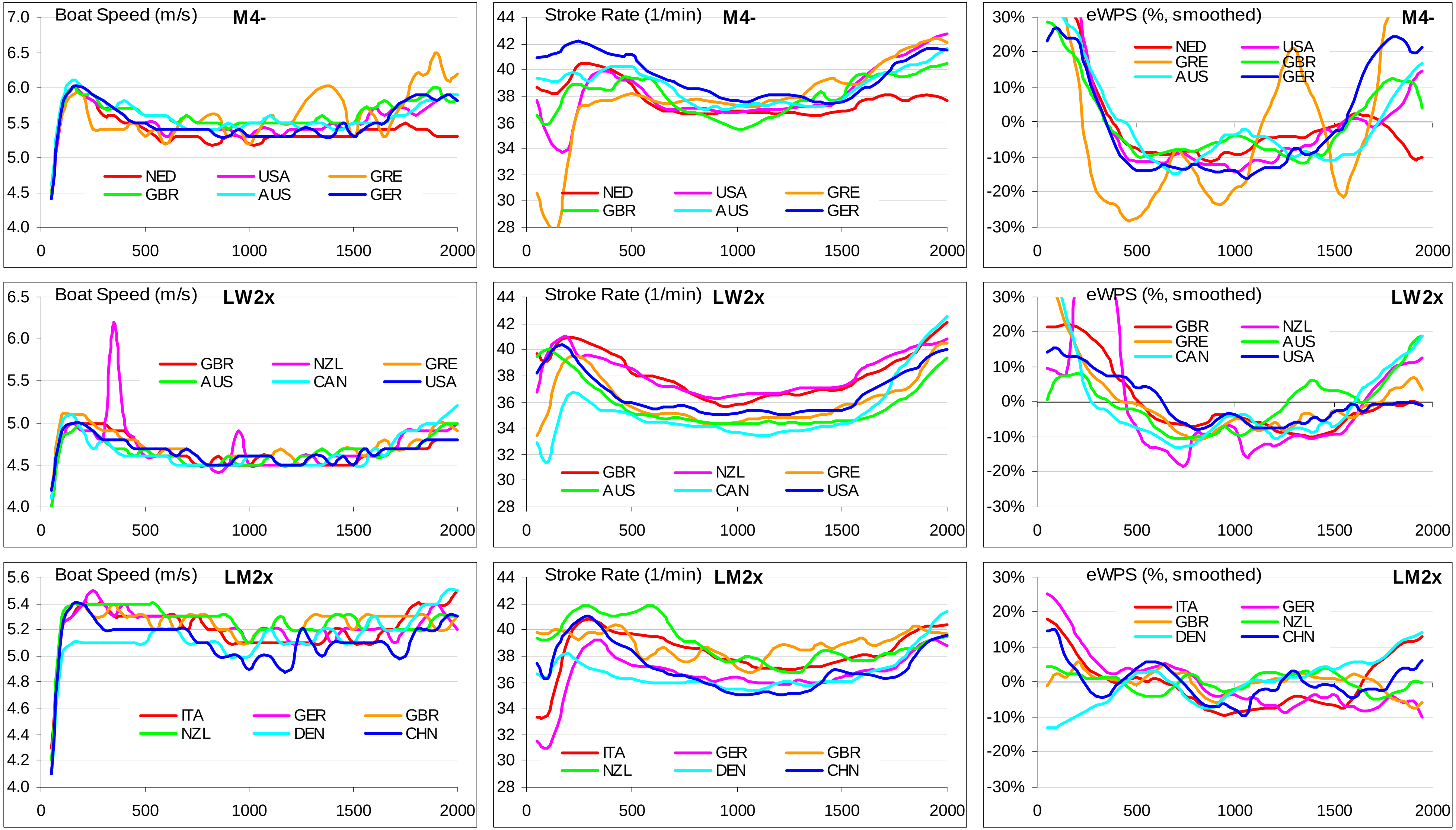
This trend is opposite to what was found in previous World regattas (RBN 2001/05, 2002/10, 2008/09), where the winners were usually faster during the fist 500m. The main "contributors" to this phenomenon in Bled are four winners: Mirka Knapkova in W1x CZE (-4.1% in the first 500m), W8+ USA (-0.5%), LM4- AUS (-0.3%) and M4- GBR (-0.2%). This fact is still significant even if we reject W1x split times as an error. Future competitions will show us if this phenomenon is an occasional coincidence or a new trend of leading crews.

Appendix 1 to the Rowing Biomechanics Newsletter 2011/08

Based on GPS data: Boat speed, stroke rate and relative Effective Work per Stroke in the finals A of Rowing World Championships in Bled, Slovenia




Boat Speed (m/s) M2-
GRE ITA NZL
GBR CAN GER
6.0 5.5 5.0 4.5 4.0
0 500 1000 1500 2000
Stroke Rate (1/min) M2-
GRE ITA NZL
GBR CAN GER
44 42 40 38 36 34 32 30 28
0 500 1000 1500 2000
eWPS (%, smoothed) M2-
GRE ITA
NZL GBR
CAN GER
30% 20% 10% 0% -10% -20% -30%
0 500 1000 1500 2000
Boat Speed (m/s) W2x
CZE NZL AUS
GBR UKR POL
5.6 5.4 5.2 5.0 4.8 4.6 4.4 4.2 4.0
0 500 1000 1500 2000
Stroke Rate (1/min) W2x
CZE NZL AUS
GBR UKR POL
44 42 40 38 36 34 32 30 28
0 500 1000 1500 2000
eWPS (%, smoothed) W2x
CZE NZL
AUS GBR
UKR POL
30% 20% 10% 0% -10% -20% -30%
0 500 1000 1500 2000
Boat Speed (m/s) M2x
AUS GBR NZL
GER SLO FRA
5.8 5.6 5.4 5.2 5.0 4.8 4.6 4.4 4.2 4.0
0 500 1000 1500 2000
Stroke Rate (1/min) M2x
AUS GBR NZL
GER SLO FRA
44 42 40 38 36 34 32 30 28
0 500 1000 1500 2000
eWPS (%, smoothed) M2x
AUS GBR
NZL GER
SLO FRA
30% 20% 10% 0% -10% -20% -30%
0 500 1000 1500 2000

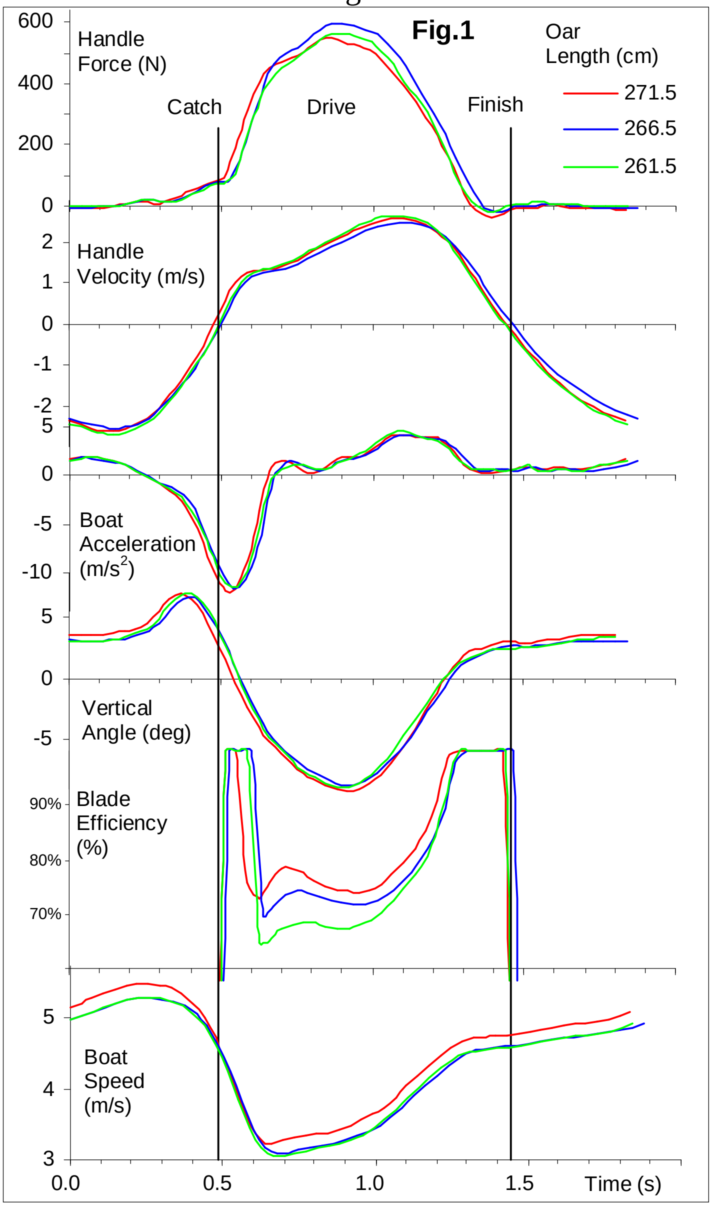


Boat Speed (m/s) M4-
NED USA GRE
GBR AUS GER
Stroke Rate (1/min) M4-
NED USA GRE
GBR AUS GER
eWPS (%, smoothed) M4-
NED USA
GRE GBR
AUS GER
Boat Speed (m/s) LW2x
GBR NZL GRE
AUS CAN USA
Stroke Rate (1/min) LW2x
GBR NZL GRE
AUS CAN USA
eWPS (%, smoothed) LW2x
GBR NZL
GRE AUS
CAN USA
Boat Speed (m/s) LM2x
ITA GER GBR
NZL DEN CHN
Stroke Rate (1/min) LM2x
ITA GER GBR
NZL DEN CHN
eWPS (%, smoothed) LM2x
ITA GER
GBR NZL
DEN CHN
0
500
1000
1500
2000

Facts. Do you know that…

…changing oar length a few cm does not dramatically affects rowing biomechanics? Recently, an experiment was conducted on two single scullers with three sets of sculls of the same Concept2 vortex-smoothie type, but of different lengths: 271.5 cm, 266.5 cm and 261.5 cm. Inboard was set to 86.5 cm in all sets. In each session data samples were taken during 20 stroke pieces at stroke rates 20, 24, 28, 32 str/min and max.

The Fig.1 shows comparison of the main biomechanical variables of one of scullers at the stroke rate 32 str/min with various lengths of sculls:



Some variation in force application is noticeable, but the majority of variables are quite similar in these very different rigging settings. Boat acceleration with the shortest oar length was slightly higher in the middle of the drive, but it was lower during the first half of the drive. The highest average boat speed with the longest sculls was related to a light tail wind. The main difference was found in the blade efficiency, which decreases significantly with decreasing the oar length, especially during the first half of the drive.

Table 1 represents average values of the main biomechanical variables of two scullers at all stroke rates:

Table 1. Biomechanical Variables	Oar Length (cm) 271.5	266.5	261.5
Gearing	1.976	1.915	1.855
Average stroke rate (1/min)	28.2	30.7	31.5
Drive Time (s)	1.051	0.966	0.930
Angle (deg)	108.5	107.9	111.8
Effective Angle (%)	74.7%	76.5%	77.7%
Blade Efficiency (%)	78.5%	77.2%	73.7%
Max. Handle Velocity (m/s)	2.35	2.52	2.71
Average Handle Velocity (m/s)	1.52	1.64	1.77
Max.Force (N)	574	629	616
Average Force (N)	336.8	368.7	370.5
Max.Force Position (% Angle)	33.3%	35.3%	35.5%
Work per stroke (J)	618.6	663.5	694.0
Rowing Power ***P*** (W)	299.0	349.0	375.9
Propulsive Power ***Pprop*** (W)	234.6	269.6	277.2
Boat Speed ***V*** (m/s)	4.17	4.32	4.38
Drag Factor **=** $Pprop / V^3$	3.25	3.34	3.30
Total Drag Factor =P / V^3	4.14	4.32	4.48
Handle Drag Factor ***HDF***	81.6	75.8	64.5

Shorter scull allow faster handle velocity, which leads to shorter drive time even at slightly longer rowing angles and, hence, allow higher stroke rate and rowing power. However, shorter outboard at the same inboard makes the gearing lighter by about 12%, which means blade force became higher at the same handle force. Higher blade force at the same blade area increases water pressure per square cm and, hence, blade slippage through the water. Therefore, blade efficiency of lighter gearing appeared to be lower and rower have to spend more energy for moving water at the blade.

However, lighter gearing allow faster rower's movements, so it could increase power production (see Hill law in RBN 2007/09). HDF factor (RBN 2011/01) shows that "heaviness" of the shortest sculls was similar to rowing in a quad or on Concept2 erg with the damper settings 1. Medium oar length 266.5 was close to a double or erg damper setting 2 and was the optimal for the given sculler, which corresponded with results, produces by our Rigging Chart (http://biorow.com/RigChart.aspx).

Concluding:

- **<u>Changing oar length in quite large scale doesn't affect significantly forces, power and boat speed, so it should not scare coaches and rowers.</u>**
- **<u>Shorter oars and lighter gearing allow faster drive and, hence, higher stroke rate, but decrease blade efficiency.</u>**
- **<u>An optimal gearing is a balance between rower's and blade efficiencies and depends on rower's dimensions and boat speed.</u>**

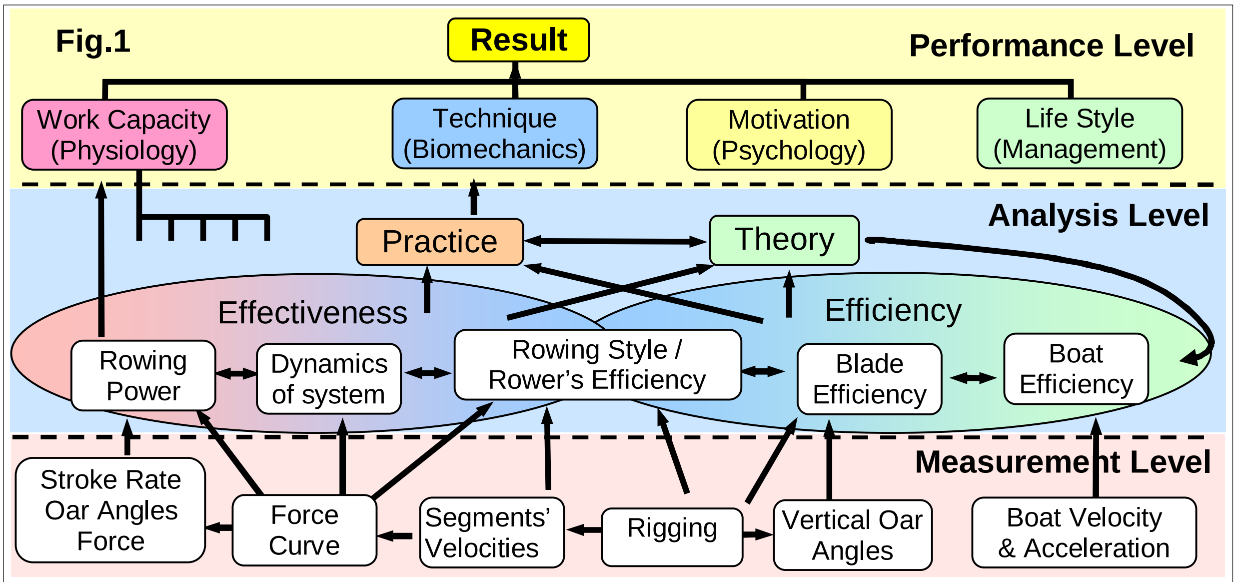
Roadmap on Rowing Biomechanics

Some coaches think that to effectively use biomechanics they must prepare for the onslaught of numbers and high level math. Here we illustrate a straight and logical path to the successful application of biomechanics in rowing.

Performance in rowing is a complex matter as it is in any sport. It requires high physiological power production, effective technique, mental toughness and smart management of an athlete's lifestyle and training. The main purpose of biomechanics in rowing is improvement of technique. The main questions are:

- **What components of rower's skills can be analysed to develop optimal technique?**
- **What biomechanical variables need to be measured to provide data for the analysis?**

Fig.1 schematically shows relationships between components of rower's skills and biomechanical variables. The real picture is more complicated, since the components of technique are interrelated and usually affected by many other biomechanical variables.



The road map of rowing biomechanics has three levels: *measurement, analysis* and *performance*. At the *Measurement* level we collect information from sensors, process it (apply calibration, filters, averaging, etc.), store and feed into the next analysis level.

During *Analysis*, we combine data from various variables, calculate derivative variables (e.g., power from measured force and oar angle, etc.) and values (e.g., max. and average force), and produce some meaningful information. There are two separate areas at the analysis level: theory and practice. In the *Theory*, we produce and publish some common knowledge, e.g., average values in athlete groups, correlations, normative criteria, etc. In the *Practice* area, we compare the acquired data with the normative criteria and produce recommendations for a specific athlete or crew, which are then fed into the next *Performance* level.

At the *Performance* level we try to correct rowing technique with instructions obtained at the *Analysis* level. Various methods of feedback can be used at this level: after a session, post-exercise and real-time feedback as well as various drills and rigging adjustments. After a technical correction is made, variations of rowing technique should be measured and analysed to check their impact and evaluate an athlete's adaptability.

At the *Measurement* level, there are three groups of variables related to very basic mechanical categories: *Time* (stroke rate), *Space* (drive length – rowing angles) and *Force* (applied by a rower). Together these three variables produce the fourth mechanical category: *Energy* (rowing power), which is very closely related to the average speed of the rower-boat system and, hence, with *Result*. To evaluate these four types of variables we usually compare them with target values (see RBN 2007/08, 2009/06) and established Biomechanical Gold Standards.

Force curve defines the total impulse supplied by the rower as well as dynamics of the system (RBN2006/02). An optimal force curve must be "frontloaded", full and not have any humps (RBN 2006/06, 2008/02).

Coordination of the body segments velocities is related to the force curve and defines rowing style, which is the key component of technique (RBN 2006/03, 05).

Rigging defines kinematics of oar and rower and through gearing ratio – kinetics of the system. Lighter gearing makes rower's movements faster and, possibly, increases power production but reduces blade efficiency (RBN 2011/09).

Oar handling skills of a rower could be evaluated using measurements of vertical angle, which is related to the rigging (blade pitch and height of the gate, RBN 2010/09) and could impact blade efficiency.

Patterns of the boat velocity and acceleration during the stroke cycle result from the dynamics of the system and should be good indicators of quality of rowing technique (RBN 2002/06, 2002/08).

Q&A

Q: Michael Shannon, USOC Sports Physiologist from Chula Vista, California is asking: "In recreational rowing boats, it is common to swivel the gate at the centre of the pin. Would there be any advantage to locating the oarlock above the centre of the pin?"

A: We would generalise the question in this following way: "How does offsetting the oarlock (and, hence, the axis of the oar) from the centre of rotation at the pin affect~~s~~ rowing mechanics?"

It is possible to design swivels with different offsets, in front of the pin (closer to the stern, negative offset), or behind the pin (closer to the bow, positive offset), or zero offset. This would lead to the following changes in the handle position and or angles (Fig.1):

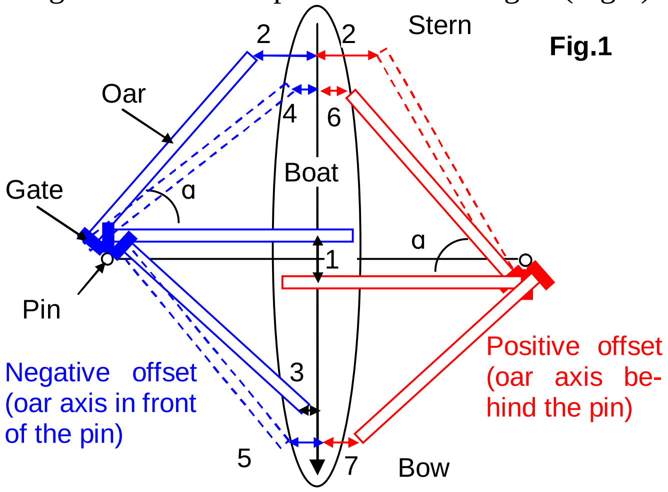


Fig.1

1. In saggital plane (longitudinal axis of the boat), offsetting the oar axis is similar to moving the pin relative to the boat in the same direction (Fig.1, 1), so the stretcher needs to be moved to preserve the oar angles.
2. In frontal plane (sideward), negative offset moves the handle position outwards at catch (2, works similar to wider span/spread) and inwards at finish (3). If the distances between handles at catch and finish are preserved, then the angle at catch must be shorter (4) and the finish angle, longer (5). If catch angles (55-70deg) are usually larger than finish angles (30-45 deg), offsetting oars in front of the pin would make them more even.
3. Positive offset moves the handle position inwards at catch (6, works similar to narrower span/spread) and outwards at finish (7). If the rower preserves distances between handles at catch and finish, this would lead to a longer angle at catch and a shorter angle at finish, i.e., would increase this difference.

In the current swivel design, the axis of the oar has a negative offset about -4 cm. Michael's question is about an oarlock with 0 cm offset from the pin, i.e. the oar axis should be moved +4 cm relative to the current design. In sculling, if the oar angles are preserved, this would make the handle~~s~~ position 4 cm wider ~~in~~ at catch (60 deg) and about 3 cm narrower at finish (45 deg). In sweep rowing, ~~it~~ moves the handle 2 cm outwards at catch and 1cm inwards at finish. If the handles positions are preserved, zero offset would make oar angle about 3deg longer at catch and similarly shorter at finish, i.e. it would make the catch and finish angles more uneven, which is unlikely to be beneficial.

Also, in a zero offset gate the axis of rotation would go through the oar shaft, which doesn't allow for using a solid pin and require a more complicated design. Alternatively, developing swivels with bigger negative offsets requires special efforts for preventing oar backlash in the swivel when axial force is applied. Therefore, **the current gate design looks quite balanced and optimised**.

Q: A 16yo sculler from India Karn Rao is asking about Drag Factor (DF) on the Dynamic ergometer:

a) From informal communications with US rowing coaches I've found that they tend to use DF of 110.

b) The Concept2 UK website suggests DF 130-140 for Junior rowers (http://concept2.co.uk/training/guide/damper_lever).

c) Australian Rowing website based on a research report suggests DF 105 for Lightweight men. (http://www.concept2.com.au/app_cmslib/media/lib/1003/m40198_v1_the%20erg%20-%20ivan%20hooper%20study.pdf)

d) Crossfit.com site suggests that, based on my current weight 70kg, I should use DF of 120. (http://board.crossfit.com/showthread.php?t=5310).

e) BioRow site suggests DF of 133 for sculling on the DIR (http://www.biorow.com/RBN_en_2011_files/2011RowBiomNews01.pdf)

What would be the most appropriate drag setting on a dynamic ergometer for the purpose of improving on-water sculling speeds?

A: We would suggest that all DFs recommended above could work well for various training purposes. Remember, that **an erg is a cross-training tool for rowing** (RBN 2005/01). Rowing on the erg is the most similar exercise to rowing on the water; however, there are significant biomechanical differences between these efforts (RBN 2005/03, 2010/10). Training on an erg is mainly intended for development of power and endurance and can be done across a wide range of DFs: higher DFs are good for strength training; lower DFs can be used for speed training.

When testing on the erg, it is better to use a standardized DF, which allows the closest "heaviness" to on-water rowing. We proposed to use HDF factor for this purpose (RBN 2011/01), but the correspondence with the boat is quite approximate, because DF of water changes dramatically with weather conditions.

Q&A

Q: A sculler Dmitry Khmylnin from Kamensk-Uralskiy, Russia asks: "How to set up the stretcher properly in sculling?"

A: It is difficult to give exact settings of the stretcher as they depend on many variables of the rower, boat and oars, which need to be measured and modelled. The most efficient method is to use the practical recommendations, which are suggested below. The following measures define settings of the stretcher (Fig.1): 1) Stretcher angle and 2) opening angle (splay), 3) depth, 4) positions of toes and 5) heels. Size of shoes (6) affects geometry of the stretcher, but can not be chosen freely as it must fit the feet.

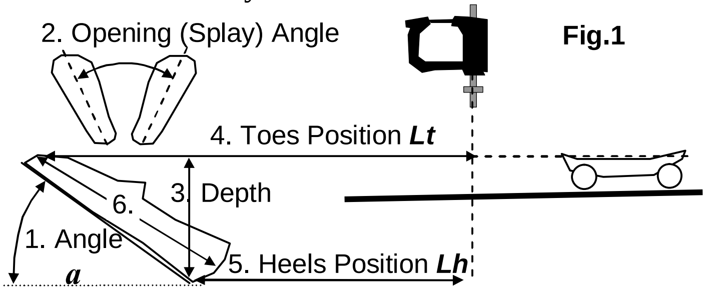


Fig.1

Opening angle 2 (splay) is usually fixed by boat design and can't be changed without redesigning of the shoes mounting plate. Only "New Wave rowing shoe fixing system" (14) allows its easy adjustment. Though manuals suggest splay 25 deg (7, 13), measurements give it in a range 0-12 deg with average 6 deg (1). Splay affects feet pressure distribution: wider angle shifts it to the inside of the feet and vice versa.

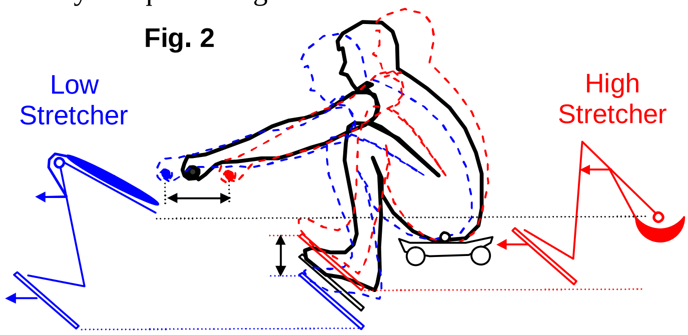
Stretcher angle should be set first as it affects other settings. Usually was measured (1) in the range 37-47 deg, average 42 deg and the recommended value (6, 13) 40 deg. The principles are:

- Flatter angle allows quicker placement of the heels during the drive (so, the gluts and hamstrings muscles can be used earlier, see RBN 2008/07), but it is limited by ankle flexibility at extension: too flat angle doesn't allow full knees extension at finish.
- Steeper angle allows more horizontal force application during the drive, which makes it more effective (RBN 2011/03), but it is limited by ankle flexibility at flexion: too steep angle makes it more difficult to compress at catch.

Attempts were made to combine above advantages, so the stretcher plate was made angled with a steeper toes part and a flatter heels part (3). Our advice: **Set the stretcher angle as flat as it doesn't make any ankle tension at extension at finish**.

The stretcher depth is traditionally measured as a vertical distance between the bottom corner inside the shoes and top of the seat. Its recommended range is 15-19 cm, measured (1) 12-22cm, average 17 cm. The following rules affect individual adjustments (Fig.2):

- Lower stretcher allows longer handle position at catch, but limits force application, because a rower could be lifted from the seat and lose it (RBN 2002/05). Also, lower stretcher allows easier compression at catch, increases quads utilisation, but prevents early usage of hamstrings and gluts. Quite often lowering the stretcher is limited by ends of the seat tracks, which cut into the rower's calves
- Higher (and steeper) stretcher allows more horizontal drive and bigger force application (5, 21), but makes compression at catch more difficult. It allows early usage of hamstrings and gluts (and trunk opening), but not easy for quads usage.

Fig. 2


Our advice: **Set the stretcher depth to provide an optimal compression at catch: shins are vertical, knees at armpit level and contact with seat is maintained at your strongest efforts**.

Finally, the horizontal position of the stretcher should be set up as it can be adjusted quickly and does not affect other settings. It is measured from the line of the pins and various sources recommend measuring at the toes ***Lt*** (Fig.1, 4) or heels ***Lh*** (5). Both of these measures can be used as they are simply interrelated:

$$Lt = Lh + Ls * \cos(a)$$

,where ***Ls*** – length of the shoes, ***a*** - stretcher angle. Measured at toes, ***Lt*** ranges at 50-70 cm and it depends on many factors: rower's height / legs length, shoulders width and trunk breadth, inboard/span/overlap, trunk angle at finish. The position of the stretcher affects the catch and finish angles:

- Moving the stretcher towards the stern increases catch angle (see the ratio in RBN 2007/02) and, possibly, total angle, if the finish angle is maintained. However, this requires longer trunk work at finish, which may cause excessive energy losses.
- Moving the stretcher towards the bow increases finish angle and could be used to reduce trunk activity at finish, providing there is good compression at catch. Excessive finish angle could cause pulling the oars inwards, especially at narrow sculler's shoulders, wide span and low handles.

We would suggest following the traditional advice: **At correct stretcher position, the top of the handles must slightly touch ribs, when legs are straight and trunk is vertical**. Also, a good indicator is a perpendicular angle between a forearm and an oar at finish.

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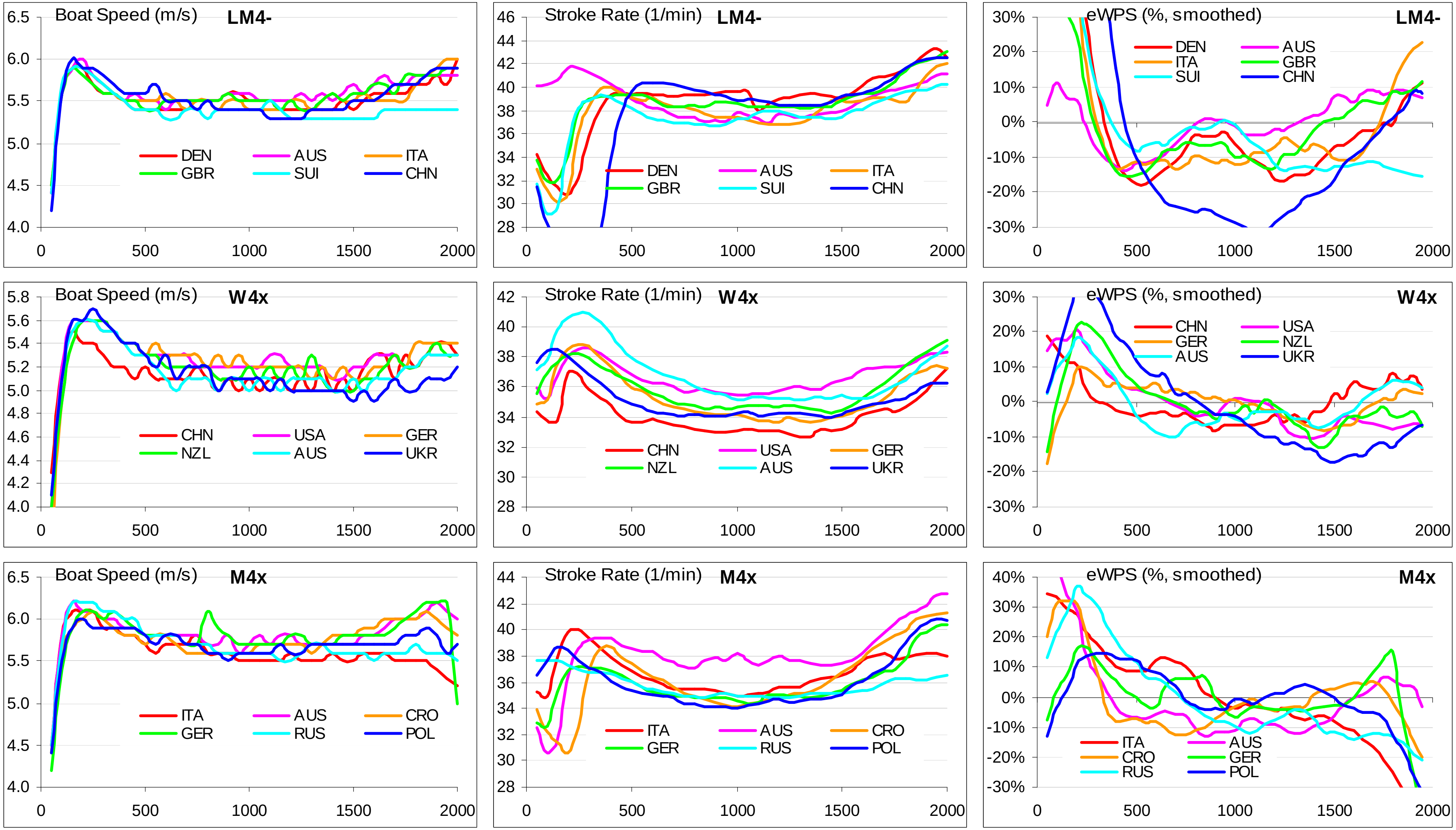
Thanks to Stephen Aitken for the help in compiling the literature references.


Boat Speed (m/s) LM4-
DEN AUS ITA
GBR SUI CHN
Stroke Rate (1/min) LM4-
DEN AUS ITA
GBR SUI CHN
eWPS (%, smoothed) LM4-
DEN AUS
ITA GBR
SUI CHN
Boat Speed (m/s) W4x
CHN USA GER
NZL AUS UKR
Stroke Rate (1/min) W4x
CHN USA GER
NZL AUS UKR
eWPS (%, smoothed) W4x
CHN USA
GER NZL
AUS UKR
Boat Speed (m/s) M4x
ITA AUS CRO
GER RUS POL
Stroke Rate (1/min) M4x
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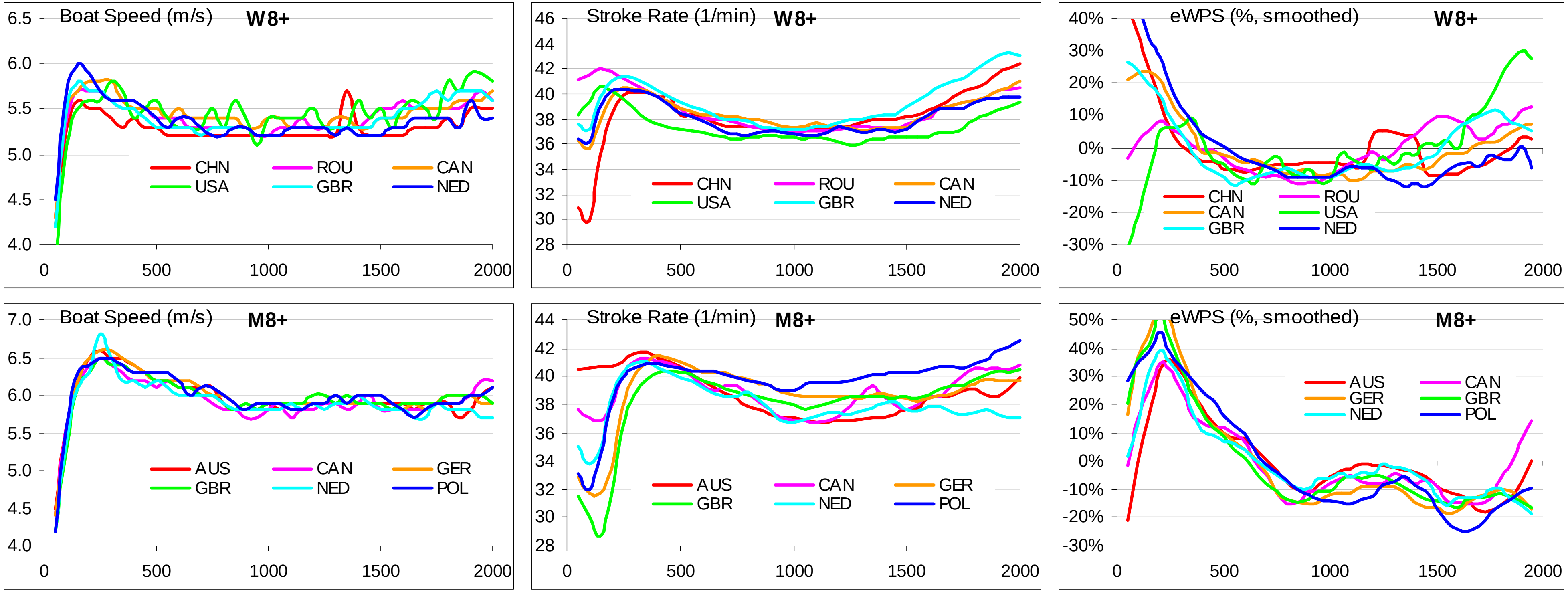
eWPS (%, smoothed) M4x
ITA AUS
CRO GER
RUS POL
0 500 1000 1500 2000


Boat Speed (m/s) W8+
CHN ROU CAN USA GBR NED
Stroke Rate (1/min) W8+
CHN ROU CAN USA GBR NED
eWPS (%, smoothed) W8+
CHN ROU CAN USA GBR NED
Boat Speed (m/s) M8+
AUS CAN GER GBR NED POL
Stroke Rate (1/min) M8+
AUS CAN GER GBR NED POL
eWPS (%, smoothed) M8+
AUS CAN GER GBR NED POL