Stroke Rate vs. Distance in Rowing during the Sydney Olympics

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1 Introduction

Perfect organization of the Sydney Olympic rowing regatta and excellent weather conditions allowed the conduction of analysis of racing strategy, something not always possible at major world regattas (Kleshnev, 2001). Moreover, high quality video-footage of all races allowed the possibility to perform measurements of racing rate, analysis of which is presented below.

Surprisingly, characteristics of the stroke rate (SR) versus stroke distance (SD) in rowing have not been examined for a long period of time (Celentano et al., 1974). Some theoretical studies (Martin and Bernfield, 1980, Sanderson, 1986, Zatsiorsky and Yakunin, 1991, Kleshnev, 1996) have made suggestions, however, all such works have a lack of real rowing data and, therefore, cannot assist coaches in their practical work.

The problem of the choice of adequate SR is one of the first and most important considered by a coach during preparation for races and the race itself. If one is targeting higher stroke rate then he/she should emphasise speed and speed-endurance training. If coach wants to achieve longer stroke distance then he/she should put more efforts in strength, strength-endurance and flexibility work. Variation of SR can play a decisive role during the race.

In this study we will attempt to analyse the following characteristics of rowing performance:

- common trends of the SR and SD relative to boat speed;
- prognostic SR and SD in different boat types;
- distribution of “SR vs. SD” accents in medal winners;
- “SR vs. SD” during the race (over the start, middle and finish);
- specific features of the crews from different countries;
- some modelling of SR and SD.

2 Methods

Boat speed for each quarter of the race was derived from the official results of Sydney Olympic rowing regatta. Stroke rate was taken from video footage of the races.

The measurements were computed using a self-designed eight-channel system. The system consists of one master unit connected to PC though a serial port and eight smaller units connected to the master. Each of the eight units has two buttons, which can be used for timing of the race and SR measurement. One button was clicked at the beginning of each stroke (at catch) over the race from the captured footage being played through a monitor. Time data was collected in a PC using self-designed software. Then data was filtered and average SR for each 500m piece was calculated.

The total number of measured races was 53 (39 heats and all 14 A finals). The first three places from each race were measured, because the data on other crews was usually not available over the final sections of the race. The total number of 159 (53 races by 3 lanes) average SR values over 2000m and 636 (159 by 4pieces) values over 500m were analysed.

To estimate representation of the measurements we derived the ratio of the measured strokes to their total number over each piece of the race, which was calculated on the basis of piece time and average SR. Only pieces with ratio of measured strokes higher than 10% (6-7 strokes) were taken into account (nineteen 500m measurements were rejected). The average ratio of 40.9% was sufficient to prove validity of the measurements.

3 Results and Discussion

3.1 SR and SD at different boat speed

First of all, let us mention that boat speed highly correlates with observed SR (r = +0.75) and SD (r = +0.71). Figure 1 graphically shows these dependencies. This means that faster (bigger) boats usually have higher SR and longer SD.

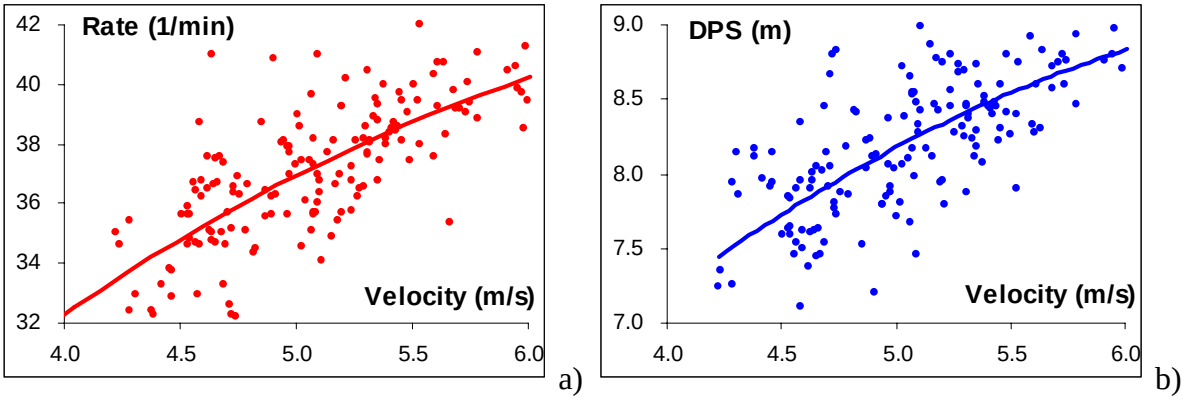

Figure 1. Dependencies of the SR (a) and SD (b) on boat speed (Average data over 2000m).

The dependence of SR on boat speed can be expressed by the following equation:

$$y = -0.603813x^2 + 10.397554x \qquad (1)$$

and the equation for SD(speed) dependence was:

$$y = -0.000586x^2 + 0.158820x \qquad (2)$$

3.2 Prognostic SR and SD in different boat types

Having the above regressions and prognostic speed ("Gold Standards") in different boat types, we can derive prognostic SR and SD.

Table 1. Prognostic and measured parameters of the medal winners in different boat types on Sydney Olympics.

	Prognostic				Measured			Ratio to Prognostic		
Boat Type	Time (min:sec)	Speed (m/s)	Rate (1/min)	SD (m)	Speed (m/s)	Rate (1/min)	SD (m)	Speed (%)	Rate (%)	SD (%)
W1x	7:12	4.63	35.2	7.89	4.46	33.5	7.99	96.3%	95.2%	101.2%
M1x	6:32	5.10	37.3	8.20	4.88	35.9	8.16	95.6%	96.1%	99.5%
W2-	6:53	4.84	36.2	8.03	4.63	38.4	7.24	95.6%	106.0%	90.2%
M2-	6:14	5.35	38.3	8.37	5.08	38.8	7.85	95.0%	101.3%	93.8%
W2x	6:38	5.03	37.0	8.15	4.77	35.8	7.99	95.0%	96.8%	98.1%
M2x	6:02	5.52	39.0	8.50	5.29	38.0	8.34	95.7%	97.4%	98.2%
M4-	5:44	5.81	40.0	8.71	5.61	40.1	8.39	96.4%	100.1%	96.3%
LW2x	6:46	4.93	36.6	8.08	4.72	36.8	7.70	95.8%	100.5%	95.2%
LM2x	6:11	5.39	38.5	8.40	5.22	38.9	8.05	96.8%	101.0%	95.8%
LM4-	5:48	5.75	39.8	8.66	5.52	40.5	8.18	96.0%	101.7%	94.4%
W4x	6:06	5.46	38.8	8.45	5.25	36.2	8.69	96.1%	93.4%	102.8%
M4x	5:34	5.99	40.6	8.85	5.76	40.2	8.60	96.2%	98.9%	97.2%
W8+	5:54	5.65	39.5	8.59	5.42	39.3	8.27	95.9%	99.6%	96.3%
M8+	5:20	6.25	41.4	9.06	5.99	40.7	8.83	95.8%	98.3%	97.5%

"Ratio to prognostic" columns in above table show that in some boat types (W2-, M2-, LM2x, LM4-) SR was higher, in others (W1x, W4x) stroke length was emphasised. The remaining boat types had a balanced ratio of SR to SD.

3.3 Distribution of "Rate vs. Length" accents in medal winners

What SR and SD did medal winners at the Sydney Olympics use? To answer this question, normalised deviations of SR from the common regression line were put into the matrix (Table 2). As could be expected, the highest number of medal winners (20 out of 42 that is 47%) was in the middle of the matrix (balanced combination of SR and length).

Table 2. Matrix of distribution of normalised deviations of the SR in medal winners. Rows represent crews ranking, columns represent SR-SD ratio. In parentheses deviations of the SR (the first) and SD (the second value) from regression line.

	Very low SR Very High SD	Low SR High SD	Middle SR Middle SD	High SR Low SD	Very high SR Very low SD
Gold	W2x(-6.4%,6.8%), W4x(-6.0%,6.4%)	W1x(-3.7%,3.8%), M1x(-3.7%,3.8%), M2x(-2.5%,2.6%), LM2x(-3.1%,3.2%)	M4-(-1.4%,1.4%), LW2x(0.8%,-0.8%), M4x(1.8%,-1.8%), W8+(0.5%,-0.5%), M8+(0.2%,-0.2%)		W2-(14.3%,-12.5%), M2-(8.4%,-7.8%), LM4-(6.4%,-6.0%)
n	2	4	5		3
Silver	W1x(-6.1%,6.5%)	W4x(-4.3%,4.5%), M4x(-2.0%,2.0%)	M1x(-1.3%,1.3%), W2-(2.0%,-2.0%), M2-(1.1%,-1.1%), W2x(-0.4%,0.4%), M2x(-1.0%,1.1%), LW2x(0.3%,-0.3%), LM4-(0.0%,0.0%), W8+(-1.4%,1.4%), M8+(0.8%,-0.8%)	M4-(2.4%,-2.3%), LM2x(4.9%,-4.7%)	
n	1	2	9	2	
Bronze	W4x(-6.9%,7.5%)	W1x(-3.3%,3.4%), M1x(-3.7%,3.8%), M8+(-2.8%,2.9%)	M2-(-1.2%,1.2%), W2x(1.5%,-1.4%), M2x(-0.9%,0.9%), M4-(1.6%,-1.5%), LM4-(1.5%,-1.5%), M4x(-0.2%,0.2%)	W2-(5.1%,-4.8%), LW2x(3.4%,-3.3%), LM2x(2.7%,-2.6%), W8+(2.7%,-2.6%)	
n	1	3	6	4	
Total	4	9	20	6	3

Distribution in the top row was skewed: six gold medallists had a lower SR with correspondingly longer SD and only three of them used extremely high rate. It is interesting, that we observe only scullers in the first group and only sweep rowers in the second one.

3.4 Specific features of the crews from different countries.

Table 2 gives the overall impression about how different crews emphasise either SR or SD.

Table 3. Average SR and SD in medal winners from different countries.

	GER	AUS	ITA	ROM	USA	GBR	FRA
n	6	5	4	3	3	3	3
SR	97.8%	101.5%	102.9%	106.3%	104.3%	98.9%	106.8%
SD	102.4%	98.5%	97.3%	94.4%	95.9%	101.2%	93.7%

Table 3 gives average values of the Rate vs. SD ratio in medal winners from different countries. Germans and British rowers emphasised a longer SD at relatively lower SR. Romanians,

French and Americans rowers had higher SR at shorter SD. Australians and Italians had the most balanced SR and SD.

3.5 SR vs. SD during the race;

How did SR and SD change during the race? Figure 2 shows that on average rowers used higher rate over start and finish pieces of the race and they had longer SD over the middle of the race.

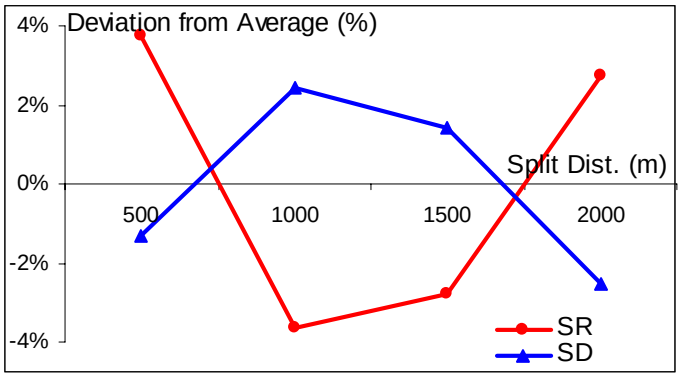

Figure 2. Average deviations of the Rate and SD from regression line over each 500m piece during the race.

The following differences between prognostic SR and measured average over each 500m interval were observed:

- +1.1 str/min over the first one,
- -1.8 over the second,
- -1.4 over the third and,
- +0.7 over the fourth.

No significant differences were found in these parameters between gold and other medallists.

3.6 Some modelling of SR vs. SD

How does the "Rate vs. SD" factor correspond to different levels of boat speed? To draw a more understandable picture we put on the plot (Figure 3) deviations of the Rate and SD from prognostic line together with regression lines that correspond to different boat speeds.

Data points were grouped along the 95% line that reflects the average level of boat speed during regatta (95.9% to prognostic for medal winners and 94.1% for all measured heats and finals).

The normal to the regressions lines corresponds with direction of the boat speed increasing by means of both Rate and SD. However, one can increase boat speed by means of only SR (along with horizontal axis on the plot) or only SD (along with vertical axis). Which way was the most popular?

To answer this question we put numbers on each of four quadrants, which were cut on the plot by the X and Y-axes. The majority of the data points (87 out of 159, 54.7%) were observed in the third quadrant, which corresponds to both negative Rate and SD deviations. Fifty-five data points (34.6%) were observed in the second quadrant, which has negative Rate and positive SD deviations. Only seventeen data points (10.7%) were observed in the fourth quadrant with positive Rate and negative SD deviations. This means that most of the crews used a balanced ratio of the Rate and SD, the second popular trend was towards longer SD and only a few crews emphasised higher SR.

We analysed dependence of modelling speed on both SR and SD. Correlation of percentage to prognostic boat speed with the SR deviation was absolutely insignificant (r=-0.06). However, its correlation with SD deviation was positive and just a little below significance criterion (r=0.22). This means that that longer SD at sufficient SR is more preferable for achieving higher boat speed.

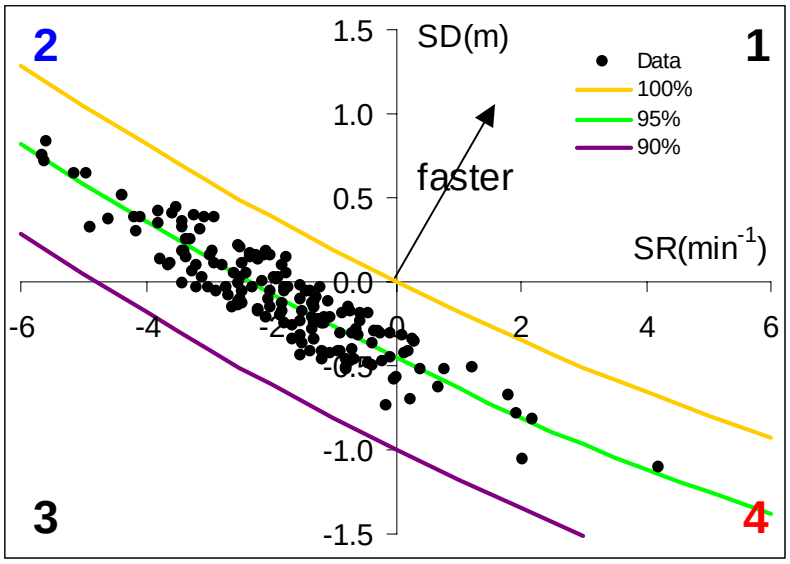

Figure 3. Deviations of the Rate and SD from prognostic line (measured data) relative regression lines that correspond to different boat speeds.

4 Conclusion

The results of this paper could be useful for rowing coaches in a number of ways, including:

- Regressions and prognostic SR and SD can be used for more accurate evaluation of the race and training parameters in any boat type;
- Analysis shows that gold medals were won by means of either higher SR or longer SD. However, this depends upon boat type. Sweep crews used the first way (SR) and scullers the second (SD).
- Significant differences were found between rowers of different countries in “SR vs. SD” accents;
- Modelling the “SR vs. SD” factor brings an idea that balanced or “longer SD” approaches are more preferable for increasing of boat speed than “higher SR” approach.

5 References

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