Work per stroke

This very important biomechanical variable is not used by coaches and rowers very often yet. We are now focusing on the work per stroke (***WpS***) and defining its main relationships with the rower's performance.

WpS can be defined as an integral (sum) of the products of the immediate force ***F*** and linear displacement ΔL, or the torque ***M*** and angular displacement $\Delta\varphi$ over the drive time:

$$WpS = \int F\, \Delta L = \int M\, \Delta\varphi \qquad (1)$$

The main determinant of the performance is rowing power ***P***, which is ***WpS*** per unit of time ***T*** (s), or product of ***WpS*** and rowing rate ***R*** (1/min):

$$P = WpS / T = WpS\ R/60 \qquad (2)$$

Therefore, the ***WpS*** combines two of the three main components of power: force and length, but excludes the third one – stroke rate. As **<u>*WpS* does not depend on the stroke rate, it is a very useful indicator of the effectiveness of a rowing stroke at various training and racing intensities</u>**: from long steady-state rowing, to short sprints.

If the handle force is plotted relative to the drive length or oar angle, the ***WpS*** is equal to the area under the force curve. Fig.1 shows an example of force curves in a pair, where the ***WpS*** of both the stroke and bow rowers is the same, but the force and length are quite different: stroke has a higher peak force, but shorter length, than bow.

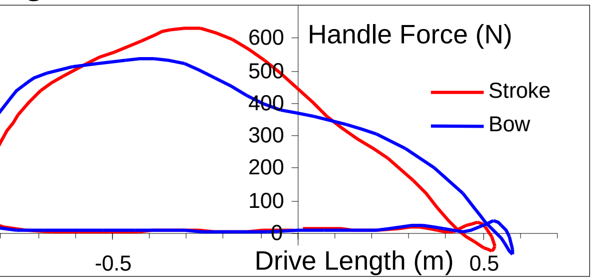

Fig.1

What is better for increasing ***WpS***: to maximise drive length, or increase force? Of course, it is impossible to give a single answer for all rowers, because the optimal ratio of the length and force depend on individual specifics and circumstances (boat type/speed and duration of the exercise). The following considerations may help to find the optimum.

As ***WpS*** is a product of length and force, shortening the length by, say, 1% requires the same 1% higher average force to maintain the constant ***WpS***. At values of stroke length 1.6m and an average force of 350N (average target values in 14 Olympic categories), 1.6cm shorter length (about 1.1deg in sculling and 0.9deg in rowing) require 3.5N higher average force and 6.5N higher maximal force (at a constant shape of the force curve with 55% ratio of the average to maximal forces). This number varies depending on the rower's category (from 5.5N in lightweight women to 8.5N in open men) and the shape of the force curve: it could be up to 10N at a "slim" shape with a 45% ratio, which is very common in novice and intermediate level rowers. Also, at a shorter length, it is quite likely that the force curve becomes "slimmer" (correlation factor r=0.42), because shorter catch angles make the gearing lighter (RBN 2007/03), which requires faster movement at catch, so it is more difficult to increase force quickly. With very rough approximation**: <u>1° shorter length would require up to 1 kg (10N) higher maximal force to keep the work per stroke constant, and vice versa</u>.** There are two other factors to consider for selection of an optimal length/force ratio:

1. Rowing rhythm. Shorter length makes the drive time shorter and rowing rhythm lower (RBN 2012/05), and vice versa, which gives more time on recovery, but shortens the propulsive phase. So the length is important, but it should not be too long, otherwise a rower has to rush on recovery.
2. Endurance factor. At long distances, it is more difficult to maintain high force, than long length, while at sprints; rowers usually shorten the length at higher forces.

To compare ***WpS*** at various stroke rates, we invented a method, which requires only speed and stroke rate inputs (1, RBN 2004/03, 2005/10, 2007/10). The following table shows the target ***WpS*** for Olympic boat types, which required achieving prognostic boat speed (at the level of world records, RBN 2012/07). The right columns show 500m splits on a Concept2 erg, which corresponds to the target ***WpS*** at various rates.

Boat type	Target time	Target rate	*WpS* (J)	500м erg splits					
				20	24	28	32	36	40
M1x	06:32.5	37	892	1:46	1:39	1:34	1:30	1:27	1:24
M2x	06:02.1	39	846	1:47	1:41	1:36	1:32	1:28	1:25
M4x	05:33.2	40	825	1:48	1:42	1:37	1:33	1:29	1:26
M2-	06:08.0	38	789	1:50	1:43	1:38	1:34	1:30	1:27
LM2x	06:07.2	36	783	1:50	1:44	1:39	1:34	1:31	1:28
M4-	05:37.0	40	750	1:52	1:45	1:40	1:36	1:32	1:29
M8+	05:18.6	41	732	1:53	1:46	1:41	1:36	1:33	1:30
LM4-	05:42.0	40	705	1:54	1:47	1:42	1:38	1:34	1:31
W1x	07:11.5	35	686	1:55	1:48	1:43	1:39	1:35	1:31
W2-	06:52.9	36	667	1:56	1:49	1:44	1:39	1:36	1:32
W2x	06:39.5	37	649	1:57	1:50	1:45	1:40	1:37	1:33
W4x	06:08.5	38	632	1:58	1:51	1:46	1:41	1:37	1:34
W8+	05:53.1	39	615	1:59	1:52	1:47	1:42	1:38	1:35
LW2x	06:47.0	36	550	2:04	1:57	1:51	1:46	1:42	1:38

For different target speeds, corresponding percentages of the splits above could be used, but ***WpS*** values should be changed as a cube of the proportion to the target speed: e.g. 10% lower speed corresponds to about 27% lower ***WpS*** ($0.9^3 = 0.73$). This table may help to find an optimal combination of the stroke length and force at various durations and intensities.

References

Kleshnev V. (2006) Method of analysis of speed, stroke rate and stroke distance in aquatic locomotion. In: XXII International Symposium on Biomechanics in Sports, Salzburg. pp 104-107.