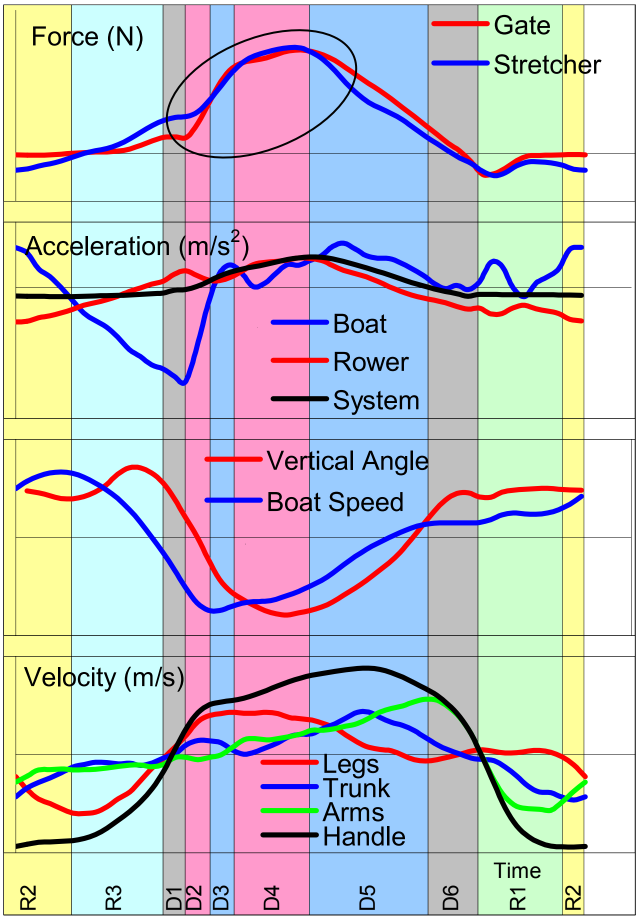
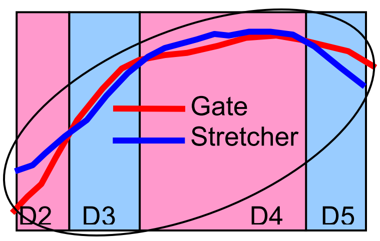
Facts. Did you know that...

✓ …coordination of the handle/gate and foot-stretcher forces during the drive phase is not as simple as it appeared to be from the first glance? Below are typical graphs of biomechanical parameters in M1x together with micro-phases of the stroke cycle (D1-D6 drive, R1-R3 recovery):





There are six micro-phases in the drive phase: D1 blade insertion, D2 initial rower's acceleration, D3 initial boat acceleration, D4 the main rower's acceleration, D5 the main boat acceleration, D6 blade extraction.

The main rules of interaction between the rower and boat masses are: more push (higher foot-stretcher force, legs work) means greater acceleration of the rower's mass; more pull (higher handle/gate force, upper body work) means greater boat acceleration. In previous publications (RBN 6,11/2002) we have emphasized the importance of the rower's mass acceleration, which determines amount of kinetic energy accumulated during the drive and, hence, average speed of the rowers-boat system. This remains true with one important addition: rowers need a good support to push their bodies forward. Emphasis on push or pull (rower's or boat acceleration) changes four times during the drive phase:

- First, rowers have to push to accelerate their body mass and decelerate the boat, because they have to change direction of their movement from the stern to bow at catch (D1 – D2). The quicker these micro-phases, the better.
- Then, during the first pull phase rowers accelerate the boat to create faster moving support on the foot-stretcher to further accelerate their bodies. This micro-phase D3 **initial boat acceleration is extremely important for performing effective drive phase**. In some crews this phase can absent. Fast increasing of the handle force is the main condition of its presence.
- During D4 rowers push the stretcher again to accelerate themselves and accumulate the main part of kinetic energy. Effectiveness of this phase depends on amount of gained boat speed during the previous D2 and fast powerful legs drive.
- The final boat acceleration micro-phases D5 and D6 utilize more pull by means of trunk and arms work. Forces and total system acceleration decrease during this phase and rower's acceleration become negative transferring kinetic energy to the boat.

This push-pull-push-pull coordination during the drive requires significant coordination and "boat feel" from rowers.

Ideas. What if...

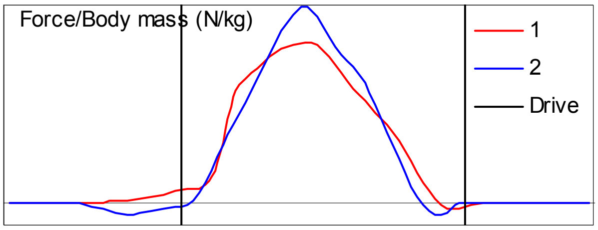
? …we correlate above facts with specifics of rowing technique, which can be found in some top rowers? Famous coach Marty Aitken expressed a guess that "grabbing the arms" at the beginning of the drive can help more effective initial boat acceleration during D3. This "arms grabbing" generally considered as a technical mistake by majority of rowing coaches, but it can be found in technique of such a great rowers as Steven Redgrave, Kathrin Boron and other Olympic and World champions. I think that this guess is correct and "arms grabbing" helps them to increase the handle force quicker and create faster moving support on the stretcher. However, some other great rowers manage to do initial boat acceleration without "arms grabbing".

Contact Us:

✉ ©2003 Dr. Valery Kleshnev, AIS/Biomechanics
tel. (+61 2) 6214 1659, (m) 0413 223 290, fax: 6214 1593
e-mail: kleshnevv@ausport.gov.au

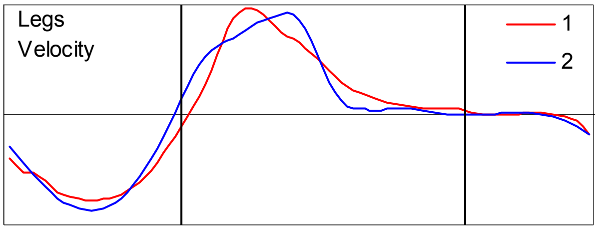
Facts. Did you know that...

✓ … increasing the force faster at catch is very important for achieving efficient rowing technique? Below are force curves (as a ratio to body mass) of two crews, where the crew 1 increases the force much quicker than the crew 2, but crew 1 has relatively lower maximal (7.27 and 8.84 N/kg, correspondingly) and average (3.84 and 4.09 N/kg) force application:

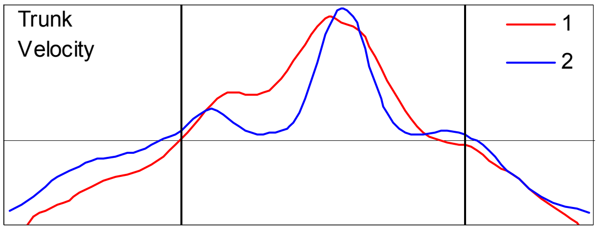


1

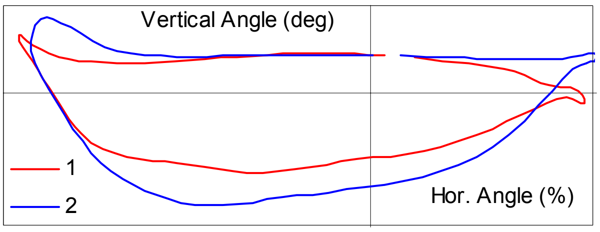
It is also important, that the first crew increases the force by means of faster leg drive, good connection with the trunk work and more horizontal and shallower blade path:



2

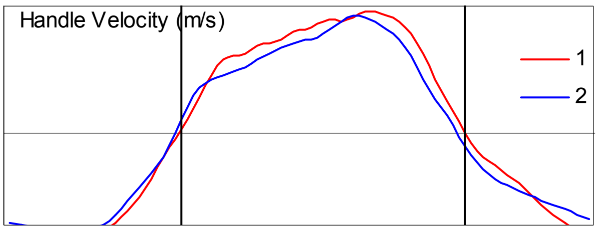


3



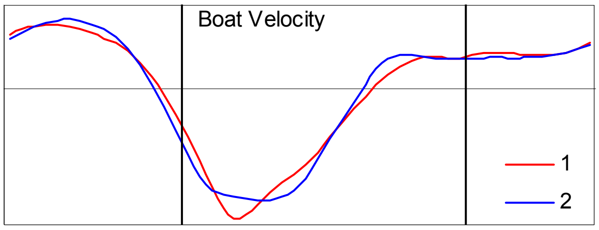
4

As the consequence, the handle velocity of the first crew increases at catch up to higher value and maintain it longer during the drive:

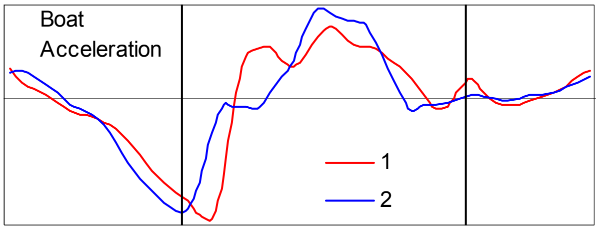


5

The boat speed and acceleration curves of the first crew have deeper negative peak at catch (7.6 and 7.1 m/s^2), but much quicker increase afterwards.

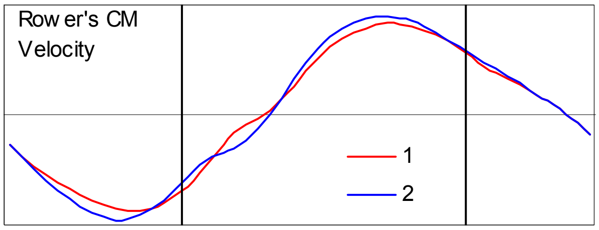


6

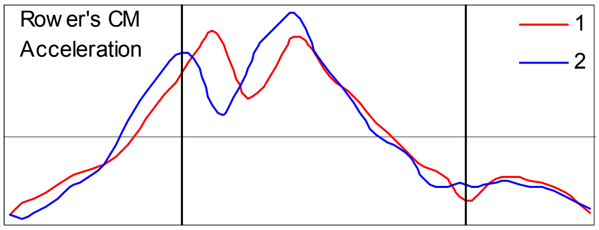


7

This creates faster moving support on the stretcher and helps to accelerate rower's centre of mass (RBN 1/2004):



8



9

We can figure out three main reasons of higher efficiency and better performance of the first crew:

- Higher power production due to higher handle speed and in spite of lower force application (4.06 and 3.83 W/kg, 5.6% difference equal to 6s gain over 2000m);
- Lower fluctuations of the boat speed (deviations were 0.70 and 0.72 m/s), which cause higher boat velocity efficiency (98.17% and 97.64%, 2s faster over 2000m);
- Lower inertial losses caused by lower fluctuations of the rower's CM speed (9.4% and 11.4%, 2s faster over 2000m).

Finally, the overall gain due to better technique of the first crew was approximately 10s over 2000, which was nearly equal to the margin between two crews in the race.

Contact Us:

✉ *©2003 Dr. Valery Kleshnev*
kleval@optusnet.com.au (m) +61(0)413 223 290

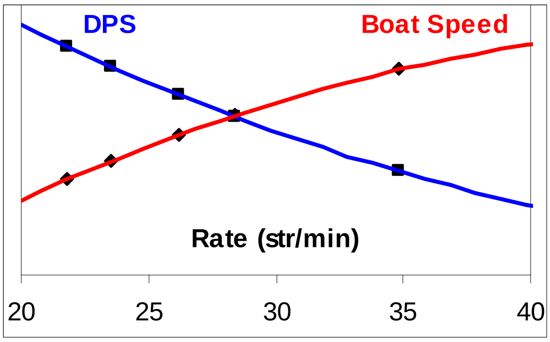
Ideas. What if...

✓ …you use the shape of the DPS (Distance per Stroke) trend as a measure of stability of the force application and stroke length at different rates? Importantly, you don't need any biomechanical equipment to find it out.

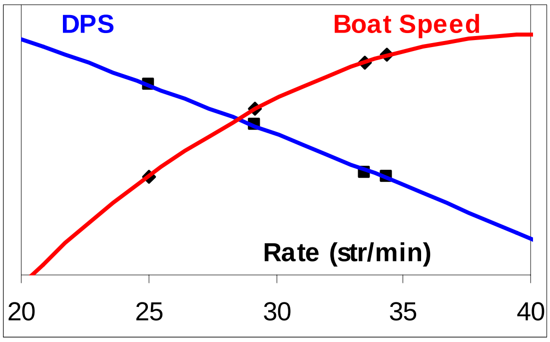
To do this, firstly, you should perform a step test with increasing stroke rate. You need to measure the rate very accurately or, better, count number of strokes during whole piece and then derive the rate.

Secondly, you need to input the data into a spreadsheet (e.g. Microsoft Excel) and plot the boat speed and DPS relative to the stroke rate.

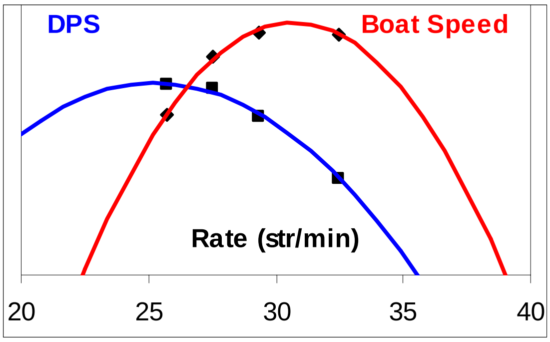
Finally, add the 2nd order polynomial trend lines using right click and local menu. Set desired "Forecast" in "Format Trendline-Options".



1



2



3

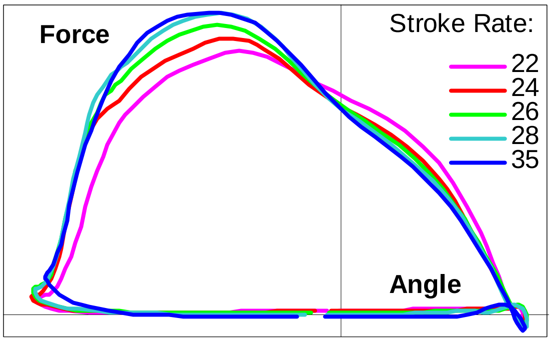
In the figures above there are three examples of the DPS and boat speed trends for different crews. The first crew increases the boat speed with the stroke rate nearly linearly. The DPS trend is concave at the top. It always goes down in all crews because the cycle time shortens at higher rate and boat travels shorter distance per cycle.

The second crew has linear DPS trend, but the speed trend bends down.

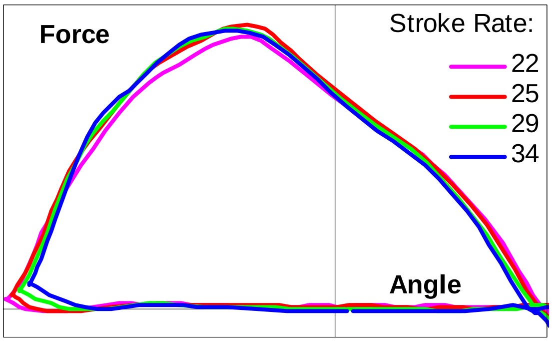
With the third crew both DPS and speed trends are concave at the bottom. This crew starts decreasing the boat speed, when the stroke rate increases higher than certain value (here it is 32 str/min).

Below are corresponding force-angle curves of these three crews. You can see that the first crew managed to increase average force significantly at high rates, providing nearly constant stroke length. Usually, good crews increase force more during the first half of the drive and drop it down a little during the second half. It is interesting that this ability correlates with the earliest position of peak force.

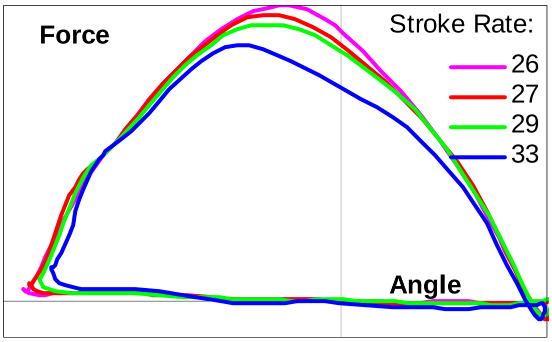
The second crew maintains nearly constant forces, but decrease stroke length at high rate. The third crew decreases significantly both stroke length and force application.



1



2



3

You can practice this method at different distances and comparing the trends, which brings the endurance factor into analysis. Just don't let rowers cheat applying less force at lower rate ☺.

Contact Us:

✉ ©2004 Dr. Valery Kleshnev
kleval@optusnet.com.au (m) +61(0)413 223 290

Ideas. What if...

✓ …you use simple "gadgetry" to give feedback on some biomechanical parameters and to correct them in a desired direction? Below are three examples of some "gadgetry":

1. You can use small plastic straw mounted on the stern of the boat to monitor instantaneous boat speed. The straw should be bent around the stern and fixed with some tape in such a way that under-water end is horizontal and above-water end is vertical.

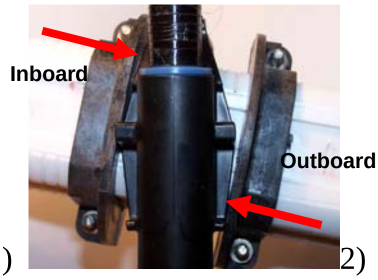
The height of the water jet is proportional to the square of instantaneous boat velocity. This means that the height increases four times, when the boat speed increases twice. It is difficult to give a table of corresponding values because they depend on geometry of the straw. You can calibrate the jet, when towing the boat, if you need.

You can make the straw longer and place its vertical end on a rigger, which allows it to be seen by all crew members. A small colorful ruler can help to evaluate the boat speed.

The best crews have increasing boat speed during the drive phase, as we shown it in the RBN 2/2004. Therefore, it is important to see the increasing of the height of the water jet during the drive, instead of maintaining it at a constant level.

The picture of the straw-jet below was kindly supplied by Australian coach Nick Garratt, who successfully uses this gadget.


1)



2)

2. You can use the second button on the oar sleeve to control depth of the blade in the water
and make the drive more horizontal. The second button should be mounted on the outboard part of the sleeve:

When the oar blade goes down during the drive, the top of the original button pushes the gate from inside and the bottom of the sleeve slides inward the gate. The second button prevents this sliding at certain point and, therefore, limits the maximal depth of the blade in the water.

Position the second button in the following way: Level the boat with rowers on water and put at the blade at desired depth, then contact the second button with the gate and tighten it. Because of the big leverage, the force at the second button is quite high, so it makes sense to fix it with screws to the sleeve, when you find its optimal position.

As a positive side effect, the second button will prevent pulling the oar inward, which happens in some rowers at the end of the drive.

3. Another very simple gadget is a piece of string, which can be used for synchronization of the rowers' movements in crew boats.

You can connect sliding seats of two or more rowers with the string, which will give you synchronization of the legs movements. Obviously, the length of the string must be equal to the distance between riggers. You can attach a small rigger to the side of the seat, which prevents catching the string on the stretcher or the rower's legs.

You can connect the rowers' trunks at shoulder level, which helps to synchronize the body swing. The simplest way is to use just safety pin to attach the string to the rower's cloth. In this case, subtract the trunk depth from the length of the rope.

With some creativity you can do it even with oars! Connect them together at the middle of inboard or outboard and you will see synchronization at the oar angles. You can attach a little wire loops to the oar shaft with a tape. Then hook the string to one oar, wrap it around the shaft and hook to the other one.

General recommendations for using these gadgets are:

- ✓ The main target is giving feedback to the athletes and coach and correction of the rowers technique that assume changes in motor pattern in the brain;
- ✓ Coach and rowers must clearly understand what they use a gadget for, what problems it'll help to fix and what can be the side effects;
- ✓ Quite often you can fix one thing, but break another one (or two, or more);
- ✓ Do not try to replace the rowers' motor pattern with their habit to use the gadget, i.e. rowers should maintain achieved improvements after the gadgets removal.

We would greatly appreciate any information about other gadgets, which you use in rowing.

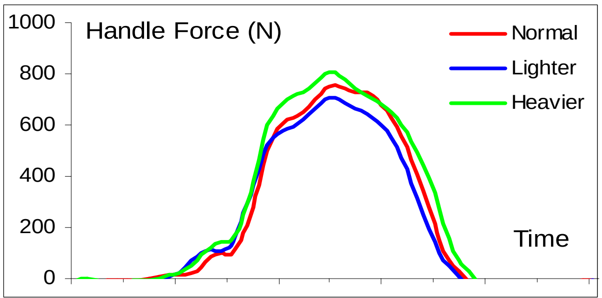
Contact Us:

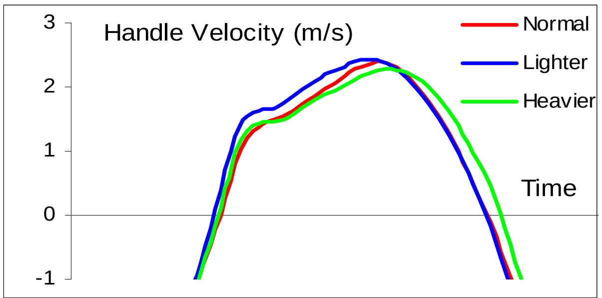
✉ *©2004 Dr. Valery Kleshnev*
kleval@optusnet.com.au *(m) +61(0)413 223 290*

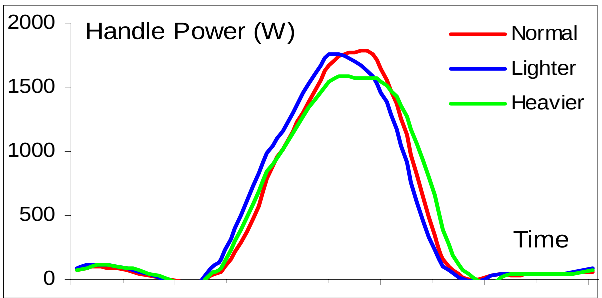
Facts. Did you know that...

✓ …changing the gearing ratio is the simplest method of speed and power drilling in rowing? The best way is to vary outboard oar length, because in this case you do not need to change geometry of the rower's movements. Rowing with shortened outboard will make the gearing ratio lighter and increase the speed of the drive, but decrease force application. On the contrary, increasing of the outboard will make the gearing heavier and change force/velocity ratio in other direction.

Below are graphs of the handle force, velocity and power during rowing (single scull) with normal gearing (88cm inboard, 290cm oar length), lighter (3cm shorter outboard) and heavier gearing (3cm longer outboard). Stroke rate was 32-33str/mim.







If we compare the normal and light gearing, then the main difference in the force curves is during the second half of the drive, where the force was about 40N less with lighter gearing. On the contrary, handle velocity was about 0.2m/s higher during the first half, although it was the same "after the pin". These changes were opposite during the heavier gearing. The rower apply about 40N higher force at the same speed "before pin", but then the handle speed was 0.1m/s slower and the force is similar to the normal gearing. The drive time appeared to be 0.06s longer with heavier gearing.

Peak power was similar during the normal and lighter gearing, although achieved earlier during the lighter gearing. Peak power was lower during the heavier gearing, but average rowing power was the highest (495W), because of longer drive time. It was lower during the lighter gearing (491W) and the lowest during the normal gearing (481W).

Ideas. What if...

✓ …: In RBN 4 and 5/2001 some examples of speed and force drills were described with regards to their biomechanical features. Here are some more examples of these sorts of drills.

Power drills:

You can increase load on desired body segment by means of applying extra mass to a specific part of the rower-boat-oars system:

✓ If you attach some extra weight onto the boat, you'll increase the load to the legs.

✓ To increase load on the trunk, you can use sand-bags attached to the rower's shoulders. Alternatively, you can make a jacket with pockets on the shoulders and fill them with sand. This drill is very useful for developing a good drive finish and body return.

✓ If you want to emphasise arms work and oar handling, you can attached extra mass to the oar. Put the extra mass on both inboard and outboard maintaining balance of the oar.

Preserving of the rowing kinematical structure is a general rule for these drills. Therefore, the added mass must not be higher than 4-5% of the body weight.

Speed drills.

Towing with speed boat has already been described (4/2001). This is alternative method:

✓ Rowing in faster boats (8+, 4x) is widely used as a very good speed drill for small boats (2-, 1x). However, some coaches used quite interesting modifications of this method. They put sculling riggers on the bow seats of the eight and make the sculler row at a very fast speed. Alternatively, two sweep seats can be set up on a bow of the quad. These combinations could be useful in small clubs, where there are not enough rowers or scullers to make big boats.

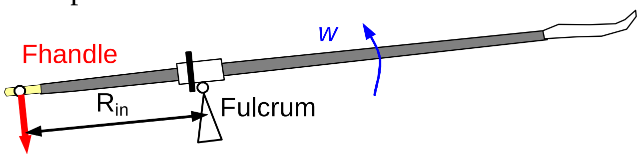
Contact Us:

✉ *©2004 Dr. Valery Kleshnev*
kleval@optusnet.com.au (m) +61(0)413 223 290

Facts. Did you know that...

✓ …the method of power calculation in rowing is quite complicated issue? It is very important because power production is the main characteristic of a rower's performance and the main component for calculation of the rowing efficiency. We can calculate power in rowing in three ways:

1. Traditional method of the power calculation in rowing is based on the assumption that the rower applies power to the handle only. Oar works as a lever with a pivot point (fulcrum) at the pin:

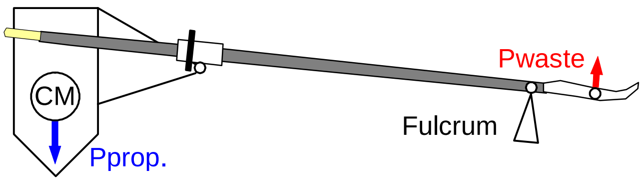


In this case power equates to a product of the torque τ and angular velocity ω, or to a product of the force applied to the handle ***Fh*** and the linear velocity of the handle ***Vh***:

$$P = \tau\,\omega = (\tau / R_{in})\,(\omega\,R_{in}) = Fh\,Vh \qquad (1)$$

, where R_{in} is the inboard length. To be more accurate, R_{in} is the distance from the pin (+2cm = half of the gate width) to the middle of the handle (-6cm for sculling, -15cm for sweep).

2. Propulsive-waste power. Why we assume that the pin is the fulcrum? In fact, pin moves with the boat with quite irregular acceleration. Therefore, the boat is not an inertial reference frame in Newton mechanics. If we set the reference frame based on Earth (or water), we will find the oar fulcrum somewhere close to the blade:



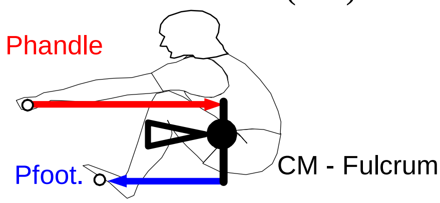
There are two components of the power here: propulsive power **Pprop** on the inboard side from the fulcrum and waste power **Pwaste** on the blade side. Propulsive power equates to the scalar product of the force vector acting on the rower-boat system ***Fprop*** and velocity of the system centre of mass ***Vcm***: ***Pprop = Fprop Vcm (2)***

Waste power equates to the scalar product of the blade force vector ***Fblade*** and velocity of the centre of pressure on the blade (slippage of the blade through the water) ***Vslip***.

$$Pwaste = Fblade\;Vslip \qquad (3)$$

This method is not very practical, because velocity of the system centre of mass ***Vcm*** can not be determined accurately and easily. The position of the centre of pressure on the blade affected by the blade hydrodynamics, boat speed and oar angle and also can't be determined easily.

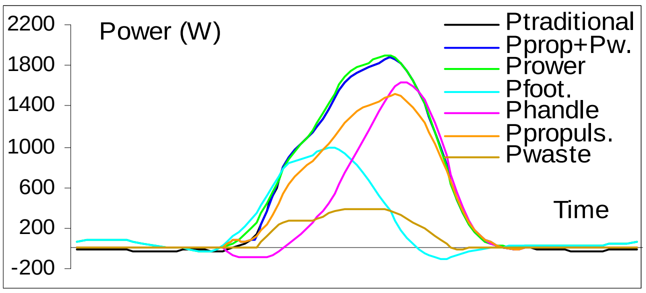
3. Rower's power. In fact, the rower is the only source of mechanical energy in rowing. The rower applies force (i.e. power) only at two points: the handle and the foot-stretcher. The fulcrum here is the rower's centre of mass (CM):



The power can be calculated as a sum of the handle and foot-stretcher powers and each of them equates to a scalar product of correspondent force and velocity vectors:

$$P = Ph + Pf = Fh\,Vh + Ff\,Vf \qquad (4)$$

✓ Graphs below show the power calculated using all three methods, and also their components: propulsive, waste, handle and foot-stretcher powers (M1x, rate 32str\min)



You can see a very good correspondence between the traditional and the propulsive-waste power curves. The average rowing powers were P_1 = 462.9W, P_2 = 465.5W and P_3 = 494.4W. The reason of the difference between the first two and the rower's power is that the last includes inertial component, which is necessary to move the boat relative to the rower. In this case inertial losses were 6.4% of the total rower's power. The blade propulsive efficiency equates to a ratio of the propulsive to the total power, which was 80.4% in this case. The handle/foot-stretcher power ratio was 60%/40% in this case. It depends on the shape of the force curve: foot-stretcher share increases at force emphasis at catch.

References

Kleshnev V. 2000. Power in rowing. *Proceedings of XVIII Congress of ISBS*, (2) Chinese University of Hong Kong, 662-666

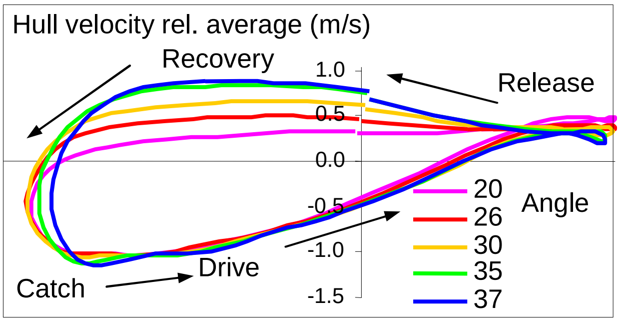
Contact Us:

✉ *©2004 Dr. Valery Kleshnev*
kleval@optusnet.com.au (m) +61(0)413 223 290

Questions and Answers:

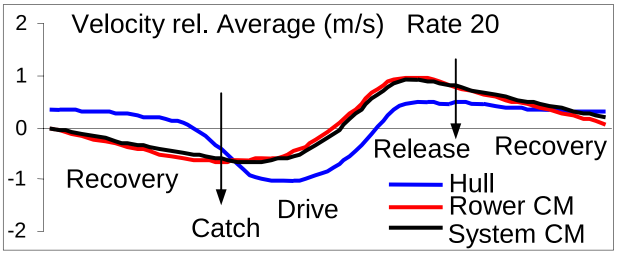
Q: Stuart Wilson of Jeff Sykes & Associates asked: Is that true that "…the peak speed of the hull is just before the catch, not as previously thought, just after the finish?"

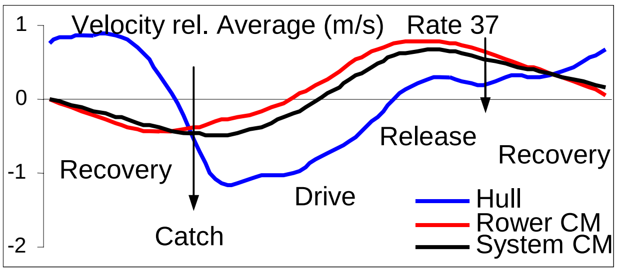
A: In fact, this depends on the stroke rate. Below are typical graphs of the hull speed at different stroke rates (M1x, X-axis is the oar angle):



You can see that at low rate 20 str/min (pink line) the old thought is true. However, the hull speed increases through recovery at higher stroke rates. The higher the rate, the closer the peak speed to the catch.

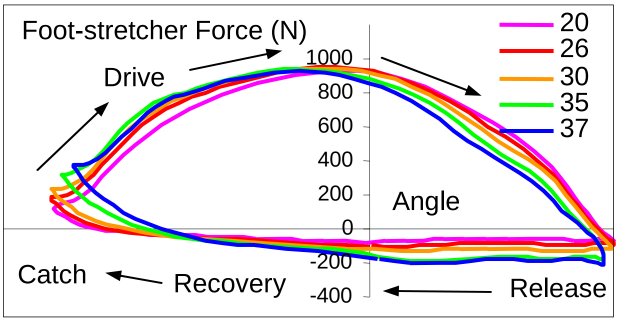
The reason for this phenomenon is in interaction of the rower's and the boat masses. The following graphs show velocities of the hull, the rower's centre of mass (CM) and the system CM (rower + hull + oars) at stroke rates 20 and 37:





In both cases, the peak velocity of the system CM happens at the end of the drive, when the propulsive force became lower then drags force acting on the hull. At the higher rate the rower's CM velocity decreases much faster during recovery, but boat speed increases. This means the transmission of the kinetic energy from the rower's mass is to the hull. This happens by means of more active pull through the foot-stretcher.

The graphs below show foot-stretcher forces, measured simultaneously with the hull speed:



We assume positive force acts towards the stern (push) and negative acts towards the bow (pull). At lower rating the pull force was about 50N that was lower than the drag force (60N). At the higher rating the pull force exceeds 200N and overcomes the even higher drag force (100N). This creates acceleration of the hull during recovery and increasing of the hull speed.

Above acceleration increases fluctuations of the hull speed and create excessive energy losses. The measure of fluctuations is a variation of the hull speed (ratio of its standard deviation to the average). Generally, the variation increases from 11.7% at the stroke rate 20 up to 13.7% at the rate 40. This decreases the efficiency of the boat speed (ratio of the actual propulsive power to the minimal required for the same average speed) from 96.25% down to 94.79%. This difference (1.5s over 2000m) is quite small compare to the difference in the speed between 20 and 40 str/min.

What can we do to decrease the losses even more? The obvious solution is to minimize the foot-stretcher pull and make the hull speed smoother during recovery. There are two methods of doing this:

1. Avoid too fast body return at the finish of the drive. This method is well described mathematically in (1). From this point, Australian rowing style looks very efficient.

2. Increase the recovery time that means shortening the drive time at the same stroke rate and decreasing the rhythm value (RBN 2003/03). Crews with a fast dynamic drive have more time for the recovery phase and muscles relaxation, and can make boat run more evenly.

References

1. Sanderson, B., Martindale, W. (1986). Towards optimizing rowing technique. Medicine and science in sports and exercise, 18, 454-468.

Contact Us:

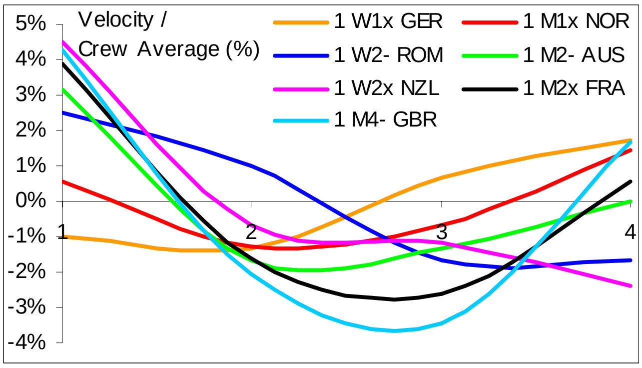
✉ ©2004 Dr. Valery Kleshnev
kleval@optusnet.com.au (m) +61(0)413 223 290

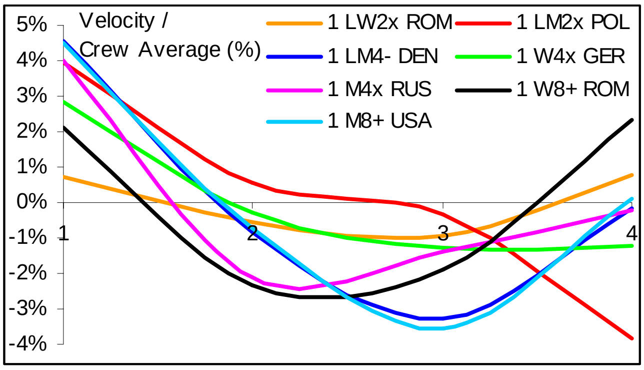
News

The Games of XXVIII Olympiad have just finished in Athens. This Greatest Celebration of Humanity was really marvelous and unforgettable. We all witnessed a very tough competition for medals. Congratulations to all the winners! We wish the unsuccessful crews success with goals next time and hope that biomechanics can be a little help to them.

Facts. Did you know that...

✓ …the average race strategy of the winners of the Athens Olympic games was: 2.9%, -1.0%, -1.6%, -0.1%. This is a slightly different from average over the last 12 years 3.1%, -1.1%, -1.8%, -0.1%. The two charts below show the strategy of each winning crew:





You can see that majority of the winners made their first 500m 3-5% faster than average speed over 2000m. However, there were four outliers: both singles, Romanian LW2x and W8+ began the race much slower than other winners. The most unusual strategy was used by German W1x: -1.0%, -1.3%, 0.7%, 1.7%, which makes the second half 5.1s faster than the first one.

✓ …the lowest variation of the boat speed was shown by Bulgarian and Estonian M1x: 0.70% and 0.71% respectively. Among the winners the most even boat speed was achieved by ROM LW2x (0.87%), NOR M1x (1.21%) and GER W1x (1.42%).

✓ The highest variation of the boat speed was recorded in GER M2-, M8+ and M4x (4.5-4.5%). Among the winners the most uneven boat speed was noticed in GBR M4-(3.52%), USA M8+ (3.32%) and DEN LM4- (3.27%). This sort of variation caused losses about 0.6s over 2000m race (RBN 2003/12).

✓ …we can suspect that the wind didn't blow uniformly during the races at Schinias rowing course, which affect the race strategy. Analysis of the race tactics can be useful, because it shows where the winners gain their advantage RELATIVE to other competitors.

The table below shows a count of each of 12 tactics in each place-takers category. Let us remember that the first number in the tactics represents the fastest 500m piece, and the second is the slowest section RELATIVE average speed of all competitors in the race. (RBN 2003/07)

	Place						
Tactics	1st	2nd	3rd	4th	5th	6th	Total
1-2	1						1
1-3	1			2	4		7
1-4		1	1	6	4	5	17
2-1	1					1	2
2-3	1				1		2
2-4	1			1		3	5
3-1	1	3	1			2	7
3-2	1		1	2		1	5
3-4	2		1		1	1	5
4-1	2	4	6	1	2		15
4-2	2	3	3	2		1	11
4-3	1	3	1		2		7
Total	14	14	14	14	14	14	84

It is interesting that the winners used all tactics except 1-4, which was previously the most popular over the last 12 years. Majority of the winners (9 out of 14) got their advantage over the second half of the race. This could be evidence of very even level of competitors, where nobody can be suppressed psychologically at the start of the race and all crews are prepared to fight until the finish.

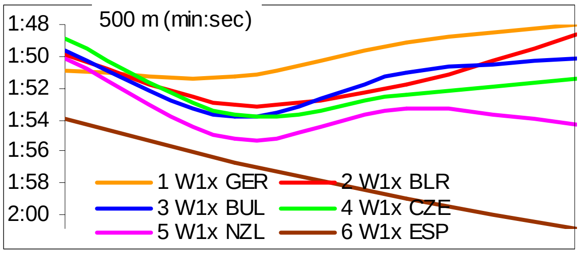
10 silver and 10 bronze medalists out of 14 gained advantage over the final section (tactics 4-1, 4-2, 4-3), while only five winners did the same. This confirms our previous conclusion: "If a crew saves energy for the last 500m, then they have more chances to win a medal, but fewer chances to win a gold medal."

Contact Us:

✉ *©2004 Dr. Valery Kleshnev*
kleval@optusnet.com.au (m) +61(0)413 223 290

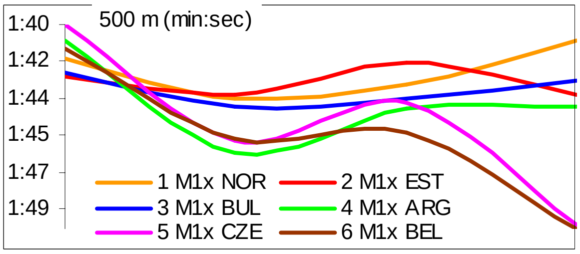
Appendix 1 of the Rowing Biomechanics Newsletter 8(4), August 2004.
Race strategy and tactics in rowing Finals A in the XXVIII Olympic Games in Athens.

W1x



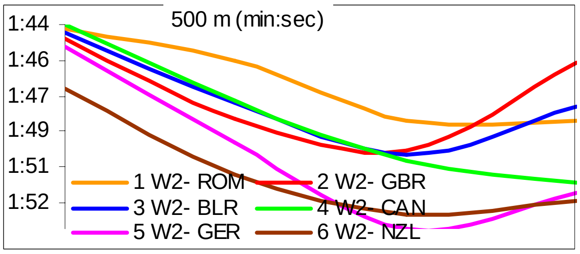
		Strategy				Var.	Tactics
1	GER	-1.0%	-1.3%	0.7%	1.7%	1.42%	4-1
2	BLR	0.8%	-1.9%	-0.8%	2.0%	1.76%	4-1
3	BUL	1.4%	-2.3%	0.1%	0.9%	1.64%	4-2
4	CZE	2.5%	-1.8%	-0.7%	0.2%	1.80%	1-3
5	NZL	2.8%	-1.7%	0.0%	-0.9%	1.97%	1-4
6	ESP	3.2%	0.8%	-1.2%	-2.7%	2.55%	2-4

M1x



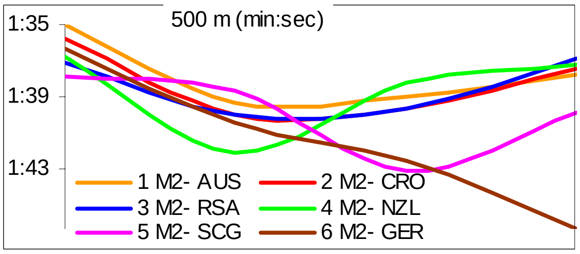
		Strategy				Var.	Tactics
1	NOR	0.5%	-1.3%	-0.7%	1.4%	1.21%	4-1
2	EST	0.2%	-0.6%	0.9%	-0.5%	0.71%	3-1
3	BUL	0.8%	-0.8%	-0.4%	0.4%	0.70%	4-1
4	ARG	2.9%	-2.3%	-0.3%	-0.2%	2.14%	4-2
5	CZE	4.6%	-0.8%	0.9%	-4.4%	3.73%	1-4
6	BEL	4.1%	0.0%	0.2%	-3.9%	3.29%	1-4

W2-



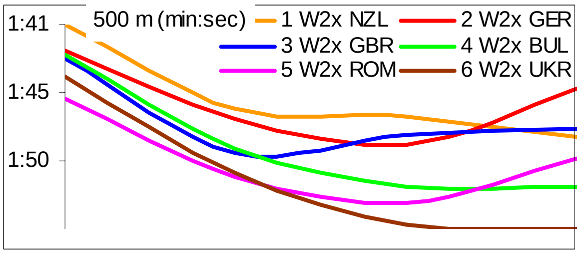
		Strategy				Var.	Tactics
1	ROM	2.5%	1.0%	-1.7%	-1.7%	2.07%	2-1
2	GBR	2.5%	-1.2%	-2.6%	1.4%	2.33%	4-2
3	BLR	3.1%	-0.2%	-2.5%	-0.3%	2.31%	4-1
4	CAN	4.3%	0.7%	-1.9%	-2.8%	3.21%	1-4
5	GER	4.9%	0.5%	-3.3%	-1.8%	3.58%	1-3
6	NZL	3.7%	-0.2%	-2.0%	-1.3%	2.53%	3-2

M2-



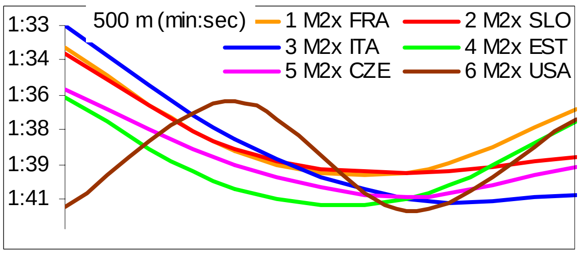
		Strategy				Var.	Tactics
1	AUS	3.2%	-1.7%	-1.4%	0.0%	2.22%	1-2
2	CRO	2.7%	-1.9%	-1.5%	0.9%	2.18%	4-2
3	RSA	1.5%	-1.7%	-1.4%	1.7%	1.83%	4-1
4	NZL	2.1%	-3.7%	0.4%	1.5%	2.59%	3-2
5	SCG	2.2%	1.3%	-3.4%	0.0%	2.44%	2-3
6	GER	5.7%	1.1%	-1.2%	-5.0%	4.45%	1-4

W2x



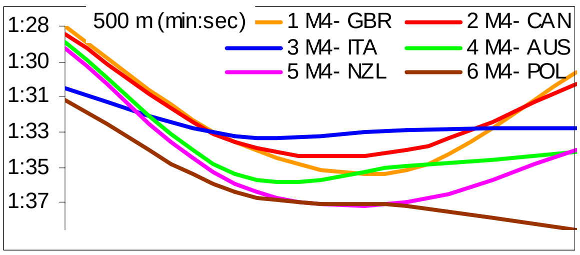
		Strategy				Var.	Tactics
1	NZL	4.5%	-0.7%	-1.2%	-2.4%	3.05%	3-4
2	GER	3.0%	-1.0%	-2.5%	0.7%	2.40%	4-1
3	GBR	3.7%	-2.0%	-0.9%	-0.6%	2.50%	3-2
4	BUL	5.5%	-0.2%	-2.4%	-2.5%	3.74%	1-4
5	ROM	3.6%	-1.0%	-2.4%	0.0%	2.58%	4-1
6	UKR	6.1%	0.2%	-2.8%	-3.0%	4.21%	1-4

M2x



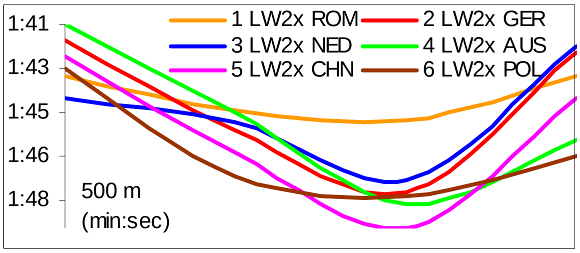
		Strategy				Var.	Tactics
1	FRA	3.9%	-1.6%	-2.6%	0.6%	2.86%	4-2
2	SLO	4.2%	-0.8%	-2.0%	-1.2%	2.80%	1-4
3	ITA	6.1%	0.1%	-2.9%	-2.7%	4.21%	1-4
4	EST	2.8%	-1.9%	-2.3%	1.6%	2.50%	4-2
5	CZE	3.4%	-0.5%	-2.1%	-0.6%	2.36%	3-4
6	USA	-2.3%	3.0%	-2.5%	2.1%	2.88%	2-1

M4-



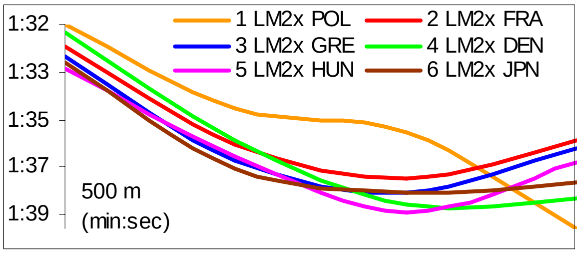
		Strategy				Var.	Tactics
1	GBR	4.3%	-2.1%	-3.5%	1.6%	3.52%	4-3
2	CAN	3.8%	-2.1%	-2.5%	1.0%	2.93%	4-2
3	ITA	1.8%	-0.8%	-0.5%	-0.4%	1.18%	3-1
4	AUS	5.0%	-2.1%	-1.7%	-1.0%	3.34%	1-4
5	NZL	5.4%	-1.9%	-2.8%	-0.2%	3.69%	1-3
6	POL	4.4%	-0.5%	-1.2%	-2.4%	2.97%	2-4

LW2x



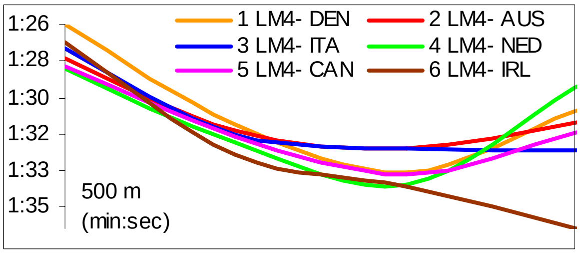
		Strategy				Var.	Tactics
1	ROM	0.7%	-0.5%	-0.9%	0.8%	0.87%	3-1
2	GER	2.4%	-1.0%	-3.3%	2.0%	2.69%	4-3
3	NED	0.5%	-0.4%	-2.5%	2.5%	2.07%	4-1
4	AUS	3.7%	0.3%	-3.1%	-0.7%	2.84%	1-4
5	CHN	3.0%	-0.7%	-3.4%	1.4%	2.77%	1-3
6	POL	3.1%	-1.0%	-1.7%	-0.3%	2.16%	1-4

LM2x



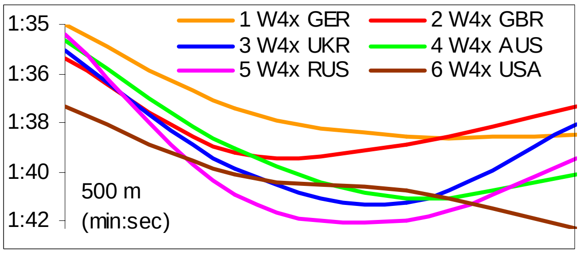
		Strategy				Var.	Tactics
1	POL	3.9%	0.6%	-0.4%	-3.8%	3.20%	3-4
2	FRA	3.2%	-0.6%	-1.9%	-0.5%	2.20%	4-1
3	GRE	3.2%	-0.8%	-1.9%	-0.3%	2.24%	4-2
4	DEN	4.4%	0.1%	-2.2%	-2.0%	3.06%	1-4
5	HUN	3.2%	-0.3%	-2.3%	-0.5%	2.29%	4-3
6	JPN	3.5%	-0.6%	-1.5%	-1.1%	2.31%	4-2

LM4-



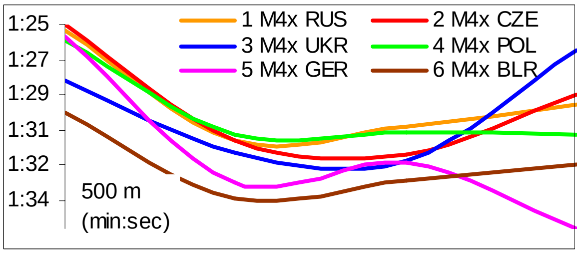
		Strategy				Var.	Tactics
1	DEN	4.6%	-0.8%	-3.3%	-0.2%	3.27%	1-3
2	AUS	3.0%	-0.8%	-1.7%	-0.4%	2.05%	3-1
3	ITA	3.9%	-0.7%	-1.4%	-1.5%	2.59%	3-4
4	NED	2.8%	-1.1%	-3.2%	1.8%	2.72%	4-1
5	CAN	3.2%	-0.5%	-2.4%	-0.2%	2.34%	4-1
6	IRL	6.0%	-0.1%	-1.7%	-3.7%	4.17%	1-4

W4x



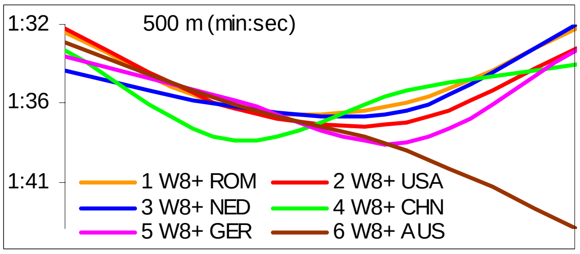
		Strategy				Var.	Tactics
1	GER	2.8%	-0.3%	-1.3%	-1.2%	1.93%	2-4
2	GBR	2.1%	-1.3%	-1.0%	0.3%	1.56%	4-1
3	UKR	3.2%	-1.1%	-2.3%	0.4%	2.36%	4-3
4	AUS	3.7%	-0.3%	-2.0%	-1.2%	2.54%	1-4
5	RUS	4.4%	-1.5%	-2.4%	-0.2%	3.00%	1-3
6	USA	2.5%	0.0%	-0.6%	-1.9%	1.82%	3-4

M4x



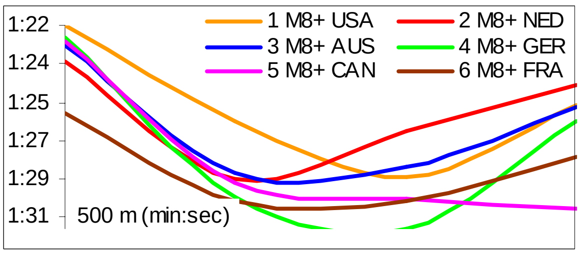
		Strategy				Var.	Tactics
1	RUS	4.0%	-2.1%	-1.4%	-0.2%	2.74%	3-2
2	CZE	4.5%	-2.0%	-2.7%	0.5%	3.27%	4-3
3	UKR	1.7%	-2.2%	-2.6%	3.4%	2.95%	4-1
4	POL	4.0%	-1.3%	-1.2%	-1.3%	2.63%	2-4
5	GER	6.6%	-1.6%	-0.5%	-3.9%	4.51%	1-4
6	BLR	2.8%	-1.8%	-0.9%	0.0%	2.00%	3-1

W8+



		Strategy				Var.	Tactics
1	ROM	2.1%	-2.3%	-1.9%	2.3%	2.50%	4-2
2	USA	2.9%	-1.8%	-2.5%	1.7%	2.64%	4-3
3	NED	0.5%	-1.6%	-1.8%	3.2%	2.34%	4-1
4	CHN	2.1%	-3.0%	-0.2%	1.3%	2.25%	3-2
5	GER	1.8%	-0.8%	-3.1%	2.2%	2.48%	4-3
6	AUS	5.2%	1.6%	-1.1%	-5.2%	4.37%	2-4

M8+



		Strategy				Var.	Tactics
1	USA	4.5%	-0.7%	-3.5%	0.1%	3.32%	2-3
2	NED	2.8%	-3.3%	-0.9%	1.6%	2.71%	3-1
3	AUS	4.2%	-2.5%	-2.2%	0.8%	3.14%	4-2
4	GER	5.9%	-2.6%	-4.1%	1.3%	4.47%	1-3
5	CAN	6.3%	-1.2%	-2.0%	-2.6%	4.16%	1-4
6	FRA	2.9%	-1.7%	-1.7%	0.6%	2.18%	3-1

Questions and Answers:

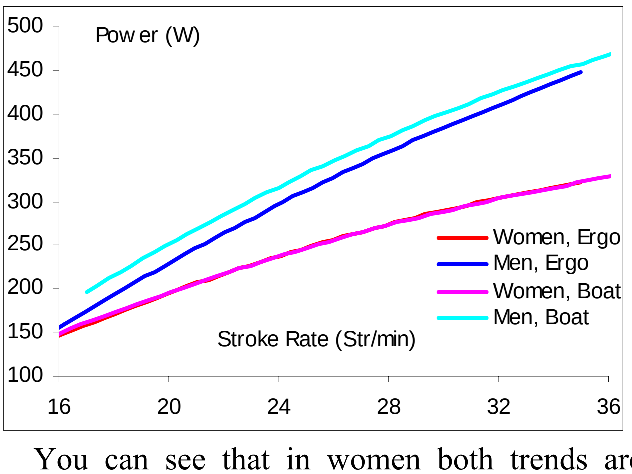
Q: Robert Dauncey from Pembroke College, Oxford asks: “I was wondering whether the power to stroke rate tables you published in January 2002 could be … transferred to the ergo? If not directly, is there a formula to adjust for the ergo?” Other coaches asked similar questions about evaluation of the ergo performance.

A: In general, the answer will be “Yes” for women and “No” for men. This conclusion comes from comparative analysis of our on-water data and ergo data, which was kindly provided by AIS physiologists Dr. Tony Rice and Gary Slater. The data represents rowing power at different stroke rates. The samples volumes were: Men/Ergo n=950, Men/Boat n=3200, Women/Ergo n=854, Women/Boat n=2538. The duration of the workload was four minutes on ergo, and 1.5-2 min on-water.

We assumed that the rowing power **P** is proportional to cube root of square of the athlete weight **W** (1): $\mathbf{P = kW^{2/3}}$. Relative power **k** was calculated for each rower as $\mathbf{k = P/W^{2/3}}$. Then, we derived regressions (trends) of dependencies of the relative power **k** on the stroke rate **r**:

Men/Ergo $k = -0.0106r^2 + 1.3321r - 10.6167$
Men/Boat $k = -0.0124r^2 + 1.3933r - 10.0180$
Women/Ergo $k = -0.0112r^2 + 1.1094r - 6.4277$
Women/Boat $k = -0.0100r^2 + 1.0383r - 5.4343$

Below is the comparison of the trend lines of power on Concept-II ergo and in the boat, derived from the above regressions for 86kg man and 72kg woman (average weights in the samples):



You can see that in women both trends are represented by virtually the same line. In men the boat trend lays noticeably higher. If we assume the **on-water power as 100%** at each stroke rate, then the corresponding **ergo power** will be:

Rate	16	20	24	28	32	36	40
Men	88%	91%	94%	95%	97%	98%	99%
Women	98%	99%	100%	100%	100%	100%	100%

We can speculate two different reasons of this difference in power.

Firstly, shorter duration of on-water workload allowы men to use their strength reserve better, while women do not have such strength.

Secondly, this fact corresponds to findings of Ingham et al. (1), where male rowers were 7.7% faster than female on ergo, but this difference was increased up to 10.9% on water. We can only guess the reason of this phenomena and further research required to make it clear.

Solutions.

Enclosed is a MS Excel™ spreadsheet that will help you to evaluate the power on ergo at different stroke rates and for athletes with different weight. The spreadsheet is built on the basis of above analysis. You can use both power and/or distance/time data in the worksheet.

We would greatly appreciate your feedback on the worksheet. Also, it would be great if you can send us your ergo data, which will help us to develop more accurate evaluation method.

Ideas. What if…

…you use above evaluation for building a training method, which will help to increase drive power of each stroke. This method is similar to DPS-assisted on water method (RBN 4/2001), but it is much easier to implement on ergo with accurate feedback on power and rate.

The idea is to build the power/rate profile for each rower and then try to lift it up, that means more power for each stroke.

When you input the rower’s weight, stroke rate and power into the attached spread sheet, you can use the “Score” values for evaluation of the rower’s performance at each stroke. If you have low scores at low stroke rate, then you need more strength and muscle volume. If your score decrease at higher rate, then you need speed qualities in your muscles.

The next step consists in setting desired higher scores and corresponding power for each rating and attempting to achieve them. Start with lower rate and then move it up.

References

1. S.A. Ingham, G.P. Whyte, K. Jones, A.M. Nevill. Determinants of 2,000 m rowing ergometer performance in elite rowers. Eur J Appl Physiol (2002) 88: 243–246.

Contact Us:

✉ *©2004 Dr. Valery Kleshnev*
kleval@optusnet.com.au (m) +61(0)413 223 290

Questions and Answers:

✓ **Q:** Ben Stevenson of Richmond RC in Victoria wrote: "I was very interested by the topics of January and February this year…

I am particularly interested in the D3 phase. My interpretation of this phase is that it represents the time in which the body 'takes up the strain' and the oar flexes etc. The feeling of this micro-phase would be the 'lock' sensation. As this is wasted energy, and shortens the effective length of the stroke, wouldn't it be better to use a weaker part of the body to effect this stage (ie arm grabbing)? However wouldn't this be counteracted by the arms letting go once the stronger leg pressure comes on, and wouldn't this then reduce the effectiveness of the strongest drive phase?

How about other options like extending the shoulder joint before the catch? Or because the legs are in a relatively weak position at the catch, wouldn't they be a better tool for locking on?

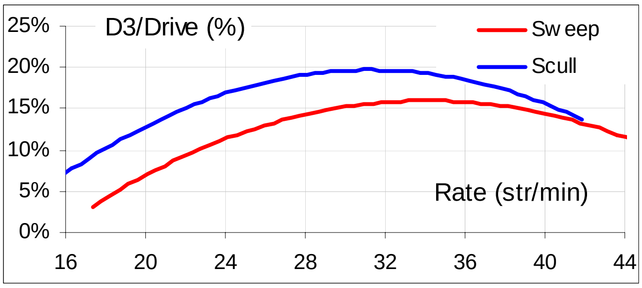
A related topic to this is how D1-D2 affects lock on. At higher rating, the increased forward/back momentum forces the body to take up the strain during D1-D2, because the legs are stopping while the body continues. Does this mean that D3 shortens or disappears at higher ratings?"

A: We analyzed behavior of the drive micro-phases at different stroke rates in 538 sweep and 743 sculling samples. The following table shows average ratio of each micro-phase to the drive time, its standard deviation, minimal and maximal values, and correlation with the stroke rate:

Phase/ Drive (%)	D1	D2	D3	D4	D5	D6
Sweep	13.3	11.6	13.7	20.9	28.1	12.5
STD	2.5	3.1	5.3	6.2	7.4	5.3
Min	6.1	4.0	0.0	0.0	11.2	0.5
Max	20.0	20.3	25.0	37.2	46.8	23.5
Corr.	0.13	-0.15	0.43	-0.02	-0.23	0.02
Scull	10.4	9.8	18.0	24.5	21.8	15.5
STD	1.9	2.6	6.8	4.9	4.6	3.4
Min	5.0	2.8	0.0	11.5	11.0	6.2
Max	14.9	17.4	31.6	37.6	36.5	25.1
Corr.	-0.11	0.06	0.35	-0.10	-0.28	0.04

The first two phases D1 (blade immersion) and D2 (initial rower's acceleration) decrease their time proportionally with decreasing of the drive time at higher rates. Therefore, its shares in the drive time remain nearly constant. These phases are a bit shorter in sculling, which can be explained by the differences in the oar geometry that allow quicker placement of the sculls. Inertial forces appear to be ineffective on these phases.

On contrary, time of the D3 (initial boat acceleration) has no direct relationship with the stroke rate. Therefore, its share increases as the drive time decreases and this phase has the most significant correlation with the stroke rate. We found the trends of D3 shares are non-linear:



The D3 share achieves its maximum at the stroke rates 32-36 and then goes down, but not disappears. It is 5-6% higher in sculling at low rates, but the trends coincide at about 15% at the rate 40. Don't think that the longer D3 phase is better, because its longest values were found in the poorest crews. Some inefficient crews don't have this phase at all. The duration of the D3 must be optimal at the level of 0.08-0.12s. This means that the switching from push into the stretcher during D2 to pull the handle during D3 and back to push during D4 must be present, but it must be done quickly.

Some very successful rowers do D3 using "grabbing" with arms, but we are not saying that this is the best method. It is inefficient, when arms as the weakest part of the body maintain static tension from beginning till the end of the drive. Other great crews (Appendix 1) manage to pull without "grabbing", by means of stretching the shoulders at catch and using them together with trunk during D3, exactly as Ben questioned.

The next two phases D4 (rower's acceleration) and D5 (boat acceleration) are the longest ones. D4 has the constant time share in the drive. This is very important phase, when rower's mass accumulating kinetic energy, but its duration is not connected with better performance. D5 share has negative correlation with the stroke rate, i.e. its duration decreases at higher rates. Good rowers manage to maintain it longer that means better transfer of the kinetic energy to the boat. The D6 (blade removal) phase share is nearly constant at different rates. It is shorter in good crews.

Contact Us:

✉ ©2004 Dr. Valery Kleshnev
kleval@optusnet.com.au (m) +61(0)413 223 290

Appendix 1 to the Rowing Biomechanics Newsletter Volume 4 No 10 October 2004

Micro-phases of the stroke cycle.

Men's pair James Tomkins and Drew Ginn, Olympic Champions of Athens Games 2004.
Stroke rate 36.5 str/min, video 25 fps, frame number – micro-phase.


1 - R2


2 - R2


3 - R2


4 - R2


5 - R2


6 - R2


7 - R3


8 - R3


9 - R3


10 - R3


11 - R3


12 - D1


13 - D1


14 - D1


15 - D2


16 - D2


17 – D3


18 - D3


19 – D4


20 - D4


21 - D4


22 - D4


23 - D4


24 – D4


25 - D5


26 - D5


27 - D5


28 - D5


29 - D5


30 - D5


31 - D6


32 - D6


33 - D6


34 - D6


35 - R1


36 - R1


37 - R1


38 - R1


39 - R1


40 - R1

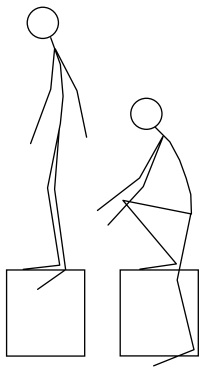

41 - R1


42 - R2


43 - R2

Questions and Answers:

✓ **Q:** Wilson Reeberg, Technical Director of Rio de Janeiro Rowing Federation, Brazil asks: “In your newsletter from July 2001 (Vol 1 N 7), you wrote "...one-leg squat, when you use the other leg for initial acceleration, looks much more similar to rowing than normal squat or jump-squat." Could you describe the "one-leg squat using the other leg for initial acceleration"? Is it like a jump-squat, but with one leg in front of the other? I would like to try it with our athletes, but in the right way.”



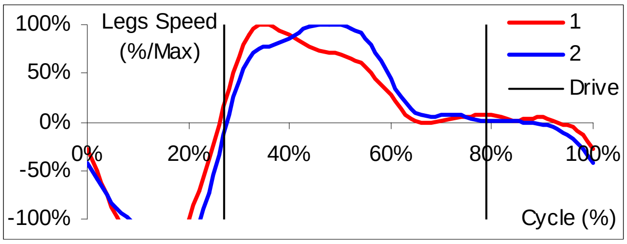
A: Use a block 5-10cm higher than the knee level of the athlete. Bend the working leg slowly; do not accelerate too much during downward motion. At the bottom point push the ground sharply with other leg and foot to change direction and accelerate body upward. This moment simulates change the direction of motion on water, when blade has no support yet. Then quickly shift the load onto working leg and continue motion upward in slightly decelerated manner.

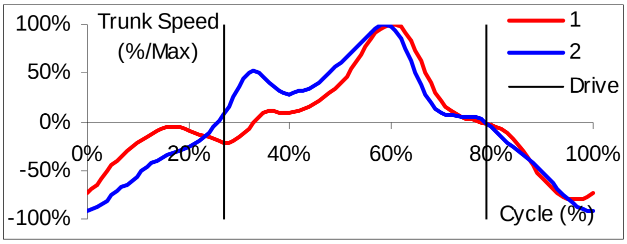
✓ **Q:** This has been some interesting questions from Concept-II Training forum: “…Is the catch and the beginning of the drive initiated with the hands or the feet? Is there a catch that is distinguished from the beginning of the drive? Where do I feel resistance first, hands or feet? Hank” (http://concept2.ipbhost.com/index.php?showtopic=802)

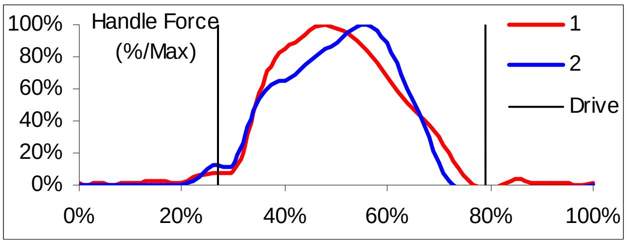
A: If we understand the term “initiate” as movement of the legs or upper body, then emphasis at catch on the legs drive (stretcher push) or upper body work (handle pull) depends on rowing style. In RBN 2001/7 we defined consecutive (or classical, legs first) and simultaneous (legs and trunk together) rowing styles. We can see very successful rowers in both rowing styles: e.g., some Italian crews clearly belong to the first one, a number of German rowers use the second style (see Appendix).

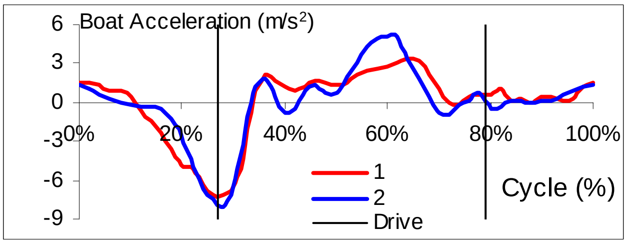
Below are parameters of two single scullers, which styles can be defined as consecutive (1) and simultaneous (2). The first sculler has force peak earlier and the boat acceleration is more even during the drive. The second sculler has the force peak later and the boat acceleration is unstable.

However, we believe that the most efficient style is somewhere in between these two polar ones: legs initiate the drive and trunk starts working very soon after that.









Now we will try to make the second question clearer. We call “drive” when we drive or move something forward. This “something” can be the handle, or the boat, or whole rowers-boat system. We define drive phase using the handle movement, because this is the easiest method. Following our definitions of the drive micro-phases (RBN 2004/1,2,10), D1 is clearly different from the subsequent micro-phases. The boat and the system accelerations are negative during D1, that means the rower do not move, “drive” the them forward. The main tasks of D1 are changing direction of the rower’s movement relative to the boat and placing the blade into the water. We call D1 “blade insertion”, but it also can be denotes by the term “catch”.

Considering forces applied by rower, the stretcher force always increase earlier than the handle force (e.g. RBN 2004/1, the first graph). On a stationary ergo this difference in timing is much bigger (RBN 2003/10). Therefore, we can answer is: the resistance has to be felt on the feet first.

Contact Us:

✉ *©2004 Dr. Valery Kleshnev*
kleval@optusnet.com.au *(m) +61(0)413 223 290*

Appendix 1 to the Rowing Biomechanics Newsletter Volume 4 No 11 November 2004

Examples of the simultaneous and consecutive rowing styles.

Top: simultaneous style, M4x Germany, World Championship 2003, Milan, 1st place.
Bottom: consecutive style, LM2x Italy, World Championship 2003, Milan, 1st place.
Video 25 fps, drive phase only.

1

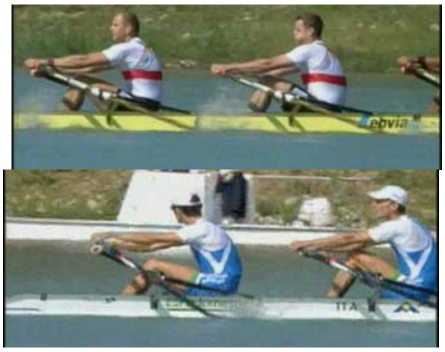
2

2

4

5

6



7

8

9

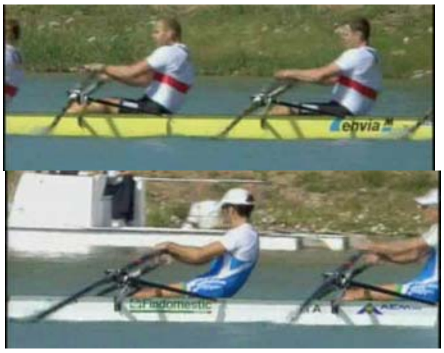
10

11

12

13

14



15

16

17

18

19

20

21

Dear rowing coaches, rowers and all rowing people!
☺ We wish you a Merry Christmas and Happy New 2005 Year!

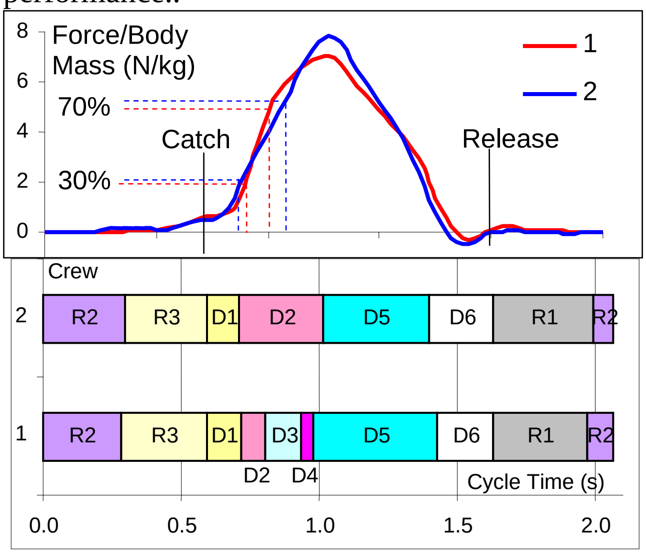
Fact. Did you know that…

✓ **…it is very important to increase force up to 70% of its maximal value as quickly as possible?** We now use criterion 30% for evaluation of the quickness of the force increase at the beginning of the drive. Traditionally, the arc between the catch and the point where force increases up to this level, is called a "catch slip".

We investigated all criterion from 10% to 100% with 10% increments and found that criterion 70% had the highest correlation (r=-0.46) with the duration of the micro-phase D3 (initial boat acceleration). This means: the faster you increase force up to 70% of your maximum, the longer the duration of the D3 micro-phase. This creates faster moving support for further acceleration of the rowers' mass.

Current criterion 30% has the highest correlation r=0.91 with duration of D1 "blade insertion" micro-phase. This means: the faster you increase force up to 30% of your maximum, the sooner you will start acceleration of the system.

A good illustration of this fact can be found in RBN 2004/2. On the figures below you can see the force curves of two crews together with timing of the micro-phases. It was postulated that crew 1 had much more efficient technique and better performance..

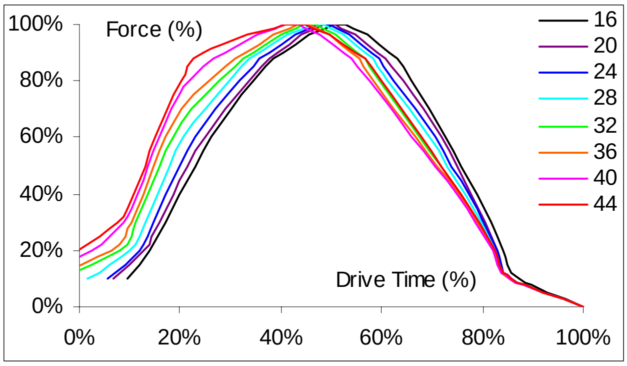


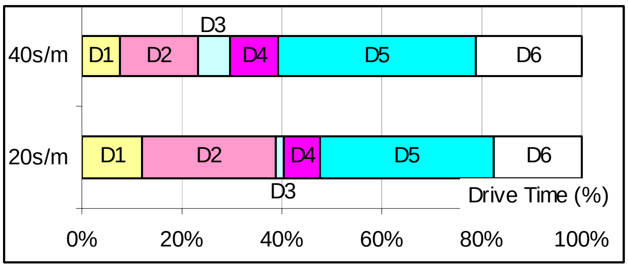
If we measure the time of the force increasing using 70% criterion, then it was shorter in crew 1 (23.1% of the drive time) compared to crew 2 (30.5%).

However, if we were to define "catch slip" using the 30% criterion, then we would find that the second crew increases force faster (14.2%) compared to that of crew 1 (15.1%). All other features of the rowing technique of these two crews are well described in the referred Newsletter.

Ideas. What if…

✓ …**we try to find some new methods for training of the quickness of the force application after catch.** The first thing we should take into account is dependence of the force application on the stroke rate. The figures below show average force curve profiles at stroke rates from 16 to 44 and the temporal structure of the drive at 20 and 40s/m. More than 1500 samples were used to obtain these curves.





It is obvious that the higher the stroke rate, the earlier force application occurred. The biggest changes in the profile happened at force levels from 70 to 90% of maximum. It required 14-16% less relative time to achieve 70-90% of the max. force at 44spm than at 16spm. In comparison, using the 30% criterion this difference is 8.1%, and for the 100% criterion it is 8.1%. Correspondingly, D1 and D2 are much shorter, but D3 and D4 are much longer at 40s/m.

One great coach said that rowing at a high rate differs from rowing at a low rate as much as running differs from walking. During long low rate training we should remember that we will race at high rate. Always try to maintain fast force application and temporal structure of the drive as it was described above.

Contact Us:
✉ *©2004 Dr. Valery Kleshnev*
kleval@optusnet.com.au (m) +61(0)413 223 290