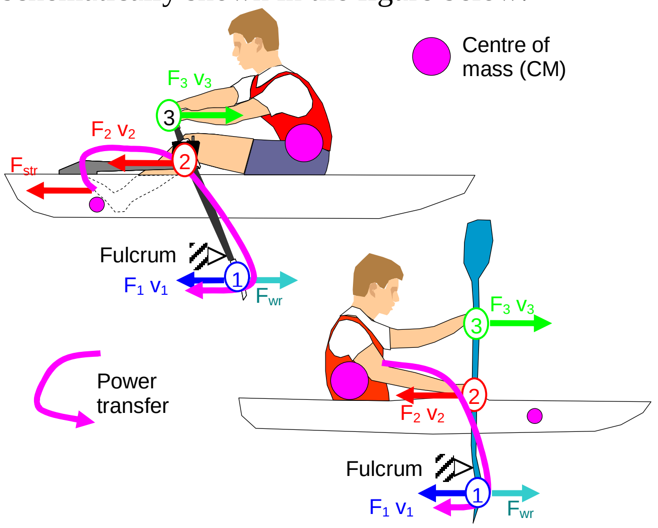
Q&A

Q: *Paul Conlin, a graduate student at Lehigh University, a coach for St. Mary's College (Maryland, US), and a competitive sculler has asked: "In my Masters thesis I have a section dedicated to asynchronous rowing. According to your paper posted at www.biorow.com ~47% of a rower's power is generated through the foot stretcher. According to Dr. Atkinson (www.atkinsopht.com), one reason asynchronous rowing does not work is because the foot stretcher becomes stationary with reference to the rower. Thus no work can be done at the stretcher (W = F*s and here s = 0). My question is simply this, how does the energy transferred through the stretcher help propel the boat when it is directed in the wrong direction?"*

A: In RBN 2004/06 we discussed methods of defining power in rowing and said that "the handle/foot-stretcher power ratio was 60/40%". For better understanding, it is useful to compare rowing mechanics with canoeing mechanics, which are schematically shown in the figure below:



In both cases, the oar works as a lever of the second order with the fulcrum somewhere close to the blade. It is not easy to determine the exact position of this fulcrum, owing to slippage of blade in the water. If we consider forces, then there are three points of force application at the oar:

1. Blade force F_1, which is directed backwards or creates water reaction force F_{wr} propelling the whole system forward;
2. Middle force F_2 (pulling arm in canoeing or gate in rowing) in the same direction as the blade force;
3. End force F_3 (pushing arm in canoeing or handle force in rowing) in the opposite direction to the above two forces.

Rowers do not apply the gate force F_2 directly, so we need to relate it to the stretcher force F_{str} as:

$$F_2 = F_{str} - m_{boat}a_{boat} \quad (1)$$

where $m_{boat}a_{boat}$ is the inertia force of the boat. The mass of the boat is significantly less than the rowers' mass, and so the gate and stretcher forces are quite closely related (RBN 2004/06).

How can we derive the power in canoeing? A canoeist applies power at the two points 2 and 3. As the mass and inertia of the paddle is negligible, the total power of the canoeist P_{tot} equal to the power applied at at the blade P_{bl}:

$$P_{tot} = P_{bl} = F_1 v_1 = F_3 v_3 + F_2 v_2 \quad (2)$$

In rowing, the boat mass is associated with point 2 (gate), so it is much bigger than the paddle mass in canoeing. The blade power P_{bl} for a rower:

$$P_{bl} = F_3 v_3 + F_{str} v_2 - m_{boat} a_{boat} v_2 \quad (3)$$

The total power produces by rower P_{tot} is:

$$P_{tot} = P_{bl} + m_{boat} a_{boat} v_2 = F_3 v_3 + F_{str} v_2 \quad (4)$$

The total power in rowing is the sum of the handle power F_3v_3 and the stretcher power $F_{str}v_2$. The blade power is less than total power by the inertial component $m_{boat}\ a_{boat}\ v_2$, which takes 6-10% of the total energy of a rower

The crucial question here is: what are the velocities v_2 and v_3? We believe that in both cases (rowing and canoeing) they must be velocities relative to the CM of the athlete. This is a very important point, concerning which some scientists appear to have made a mistake (1), by taking v_2 as the boat velocity relative to the water. At first glance, it seems quite logical to derive power as the product of force applied to the boat by its velocity. However, it is incorrect to multiply the force between two objects (boat and rower) by the velocity relative to a third (the water or the earth).

Conclusions:

1. In fact, the stretcher and the blade forces work in the same direction, but the handle force is directed in the "wrong" direction.
2. The power applied by the rower to the stretcher is transferred to the blade though the boat – rigger –pin –gate -shaft, and a part of it is spent on overcoming the boat inertia.
3. Rowing in asynchronous mode, on an ergo, in a rowing tank and, to some extent, "by seats" in a boat decreases power transfer through the stretcher down to zero because $v_2 = 0$.

References

1. Net Power Production & Performance at Different Stroke Rates & Abilities during Sculling. http://www.coachesinfo.com

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