Force and power in rowing

Coaches and rowers quite often mismatch the terms ‘force’ and ‘power’ and use ‘power curve’ to mean ‘force curve’. Also, they say ‘power strokes’ meaning a drill with maximal force application at low stroke rates, quite often with a water brake. In fact, the power in this drill is not very high because of low speed and stroke rate. It would be good to refresh the basics and promote correct usage of biomechanical terminology.

A force is a vector quantity, which means it has both magnitude and direction. A force ***F*** causes a free object of mass ***m*** to change its velocity, i.e. it creates acceleration ***a***, which is described by Newton’s second law:

$$F = m\,a \qquad (1)$$

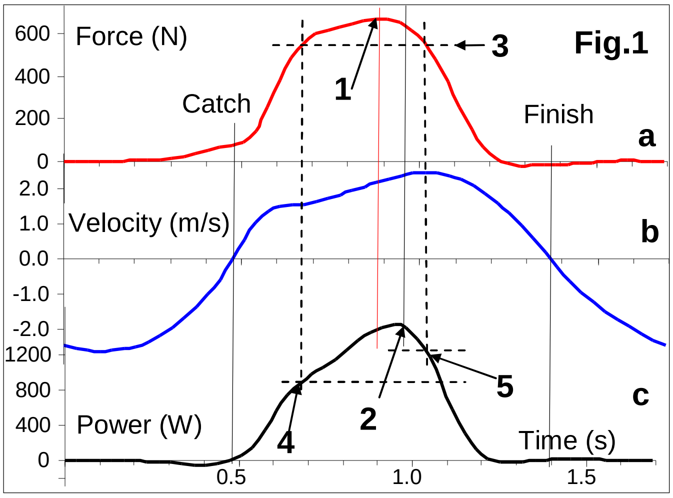
The unit of force is Newton (N) = kg m/s^2, which means 1N force changes velocity on 1kg object by 1m/s per 1s.

Power is a scalar quantity, which means it has only magnitude, but no direction. Power ***P*** is the rate of energy transfer per unit of time ***T***. In mechanics, energy usually means work ***W***, which is product of the force ***F*** applied at the distance ***L***, so:

$$P = W / T = F\,L / T = F\,v \qquad (2)$$

where ***v*** is the velocity of the objects movement. The unit of power is Watt (W) = J/s = kg m^2/s^3, where Joule J = N m is the unit of energy and work. Energy cannot be created from nothing and disappear to nowhere, which is stated by the law of energy conservation. Therefore, the energy can only be transformed from one form into another, but its amount is preserved. In rowing, a rower’s metabolic energy is transformed into mechanical work (and heat of rower’s body), then into kinetic energy of moving the boat-rower system, and finally, into heat dissipated by drag resistance. Contrarily, the amount of force can be easily changed with a simple lever mechanism like an oar.

How are force and power related in rowing? Fig.1 shows the handle force, velocity and power in M1x at 36 str/min.



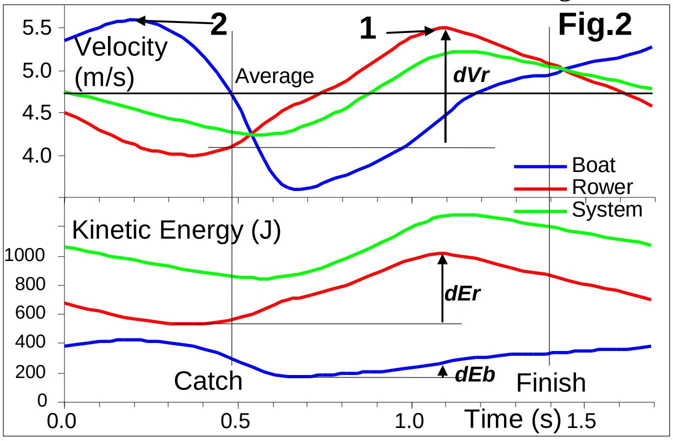
The force (a) and power (c) curves look different: the force curve is more rectangular with an earlier peak (1), the power curve is more triangular with a later peak (2). As the handle velocity (b) more than doubles from catch to finish, with the same force applied (3) the power at the catch (4) is lower than power at the finish (5), so **<u>the same force at the catch “costs” less energy than at the finish</u>**. If force ***F*** acts on free mass ***m*** during time ***T***, it creates an impulse or amount of movement ***J***:

$$J = F\,T = m\,v \qquad (3)$$

where ***v*** is final velocity of the object. Also, the force ***F*** applied at velocity ***v*** produces power ***P*** and increases kinetic energy E_k of the object:

$$E_k = 0.5\,m\,v^2 = W = P\,T = F\,L \text{ (simplified)} \qquad (4)$$

In rowing, there is interference of two objects of different mass, where a boat is 5-8 times lighter than a rower. In fact, this difference is smaller because some parts of a rower’s body (feet, partly shins and thighs) are connected to the boat and move with it. We estimate active moving mass of the rower at about 88% of the total mass, so the remaining 12% is added to the active boat mass, which gives us the range of ratios 1:3-1:4. Fig. 2 shows velocities of the boat, rower and the systems CM as well as kinetic energies of these three masses for the same data as on Fig.1.



During the drive, velocity of the rower’s CM (1) increases much more than the boat velocity, which grows mainly during recovery and has its peak before the catch (2). As the rower is also heavier, his mass accumulates 7 times more kinetic energy (***dEr***=478J) than the boat mass (***dEb***=69J). Then, at the end of the drive and during recovery, the impulse and kinetic energy is transferred from rower’s mass to the boat and spent for overcoming drag resistance. Therefore, **<u>the amount of impulse and kinetic energy accumulated by rower’s mass is the main determinant of the average boat speed and result in rowing</u>**. In fact, there is nothing new in this conclusion. A great rowing coach and founder of the modern rowing style **<u>Steve Fairbairn said</u>** more than a hundred years ago: “**<u>Find out how to use your weight and you will have solved the problem of how to move the boat</u>**”.

Only stretcher force can push the rower forward, while the handle force pulls him backwards. So, **<u>the stretcher force must be emphasised during the drive, while the handle force only provides support through the oar – gate – rigger – stretcher</u>**. Of course, the blade must be locked in the water to provide the support.