Weight adjustment of ergo-meter performance

A number of coaches have asked questions, which could be summarised as: "**How results on the erg vs. rower's weight should be used for ranking and selection of rowers?**" This question has two parts:

1. Which athlete is stronger, better trained, i.e. how the level of muscles and energy supply systems is related in two rowers of different body mass?
2. How do the erg performances affect on-water results in rowers of different body mass?

Now we will try to answer the first question. Though this topic is quite important and popular in the rowing community, there is no common opinion on it. The earliest study (McMahon, 1971) was published, when ergos were not widely used as a standard testing method of a rower's power production. The author analysed on-water performance and speculated that aerobic power Pae is proportional to $m^{2/3}$, i.e. to a body surface, which is related to the surface of membranes and oxygen transfer. As the speed is proportional to the cube root of the power $v \approx P^{1/3}$, then $v \approx m^{2/9} \approx m^{0.222}$.

Currently, this proportion is widely used for the weight adjustment. In both Concept2 (7) and RowPerfect (8) websites it was transformed into a "weight adjustment factor" k_w, which should be multiplied by the speed V, or time score T divided by it to obtain "adjusted" time Tad and speed Vad:

$$Vad = k_w V, \; Tad = T / k_w \qquad (1)$$

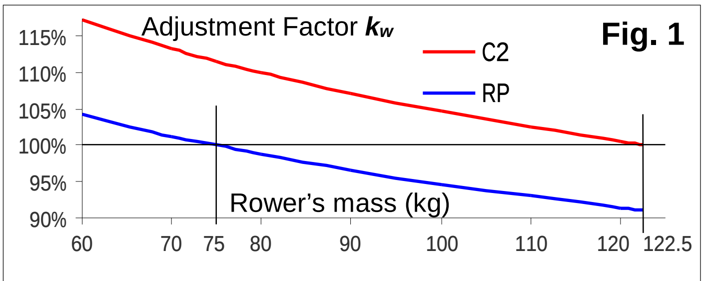
In Concept2, the adjustment k_{C2} was made relative to the "standard" mass 122.5kg (270lbs) and reversed, because "the weight adjusted score becomes a pretty good estimate of a person's potential speed in an eight":

$$k_{C2} = (m / 122.5)^{0.222} \qquad (2)$$

In RowPerfect, the "standard" mass 75kg was used and 15kg was added to both the rower's and standard masses, probably, in attempt to adjust to inertia losses for the erg with mobile flywheel:

$$k_{RP} = ((75+15) / (m+15))^{0.222} \qquad (3)$$

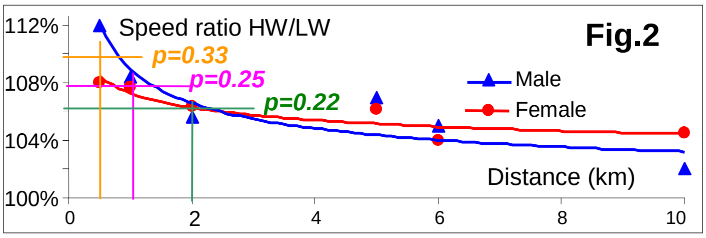
Fig. 1 shows both C2 (reversed back to use in equations 1) and RP adjustment factors. The first one gives about a 13% faster adjusted speed at 60kg; the difference decreases by 9% at 120kg:



The next significant step was made by Dudhia (1), who separated aerobic and anaerobic power: the first one remains in agreement with the equations above, but the second one was speculated to be directly proportional to the rower's mass $Pan \approx m$, because "it is defined by the muscles mass". So, simply relative power in Wt/kg should be compared $Pr = Pan/m$, or the cube root of the speeds: $v \approx m^{1/3} \approx m^{0.333}$

As the race duration of the standard rowing distance 2km ranges from 5.3 to 7.5 min, the aerobic energy contribution varies from 67 to 84% (4, 5, 6). If we assume that aerobic power contributes 75% of energy during a 2km rowing race at 6.5 min and proportionally sum up above factors 0.222 and 0.333, then we get $v \approx m^{0.25} \approx m^{1/4}$. It is interesting that exactly the same function was referred in the latest study published by Pelz and Verge, 2014 (3): "Geometric similarity is a special form of physical similarity based on Bridgman's postulate (Bridgman, 1922). Kleiber's law (Kleiber, 1932, 1975), i.e. the metabolic rate and hence the mechanical power of an organism is proportional to its body mass raised to the power of ¾th is anallometric scaling. This empirical relationship has been found to hold across the living world from bacteria to blue whales." If $P \approx m^{3/4}$, then $v \approx m^{1/4} \approx m^{0.25}$.

To compare theory with practice, the data of World records on a Concept2 erg was used. Fig. 2 shows ratios of speeds in open category vs. lightweights in both males and females at various race distances from 500m to 10km.



Assuming a weight of a lightweight and a heavyweight male rower is 75 and 103kg, and in females – 60 and 76kg, the average ratio of the speed HW/LW should be 106.3% at factor $p=0.22$ in the equation $v \approx m^p$, 107.2% at $p=0.25$ and 109.7% at $p=0.33$. In a 2km race, the real average ratio was 106.4%, so, it looks like the most traditional and popular factor ***0.22*** has the best fit to performance data. Higher factors could be suitable at shorter distances: ***0.25*** could be used in a 1km race, and ***0.33*** – at 500m, which reflects a higher contribution of anaerobic energy.

What "standard" mass M should be used in an adjustment equation? It is important to keep it the same for all rowers to be compared, but selection of the value is a matter of taste: lower values keep lightweights' results the same, but decrease speed of heavyweights, higher values make lighter rowers faster (Table 1 below). "Added" mass decreases the weight adjustment factor (Table 2 below), and doesn't really make sense, especially on a stationary erg.

Concluding: **An erg speed should be multiplied by the following weight adjustment factor k_w or the time score divided by k_w:**

$$k_w = (M / m)^p \qquad (4)$$

where m is the athlete mass, M - some "standard" mass, $p=0.222$ for 2 and 5km tests. Higher factors $p=0.25$ and $p=0.333$ to be used in shorter tests.

Here we have touched only the first question and will try to answer the second one later.

References

1. *Dudhia A. 2001. Effect of Weight in Rowing. http://www.atm.ox.ac.uk/rowing/physics/weight.html*
2. *McMahon, T.A., 1971. Rowing: a similarity analysis. Science 173, 349.*
3. *Pelz P., Vergé A. 2014. Validated biomechanical model for efficiency and speed of rowing. J. of Biomechanics 47(2014) 3415–3422.*
4. *Pripstein L.P., Rhodes E.C., McKenzie D.C., Coutts K.D. 1999. Aerobic and anaerobic energy during a 2-km race simulation in female rowers. Eur J Appl Physiol (1999) 79: 491±494.*
5. *Russell A.P., Le Rossignol P.F., Sparrow W.A. 1998. Prediction of elite schoolboy 2000-m rowing ergometer performance from metabolic, anthropometric and strength variables. Journal of Sports Sciences, 1998, 16, 749± 754*
6. *Secher NH. 1993 Physiological and biomechanical aspects of rowing: Sports Med 15:24±42*
7. *http://www.concept2.com/indoor-rowers/training/calculators/weight-adjustment-calculator*
8. *https://www.rowperfect.co.uk/erg-scores-how-to-adjust-for-athlete-weight/*

*Table 1. Weight adjustment factors at various "standard" masses **M** and rower's weights **m***

Table 1	*m* in $k = (M / m)^{0.222}$						
M	60	70	80	90	100	110	120
60	100.0%	96.6%	93.8%	91.4%	89.3%	87.4%	85.7%
70	103.5%	100.0%	97.1%	94.6%	92.4%	90.4%	88.7%
80	106.6%	103.0%	100.0%	97.4%	95.2%	93.2%	91.4%
90	109.4%	105.7%	102.7%	100.0%	97.7%	95.6%	93.8%
100	112.0%	108.2%	105.1%	102.4%	100.0%	97.9%	96.0%
110	114.4%	110.6%	107.3%	104.6%	102.1%	100.0%	98.1%
120	116.7%	112.7%	109.4%	106.6%	104.1%	102.0%	100.0%

Values above 100% mean faster speed / shorter race time, below 100% – slower speed / longer time.
This table can also be used for direct comparison of rowers of different weights. E.g., if 90kg rower is 5.7% faster than a 70kg rower, then their performance is the same.

*Table 2. Weight adjustment factors at various "added" mass M_{ad} and fixed "standard" mass **M***

Table 2	*m* in $k = ((M+M_{ad}) / (m+M_{ad}))^{0.222}$ at M=90						
M_{ad}	60	70	80	90	100	110	120
0	109.4%	105.7%	102.7%	100.0%	97.7%	95.6%	93.8%
10	108.2%	105.1%	102.4%	100.0%	97.9%	96.0%	94.3%
20	107.3%	104.6%	102.1%	100.0%	98.1%	96.4%	94.8%
30	106.6%	104.1%	102.0%	100.0%	98.2%	96.6%	95.2%
40	106.0%	103.8%	101.8%	100.0%	98.4%	96.9%	95.5%
50	105.5%	103.5%	101.7%	100.0%	98.5%	97.1%	95.8%
60	105.1%	103.2%	101.5%	100.0%	98.6%	97.3%	96.0%