DOES ISOINERTIAL ERGOMETRY PROFILING REPRESENT ON-WATER SPRINT CAPACITY IN KAYAKERS?

Catherine Shin[1,2], Alexander P. Willmott[1] and David R Mullineaux[1]

University of Lincoln, UK[1]; English Institute of Sport, UK[2]

Despite frequent use of kayak ergometers for research and monitoring, there are questions over the transference of information gained on ergometers to on-water performance. The aim was to investigate if power and force-velocity (FV) profiles measured on an ergometer reflect sprint velocity (SSVel), stroke rate (SR) and distance per stroke (DPS), on-water. National level kayakers (n = 27) completed maximal on-water 100 m sprints and profiling on an isoinertial kayak ergometer. Pull power (PullP) on the ergometer was found to explain 85% of variance in SSvel, as well as being significantly related to SR ($r = 0.80$; $p < 0.01$). Maximal force was found to correlate to PullP ($r = 0.80$; $p < 0.01$), SSVel ($r = 0.78$; $p < 0.01$) and SR ($r = 0.70$; $p < 0.01$), but not to DPS. Ergometer data can be used to predict on-water performance factors but SR/DPS use does not appear to be linked to FV gradient.

KEYWORDS: Force-velocity, power, sprint kayak.

INTRODUCTION: Kayak ergometers are frequently used to assess or monitor athletes for both research and training purposes. While there is evidence demonstrating the similarities in kinematics between ergometer and on-water paddling (Begon et al., 2008), research has shown some differences in muscle activity, with higher anterior deltoid activity on the ergometer and higher triceps and latissimus dorsi activity on the water (Fleming et al., 2012).
Power has previously been shown to be a determinant of sprint performance in a number of sports, including kayaking (van Someren & Palmer, 2003). Mechanically, power is the product of force and velocity, and in sporting movements (e.g. Martin et al., 1997; Sprague et al., 2007) including kayaking (Schofield, 2015), force has been found to decrease with increasing velocity in a linear relationship. In ballistic movements such as vertical jumping, Samozino et al. (2012) describe an “optimal” relationship between force and velocity; however, it is not clear if there is a more advantageous profile for cyclic activity.
In kayaking, as in other cyclical sports, velocity is the product of cycle frequency (stroke rate; SR) and cycle distance (distance per stroke; DPS). The unconstrained duty cycle in kayaking means athletes dictate their own SR and a range of SR have been found to be used in achieving the highest velocities at international level (McDonnell et al., 2013). Within runners sprinting, group level conclusions have tended towards the conclusion that step length is more strongly correlated with maximal performance (e.g. Ito et al., 2006; Hunter et al., 2011). However, individuals have been found to be more ‘reliant’ on either step length or step frequency (Salo et al., 2011), a categorisation the authors described as a situation in which a reduction in the favoured variable resulted in a decrease in performance that could not be accounted for by a change in the other variable. In sprint cycling, researchers are able to use power and force-velocity profiles (FV) to optimise cycle set-up (Martin & Spirduso, 2001).
Previous research in other sports has alluded to a link between physical capacity and technical performance. For example, Hunter et al. (2004) postulated that increasing step length in sprinting would require development of strength and power, while the importance of creating high forces quickly could be linked to higher step frequencies. Recently, researchers have attempted to link power and FV to 100 m sprint performance (Slawinski et al., 2017) and found performance to be linked to both power and velocity, but not maximal force capacity. This study used televised data to calculate power and looked at the entire distance. No studies could be found which have compared directly-measured power and FV to sporting performance.
The aim of this research was to investigate the relationship between power and FV ergometry profiling and sprint performance in kayaking. We hypothesised that power would be positively correlated with sprint performance, and that FV gradient would be negatively

correlated with SR, indicating that those who are more force-dominant on the ergometer utilise a higher DPS technique on water, while velocity-dominant athletes would use a higher SR.

METHODS: Twenty seven kayakers (14 male, 13 female) took part in the study, all of whom competed nationally or internationally. Testing consisted of two sessions, one on water and one on the ergometer, both completed on the same day. A minimum of two familiarisation sessions consisting of five trials of 14 maximal strokes, were completed on the ergometer prior to testing to account for any learning effect. The on-water session consisted of a full race-day warm up, followed by six maximal effort 100 m sprints from standing with 12 minutes of off-water recovery in between. An on-boat differential GPS (10 Hz) and inertial measurement unit (IMU; 100 Hz) unit (YachtBot, Igtimi, New Zealand) was attached immediately behind the cockpit. Following a minimum of 90 min recovery, the ergometer testing was completed. This consisted of a warm up and then five trials of 14 maximal strokes on a custom built iso-inertial kayak ergometer (Schofield, 2015), with three min recovery between trials.

From the on-boat data, boat velocity, SR and DPS were calculated for the whole effort. The start of steady state (SS) was defined using a breakpoint detection, whereby a curve is fitted to the data, rotated so that the first and last points are equal to zero, and the trough represents the breakpoint. The end of SS is defined as the end of the effort or when velocity decreased by 10%. For each effort, SS averages for velocity (SSVel), SR and DPS were calculated.

From the iso-inertial ergometer, flywheel position-time data were recorded via a photodiode and logger every 11.25° (π/16) and flywheel acceleration was used to calculate torque applied. With the known inertia of the flywheel and distance of the sprocket, applied force (F_a) and velocity of the paddle (Vel_P) were calculated instantaneously. The end of the bungees, which retract the rope which was attached to the paddle shaft, were connected to load cells so that force applied to stretch the bungee (F_b) could be quantified. This allowed calculation of power instantaneously as: $(F_a + F_b) * Vel_P$. Pull power (PullP) was the average power for each stroke, defined as being from onset of force on one side, until the end of the pull phase when force returns to zero on the same side. Force-velocity and power-velocity profiles were then constructed from the 12 stroke means, defined as above. Maximal force (F_0) was calculated as force attained when velocity was equal to zero from the force-velocity profile; maximal velocity (V_0) was calculated as the velocity when force was equal to zero. Force-velocity gradient (FVgrad) was calculated as F_0/V_0. Maximal force and pull power were normalised by dividing by body mass^0.67, as allometric scaling has been shown to better represent differences in physical performance due to body size (Jaric et al., 2005).

Pearson's correlations were calculated at group level between each of the seven key variables: SSVel, SR, DPS, PullP, FVgrad, F_0 and V_0. A Bonferroni correction was applied to reduce the risk of family-wise error and therefore significance was set at $p \leq 0.002$ (0.05/21).

RESULTS: Correlations showed that PullP as measured during a maximal test was strongly correlated to steady state velocity during maximal sprinting. This measure of maximal velocity was also strongly correlated with both SR and DPS on-water and F_0 on the ergometer but was not statistically significantly linked to V_0 or FVgrad (Table 1).

Table 1: Pearson's correlation matrix results. *indicates statistical significance (p < 0.002).

		SSVel	SR	DPS	PullP	F_0	V_0
SR	r	.847*					
	p	.000					
DPS	r	.574*	.052				
	p	.002	.802				
PullP	r	.921*	.801*	.498			
	p	.000	.000	.010			
F_0	r	.776*	.695*	.387	.801*		
	p	.000	.000	.051	.000		

V_0	r	.156	.133	.096	.209	-.346	
	p	.447	.516	.640	.305	.084	
FVgrad	r	.544	.503	.245	.536	.930*	-.652*
	p	.004	.009	.227	.005	.000	.000

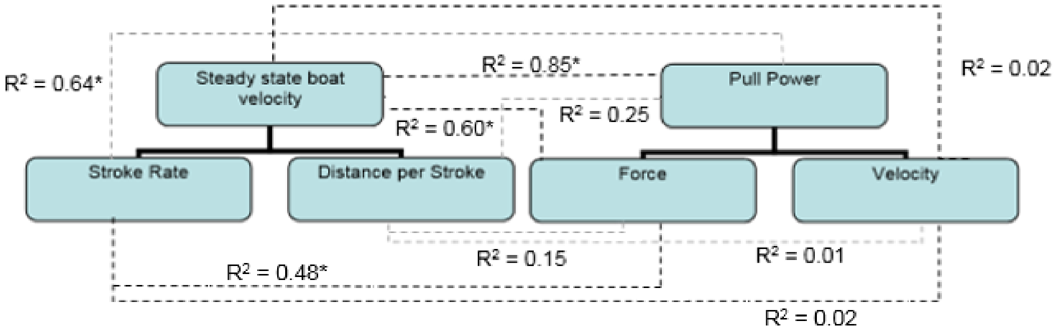

Figure 1: investigated factors and their relationships. Solid lines indicate mechanical relationship, dashed lines show statistical relationship, *indicates statistical significance at p<0.002.

DISCUSSION: The data show that pull power is a determinant of performance in sprint kayaking, as athletes who demonstrated a higher pull power had a faster steady state velocity. The Pearson correlation value shows 85% of the variance in velocity was explained by changes in pull power.

The link of SSVel with F_0 but not V_0 on the ergometer is interesting. This suggests that maximal force capacity, but not maximal velocity capacity, is important in kayaking performance, directly opposing findings from athletics sprinting (Slawinski et al., 2017). Slawinski and colleagues were looking at the whole effort including acceleration, rather than just the steady state portion, which would affect the outcome. Previous research found no correlation between strength and on-water performance (McKean and Burkett, 2010) when comparing on water performance to bench press and pull up one repetition maximum, indicating the importance of measuring force generating capacity in a movement as close to the performance movement as possible. Maximal velocity was not statistically significantly linked to any of the other key variables. The findings of this study refute the hypothesis that those athletes who are highly force-dominant would use longer, more powerful strokes (higher DPS) and that those who are velocity-dominant would use a higher stroke rate. In kayaking, increasing movement speed will not necessarily result in increasing boat speed if technical efficiency does not support the increase and DPS is reduced to a greater extent than SR is increased. This may explain why maximal velocity on the ergometer is not significantly correlated with on-water performance.

The ergometer data supports previous research which has shown FVgrad does not correlate with maximal power production (Samozino et al., 2012), demonstrating that individuals are able to produce similar amounts of power via different combinations of force and velocity. Morin et al. (2012) looked at the mechanical determinants of sprint running performance and concluded, in opposition to the current study, that a more velocity-oriented FV profile produced best performance.

Three difference factors between the ergometer and on-water task are that of balance, connection to the water and equipment. The current study appears to indicate that some athletes are not utilising their physiological capacity on-water, particularly their maximal velocity capacity, potentially due to an offset in one of the three above factors. For example, a forceful athlete may not have the balance to be able to use a high percentage of their force; they may have technical inefficiencies with the blade moving though the water without increasing boat speed; or they may have a sub-optimal paddle set-up which causes them to artificially raise or decrease their SR through changes in blade surface area or moment arm.

Previous research has concluded that an optimal SR must exist for each individual athlete (Plagenhoef, 1979; McDonnell et al., 2013) as although the current study, and other group level analysis shows strong correlations between SR and velocity, world medallists do not always have the highest SR. McDonnell and colleagues attributed differences in optimal SR to strength, anthropometry, physiology and equipment, the significance of the correlation of F_0 and PullP with SR goes some way to supporting some of these ideas. More research is needed to investigate the within athlete relationships of these factors.

CONCLUSION: The use of ergometry to provide performance indications in sprint kayaking has long been questioned and the transfer of skill between the water and the ergometer is not well understood by the coaching community. The high correlation found here between power measured on an ergometer and on-water performance, used in conjunction with reported kinematic similarities (Begon et al., 2008) and differences in muscle activity (Fleming et al., 2012), allows practitioners and coaches to understand the extent to which ergometer performance data can be used to infer on-water performance changes.

REFERENCES

Begon, M., Lacouture, P. & Colloud, F. (2008). 3D kinematic comparison between on-water and on ergometer kayaking. *26th ISBS Conference, Seoul, Korea.* 502-05. https://ojs.ub.uni-konstanz.de/cpa/article/view/1913

Fleming, N., Donne, B., Fletcher, D. & Mahony, N. (2012). A biomechanical assessment of ergometer task specificity in elite flatwater kayakers. *Journal of Sports Science and Medicine, 11,* 16-25.

Hunter J.P., Marshall R.N. & McNair P.J. (2004). Interaction of step length and step rate during sprint running. *Medicine and Science in Sports and Exercise, 36(2),* 261–71.

Ito A., Ishikawa M., Isolehto J. & Komi P.V. (2006). Changes in the step width, step length, and step frequency of the world's top sprinters during the 100 metres. *New Studies in Athletics, 21(3),* 35–9.

Martin, J.C. & Spirduso, W.W. (2001). Determinants of maximal cycling power: crank length, pedalling rate and pedal speed. *European Journal of Applied Physiology, 84,* 413-18.

Martin, J. C., Wagner, B. M., & Coyle, E. F. (1997). Inertial-load method determines maximal cycling power in a single exercise bout. *Medicine and Science in Sports and Exercise, 29(11),* 1505-12.

McDonnell, L.K., Hume, P.A. & Nolte, V. (2013). Place time consistency and stroke rates required for success in K1 200-m sprint kayaking elite competition. *International Journal of Performance Analysis in Sport, 13,* 38-50.

McKean, M. R., & Burkett, B. (2010). The relationship between joint range of motion, muscular strength, and race time for sub-elite flat-water kayakers. *Journal of Science and Medicine in Sport, 13(5),* 537-42.

Morin, J.-B., Bourdin, M., Edouard, P., Peyrot, N., Samozino, P. & Lacour, J-R. (2012). Mechanical determinant of 100-m sprint running performance. *European Journal of Phsyiology, 112,* 3921-30.

Plagenhoef, S. (1979). Biomechanical analysis of Olympic flatwater kayaking and canoeing. *Research Quarterly, 50,* 443-59.

Salo, A. I. T., Bezodis, I. N., Batterham, A. M., & Kerwin, D. G. (2011). Elite sprinting: are athletes individually step-frequency or step-length reliant? *Medicine and Science in Sports and Exercise, 43*(6), 1055-62.

Samozino, P., Rejc, E., Di Prampero, P.E., Belli, A. & Morin, J.-B. (2012). Optimal force–velocity profile in ballistic movements- altius: citius or fortius? *Medicine and Science in Sports and Exercise, 44 (2),* 313–22.

Schofield (2015). Peak power profiling of elite flatwater kayakers (unpublished Masters thesis). Brunel University: London.

Slawinski, J., Termoz, N., Rabita, G., Guilhim, G., Dorel, S., Morin, J.-B. & Samozino, P. (2017). How 100-m event analyses improve our understanding of world-class men's and women's sprint performance. *Scandinavian Journal of Medicine and Science in Sports, 27,* 45-54.

Sprague, R. C., Martin, J. C., Davidson, C. J., & Farrar, R. P. (2007). Force-velocity and power-velocity relationships during maximal short-term rowing ergometry. *Medicine and Science in Sports and Exercise, 39(2),* 358-64.

van Someren, K. A., & Palmer, G. S. (2003). Prediction of 200-m sprint kayaking performance. *Canadian Journal of Applied Physiology, 28*(4), 505-17.