COMPARISON OF FORCE CURVES BETWEEN ON-WATER SINGLE SCULL ROWING AND THE ROWPERFECT ERGOMETER

Andrew Lyttle[1], Bruce Elliott[2] and Olivia Birkett[2]
[1]The Western Australian Institute of Sport, Perth, WA, Australia
[2] The Department of Human Movement and Exercise Science,
The University of Western Australia, Perth, WA, Australia

The purpose of this study was to compare the RowPerfect ergometer to single scull rowing in order to validate its use in rowing training and crew selection. Eight national-level rowers were tested over three sets of 500 m, at stroke rates of 24, 26 and 28, on both the RowPerfect ergometer and on-water in a single scull. Blade force and oar angle were measured on-water while force and stroke length were measured on the ergometer. Both force and angle/length were normalised for comparison between the two forms of rowing. Co-efficient of multiple determination revealed high consistency levels for the 5 representative normalised stokes of each subject. Cross-correlation demonstrated high correlations between the force curves of the ergometer and on-water sculling. Thus, the results indicate that the RowPerfect ergometer successfully simulates on-water sculling.

KEY WORDS: rowing, dynamic ergometers, sculling, force curves

INTRODUCTION: Rowing coaches have endeavoured to modify technique in an attempt to increase boat velocity for centuries. A high proportion of rowing training, particularly in colder months and periods of inclement weather, is performed on various traditional static ergometers. In many countries, these instruments are also being used to assist in crew selection at the elite level. However, their effectiveness in replicating on-water rowing technique has been questioned (Steinacker & Secher, 1993; Torres-Moreno, et al., 2000), therefore so has their usefulness.

The technique of how a rower moves a boat through the water is thought to be different to the technique used to row a traditional ergometer (Rekers, 1993). The main difference between on-water rowing and traditional static ergometer rowing is that the ergometer is fixed to the land. With a static ergometer, when the rower's feet apply force to the stationary foot-stretcher, the force is transferred back to the rower. As the stretcher is fixed, no force is lost as it is transferred to the rower's body equally and in the opposite direction to which it was applied. This fixed base for force transfer does not exist in a boat. Steinacker and Secher (1993) reported that there was a need to improve ergometer simulation of on-water rowing. The dynamic RowPerfect ergometer was designed to meet this need and emulate on-water rowing more closely than traditional ergometers by having a moveable foot stretcher/flywheel system and moveable seat. The RowPerfect ergometer was designed so that the inertial forces were similar to those recorded in a boat and therefore the coordination of segment velocities is more closely related to that of rowing on-water (Rekers, 1993). In a descriptive study by the manufacturer, it was reported that the force-time curves produced on the RowPerfect ergometer coincide well with the force-time curves produced in a sweep boat (Rekers, 1993).

While traditional ergometers may be useful for training physical fitness, they may adversely alter the coordination of the muscles used in on-water rowing (Rekers, 1993). There is a dearth of studies that have analysed the RowPerfect ergometer, so its value is still open to debate. As the RowPerfect ergometer has only been compared to sweep rowers, objective data on the RowPerfect compared to single scull rowing is warranted.

METHODS: Four males and four female rowers aged between 17 and 20 years, who were all national junior and U/23 heavyweight rowers, were selected as subjects for the study. As the force profiles were normalised in the analysis, the data for both genders were pooled.

A linear proximity system was used for on-water measurements The system provided information on blade force, oar angle and time of events during sampling. This information was transmitted to a master computer on-shore for further processing. A commercially available SpeedCoach™ was used to inform subjects of their stroke rating.

Ergometer force and stroke length was calculated via the RowPerfect software and based on the rotation of the flywheel. Subjects were able to view the stroke rating and force curves on the computer screen while rowing.

A kinematic analysis was performed using *Video Expert* during both the on-water and ergometer trials. This analysis consisted of quantifying the vertical trunk angle, normal knee angle and vertical shank angle in the catch position; as well the vertical trunk angle and horizontal thigh angle at the finish position.

The force-angle (on-water) and force-length curves (ergometer) were normalised on a scale of 0-100, where 100 was the peak value (for both force and angle/length). Five consecutive normalized force curves for the on-water left and right oars and the RowPerfect ergometer were used in the statistical comparison. The coefficient of multiple determination (CMD) was used to compare the similarity of curves to quantify each rower's inter-cycle consistency. These normalized force-angle/length curves were then averaged for each subject to produce an average normalized force profile.

The correlation of force curves for both the RowPerfect ergometer and on-water rowing was performed using the adjusted CMD, to determine the repeatability of waveforms. This technique has been recommended by Kadaba et al. (1989) and used by Doyle (1999) to compare hand curves in rowing. The comparison of normalized force-angle curves at the different stroke rates, on both the RowPerfect and on-water rowing, was performed using cross-correlations. The cross-correlations provided a measure of similarity of waveforms, such as a force curve.

RESULTS AND DISCUSSION: The average force/length and force/angle results are listed in Tables 1 and 2 for the RowPerfect and on-water trials, respectively. Despite the differences in absolute values for the force and length/angle variables for males and females, the data were pooled given that normalized force curves were used in the statistical analysis rather than absolute values. The normalisation of the curves allowed us to directly compare the similarities in the shape of the force profiles between the ergometer handle force and on-water blade force.

Table 1 Average Force/Length Results for the RowPerfect Ergometer Trials

	24 strokes/min		26 strokes/min		28 strokes/min	
	Length (m)	Max. Force (N)	Length (m)	Max. Force (N)	Length (m)	Max. Force (N)
Female	1.41 ± 0.02	349.41 ± 15.3	1.37 ± 0.05	348.06 ± 11.5	1.35 ± 0.10	356.5 ± 27.9
Male	1.40 ± 0.08	432.42 ± 95.2	1.40 ± 0.05	453.5 ± 64.4	1.36 ± 0.07	441.67 ± 78.3
Total	1.40 ± 0.05	390.91 ± 77.1	1.38 ± 0.05	400.78 ± 70.8	1.36 ± 0.08	399.08 ± 70.9

Table 2 Average Force/Angle Results for Left and Right Oars Recorded During On-Water Trials

	Stroke Rating (strokes/min)	Left Oar Angle Range (°)	Left Oar Max. Force (N)	Right Oar Angle Range (°)	Right Oar Max. Force (N)
Female	24	101.11 ± 4.75	132.39 ± 8.51	98.98 ±7.42	124.54 ± 5.49
Male	24	119.68 ± 1.64	158.02 ± 13.48	114.88 ± 3.17	131.91 ± 15.13
Total	24	110.39 ± 10.46	145.21 ± 17.22	106.93 ± 10.01	128.23 ± 11.25
Female	26	101.71 ± 6.21	121.51 ± 15.46	96.92 ± 7.36	126.75 ± 12.84
Male	26	119.57 ± 2.97	163.78 ± 7.47	115.93 ± 4.77	131.53 ± 5.56
Total	26	110.64 ± 10.55	142.64 ± 25.23	106.43 ± 11.67	129.14 ± 9.51
Female	28	105.76 ± 4.85	122.60 ± 4.66	100.25 ± 4.25	140.38 ± 6.84
Male	28	119.49 ± 3.14	170.52 ± 11.41	115.55 ± 5.95	141.00 ± 1.89
Total	28	112.62 ± 8.26	146.56 ± 26.86	107.90 ± 9.48	140.69 ± 4.66

Five consecutive force/angle (on-water) and force/length (RowPerfect) curves were normalized to maximum force and length (0 – 100) to allow the shape of the curves to be directly compared. Coefficient of multiple determination measures were applied to the 5 consecutive, normalized curves for both the left and right oar on-water curves and the ergometer curves in order to determine the level of consistency. Figure 1 outlines a sample curve from an ergometer trial.

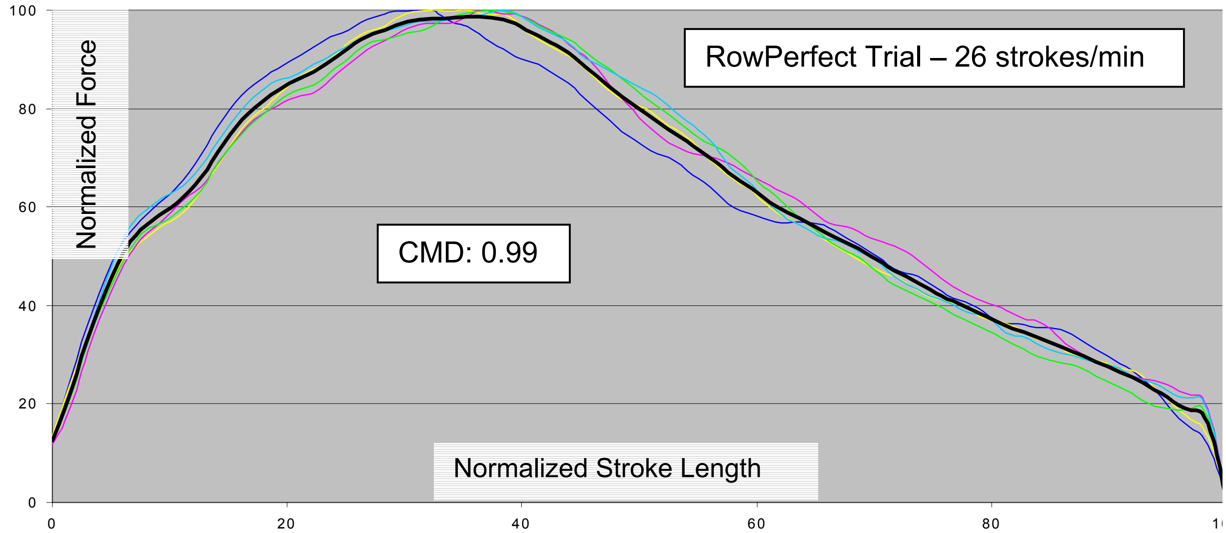


Figure1 - Sample normalised RowPerfect curves demonstrating high inter-stroke consistency.

The CMD tests demonstrated that the 5 consecutive, normalized force curves were very consistent for each stroke rate (see Table 3). The RowPerfect CMD scores were slightly higher due to the controlled nature of laboratory compared to field-testing. Given the high inter-stroke consistency, the 5 normalized curves were averaged to obtain a single average, normalised curve, which was used in the subsequent analysis.

Table 3 CMD Consistency Values for the RowPerfect and On-Water Normalized Force Curves.

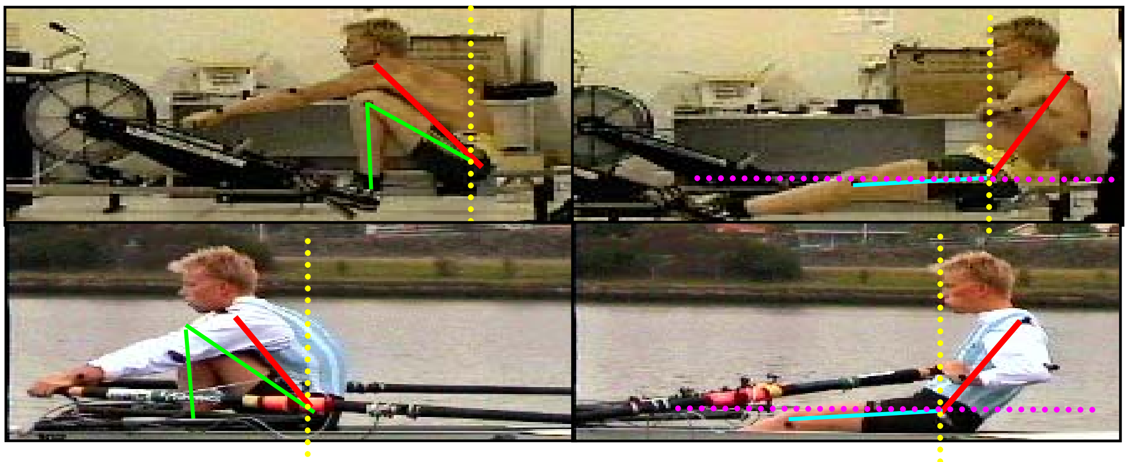
Stroke Rate	RowPerfect Ergometer	Left Oar (on-water)	Right Oar (on-water)
24 strokes/min	0.99 ± 0.01	0.98 ± 0.02	0.98 ± 0.01
26 strokes/min	0.99 ± 0.00	0.98 ± 0.01	0.97 ± 0.01
28 strokes/min	0.99 ± 0.01	0.98 ± 0.01	0.98 ± 0.01

Cross correlations were also performed on the left and right oar normalized curves. Results indicated that the left and right force curves for each subject were highly correlated at the three different stroke rates of 24, 26 and 28 strokes/minute (0.97± 0.03, 0.98 ± 0.02, 0.98 ± 0.01; respectively). Thus, while the force profile between the subjects may have varied, each individual had a consistent pattern regardless of the side of the body or stroke rating as has previously been reported (Smith et al., 1988). The data from the left and right oar from the on-water trials were averaged at each stroke rating to provide a single on-water force curve.

Cross-correlations were then applied to the average, normalized on-water force profiles and the average, normalised RowPerfect force curves. Results demonstrated that the on-water force profiles were highly correlated with the RowPerfect force profiles at each of the stroke ratings (24 spm = 0.91 ± 0.07; 26 spm = 0.92 ± 0.08; 28 spm = 0.93 ± 0.10). From the high correlation between on-water and RowPerfect force curves, it may be assumed that the RowPerfect ergometer replicates the kinetic profiles found in on-water rowing. As force curves have been identified in the literature as an important determinant of performance, if the shape of the force profile is similar, performance might also be expected to be similar.

The kinematic data served as another measure to compare the RowPerfect ergometer to the single scull rowing. Analyses of the body position at catch and at finish demonstrated that all but one of the body positions were statistically similar between the ergometer and on-water (see Figure 2). Only the knee angle at 24 strokes/minute in the catch position was significantly different and this was likely due to the low subject numbers involved.

Figure 2 - Subject in the catch and finish position on the RowPerfect ergometer and on-water.



CONCLUSIONS: Static ergometers have previously been used almost exclusively for on-shore training and crew selection despite research indicating that they may not represent on-water rowing. The advent of dynamic ergometers such as the RowPerfect are reported to more closely replicate the inertial properties of on-water rowing and would therefore be more specific as a training and selection tool. The current study demonstrated a very high association between the force profiles from the RowPerfect ergometer and on-water indicating that this ergometer replicated the patterns of on-water sculling. In addition, the body positions at the catch and finish for both styles of rowing closely resemble each other. A more efficient transfer of learning may therefore apply across the two forms of rowing as they demonstrate similar kinetic and kinematic elements during the performance of the skill. These findings support the use of dynamic ergometers such as the RowPerfect as a more specific training regime and crew selection tool.

REFERENCES:

Doyle, M. (1999). *The continuous registration of hand curves exhibited by high performance rowers*. Unpublished honours thesis, the University of Western Australia.

Kadaba, M.P., Ramakrishnan, H.K., Wooten, M.E., Gainey, J., Gorton, G., & Cochran, G.V.B. (1989). Repeatability of kinematic, kinetic and electromyographic data in normal adult gait. *Journal of Orthopaedic Research*, 1, 849-860.

Rekers, C. (1993). Verification of the RowPerfect ergometer. A.R.A. Senior Rowing Conference, London.

Smith, R., Spinks, W., & Moncrieff, J. (1988). *Rowsys: An 'on water' biomechanical analysis system for rowing*. In J. Draper (Ed)., 2nd Report on the National Sports Research Program (10-13). Australian Sports Commission.

Steinacker, J.M. & Secher, N.H. (1993). Advances in physiology and biomechanics of rowing. *International journal of sports medicine,* 14, S1-S2.

Torres-Moreno, R., Tanaka, C. & Penney, K.L. (2000) Joint excursion, handle velocity and applied force: a biomechanical analysis of ergometric rowing. *International journal of sports medicine,* 21, 41-44.