RELIABILITY OF POWER OUTPUT DURING ROWING CHANGES WITH ERGOMETER TYPE AND RACE DISTANCE

Clara Soper and Patria A. Hume
New Zealand Institute of Sport and Recreation Research, Auckland University of Technology, New Zealand

The percent standard error of measurement (%SEM) in performance of fifteen national level rowers was determined for five repeated 500 m and two repeated 2000 m races on a Concept II and RowPerfect ergometer. The %SEM in mean power between 5 x 500 m races, regardless of gender, was 2.8% (95% CL = 2.3 to 3.4%) for the Concept II ergometer and 3.3% (95% CL = 2.5 to 3.9%) for the RowPerfect ergometer. Over 2000 m the %SEM in mean power was 1.3% (95% CL 0.9 - 2.9%) for the Concept II ergometer and 3.3% (95% CL 2.2 - 7.0%) for the RowPerfect ergometer. The results highlight an increase in %SEM during: (1) performance races of less than 2000 m on the Concept II ergometer, and (2) performance races on the RowPerfect ergometer compared with the Concept II ergometer over 500 m and 2000 m.

KEY WORDS: Rowing, Reliability, Performance, Concept II, RowPerfect.

INTRODUCTION: At international level, sculling (two oars) and rowing (one oar) races are competed on-water over 2000 m. Race time is the critical measure of performance and is determined from mean boat velocity during a race. Although a high proportion of race training is completed on-water, rowing ergometers are commonly used for performance testing, technique coaching, crew selection, or for training during poor weather. The Concept II ergometer is arguably the most frequently used air-braked ergometer. Rowing performance on a Concept II ergometer has been reported as being repeatable when testing trained rowers over 2000 m (Schabort et al., 1999). The percent standard error of measurement (%SEM) for mean power was reported as being 2.0% (95% CL = 1.3 - 3.1%) when eight trained rowers completed three 2000 m time trials separated by three days each. The retest correlation coefficient was 0.96 (95% CL = 0.87 - 0.99). A 2.0% change in mean power equates to a 0.7% change in velocity using the formulae provided by Hopkins and colleagues (2001). Therefore, a change in mean power of 2.0% for a world class male single sculler with a mean velocity of 5.0 m.s2 will result in an equivalent change in performance time of 2.7 s over 2000 m. For a lower mean velocity of 3.5 m.s2 and a change in mean power of 2.0%, a 4.0 s change in total time will be seen. The high reliability is likely due to the Concept II ergometer being inherently stable and that rowers are accustomed to completing 2000 m time trials on this ergometer (Schabort et al., 1999). A good comparison of the kinematics and kinetics of Concept II ergometer and on-water rowing has not been completed to the authors' knowledge. Although distinctly different from the Concept II ergometer, the RowPerfect ergometer is also used by many rowers during land training sessions. The foot-stretcher and flywheel of the RowPerfect ergometer freely moves along a rail to more closely match the inertial forces exerted on a rower whilst on-water (Rekers, 1993). Elliot et al., (2002) reported a similar profile of force output and joint kinematics during on-water rowing and rowing on a RowPerfect ergometer. With the exception of knee angle at the catch no significant differences between rowing on-water and on a RowPerfect ergometer were reported. An earlier study by Buck et al., (2000) reported that peak horizontal handle force, time to peak handle force, and time to peak horizontal foot-stretcher force were not significantly different between the RowPerfect and Concept II ergometers. However, peak horizontal foot-stretcher force was significantly greater on the RowPerfect ergometer. Although the RowPerfect ergometer is purported to be a more valid ergometer for rowing (Rekers, 1993), no published research has reported the %SEM in performance, kinetic or kinematics variables during repeated trials.

A meta-analysis of studies measuring power in physical performance tests (such as cycling) revealed that the coefficient of variation between the first two trials was 1.3 times (95% CL = 1.1 - 1.6) larger than between any subsequent trials (Hopkins et al., 2001). Repeated 2000 m rowing tests within one training session may not be appropriate because the cumulative fatigue can affect performance (Smith & Milburn, 1996). To our knowledge, the reliability of repeated short duration maximal effort ergometer rowing trials has not yet been addressed. The reproducibility of short duration (0.55 0.11 min) laboratory cycling trials were reported as being significantly less reliable than trials lasting 12.0 0.2 min and 105.1 0.4 min (Hickey et al., 1992). The %SEM for cycling performance time was 2.4% for the short duration trials compared with 1.0% for medium and long duration trials. It is currently unclear why shorter (time or distance) performance trials are less reliable than relatively longer ones. Subject familiarity with the testing distance may be one reason for increased reliability. Alternatively, shorter tests may not need a pacing strategy to be employed, which could lead to increased reliability due to the 'all-out' nature of the tests. Further research is required to determine why reliability changes with test duration. On the basis of research by Hickey et al., (1992) it is reasonable that the %SEM of short duration ergometer rowing performance trials may be greater than standard 2000 m races.

To improve rowing performance through effective intervention it is first essential to quantify the reliability of ergometer measures. The present study determined the expected normal variation in mean power and total time when national calibre rowers repeated five 500-m and two 2000-m trials on a Concept II ergometer and RowPerfect ergometer.

METHODS: Ergometer testing was completed six weeks prior to the rowers competing internationally. All rowers were informed of testing requirements and each gave their written informed consent as required by the Auckland University of Technology ethics committee.

Participants: Eight male and seven female Rowing New Zealand (RNZ) national rowers (n=15) participated in the study. Each rower had been identified as a potential elite rower by the RNZ national development coach. In addition to land-based conditioning, all rowers regularly trained on the Concept II and RowPerfect ergometers; however, in-house monitoring tests are performed solely on the Concept II ergometer.

Procedures: All 15 rowers completed two 500-m races on the Concept II ergometer and two 500-m races and RowPerfect ergometer the day prior to data collection to ensure they were familiar with the shorter distance race. On day 1 of data collection each rower completed five 500-m races on either the Concept II or the RowPerfect ergometer. On day 2 the rower used the other ergometer. Ergometer order was randomly allocated across days and balanced between gender groups. Following a rest day, each rower completed a 2000-m race on three consecutive days using either the Concept II ergometer (4 males, 3 females) or the RowPerfect ergometer (4 males, 4 females). Although administered as a true race, the first 2000-m race was test familiarisation. All 500-m and 2000-m races were completed at the same time of day, with a minimum of 20 minutes rest between each 500-m trial.

The Concept II and RowPerfect ergometers were positioned next to each other, far enough apart to prohibit interference between their air braking mechanisms (Schabort et al., 1999). Individual rowers were paired to match performance ability by their coach. Using the Concept II and RowPerfect ergometers, the rowers in each pair raced against one another during the five 500-m and two 2000-m races. The authors believe maximal effort by the rowers was most likely to be achieved in the competitive race environment. The rowers were instructed to travel 500-m and 2000-m in the shortest possible time. The display panel on the Concept II ergometer and the computer attached to the RowPerfect ergometer were positioned so that the rowers could not view elapsed time. The rowers were not informed of their overall times for each 500-m and 2000-m race until completion of their final race on day 7. Stroke rate and remaining distance were continually verbally fed back to the rowers via the crews' coxswain during all races. Additionally, the coxswain, fellow crewmembers and the coach provided the same strong verbal motivation to the rowers during each race.

Stroke by stroke power output was recorded by video from the display panel on the Concept II ergometer and saved to file on the computer connected to the RowPerfect ergometer. The total time and mean power output for each ergometer race were calculated.

Statistical analysis: Descriptive statistics for all variables are represented as mean and standard deviations (spread of results among participants). There were some lost data due to malfunction of the RowPerfect ergometer during the repeated 500 m races. There were no missing data for repeated 500 m races on the Concept II ergometer or any 2000 m races. Measures of reliability (change in mean, %SEM and interclass correlation coefficients) were determined using a repeated measures analysis of variance in Statistical Analysis Systems. Data were log transformed for mean power output to provide measures of reliability as %SEM and interclass correlation coefficients (ICC) were calculated. The likely ranges of the true values are provided by 95% confidence limits (CL).

RESULTS: There were small changes in the mean overall time and mean power output on the Concept II and RowPerfect ergometers over 500-m and 2000-m distances (see Table 1). The %SEM for mean power on the Concept II ergometer was less than that for the RowPerfect ergometer regardless of race length. On the Concept II ergometer the %SEM for mean power and total time were smallest between repeated 2000 m than during repeated 500 m trials. The smallest %SEM on the RowPerfect ergometer was recorded during the 500 m trials for mean power and the 2000 m trials for total time. The test-retest correlation coefficients were all greater than 0.88 (95% CL = 0.53 to 0.96%).

Table 1 Mean power & mean overall time during 500-m and 2000-m ergometer races with the corresponding reliability statistics (95% Confidence Limits).

	Concept II		RowPerfect	
	Time (min:s)	Power Output (W)	Time (min:s)	Power Output (W)
500-m **Mean**	1:34 ± 0:01	418.1 ± 7.4	1:43 ± 0:01	474.0 ± 11.4
Change in mean	-0.2% (-2.0 – 1.6)	0.8%(-1.0 – 2.7)	-0.8%(-4.0 – 2.5)	-0.5%(-3.4 – 2.5)
%SEM	1.0% (0.8 – 1.1)	2.8% (2.3 – 3.4)	1.6% (1.3 – 2.0)	3.0% (2.5 – 3.9)
ICC	0.93 (0.80 – 0.98)	0.99 (0.99 – 1.0)	0.88 (0.53 – 0.96)	0.98 (0.96 – 1.0)
2000-m **Mean**	6:58 ± 0:05	312.4 ± 0.5	7:38 ± 0:07	360.4 ± 7.4
Change in mean	0.03% (-0.6 – 1.2)	0.02% (-1.9 – 1.5)	0.3% (-0.3 – 0.9)	-1.9% (-5.6 – 2.0
%SEM	0.7% (0.4 – 1.5)	1.3% (0.8 – 2.9)	0.5% (0.3 – 1.1)	3.3% (2.2 – 7.0)
ICC	0.99 (0.95 – 1.0)	0.99 (0.98 – 1.0)	0.99 (0.97 – 1.0)	0.98 (0.91 – 0.10)

DISCUSSION AND IMPLICATIONS: Knowing the reliability of a test is essential for the investigation of rowing performance, irrespective of whether an on-water or ergometer based research project is intended. A performance test is valuable when reliability is high enough to allow researchers to use realistic sample sizes but still detect small differences in performances that are beneficial to elite athletes (Schabort et al., 1999).

Performance reliability on different ergometers: The reliability of power output is dependent on the ergometer-athlete relationship and not solely one or the other. Rowers were able to reproduce mean power output during the 500-m and 2000-m maximal effort performance trials with a smaller %SEM on the Concept II ergometer than on the RowPerfect ergometer. The high test-retest reliability of the Concept II ergometer is most likely due to its inherent stability and subject test familiarity as suggested by Schabort et al., (1999). The larger %SEMs recorded on the RowPerfect ergometer compared to the Concept II ergometer during the 500-m and 2000-m races may be due to the lower mean velocity during the races or the increased dynamical movement pattern required. The greater dynamics of the RowPerfect ergometer comes from the absence of a fixed base at the foot-stretcher that transfers an equal and opposite force back to the rower during the drive phase of the stroke cycle (as found on the Concept II ergometer). This primary difference between the two ergometers leads to greater coordination and technical proficiency requirements during RowPerfect ergometer use. An ergometer that requires a higher skill level may result in greater changes in performance repeatability and as such the higher %SEM (lower reliability) reported in this research. Alternatively, experienced competitive rowers (as used in this research) should be more familiar with the movement patterns on the RowPerfect ergometer than on any other ergometer due to the reported similarities with respect to inertial properties (Rekers, 1993) and force-time curves development (Elliott et al., 2002) between the RowPerfect ergometer and on-water rowing. A three-way comparison of technical proficiency requirements and repeatability of rowers' power output performance on the Concept II ergometer, the RowPerfect ergometer and on-water rowing is required before the most reliable and valid ergometer test can be recommended.

Performance reliability over 500-m and 2000-m distances: No clear conclusions regarding the effect of trial length on mean power reliability could be drawn for the RowPerfect ergometer given the similar %SEM for mean power and overlap of the confidence limits. The opposite was evident on the Concept II ergometer with the 2000-m races being clearly more reliable than the 500-m races for mean power output. The rowers results whilst on the Concept II ergometer support earlier research by Hickey (1992) who found cycling trials lasting approximately one minute to be significantly less reliable than 12 minute and 105 minute trials. However, Schabort et al., (1999) suggested that power output during a 2000-m (~ seven minutes) rowing ergometer test was more reliable than a 60 minute cycling test due to its shorter duration. There may be an optimal trial duration for test-retest reliability with reduced reliability during very short or very long tests. It seems likely that optimal performance reliability would be achieved using a protocol that matches the duration of normal competitive races in a particular sports event.

Mean power output and total time in the 500-m races tracked mean power output and total time in the 2000-m races closely, as illustrated by the high test-retest correlation coefficients (0.88-0.99; 95%CL = 0.53 - 1.0). The lower (0.88; 95% CL = 0.53 - 0.96) correlation coefficients for 500 m races on the RowPerfect ergometer may be directly attributable to the ergometers higher test-retest variation.

CONCLUSION: The most appropriate protocol for testing the influence of an intervention on the ability of a rower to improve mean power output would be 2000-m races on a Concept II ergometer, following a familiarisation trial. Whether this protocol is optimal for technique assessment is yet to be determined. When using the RowPerfect ergometer researchers, coaches and trainers need to be aware that between 2.2 - 7.0% of any changes in mean power output may be normal rower variability and may not be associated with any training gain/loss or intervention. Researchers need to be aware of the greater measurement error exhibited during performance trials less than 2000-m and on the RowPerfect ergometer.

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