ELITE ROWERS APPLY DIFFERENT FORCES BETWEEN STATIONARY AND SLIDING ERGOMETERS, & ON-WATER ROWING

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Rowing on ergometers is often required due to on-water conditions and testing requirements. Force generation between on-water sculling, fixed and sliding ergometers, has been examined, but there are only a few studies with elite level rowers. Forces at the handle, rowing gate, and foot block were recorded for four elite rowers during 1,000-m on a fixed ergometer, sliding ergometer and an on-water double scull. Handle forces were greater on the fixed and sliding ergometer than the on-water double. There was a trend for the foot forces to be similar between all three conditions. However, the timing of application of force was considerably earlier on the fixed and sliding ergometer than the on-water condition. The use of ergometers as a substitute for on-water rowing needs to be reconsidered in light of these results.

KEY WORDS: rowing mechanics, force, temporal, high-performance, feet, handle.

INTRODUCTION: Rowing requires extreme physical strength and endurance coupled with high training volumes (Nolte, 2011). Rowing machines or ergometers (Figure 1) are commonly used for performance testing, technique coaching, crew selection, and bad weather training (Soper & Hume, 2004). To varying levels, ergometers have been shown to simulate both physiological and biomechanical demands of on-water rowing (Christov, Christov, & Zdravkov, 1988; Dawson, Lockwood, Wilson, & Freeman, 1998; Elliott, Lyttle, & Birkett, 2002; Lamb, 1989) and also allow for control in testing situations, which is not always possible on the water, due to the variability in environmental conditions. A variation of the traditionally and most commonly used Concept2 ergometer is placing it on sliders (Figure 2) in order to try and imitate on-water rowing more closely. Whilst these sliding ergometers have been shown to be more specific to rowers physiological on-water rowing demands (De Campos, Bertuzzi, & Franchini, 2014), there still remains the question about how similar the sliding and stationary ergometer is to on-water rowing in terms of forces applied at the handle and the feet. Some studies have investigated handle forces applied on stationary ergometers compared to on-water, or between stationary and floating or sliding ergometers (Collouda, Bahuaudb, Doriota, Champelyc, & Chèzea, 2006). However, there is limited research that compares the same high performance rowers across three performance conditions; stationary and sliding ergometers with on-water rowing. The aim of this study was to compare foot and handle forces for high-performance rowers for a stationary ergometer, sliding ergometer, and on-water sculling.

Figure 1: Fixed ergometer.

Figure 2: Sliding ergometer.

METHODS: Four elite female adult rowers volunteered for this study (height: 1.78 ±5.6 cm; weight: 77.5 ±8.1 kg). All rowers had international representation experience with typical 2000-m erg times (m:ss.0) of 7:04.5 ±3.7 s. Each rower performed a single 1000-m time-trial for each of a fixed ergometer (Concept2), a sliding ergometer (the same Concept2 ergometer placed on Concept2 slides), and in an on-water double scull. Force data at the oarlock and footplate were collected with the PowerLine^{TM} Instrumentation system (Peach Innovations Ltd., Cambridge, UK) in the double scull. This system was also used on the ergometer for the foot force measurement synchronized to a calibrated strain gauge attached to the oar handle on the rowing ergometer. A sample of three strokes was taken at 85% of the trial's time to assess the differences in conditions under a more fatigued state where differences (if any) would likely be more pronounced. For each variable, the average of three strokes for each participant for each condition was used for statistical analysis. Data were treated with log-transformation before examining changes. Differences between conditions were assessed using Cohen's effect sizes (ES) and 95% confidence intervals presented to determine the likelihood of a real change. The scale used for effect size interpretations was: <0.2 = trivial; 0.2-0.5 = small; 0.6-1.1 = moderate; 1.2-1.9 = large; 2.0+ = very large (Hopkins, 2002). Confidence intervals including at least -0.2 to 0.2 were deemed unclear effects despite the observed effect size and these changes were discussed as "tendencies" based on the observed ES. The null-hypothesis was rejected and statistical significance achieved if $p<0.05$.

Variables:

1. The percentage of time (%) into the stroke from the catch when maximum handle force was reached.
2. The percentage of time (%) into the stroke from the catch when maximum foot force was reached.
3. Maximum foot force reached (N).
4. Maximum handle (oar) force reached (N).

RESULTS: Overall, there were no statistically significant differences between the fixed and sliding ergometer in any of the variables. There were also no clear trivial effect sizes between two ergometer conditions, so differences cannot necessarily be ruled out. Table 1 shows that the timing of the maximum foot force occurred later in the stroke cycle, as the stability of the platform decreased (i.e. fixed to slides to on-water), with statistically significant effect size changes between the two ergometer conditions and the on-water condition (see Table 2). The timing of the maximum hand force tended to occur later in the stroke cycle on the water than either of the two ergometer conditions, but this difference was unclear due to the large confidence intervals observed. Maximum force of the hands decreased as the stability of the platform decreased (i.e. fixed to slides to on-water), with a statistically significant difference between fixed and on-water, where rowing on-water reduced the hand force by a very large amount. The observed maximum foot force was similar between slides and the on-water condition shown by a trivial ES, and was observed to increase by a small amount between either of these conditions and the fixed ergometer. However, all findings regarding the observed maximum foot force were unclear due to the large confidence interval, and more data is needed to confirm the results of this variable. An example of force profiles throughout the stroke is shown for one rower in Figure 3, A & B.

Table 1
Descriptive statistics for 1000-m time-trials for three rowing conditions for forces applied at the feet and hands of four rowers.

	Fixed		Slides		Water	
Variable	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Timing of Max Force – feet (%)	7	±5	13	±2	19	±4
Timing of Max Force – hands (%)	15	±2	15	±2	18	±4
Max Force – feet (N)	1167	±131	1104	±142	1111	±221
Max Force – hands (N)	676	±67	659	±79	577	±30

% indicates % of the stroke cycle when maximum force was achieved.

Table 2
Effect size statistics for 1000-m trial times for three rowing conditions for forces applied at the feet and hands of four rowers.

	Water to Fixed		Water to Slides		Fixed to Slides	
Variable	**ES**	**95% CI**	**ES**	**95% CI**	**ES**	**95% CI**
Timing of Max Force - feet	-2.9*	-5.5 to -0.4	-1.5*	-2.4 to -0.6	1.2	-0.6 to 3.0
Timing of Max Force - hands	-0.5	-2.0 to 1.0	-0.5	-1.7 to 0.8	<0.1	-0.4 to 0.5
Max Force - feet	0.2	-1.1 to 1.6	0.0	-1.3 to 1.3	-0.2	-0.7 to 0.2
Max Force - hands	2.2*	0.3 to 4.1	1.8	-0.3 to 3.9	-0.4	-1.1 to 0.3

ES = effect size, CI = confidence interval, * change is statistically significant, $p<0.05$.

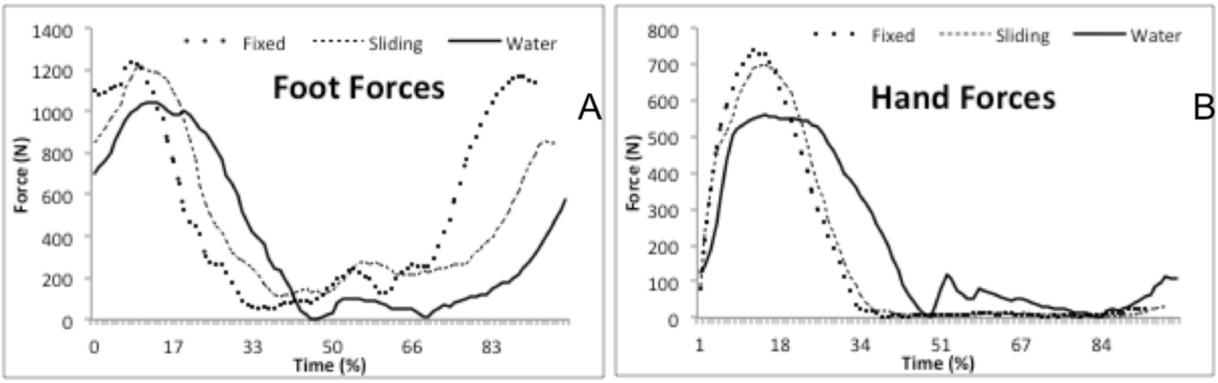

Figure 3. Example stroke from one rower of the feet forces (Fig 3,A) and the hand forces (Fig 3, B) applied in the three test conditions during one stroke, from catch to catch.

DISCUSSION: Temporal application of feet and handle forces in addition to the total forces produced by individual rowers differed between the ergometer conditions and the on-water condition. The maximal handle forces achieved were statistically different between the fixed ergometer and on water, but not statistically different between the water and sliders. There was a trend for the foot forces to be higher on the ergometer compared to on-water and in particular, maximum forces were achieved earlier on ergometers than on-water. The sliding ergometer did appear to have a more of a delay than the fixed ergometer to reaching the maximum force, which is more comparable to the on-water than fixed ergometer movement. The fixed ergometer had the situation where either the maximum foot force was already achieved by the start of the stroke (the catch) or just prior to it. Either way, this temporal coordination is significantly different to that of on-water performance. These changes imply differing demands of ergometer and on-water rowing as noted by the temporal and total force changes produced by rowers.

CONCLUSION: Handle and foot forces are different in fixed and sliding ergometers when compared to on-water. The current study demonstrated that on-water rowing has different temporal and maximal forces to fixed ergometer. In particular the need to generate large forces early in order to get the flywheel moving faster, and this differs to the movement tendencies than that required with on-water rowing. This emergent coordination appears to have evolved from the task demands of the ergometer and is relatively consistent across rowers and both sliding and fixed ergometer conditions. Therefore there are biomechanical implications for performing in one highly trained context (i.e. ergometer), which is different to what is required for performing in a dissimilar context (on-water). The impact of these changes on optimal performance requires further investigation.

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