THE DIFFERENCES IN SPINAL KINEMATICS AND LOADING IN HIGH PERFORMANCE FEMALE ROWERS DURING ERGOMETER AND ON WATER ROWING

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Low back pain (LBP) is the most prevalent injury in rowing. The high use of ergometers has been associated win increased LBP and sliding ergometers are proposed to reduce this stress. The purpose of this study was to examine the lumbar flexion angles on fixed and sliding ergometers versus on water conditions. Four elite female adult rowers volunteered for this study and completed a 1,000 meter maximal test on the stationary and fixed ergometers and then on water. Lumbar curvature (% flexion) was calculated) for the first 0.47 s following the catch position. Standardized mean differences (effect size) were calculated to examine differences in %ROM over time for each condition and between conditions. Results found that fixed rowers ergometers induced the greatest amount if lumbar flexion, with some reduction for sliding ergometers compared to on water.

KEY WORDS: Lower-back, injuries, lumbar flexion, ergometers

INTRODUCTION: Low back pain (LBP) is identified as the most prevalent and significant injury that affects rowers (Caldwell, McNair, & Williams, 2003; Clay, Mansell, & Tierney, 2016; Newlands, Reid, & Parmar, 2015; Perich, Burnett, O'Sullivan, & Perkin, 2011; Rumball et al., 2005; Thornton et al., 2016). A number of factors have been suggested to contribute to this injury rate including high training volumes combined with high levels of lumbar flexion (Reid and McNair 2000). Stationary ergometers are often used as a surrogate for on water rowing and some authors have shown that the frequency of low back injury also increases with time spent rowing on an ergometer (Wilson, Gissane, Gormley, and Simms, 2010; Wilson, Gissane, & McGregor, 2014) especially durations of over 30 minutes. (Teitz, O'Kane, Lind, and Hannafin, 2002). Other studies have also shown that lumbar flexion increased over the duration of a 2,000 meter ergometer test in female rowers (Caldwell et al 2003). More recently stationary ergometers have been supplemented by placing stationary ergometers on sliding platforms. These are thought to replicate on water rowing more closely than fixed ergometers. To date there are no studies that have compared the differences in lumbar spine angles on fixed vs sliding vs on water conditions. The ability to capture on water data has also been a challenge in previous research. The hypothesis to be tested was that fixed ergometers would induce greater increases in lumbar flexion than sliding or on water conditions

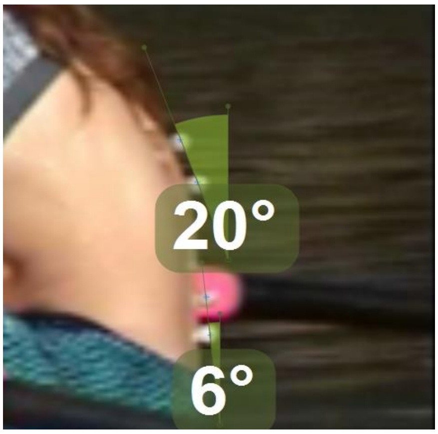

Figure 1. Lumbar and sacral angle measurements in Kinovea.

METHODS: Four elite female adult rowers volunteered for this study (height: 1.78 ±5.6 cm; weight: 77.5 ±8.1 kg) after receiving ethics approval by AUTEC. 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 an on-water double scull. Two sets of two orange visible markers were attached over the spinous processes (See Figure 1) such that one set centred on either side of the first lumbar vertebrae (L1) and another set centred on either side of sacral level 1 (S1) as described by Caldwell, McNair, and Williams (2003). Prior to testing, stationary erect position and sit-and-reach position were recorded for reference values to normalise rowing lumbar curvature measures to a rower's % lumbar flexion to allow group comparisons. In the laboratory, a digital video camera sampling at 30 frames per second, was placed perpendicular to the sagittal plane to collect samples of strokes at 15% (BEG), 50% (MID), and 85% (END) of the 1000-m trial. On-water, video was taken by the same means, however, the camera was hand-held carefully in a chase boat perpendicular to the path of motion. Quality of video on-water was monitored via taped reference points placed on the boat that would align when the camera was perpendicular to the sagittal plane.

Three strokes were selected for each section of the time-trial for each rower for analysis. Video data were digitized using Kinovea motion analysis software. Lumbar curvature (% flexion) was calculated as described by Caldwell, McNair, and Williams (2003) for the first 15 frames from the catch position (0.47 s, 26% of the stroke, or 60% of the drive phase). The catch was defined as the start of the rowing stroke and represents the phase where the loading on the lumbar spine is highest (Reid and McNair, 2000). The frame from which posteriorly-directed motion of the oar handle began was used as the catch position. Lumbar curvatures expressed as a % range of motion (%ROM) were graphed for visual assessment. Standardized mean differences (effect size) were calculated to examine differences in %ROM over time for each condition and between conditions. The scale used for effect size interpretations was: <0.2 = trivial; 0.20-0.59 = small; 0.60-1.19 = moderate; 1.20-1.99 = large. A paired-sample t-test was used to determine a p-value to explore statistical significance. The null-hypothesis was rejected if $p<0.05$.

RESULTS: Lumbar curvature as a %ROM is shown for each BEG, MID, and END section of a 1000-m time-trial for each condition (Table 1). The effect of the condition on fatigue rates in rowing is shown in Table 1 (BEG to END) for fixed, sliding, and water conditions. Comparisons between conditions for the END sample is also shown in figure 1.

Table 1. Changes in lumbar spine curvature across the duration of 1000-m time-trials for fixed ergometer, sliding ergometer, and water environments.

Time-point (s)	Fixed Erg BEG to END	Sliding Erg BEG to END	Water BEG to END	Fixed Erg to Water (END)	Sliding Erg to Water (END)
	Effect Size	Effect Size	Effect Size	Effect Size	Effect Size
0.00	-0.06	0.36	0.30	0.04	0.36
0.03	0.15	0.42	0.19	0.02	0.29
0.07	0.74	0.39	0.10	-0.48	0.30
0.10	0.63	0.25	0.21	-0.34	0.56
0.13	0.38	0.36	0.08	-0.18	0.43
0.17	0.69	0.42	0.11	-0.47	0.39
0.20	0.78	0.62	0.25	-0.56	0.35
0.23	0.80	1.00*	0.38	-0.66	0.21
0.27	0.66	1.41*	0.09	-0.62	-0.33
0.30	0.12	0.96*	0.16	-0.51	-0.04
0.33	0.00	0.67	0.09	-0.71	-0.09
0.37	0.05	0.56	0.20	-0.77	0.24
0.40	-0.36	0.33	0.29	-0.47	0.52
0.43	-1.00	0.45	0.31	-0.21	0.57
0.47	-1.28	0.35	0.49	-0.05	0.60

*indicates statistical significance ($p<0.05$).

DISCUSSION: Rowers produced the highest lumbar curvature values relative to their full ROM during fixed ergometer rowing. Under a relatively more fatigued state at the END sample, water rowing, helped reduce %ROM by a small to moderate amount in the observed sample of rowers between 0.07-0.43 s of the stroke. This time comprised from just following the catch to about ¾ of the drive phase. In contrast, from sliding ergometer to water, lumbar curve values increased by a small amount in the observed sample from 0.00-0.23 s and also 0.37-0.47 s into the stroke cycle, which comprises the catch to early drive, then near the ¾ drive time. The sample sizes were too low to determine statistical significance, but individual examination of data showed large changes between conditions for some rowers. The findings support, that for competitive rowers who are concerned with water performance, rowers' lumbar spine mechanics are changed when rowing on the ergometer, and fixed-ergometer rowing may be more dangerous as rowers near 100% of their lumbar spine range of motion in as short as a 1000-m time-trial.

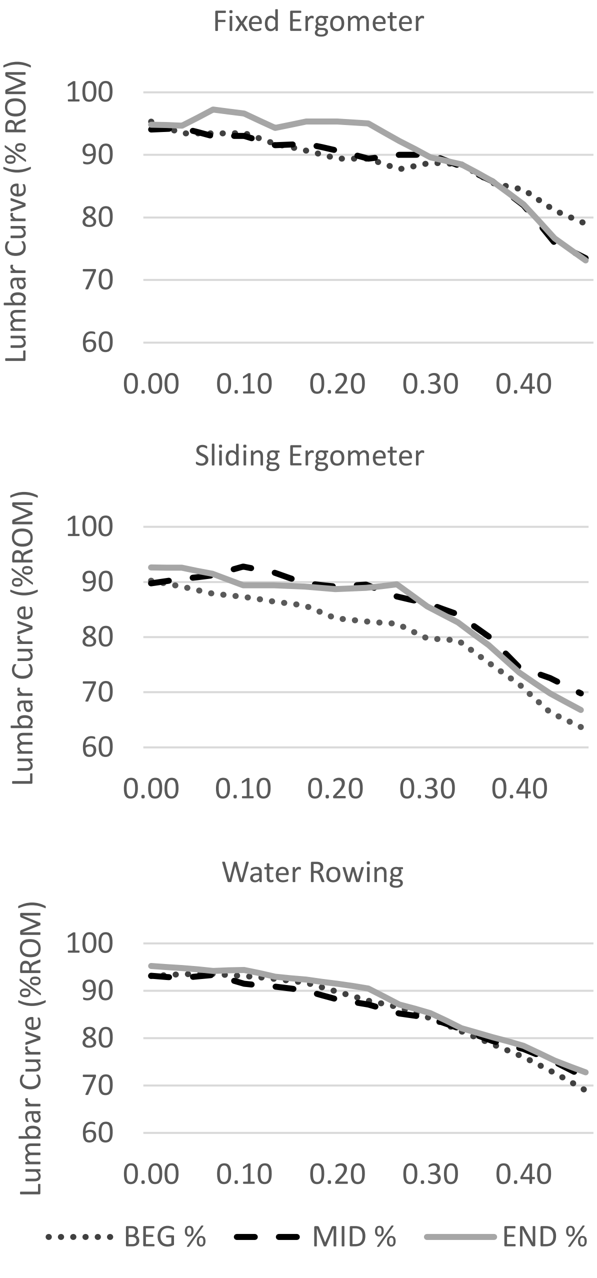

Figure 2. Average lumbar curvature (%ROM) during the first 0.00-0.47 s of rowing stroke time (x-axis) for each rowing condition sampled at the BEG, MID, and END of each time-trial.

Duration effects on lumbar spine is most pronounced in the sliding ergometer with small to large increases in lumbar curvature for the duration of the measurements across BEG to END. However, initial rowing on the sliding ergometer adopted a much more upright posture from Lumbar Curve data (see graphs – Figure 2). Effect sizes between sliding erg and water environments confirm the rower has a more upright posture on the sliding ergometer than water.

Water rowing, which is the natural environment for competitive rowers, elicits the least variability in lumbar curvature across a 1000-m time trial. In addition, previous research evaluating peak handle forces demonstrates that these are 20% less on water when compared to the fixed and sliding ergs" (Millar, Reid, McDonnell, Lee & Kim, 2017).

CONCLUSION: Key outcomes were: (1) fixed ergometer may induce greater lumbar spine flexion in some rowers from just after the catch to about ¾ drive phase. Those at risk of

lumbar spine injury or those who have stiff lumbar spines should be cautious or reduce time spent on the fixed ergometer training. (2) Sliding ergometer or a more dynamic ergometer may be safer for the low back, however over time, rowers revert to lumbar curve profiles more similar to fixed ergometer rowing. (3) Water rowing induces the least variable lumbar curve profiles with peak lumbar curves occurring at the catch, then reducing lumbar curve % ROM as the rower progresses with an increased load.
Due to the small sample size, our observations need to be treated with caution. As the null-hypothesis could not be rejected for most effects. However, the observed sample showed enough change to warrant further investigation and inform prospective injury studies in rowing.

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