VALIDITY OF THE POWERLINE BOAT INSTRUMENTATION SYSTEM

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The PowerLine Boat Instrumentation System[3] is comprised of instrumented oarlocks capable of measuring pin forces in the direction of boat travel and oarlock angles. The aim of this study was to determine the reliability and validity of the force and angle data from the PowerLine Boat Instrumentation System in a laboratory setting. Data were collected with the sculling oarlocks affixed to a horizontally aligned, stabilised wing rigger. For force analysis, signals were collected at 50 Hz from both the PowerLine system and a 1 kN load cell[4] during 10 repetitions at a rate of approximately 30 repetitions per minute. For angular analysis, whilst recording with PowerLine, oarlocks were repositioned for a minimum of two seconds at known angles in a random order using an inclinometer accurate to one tenth of a degree over a range of -80° to +60°, in 20° increments. Linear regression analysis through the origin was used to compare the PowerLine values with known values from the load cell and the inclinometer. Laboratory testing proved the force and angle sensors to be valid throughout the testing range (0 N to 554.8 ± 20.4 N, and -80° to +60° respectively) when fully functioning. The PowerLine Boat Instrumentation System appears to be appropriate for measuring biomechanical variables in an elite sculling programme. On-water reliability testing is still required to fully evaluate their application in quantifying the effect of interventions made to technique or boat set-up.

KEY WORDS: rowing, biomechanics

INTRODUCTION: The role of an applied rowing biomechanist is to supply coaches with the information they need to analyse rowing technique and boat speed (McBride, 2005). At the elite level, coaches and athletes strive to cut tenths of a second from performance times, thus a high degree of accuracy and reliability is required from any instrumentation used to supply such measures (Baudouin and Hawkins, 2004). Although athlete testing in a laboratory setting will provide a more controlled environment, it will not represent the task as it would be performed in competition (Baca, 2006; Williams and Kendall, 2007). Comparative studies between on-water and ergometer force profiles have highlighted that on-water analysis is the only option for data that truly signifies the rowing performance situation (Dawson et al., 1998; Elliott et al., 2002; Kleshnev, 2008; Lamb, 1989; Li et al., 2007). In providing highly applicable measures, it is also vital that the instrumentation does not interfere with the normal operation of the shell and the sculler (Müller et al., 2000; Smith and Spinks, 1989). The PowerLine Boat Instrumentation System represents a means of providing relevant, on-water data without noticeable change to the athlete set-up. The manufacturers claim accuracy in the force measures of up to two percent of its full scale (an error of up to 40 N) and 0.5° in the angle measures, but independently tested validity of its measures have not previously been documented (Peach Innovations). The aim of this study was therefore to provide independent validity measures for the instrumented sculling oarlocks.

METHODS: To avoid damage to Rowing New Zealand equipment and to control for movement of the pin, all validation was carried out in a laboratory setting. For all procedures, the oarlocks were fixed to a pin, horizontally oriented in a wing rigger as shown in Figure 1. Eight sculling oarlocks were tested in total. Only dynamic force validation could be performed due to an auto-zeroing function built into the oarlocks - the system assumes any force application that remains static is zero and automatic calibration occurs. This was not considered limiting as static forces are not seen in the normal rowing situation.

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Figure 1. **Laboratory rigger set-up for all validation procedures.**

Using an inclinometer (SmartTool[TM] Level[5]) the PowerLine logger zeroing function was used to set 0° as the position where the oarlock would be parallel to the midline of the shell – horizontal orientation of the working face of the oarlock in the validation set-up. Dynamic linearity and validity of the force measure was determined by recording sample data whilst a dynamic linear force was manually applied by pulling downwards on a bar hanging from the oarlock with a 1.0 kN load cell suspended in series. At a rate of 30 ± 2 repetitions per minute, 10 repetitions were recorded at 50 Hz from both the PowerLine system and the load cell in a range of 0.0 N to 554.8 ± 20.4 N. Outputs from the load cell were recorded using Labview[6] and output from the logger was downloaded later. The two entire data sets from the 10 repetitions were collated in Excel[7] and analysed, synchronising the data using the first local maximum force reading.

Although all effort was made to apply the force in the vertical direction, some deviation occurred and, because the load value presented by PowerLine is the actual force, resolved in the vertical direction, equation 1 was used to calculate the actual load.

$$L = \frac{L_{vert}}{\cos\alpha} \quad (1)$$

where L is the actual force applied, α is the oarlock angle, and L_{vert} is the resolved vertical force presented by the PowerLine software. Linear regression analyses through the origin were computed in SPSS[8] where the “dependent variable” was the oarlock reading and the “independent variable” was the load cell reading.

For angle validation, the oarlocks were repositioned for a minimum of two seconds at known angles in a random order using an inclinometer (SmartTool[TM] Level) accurate to 0.1° (MD Building Products, 2007). A range -80° to +60° was used in 20° increments. PowerLine data were downloaded and linear regression analyses through the origin computed in SPSS using the average value from each two second increment in comparison with the known angles.

RESULTS: Table 1 shows the results of the linear regression through the origin of the oarlock reading with the load cell for each of the eight oarlocks. The standard error of the estimate (SEE) was at most 8.9 N for all oarlocks except oarlock #1408 which displayed an SEE of 11.7 N. The R^2 values were all 1.00, except oarlock #1408 that displayed an R^2 value of 0.99. Oarlocks 1401 to 1407 showed a range of 15.5 N to 45.6 N in the maximal error of the estimate for each oarlock.

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[7] Microsoft, Washington, WA 98052, USA
[8] SPSS Inc. Headquarters, 233 S. Wacker Drive, 11th floor, Chicago, Illinois 60606

Table 1. Dynamic linearity statistics for the force measures from the sculling oarlocks in the range of 0 N to 554.8 ± 20.4 N compared with force measures from the load cell. Linear regression was computed through the origin.

Oarlock number	Slope	R^2	Standard error of the estimate (N)	Max error (N)
1401	1.01	1.00	8.9	44.5
1402	1.04	1.00	5.1	30.6
1403	0.99	1.00	8.0	39.3
1404	1.04	1.00	7.4	21.2
1405	1.00	1.00	4.3	15.5
1406	1.05	1.00	7.7	45.6
1407	1.01	1.00	4.2	20.3
1408	0.93	0.99	11.7	81.5

Table 2. Static linearity statistics for the angle measures from the sculling oarlocks in the range - 80° to 60° compared with the angle measure from the inclinometer. Linear regression was computed through the origin.

Oarlock number	Slope	R^2	Standard error of the estimate (°)	Max error (°)
1401	1.00	1.00	0.9	1.1
1402	1.01	1.00	0.2	0.7
1403	1.00	1.00	0.4	0.6
1404	1.00	1.00	0.7	1.0
1405	1.00	1.00	0.9	1.4
1406	1.00	1.00	0.3	0.5
1407	1.00	1.00	0.7	1.1
1408	0.98	1.00	3.1	8.2

Results of the regression analyses for oarlock angle versus inclinometer angle are presented in Table 2. The SEE was 0.9° or less for all oarlocks except for oarlock #1408 which had an error of 3.1°. R^2 was 1.00 for all oarlocks. Oarlocks 1401 to 1407 showed a range of 0.5° to 1.4° in the maximal error of the estimate for each oarlock.

DISCUSSION: Apart from sculling oarlock #1408 (which has since been replaced), the force and angle measures proved to have an acceptable level of validity in the range tested in a laboratory setting. In previous repeated short on-water bursts, elite scullers showed typical expected variation between trials of 1.2% in stroke length and 4.9% in peak propulsive force (Soper et al., 2003). This would equate to 1.1° in a sculler with a total arch of 95°, and 29.4 N in a sculler with a peak propulsive force of 600 N. For oarlocks #1401 to #1407, SEE in force was at most 8.9 N, and 0.9° for the angle measure therefore a greater percentage of variation in the overall values will come from the scullers themselves rather than the instrumentation system. For oarlocks #1401 to #1407, the SEE for the force measures falls below the manufacturers' claimed accuracy level of 40 N but the SEE of the angle measure exceeded 0.5° (claimed angle measure error) in four of these oarlocks. The maximal errors are also higher than the manufacturers' error values in some oarlocks. The non-automatic synchronisation method used in this study may account for this higher than anticipated, and potentially over-estimated, maximal error and SEE. Subjective feedback from the scullers who have used the testing system over the past 16 months has shown that there is no alteration to the feel of the boat set-up as long as the pitch of the scullers' usual oarlocks is the same as the instrumented oarlocks. Further investigation is required to determine the on-water reliability of the output variables from the PowerLine Boat Instrumentation System when used by elite scullers.

CONCLUSION: The force and angle measures from the laboratory testing of the PowerLine Boat Instrumentation System for sculling proved to have an acceptable level of validity represented by a standard error of the estimate of 8.9 N or less for force, 0.9° or less for angle, and an R^2 of 1.00 for both variables in all functioning oarlocks over the testing range. Malfunction in one sculling oarlock highlighted the need for regular validity testing.

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