DESCRIPTION OF A METHOD TO CONTINUOUSLY REGISTER THE HAND-CURVE IN ROWERS

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Previous methods of tracing the path of the rower's oar (the "hand-curve") have relied upon cinematographic methods, which have resulted in a minimal number of strokes being analysed. A method of continuously registering the hand-curve in rowers is presented. A modified Concept II oarlock was designed so that rotation of the oar about the X and Y-axes could be measured and thus the hand-curve obtained. A potential source of error in measurement is in the calibration of the potentiometers measuring the angle. Therefore, the repeatability of this procedure was examined. The calibration procedure was repeated five times and it was revealed that the construction of the calibration rig was of importance to maintain data integrity.

KEY WORDS: biomechanics, rowing, handcurve

INTRODUCTION: Traditional methods of rowing coaching have largely involved the subjective analysis of a rower's performance based on how technique corresponds to an ideal form as seen by the coach. Angst (1980) presented a paper in which he described a relationship between the pathway that the handle moved (the "hand-curve") and the shape of the force profile. The hand-curve pattern could be used as a more direct feedback to the oarsperson, with observable adjustments to technique having direct implications to the force applied.
Very little research has been presented on hand-curves, with the studies only analysing a small number of strokes due to the limitations associated with the use of cinematographic methods, due mostly to the large horizontal distance covered by the rowing shell (Deming et al., 1988).
The aims of this study were to design a method whereby the hand-curve could be continuously measured over numerous strokes and to develop a calibration rig.

METHODS: To replicate the normal rigging situation as closely as possible it was decided that the apparatus should be based around the Concept II oarlock commonly used in rowing shells. The modified oarlock consisted of a stainless steel, spring loaded wire frame, which clipped onto the oar shaft approximately 25 cm either side of the gate. A lubricant was applied to the shaft at these points to minimise friction. This frame was attached to a single turn 149 series potentiometer (RS Components: Part Number 173-849) mounted on a swing arm which pivoted about the same pin as the gate. The positive X-direction was defined as the direction the swing arm was pointing and the positive Y-direction was defined by the upward direction of the pin. Therefore, the left hand gate (looking in the same direction as the athlete when in the boat) was defined as a left hand coordinate system and the right hand gate was a right hand coordinate system. Consequently, rotation about the X-axis (γ) was considered as rotation about a 'floating' frontal plane. Furthermore, rotation about the Y-axis (α) was about a 'fixed' transverse plane. This rotation was measured by a second identical potentiometer (Figure 1).
The input sensors were attached to a 486DX100 slave computer housed within a waterproof box, which was secured within the boat. All data were converted to a digital format via an AX10411 12.5kHz analog to digital (A-D) convertor connected to the CPU of the slave computer. The slave computer was connected to the master computer (Pentium 233 MHz laptop) via radio modems (Freewave Technologies, USA) at a baud rate of 115.2K. Data were 12 bit (ie. represented as 0 to 4095) with a collection rate of 160Hz.

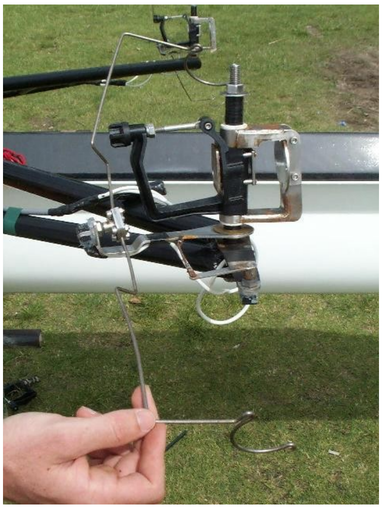

Figure 1 - The modified Concept II Oarlock used for data collection.

Calibration of the potentiometers was carried out before each testing session using customised calibration frames. For the potentiometer measuring X-axis rotation, the neutral position was obtained by holding the boat level in the plane about its long axis and adjusting the calibration frame until a spirit level mounted on the horizontal arm indicated the frame was level with the boat. The frame was then tightened to prevent movement. The oar was rotated in the vertical plane to the –20° mark on the frame, held firmly against the back plate of the oarlock and a calibration reading taken. This was repeated for the 0° and +20° positions. A linear calibration function, converting angular position to A-D units, was then fitted to the data points via customised software for later analysis.

For the potentiometer measuring Y-axis rotation, the point where the oar shaft was normal to the longitudinal axis of the boat was defined as the neutral position. From this position, oar handle movement away from the athlete towards the catch was defined as a negative angle, while oar handle movement towards the rower and the finish of the stroke was defined as positive. With the zero degree position accurately established, the oar was then rotated to the –45° position, held firmly against the back plate of the oarlock and a calibration reading taken. This was then repeated for the 0° and +45° positions. A linear calibration function was again fitted to these data.

The rower's hand-curve data are obviously collected in an outdoor environment. While every effort was made to ensure accuracy of all data collected, there will inevitably be two sources of error which are introduced into the results; namely the repeatability of the calibration process, and the influence of external factors, predominantly the weather. In order to assess the repeatability of the calibration procedure, the entire calibration procedure was conducted five times. The average A-D values obtained over the five trials at each calibration point for both X and Y rotation, were obtained.

RESULTS AND DISCUSSION: The functional precision of the potentiometers for X-axis rotation was found to be approximately 0.07^{o} per A-D unit on the left oarlock, and approximately 0.06^{o} per A-D unit for the right (Table 1). For Y-axis rotation the precision was approximately 0.07^{o} per A-D unit for both the left and right potentiometers (Table 2). As the static noise present in the potentiometers was very low (in the order of ± 1-2 A-D units) any error from this factor can then be assumed to be negligible.

Table 1 **Results of Repeated Calibrations Trials for Rotation about the X-Axis (A-D Units)**

	Channel 2 (Left)					Channel 5 (Right)				
Trial	-20	-20 to 0	0	0 to 20	20	-20	-20 to 0	0	0 to 20	20
1	1892	276	2168	310	2478	1882	302	2184	316	2500
2	1867	275	2142	319	2461	1895	319	2214	306	2520
3	1896	276	2172	290	2462	1912	293	2205	314	2519
4	1891	269	2160	304	2464	1914	291	2205	314	2519
5	1890	275	2165	307	2472	1896	300	2196	303	2499
Mean	1887.2	274.2	2161.4	306.0	2467.4	1899.8	301.0	2200.8	310.6	2511.4
S.D.	11.5	2.9	11.7	10.6	7.3	13.3	11.1	11.3	5.7	10.9

Table 2 **Results of Repeated Calibrations Trials for Rotation about the Y-Axis (A-D Units)**

	Channel 1 (Left)					Channel 4 (Right)				
Trial	-45	-45 to 0	0	0 to 45	45	-45	-45 to 0	0	0 to 45	45
1	926	666	1592	631	2223	923	674	1597	607	2204
2	920	684	1604	616	2220	932	679	1611	624	2235
3	936	675	1611	624	2235	926	677	1603	612	2215
4	937	674	1611	607	2218	938	671	1609	612	2221
5	934	673	1607	617	2224	933	674	1607	612	2219
Mean	930.6	674.4	1605.0	619.0	2224.0	930.4	675.0	1605.4	613.4	2218.8
SD	7.3	6.4	7.8	9.0	6.6	5.9	3.1	5.6	6.3	11.2

It can be seen that the ranges between the –20 and 0, and +20 and 0 calibration points varied from an average of 274.2 A-D units to 310.6 A-D units. This range of values, with no noticeable pattern between the left and right sides, indicated that the error may lie in the method used to position the oar at the specified calibration points. Alternatively, the error may lie within the positioning of the individual calibration marks. In the X-axis rotation calibration procedure, it was necessary to press and hold the button of the oar firmly up against the inside of the gate while positioning the oar against the calibration mark on the frame. It was found that when this was done the oar had a tendency to move slightly within the gate, as the edge of the oarlock was bevelled at an angle that was not the same as the angle being measured.

Examination of the variation in the confidence intervals for X-axis rotation showed a range between $\pm$ 1.0 to 1.7°. This represented approximately $\pm$ 8.2 to 14.2% error within the confidence intervals for an average X-axis rotation of 12°. While this error was much larger than the Y-axis rotation error, it is only a consideration for between-day comparisons, which were not done for individual rowers in this study. The major effect of this vertical error would be to shift the resultant hand-curve up or down.

When examining the range of A-D units between the calibration points for Y-axis rotation, the range between the –45° and 0° points (675 A-D units) differed from the range between the 0 and +45 degree points (approx. 613 to 619 A-D units). As the potentiometers were very close to being linear throughout their range, this difference must have been due to another factor. The standard deviations for these ranges reveal relatively low values, with the highest being 9.03 units. This was much smaller than the observed difference between the two ranges of approximately 55 to 60 A-D units. It would appear, due to the similarity of ranges when calibration occurred on both the left and the right side, that the main cause of this error was

the construction of the calibration rig itself.
In order to investigate the extent to which variation in the calibration points affected angular values, the average A-D values obtained at each calibration point were inserted into the average linear function obtained in the calibration study. A 95% confidence interval for accuracy of calibration was then obtained. The variation of angles at the three calibration points appear to be accurate, with the largest confidence interval of $\pm$ 1.1°. When compared to the ranges measured for Y-axis rotation, which ranged from 70.0° to 117.5°, this represented an error of $\pm$ 1.3 to 2.2%, which was definitely within acceptable limits.
In order to increase the accuracy of the calibration procedure, two methods could be considered. Firstly, it would be necessary to improve the precision of the positioning of the calibration points, by remeasuring the rigs and at the newly calculated points, attaching guides into which the oar may be firmly positioned and secondly, it may be necessary to adopt a multiple calibration procedure.
Elite level rowers have trialed the oarlocks and they have stated that it allows minimal disruption to normal rowing form. Preliminary testing has revealed that hand-curve data can be collected continuously and a sample of this data is shown in Figure 2.

Figure 2 - Sample handcurve data from an elite rower.

CONCLUSIONS: A method has been outlined which allows the continuous registration of handcurves in rowers. Data from the repeated calibration procedure reveal that it is essential that calibration rigs are accurately fabricated so that integrity of the data is maintained. Further work is ongoing to design a mechanism to measure the reactive oarlock force.

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