CONTINUOUS REGISTRATION OF THE HAND-CURVE IN ROWING: DIFFERENCES BETWEEN SCULL AND SWEEP ROWERS

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The aims of this study were to examine the shape of the rowing hand-curves, in addition to, assessing the repeatability of hand-curves, between sweep and scull rowers. Data from 10 scullers and 8 sweep State to National level rowers were collected at increasing ratings. As there were no significant differences apparent between ratings, data were pooled. The repeatability of the sculling hand-curve was higher than the sweep rowers. Scullers exhibited a significantly longer stroke arc than sweep rowers and the degree of hand drop into the catch exhibited by scullers was greater for the left hand than the right. The catch height and finish height in scullers was significantly higher in the left hand than the right hand. The normal hand-curve demonstrated by athletes of this level approached, but did not mimic the "ideal" hand path presented in the literature.

KEY WORDS: rowing, stroke, hand-curve, sweep, scull, technique.

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 observed by the coach. To facilitate such methods, many studies have been designed to quantify rowing performance. Typically, these studies have focused on the force-angle or force-time profiles during rowing (eg. Smith et al., 1994). While these approaches enable boat movement and the force applied by the rower to be examined and quantified, the collection of such data may be time consuming and feedback to the rower may not be directly linked to their technique. The hand-curve is the path that the handle of the oar travels and this could be used as a more direct feedback to the oarsperson, with observable adjustments to technique having direct implications to the force applied (Doyle et al., 2002). However, a paucity of research has been conducted that describes such hand-curves, with studies only analysing a small number of strokes due to the limitations associated with the use of cinematographic methods, mostly due to the large horizontal distance covered by the boat (Deming et al., 1988). Therefore, through continuously recording the hand-curve during the rowing stroke, the aims of this study were to examine specific variables related to the shape of the hand-curves, in addition to, assessing the repeatability of hand-curves in sweep and scull rowing.

METHODS: Eighteen state to national representative level, male and female rowers, between 17 and 27 years of age acted as subjects for this study. The sample consisted of ten scullers and eight sweep rowers (made up of four pairs) who have rowed together over a period not less than two months. Data were collected using an instrumented Concept II rowing oarlock and calibration of the potentiometers attached to the oarlock was carried out before each testing session (Burnett et al., 2000). The modified gate replaced the original gate on the athlete's boat, taking care to ensure that all rigging measurements were those used by each athlete. The positive X-direction of the modified oarlock 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 ( ) was considered as rotation about a 'floating' axis and rotation about the Y-axis ( ) was about a 'fixed' axis. Data were sampled at 160Hz and were sent to a computer via radio modems (Freewave Technologies, USA) at a baud rate of 115.2K. Athletes were instructed to row at over a 2000m course at four ratings which were increased every 500m. Rating was provided to the subjects using a Nielsen-Kellerman SpeedCoachTM mounted in the boat. This operated via a magnetic pick-up mounted on the boat decking approximately half way along the seat rails. The initial rating was 20 strokes per minute (spm) then ratings were increased in increments of 4 spm to 24, 28 and 32 spm. Continuous data

were collected for the total 2000 m trial and were stored on the master computer hard drive for later analysis. Hand-curve data were smoothed using a fourth order Butterworth filter with a cut-off frequency of 8 Hz then data were time-normalised to 101 data points (0-100) for both the drive and recovery phases. A number of variables were calculated from each rower's hand-curve. These consisted of :

- Stroke Arc ($\Delta\alpha$): Total horizontal angular displacement the oar during the rowing stroke.
- Catch Angle (α^c): Horizontal angle at which the catch occurred during the rowing stroke.
- Finish Angle (α^f : Horizontal angle at which release occurred during the rowing stroke.
- Catch Height (γ^c): Vertical angle at the catch.
- Finish Height (γf): Vertical angle at the finish of the stroke.
- Delta Y ($\Delta\gamma$): Range of vertical angle during the stroke.
- Hand drop at the catch (HDC): Measurement of change in angle of the handle approaching the catch. Defined by the difference between the lowest angle before the catch and the average angle of the middle third of the recovery hand curve.
- Crossover Point: Point during the normalised hand-curve when the drive path crosses over the recovery path.

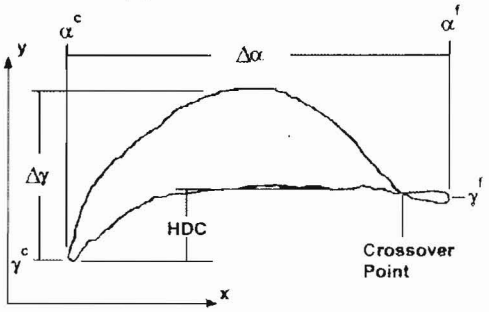

Figure 1: Indices calculated from resultant hand-curves.

A one-way ANOVA with repeated measures was conducted to determine whether any differences existed between stroke ratings for kinematic and repeatability variables. From preliminary observation of statistical data there were no significant differences ($p>0.05$) for the abovementioned variables at the different ratings therefore data were pooled for each variable across ratings to provide a single value. The newly calculated variables were then compared between scull and sweep rowers, for both the left and right sides, using a Mann-Whitney U Test. Furthermore, left and right side variables for scullers were compared using a paired t-test to determine whether any statistical differences occurred between the left and right sides. For sweep rowers the left and right sides were compared using a Mann-Whitney U Test. The repeatability, of each rower's hand-curve was then calculated using the coefficient of multiple correlation (CMC) (Kadaba et al., 1989).

RESULTS: Table 1 shows that in the sculling motion there were significant differences ($p<0.05$) between the left and right hands for γ^c, γf, $\Delta\gamma$ and the HDC. The left hand for the scullers displayed a higher catch height and finish height and a greater range of vertical movement as displayed by the HDC. For sweep rowers there were no significant differences for the abovementioned variables. Table 1 also shows that for the time at which the drive path crossed the recovery path in the normalised hand curve, there were significant differences ($p<0.05$) between the left and right hands of the scullers (left hand average = 94.8, right hand average = 98.1) that is, the right hand crossing over later in the drive than the left hand). There were no significant differences between the stroke and bow side of the sweep rowers, or evident when

the scull and sweep rowers were compared. The CMC is a statistic that describes the consistency of the hand path. There were no significant differences between the left and right hands of scull and sweep rowers. However, there was a significant difference ($p<0.05$) apparent for the consistency of hand-curve between the left hand (bow side) of scull and sweep rowers (0.976 and 0.910 for scull and sweep respectively) and the right hand (stroke side) of scull and sweep rowers (0.973 and 0.939 for scull and sweep respectively).

Table 1 Kinematic and Repeatability Data for Scull and Sweep Rowers (Mean ± SD).

	Scull (n=10)		Sweep (n=4)	
	Left	Right	Left	Right
Stroke Arc (°)	106.2 ± 8.3	105.8 ± 3.5	78.3 ± 3.8*	79.8 ± 4.8*
Catch Angle (°)	-62.1 ± 9.8	-61.1 ± 3.5	-41.1 ± 2.6*	-44.2 ± 3.5*
Finish Angle (°)	41.9 ± 6.8	42.7 ± 6.6	37.2 ± 3.7	35.6 ± 2.0
Catch Height (°)	7.1 ± 1.2	5.3 ± 1.6#	4.8 ± 2.8	1.9 ± 3.1*
Finish Height (°)	7.9 ± 1.5	5.9 ± 3.3#	5.0 ± 0.9*	4.5 ± 1.2
Delta Y (°)	13.5 ± 1.9	11.3 ± 1.5#	9.4 ± 3.6	12.0 ± 2.0
HDC (°)	4.7 ± 0.7	0.8 ± 0.9#	3.1 ± 1.2	3.9 ± 1.1*
Crossover Point (%)	94.8 ± 3.5	98.1 ± 0.9#	87.4 ± 10.5	96.6 ± 4.5
CMC	0.976 ± 0.009	0.973 ± 0.009	0.910 ± 0.072*	0.939 ± 0.036*

- indicates significant difference ($p<0.05$) between left and right oars in scull rowers.
* - indicates significant difference ($p<0.05$) between sweep and scull rowers.

DISCUSSION: It was found that there were significantly larger catch angles and stroke arcs for sculling on both sides of the boat. These findings concur with other studies which have reported sculling arcs between 100° and 110° and sweep arcs of 80° to 90° (eg. Zatsiorsky & Yakunin, 1991). The mean stroke arcs in this study varied from 103.9° to 107.6° for scullers, and between 76.9° and 80.9° for sweep rowers. It is evident that the difference in stroke arc in the sweep rowers was due to a significant ($p<0.05$) decrease in the catch angle and a non-significant decrease in finish angle. The action of sculling requires that the oar handles cross over during the beginning of the recovery, until approximately half way through the stroke, and again during the latter part of the drive phase. In all of the athletes involved in this investigation, it was the left hand which was positioned above, and generally slightly forward of the right hand during this crossover period. Consequently, there were significantly greater ($p<0.05$) vertical angles recorded by the left hand compared with the right hand at both the catch and finish, for the scullers. Further in the scullers, there was a significantly greater ($p<0.05$) range of vertical movement in the left hand than the right (average difference between the left and right hands was 2.2°). Significant differences were found between scullers and sweep rowers for both the catch and finish height. Left side sweep rowers exhibited a significantly lower ($p<0.05$) finish height than the left hand of the scullers (sweep 5.0°; scull 7.9°) and the catch height for the right hand was significantly higher ($p<0.05$) for scullers (5.3°) when compared to sweep rowers (1.9°). However, the small sample size of the sweep group makes it difficult to conclude that the difference between scull and sweep finish heights for the left hand was due to the mechanics of the sculling stroke. Furthermore, it appears that scull rowers tend to drop their left hand downwards as they approach the catch to a much larger extent than their right. It appears that for the athletes analysed in this study, dropping of the handle approaching the catch is a common technical feature of the hand-curve. It was found that the middle third of the path described by the handle during the recovery was virtually level in nature, therefore, from the middle third of the recovery an average 'recovery height' was calculated. The height from this point until the catch was then found and the difference between this and the 'recovery height' determined the HDC. An HDC value of zero would indicate no lowering of the handle into the boat as the catch phase of the stroke was approached. A degree of HDC was observed in both sweep and scull rowers. It was found that scullers demonstrated a significantly larger ($p<0.05$) HDC with the left hand than with the right. This would probably

be due to the mechanics of the sculling stroke in which the left hand is higher than the right throughout a majority of the stroke. As the sculler approached the catch it appears that in order to keep the boat balanced, the scullers tended to drop the left hand down towards the water to minimise the height difference between the hands. This was evident in almost all of the scullers examined and was further exacerbated by the tendency for the scullers to also drop the right hand as they approached the catch, although to a lesser degree. Only two of the ten scullers examined demonstrated hand lift with the right hand as they approached the catch. It seems that these two subjects relied not only on dropping of the left hand, but also raising of the right, to achieve the desired level between the two hands at the catch. An unexpected characteristic of many hand-curves exhibited by the subjects was a crossover point in the curve that appeared towards the end of the drive phase. A crossover point was calculated, representing the percentage along the normalised drive curve that the drive and recovery path intersected. A significant difference ($p<0.05$) in the crossover point between the left and right hands of scullers was recorded. The right hand recorded an average of 98.1, indicating that the release part of the stroke was approaching the ideal, however, the left hand exhibited an average crossover point of 94.8. The reason behind this may again be due to the mechanics of the sculling stroke. Due to the crossover of the oar handles, the left hand was higher than the right hand through the end of the stroke. This has been exhibited in the difference in finish heights already discussed. The athlete could also lift the left hand up through the first portion of the recovery in an effort to provide enough clearance between the two hands. Upon examination of the repeatability demonstrated by sweep rowers, it was found that the consistency of the hand-curve waveform was of a significantly lower magnitude, for both left and right-sided rowers. The probable reason behind the scullers having higher repeatability values than sweep rowers may lie in the difference between the boat categories. Single scullers have to contend with external factors such as wind, wash or waves acting upon the boat. The sweep rowers in this study were rowing a pair, where it was necessary to adjust technique to account for body movements of the other rower, as well as external influences experienced by the scullers.

CONCLUSIONS: There were many kinematic differences found in the hand-curve of scull and sweep rowers in this study. Single scullers exhibited a significantly longer stroke arc than sweep rowers and the degree of hand drop at the catch shown by scullers was greater for the left hand than the right. The catch and finish heights for scullers were significantly higher in the left hand than the right hand and there were differences recorded between the scull and sweep rowers. However, it seems that some degree of hand drop at the catch is a common technical feature of the hand-curve. Available recording of the hand-curve revealed that the repeatability of sculling hand-curves (0.976 and 0.973 for the left and right hand respectively) were higher than recorded for sweep rowers (0.910 and 0.939 for the left and right hand respectively).

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