AN ANALYSIS OF SELECTED KINEMATIC VARIABLES IN SCULL ROWING USING MACON AND HATCHET OARS

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Introduction

In rowing, as in most sports requiring equipment, the quality of performance is significantly affected by the available equipment. In sculls, an effective propulsive phase, and an efficient recovery phase are the two most critic factors involved in producing a high average boat velocity. Both of these phases are largely dependent on the athletes' skill and the equipment that is used. Investigation of boat kinematics can assist in the evaluation of equipment as it relates to each performer or crew.

It has been suggested that the Hatchet oar design affects the kinematics of the system without modifying the input kinetics (Pelham et al., 1993). With the use of on board accelerometry, this hypothesis claim can be evaluated.

With this in mind, the purposes of this study were (1) to determine whether there is a biomechanical difference between the Macon and Hatchet oar designs, (2) to determine which selected boat kinematic statistics vary between the Macon and Hatchet oar designs, and (3) to determine possible explanations for performance differences between the two oar designs based on selected kinematic results.

Methods

Subiect: The subject chosen was a 24-year old male lightweight rower with several years of competitive experience.

Equipment: The accelerometer used in this study was a g.analyst (Valentine Research). Calibration of the accelerometer and cinematography are presented in the accompanying Dalhousie paper dealing with methodological concerns on this topic.

Boat trials: On-water acceleration data was collected over a 2000 meter distance in simulated race conditions. The g.analyst and its battery were sealed in a clear, plastic bag and was securely mounted on the floor of the craft directly in front of the tracks for the seat. The subject rowed at a race pace of 2 seconds per stroke (30 strokes/minute). Although the subject's pace was well automated a stroke coach was used to ensure accuracy of the pacing. This pace was maintained throughout the entire 2000 meter distance. The acceleration data were then downloaded into a Macintosh Classic II computer and stored on disk. The information was then purged from the g.analyst.

In order to analyze the relationship between the acceleration of the scull and catch of the blade the video data and acceleration data had to be marked at the same instant in time.

An 8 mm video camera was mounted on a tripod in a coach boat. The coach boat travelled along the left side of the rowing scull during each trial. The video tape was encoded by the Peak Performance 2D System, thus a number for each frame was written to the tape.

Definition of terms: Where "a" for the acceleration data set, "v" for the velocity data set, and "i" for the impulse data set. The last character in the variable name indicates the oar design, that is, "h" for the Hatchet oar and "m" for the Macon oar.

%tap1h and %tap1m	-	Percentage of the stroke time to reach the vertex of the first concave down (CCD) curve in the appropriate data set for the Hatchet and Macon oars, respectively.
aplh and aplm	-	Value at the vertex of the first CCD curve in the appropriate data set for the Hatchet and Macon oars, respectively.
%tap2h and %tap2m	-	Same as %tap1h and %tap1m but for the second vertex of the CCD curve.
ap2h and ap2m	-	Percentage of the stroke time to reach the vertex of the first concave up (CCU) curve in the appropriate data set for the Hatchet and Macon oars, respectively.
avlh and avlm	-	Value at the vertex of the first CCU curve in the appropriate data set for the Hatchet and Macon oars, respectively.
tnih and tnim	-	Total negative impulse over the stroke, omitting the first and last 10% of the stroke for the Hatchet and Macon oars, respectively.
tpih and tpim	-	Total positive impulse over the stroke, omitting the first and last 10% of the stroke for the Hatchet and Macon oars, respectively.
tih and tim	-	Total impulse over the stroke, omitting the first and last 10% of the stroke for the Hatchet and Macon oars, respectively.
%SL	-	Percentage of the stroke length.

Division, standardization and calculations of discrete measures of acceleration, velocity and impulse data: Custom software program, divided the acceleration data into individual strokes and a cubic spline was used to standardize the stroke length. Video data was used to confirm that if the software correctly detected stroke cycles. The acceleration data was integrated using Simpson's Rule as well as the Trapezoidal Rule and second order finite differences and impulse from the catch to release was calculated. Velocity data was smoothed using a multiple low pass 2nd order Butterworth digital filter. Twelve discrete measures of percentage stroke length and the value at local vertexes, as well as three measures of impulse where examined. A more complete description of these procedures have been prepared and are presented in the Dalhousie methodological paper dealing with this topic.

Statistical methods: The primary statistical analysis used in this study involved the use of a series of analyses of variance (ANOVA). Minitab for the PC version 8.2 Extended was used to calculate the One Way ANOVA and some basic statistical describers.

Results & Discussion

The results of a series of one way ANOVAs on the discrete measures showed significant differences ($p < 0.001$) in the time required to reach the first peak in the acceleration. The Hatchet reaches its first peak (%tap1h) 35.648 ± 1.613 percent of stroke length (%SL) (range: 32.000 to 46.000 %SL) at which point it has an acceleration of (aplh) 1.880 ± 0.172 m/s2 (range: 1.178 to 2.525 m/s^2). It takes the Macon oar longer to reach its first peak; (%tap1m) 36.379 ± 1.446 %SL (range: 32.000 to 42.000 %SL) with an acceleration of (ap1m) 2.03 ± 0.131 m/s^2).

There is a significant difference ($p < 0.001$) between the %SL to the vertex at the concave up (CCU) curve, between the two oars (%tav1h and %tav1m). A significant difference ($p < 0.001$) was also found between the accelerations at these points (avlh and avlm). The Hatchet reaches its negative peak at 63.323 ± 2.174 %SL (range: 49.000 to 68.000 %SL) with an acceleration of 0.008 ± 0.230 m/s^2 (range: -2.759 to 0.294 m/s^2). The Macon reaches its negative peak much later in the stroke, 64.681 ± 1.613 %SL (range: 61.000 to 69.000 %SL) and with a significantly higher rate of acceleration, 0.250 ± 0.113 m/s^2 (range: -0.111 to 1.352 m/s^2).

The values at the second peak (ap2h and ap2m) of the %SL (%tap2h and %tap2m) that occurs during the stroke cycle are significantly different ($p < 0.001$). Again the Hatchet oar reaches its peak, 72.681 ± 2.146 %SL (range: 67.000 to 78.000 %SL) with an acceleration of 0.190 ± 0.151 m/s^2 (range: 0.017 to 1.867 m/s^2) before the Macon blade. The Macon reaches its second peak at 74.410 ± 1.58 %SL (range: 70.000 to 78.000) with a larger mean acceleration then the Hatchet, 0.461 ± 0.087 m/s^2 (range: 0.311 to 1.416 m/s^2).

While producing the same mean craft velocity, the Hatchet blade required smaller magnitudes of acceleration for shorter periods of the stroke length. It can be speculated from this observation that the drag force on the oar was less on the Hatchet than the Macon. It can be further speculated that this reduced drag force causes less deceleration.

Because the Hatchet blade is more efficient, the rower is not required to generate the larger forces required by the Macon blade to maintain racing speeds. This provides obvious physiological benefits for the rower during the final stages of a race.

The results of a series of one way ANOVAs on the discrete measures shows that there is a significant difference ($p < 0.001$) between w l h and w l m. The Hatchet reached this point (%vv1h) in 18.662 ± 1.232 %SL (range: 16.000 to 24.000 %SL) compared to the Macon, which reached this point in 17.826 ± 1.207 %SL (range: 15.000 to 20.000 %SL).

Although this difference is statistically significant, it may be a result of the cubic spline. From the raw data there was approximately 28 to 30 data points for each stroke. This raw data was passed through a spline routine and interpolated into a set of 100 points. The difference between %tvv1h and %tvv1m is less than 1%SL, which may have resulted from the increased number of data points.

The velocity at %tvv1h, (w lh) and %tvv1m, (vvlm) showed a significant difference ($p < 0.001$). The Hatchet had a value of -30.693 ± 3.954 (range: -45.815 to -23.135) while the Macon had a value of -28.186 ± 3.985 (range: -40.891 to -20.232).

Substantial and significant ($p < 0.001$) differences were found between the %tvp1h and %tvp1m. The Hatchet oar reached the vertex of the CCD curve 78.322 ± 2.336 %SL (range: 70.000 to 86.000 %SL). The Macon oar reached peak velocity much later in the stroke cycle (83.078 ± 1.480, range: 78.000 to 88.000 %SL).

The velocities at the vertex of the CCD curve between the two oar designs are significant ($p < 0.001$). The Macon oar generated a much higher peak velocity 30.499 ± 5.598 (range: 20.593 to 73.738) compared with the Hatchet oar (14.378 ± 5.732, range: 5.260 to 53.317).

The Hatchet oar had the smallest velocity at the vertex of the CCU curve, but this is insignificant compared to difference between the velocity at the vertex of the CCD curve. This data tends to suggest that the Macon oar would require more energy than the Hatchet oar in order to maintain the same mean velocity.

Total positive impulse from the catch phase to the release phase, for the Hatchet oar (tpih), was 3671.7 ± 342.1 Ns (range: 3069.5 to 4860.3 Ns). The Macon oar required a statistically significant ($p < 0.001$) higher impulse (tpim) of 4791.3 ± 300.5 Ns (range: 4146.3 to 6138.7 Ns).

Total negative impulse for the Hatchet oar (tnih) was -1280.5 ± 256.2 Ns (range: -2398.1 to -759.0 Ns) and the Macon oar (tnim) was -935.8 ± 198.6 Ns (range: -1797.9 to -526.2 Ns). The total impulse for the Hatchet oar (tih) was 2391.2 ± 358.5 Ns (range: 1056.0 to 3488.3 Ns) and the Macon oar (tim) was 3855.5 ± 324.8 Ns (range: 3100.1 to 4961.4 Ns). Since the scull was travelling at mean constant velocity over a number of strokes, the Macon oar required rnore energy from the rower in order to maintain mean velocity.

Conclusion

It is believed that the increased performance noted by coaches and rowers using the Hatchet oar may be a result of reduced slippage. Evidence suggests that the Hatchet oar transfers more energy from the rower to propel the scull and less energy is wasted on slippage of the oar. This study does not conclusively prove this but its possibility is shown to be feasible.

References

Pelham, T.W., Holt, L.E., Burke, D.G., Carter, A.G.W. & Peach, J.P. (1993). The effects of oar design on scull boat dynamics: A pilot study. Biomechanics in Sports XI 201-204.