SKILL VARIABLES DISCRIMINATE BETWEEN THE ELITE AND SUB-ELITE IN COXLESS PAIR-OARED ROWING

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The ability to develop high power output is a necessity for high performance in rowing. However rowers and coaches also direct a large amount of attention to skill development. Is the consummate execution of these skills a characteristic of the best rowers? To answer this question this study measured the wasted catch (WCA) and finish (WFA) angle, the mean to peak force ratio (MPFR), the vertical angular displacement of the oar (VADO) and the minimum boat acceleration (MinBA), on the water, in elite and sub-elite groups of rowers . On average the elite rowers were superior to the sub-elite on all these variables. MPFR, VADO and MinBA were highly significantly different between the two groups. An Olympic gold medal winning pair were superior over all other rowers The findings suggest that these are indeed important skills for high performance rowing.

KEY WORDS: rowing, skill variables, pair-oared boat.

INTRODUCTION: Coxless pair rowing is the most technically difficult of the classes of rowing boat in international competition (Morrison, 1987). This is partly due to the combination of sweep-oar rowing asymmetry and the placement of the two rowers in the boat and resulting application of forces to the boat. In a pair boat there are two rowers with one oar each. The oars are placed on opposite sides of the boat but with one towards the stern (seat 2) and the other towards the bow (seat 1). Forces are applied to the pins via the oar and to the stretcher (foot plate) via the feet. High power output is obviously a requirement of high performance rowing. However, the power must be applied skilfully and a lot of attention is paid to the development of these skills by coaches and rowers. The question arises what are the relationships between these skills and rowing performance? This paper explores this question by examining the skill differences between elite and sub-elite rowers.

To maintain a high average velocity with minimum fluctuations, the rowers must apply a net propulsive force to the boat as soon as possible after the catch (when the blades re-enter the water) to accelerate the rowers' bodies in the forward direction and to balance the drag force. One measure of performance relating to this skill is the wasted catch angle (WCA), the angle through which the oar moves after the catch without an increase in force of 20 N. The corresponding variable for the end of the drive phase is the wasted finish angle (WFA). The latter is an indication of how well the rower sustains the force to the finish (when the blade leaves the water).

Three other variables have not been explored in the literature in the sense of how well they distinguish an elite rower from a sub-elite rower. Mean to peak force ratio (MPFR) describes the "peakiness" or "flatness" of force application during the drive phase. A peaky force curve will have a low value and a flat curve a high value. A square curve would have a value of one. Another variable is vertical angular displacement of the oar (VADO). It could be hypothesised that the work done in displacing the oar vertically should be minimised and therefore this angle should be minimised within the bounds of keeping the oar sufficiently covered with water. The third variable, minimum boat acceleration (MinBA) has been shown to be a discriminating variable for single sculling performance (Draper, 2006).

The purpose of this paper was to compare elite and sub-elite rowers on the skill variables WCA, WFA, VADO, MPFR and MinBA.

METHODS: Thirty two (elite = 16, sub-elite = 16) male rowers, in 16 pairs, rowed an instrumented pair boat at a steady state cadence of 32 strokes per minute. One of the elite pair were Olympic gold medallists for the coxless pair event and two other pairs were from a coxless four that won Olympic and World Championship medals. The pair boat was instrumented with sensors that measured a number of performance variables. Pin force data were sensed using three-dimensional piezo-electric transducers (Kistler, Switzerland). The pin was mounted on the rigger and was the axis of rotation for the gate or rowlock that holds the oar. The vertical and horizontal oar angles were measured by low-friction potentiometers and a fibreglass arm attached to the inboard end of the oar so that the oar was free to rotate around its longitudinal axis. A micro-machined solid state sensor (Analog Devices, USA) monitored the propulsive acceleration of the boat. All variables were sampled at 100 Hz and the data telemetered (pocketLAB, Digital Effects) to a shore-based receiver and laptop computer (4700CT, Toshiba).

The collected data was loaded into analysis software, and a sequence of at least 15 strokes selected. The time series for the pin and stretcher forces were time-normalised and averaged. The values for peak and average propulsive pin forces WCA, WFA, VADO, MPFR and MinBA for each stroke were detected and averaged over the 15 strokes for each rower. Multivariate analysis of variance was used to indicate the significance of differences between the groups of scores. Discriminant analysis was used to explore the ability of these variables to distinguish between elite and sub-elite rowers.

RESULTS AND DISCUSSION: The mean height and weight of the rowers was 190.5 ± 5.7 cm and 91.1 ± 4.0 kg respectively. The mean stroke rate was 31.9 ± 0.3 strokes per minute. Multivariate analysis of variance revealed an overall effect of competition level ($p < 0.001$). Univariate analysis (Table 1) showed that all variables contributed to this outcome.

Table 1 Grand means and standard deviations, and significance of differences, effect size and power for the skill variables.

Variable	Group	Mean ±SD	Units	p	effect size	power
WCA	Olympic gold medallists	1.1 (stroke) 0.5 (bow)	° °			
	Elite	1.89 ±0.93	°	0.033	0.14	0.581
	sub-elite	2.64 ±0.99	°			
WFA	Olympic gold medallists	0.3 (stroke) 0.5 (bow)	° °			
	Elite	0.95 ±0.55	°	0.079	0.1	0.42
	sub-elite	1.31 ±0.56	°			
VADO	Olympic gold medallists	10.4 (stroke) 10.8 (bow)	° °			
	Elite	12.16 ±1.51	°	< 0.001	0.45	0.997
	sub-elite	14.36 ±0.96	°			
MPFR	Olympic gold medallists	0.57 (stroke) 0.58 (bow)				
	Elite	0.53 ±0.03		< 0.001	0.51	1.00
	sub-elite	0.47 ±0.03				
MinBA	Olympic gold medallists	-11.3	$m \cdot s^{-2}$			
	Elite	-14.4 ±2.1	$m \cdot s^{-2}$	0.003	0.26	0.881
	sub-elite	-16.5 ±1.51	$m \cdot s^{-2}$			

WCA and WFA: From a coaching point of view WFA at $p = 0.079$ is of interest as a rowing skill and particularly as the minimisation of WCA and WFA is an indication of the degree to which the whole range of motion of the oar is utilised for power production. On the other hand, for these two variables, the effect size was small and the power of the test was moderate. Note that the gold medal pair were well below the mean value for the elite group and had the lowest values of all for these two variables. WCA is roughly twice WFA reflecting the fact that the catch occurs with the oar at about -60° from square to the boat making the movement more difficult than at the finish at 30° to square off. More time is available to execute the finish (Figure 1).

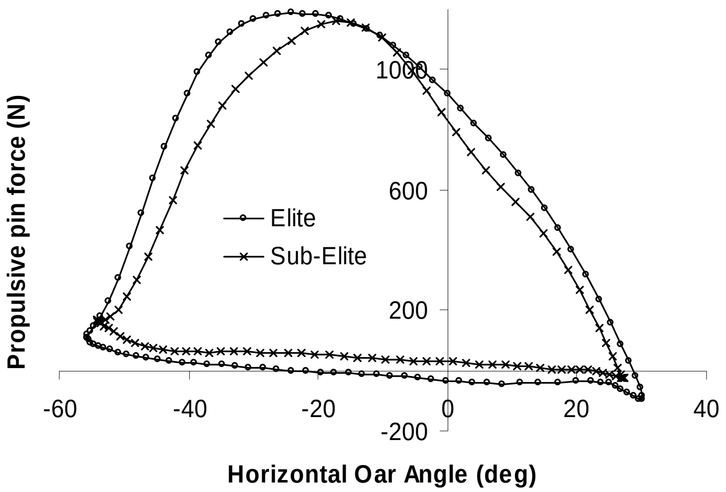

Figure 1 Propulsive pin force vs horizontal oar angle for an exemplar elite and sub-elite rowers. Fifty newtons was added to the sub-elite data to facilitate shape comparison.

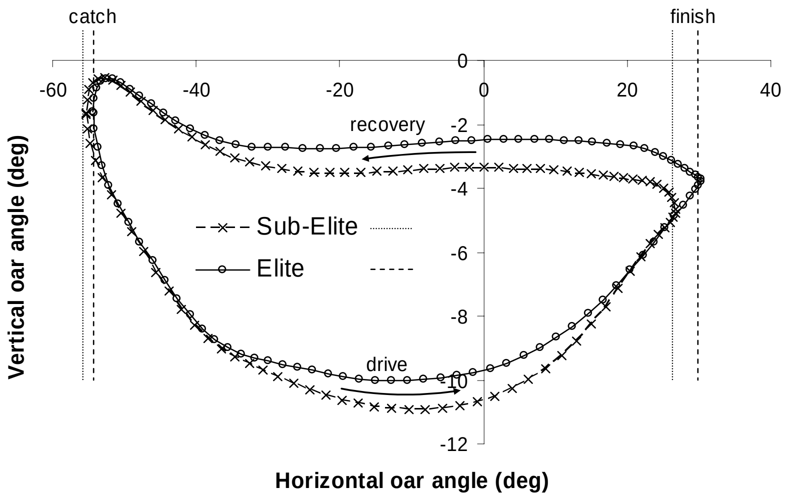

Figure 2 Vertical oar angle vs horizontal oar angle. The elite rowers show a greater range of motion in the horizontal direction but less in the vertical direction. Down on the graph is in the same direction as depth of blade in the water.

VADO: was significantly lower for the elite group ($p < 0.001$). Only one other rower had a lower value than the gold medallists. Figure 1 is drawn so that greater blade depth is represented by more negative values on the vertical axis. Rowers from both levels of competition have a similar path for the blade from the catch to about -40°. From that point the elite rowers have a more shallow draft, a longer stroke length, a more rapid change of direction at the finish, and a higher recovery angle. Force is required to move the blade down and cover it with water. The smaller the vertical range, the less force will be required. This vertical force is reflected at the pin and has a characteristic shape corresponding to these movements. The flatter trajectory during the recovery contributes to a stable boat roll orientation.

MPFR: The elite rowers had a significantly higher MPFR than the sub-elite ($p < 0.001$) with the medallists having the highest value of all rowers. Note, however, that the increase occurs in the second half of the drive phase (Figure 3). For a slow boat such as the pair, there is a limit to the rate of force development immediately after the catch without causing cavitation behind the blade regardless of strength or skill.

MinBA: The elite rowers had a significantly lower MinBA than the sub-elite rowers (p = 0.003). The medallists had the smallest value of all rowers in this sample. This variable is an indicator of how much the boat is decelerated around the catch (Figure 3) while the rower is simultaneously trying to accelerate their own body in the direction of the finish line while attempting to apply a propulsive net force to the boat. The total loss of velocity will be the time integral of the negative boat acceleration around the catch. MinBA is an indirect measure of this time integral. Minimising boat velocity fluctuations increases the efficiency of boat propulsion.
Discriminant analysis chose MPFR and VADO as the key variables that separated the rowers into the elite and sub-elite categories. The structure matrix was 0.866, -0.759, -0.374, -0.338 and 0.165 for MPFR, VADO, WCA, WFA, and MinBA respectively indicating the order of importance of the variables in the function that discriminated between the two groups. The resulting Discriminant function was 100% successful in predicting group membership.

CONCLUSION: This project has demonstrated that skill variables such as WCA, WFA, VADO, MPFR and MinBA discriminate between rowers from different levels of competition. The lead of the Olympic gold medallists in all these variables strongly suggests that they should be well developed to achieve high performance.
The five variables studied can be obtained from on-water tests using relatively simple instrumentation. Oar force, horizontal and vertical oar angles and the propulsive acceleration of the boat are the only quantities requiring sensors and provide the raw data for the calculation of the five variables.

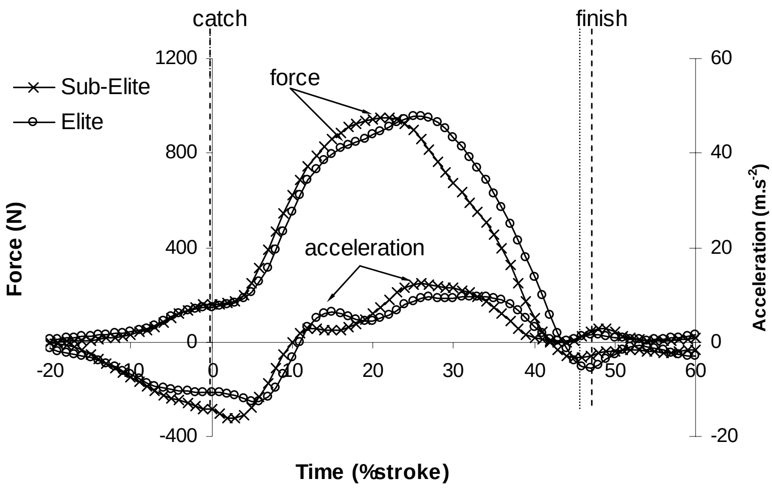

Figure 3 Propulsive pin force and boat acceleration for the elite and sub-elite groups.

The findings of the study support emphasis on development of oar force immediately after the catch, maintenance of the maximum force throughout the drive phase and continuation of the force to the exit of the blade from the water at the finish. Further, there should be focus on limiting the retarding force on the stretcher until propulsive force has been applied to the pins to minimise boat deceleration around the catch.

REFERENCES

Draper C, (2006) Optimising rowing performance in elite women's single sculling. Unpublished PhD thesis, The University of Sydney, Australia.

Morrison, M. (1987) A pair primer: conquering rowing's "least forgiving" boat. American rowing 19(4), 46-49.

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