CONSISTENCY OF TECHNICAL AND PERFORMANCE BASED ROWING VARIABLES IN SINGLE SCULLING

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Possibilities in competitive rowing exist for further performance enhancements in a well prepared race design and a more individualised training program. The purpose of this study was to examine the consistency of key biomechanical variables and to describe their effect on boat motion. Elite single scullers (n=12) rowed at five stroke rates in an instrumented single scull. The results revealed a high consistency of the technical rowing variables in sculling. In particular, the applied bow and stroke pin and footstretcher forces and angles differed across individuals and were not entirely symmetrical producing a net applied boat moment. The investigation revealed that the interaction and relationships between selected variables were more important than any single variable.

KEY WORDS: pin/footstretcher forces, boat acceleration, boat moment, boat yaw velocity.

INTRODUCTION: Competitive rowing at an elite level is characterized by a very high standard of athletic performance where a combination of the athletes' consistent technique, strength and endurance over 2,000m (200 to 250 rowing strokes) determines the result of the race. Further, a highly consistent technical skill level under different velocity conditions and stroke rates is a necessary prerequisite of an efficient race plan (Mattes, 2000).
Rowing, a cyclic motion, was always a focus of interest to scientists, because the major accepted kinematic and kinetic technique and performance variables applied by the athlete (on the boat and oars) were measurable continuously stroke by stroke. A characteristic of rowing is that force is applied to at least three parts of the boat, separated by significant moment arms in order to produce propulsion (Zatsiorsky VM & Yakunin N, 1991). The aim is to keep the moment applied in the horizontal plane of the boat as close to zero as possible, as it may affect the boat velocity by turning the boat away from "dead ahead" (Wagner J, et al., 1993). Data from a number of highly trained female single scullers would establish a benchmark for consistency in rowing technique and performance of women single scullers. Individual differences could be highlighted. In this study, all the variables required to specify the motion of the boat in the horizontal plane were quantified by an advanced instrumented on-water measuring system. There has been limited research using variables such as transverse and propulsive oar force, propulsive footstretcher force and yaw in the past (Loschner C, et al., 2000). The findings of the model and the practical applications may add to the conceptual basis of on-water rowing knowledge and to the practice of coaches, athletes and scientists. Improvement in technique variables and their consistency may contribute to greater rowing superiority in the future.

METHOD:

Data Collection: A group of twelve elite heavyweight single scullers (21.5±3.09years) were directed to row at four strictly controlled ascending rating steps (20, 24, 28, 32 strokes per minutes (Str*min^{-1})) and a race-simulated stroke rate (SRRP) over 250m. All athletes were experienced highly trained female athletes with international rowing regatta experience. All tests were conducted within a block of two weeks in the instrumented biomechanical testing single scull boat (Loschner & Smith, 1999). The variables: boat velocity (v^{boat}; magnetised impeller and coil sensor), boat acceleration (a^{boat}; mems single chip accelerometer and signal processor), propulsive and transverse pin force (F_p^{pin}, F_t^{pin}; multi-component piezo-electric sensors), propulsive footstretcher force ($F_p^{stretcher}$; shear beam load cells), oar angle (α; potentiometers) and yaw velocity (y^{boat}; gyroscope) were directly measured, propulsive net applied boat force (F^{boat}) and net applied boat moment (M^{boat}) were derived variables.

The boat was set up and adjusted to the individuals' requirement. The transducers were all calibrated before each test. Data were sampled at 100Hz and telemetered to the shore.

Data Analysis: The results were analysed for a selected sequence of 15 strokes at all five stroke rates. The data for each of the 15 strokes was taken from the original time series data. The minimum (*min*), maximum (*max*), average (*mean*), range (*range*) and standard deviation of the mean (sd^{mean}) and max (sd^{max}) scores of each variable were calculated. The range of the selected variable was chosen as the denominator for the coefficient of variation (CV^{range}) calculation to assess the stroke-to-stroke repeatability of key variables obtained from the rowers (Smith, 1996, Smith, 2005).

RESULTS: The CV^{range} values were calculated for each *measured variable*: boat velocity, boat acceleration, catch and release angles, propulsive and transverse pin force, propulsive footstretcher force, boat yaw velocity and *derived variable*: propulsive net applied boat force, net applied boat moment for each individual athlete over the five performed stroke rates. Table 1 displays the athletes' individual as well as the CV^{range} group means and standard deviations for the race-paced stroke rate (SRRP).

Table 1: Individual (n=12), mean and ±sd values for CV^{range} for all measured and derived variables at SRRP

Variables	1	2	3	4	5	6	7	8	9	10	11	12	$MeanCV^{range}$	±sd
v^{boat}	18%	5.5%	3.5%	4.6%	3.6%	2.7%	4.4%	3.2%	14%	11%	3.3%	5.2%	6.6%	5.0%
a^{boat}	8.2%	0.8%	0.7%	1.4%	1.6%	1.5%	1.2%	1.1%	1.9%	1.8%	1.7%	0.9%	1.9%	2.0%
α^{ST}	1.4%	0.4%	0.6%	0.3%	0.3%	0.4%	0.5%	0.4%	0.7%	0.5%	0.4%	0.2%	0.5%	0.3%
α^{B}	1.3%	0.4%	0.4%	0.4%	0.4%	0.6%	0.5%	0.4%	0.5%	0.7%	0.6%	0.5%	0.5%	0.3%
F_p^{stST}	4.9%	6.0%	3.3%	3.8%	4.0%	2.7%	4.8%	4.4%	5.0%	4.4%	4.5%	3.1%	4.2%	0.9%
F_p^{stST}	5.9%	3.6%	3.9%	4.0%	3.3%	4.2%	5.8%	3.2%	4.4%	5.3%	5.8%	3.1%	4.4%	1.1%
F_p^{pinST}	5.1%	3.1%	2.0%	2.1%	1.9%	2.7%	2.7%	4.3%	5.4%	3.4%	2.1%	2.7%	3.1%	1.2%
F_p^{pinB}	3.1%	2.6%	3.0%	4.0%	2.1%	5.3%	2.6%	4.0%	3.5%	3.9%	4.3%	3.2%	3.5%	0.9%
F_t^{pinST}	8.4%	1.0%	1.4%	1.7%	1.8%	2.2%	1.3%	3.2%	2.2%	1.0%	1.6%	1.8%	2.3%	2.0%
F_t^{pinB}	6.7%	1.5%	1.4%	0.8%	1.5%	2.0%	1.2%	2.0%	2.2%	1.0%	1.6%	1.8%	2.0%	1.6%
F^{boat}	8.4%	3.0%	1.2%	1.5%	2.2%	1.8%	1.6%	2.0%	3.6%	3.5%	1.6%	1.5%	2.7%	2.0%
M^{boat}	13%	24%	31%	23%	33%	34%	19%	19%	28%	13%	14%	30%	23%	7.9%
y^{boat}	58%	84%	52%	176%	40%	3%	34%	91%	103%	134%	8%	136%	76%	53.7%

All CV^{range} results, excluding net applied boat moment and boat yaw velocity, showed small variations between the 15 selected analysed strokes from the 250m race pace piece. However, athlete (W1) had generally the highest variations for each technical variable of the group results, perhaps due to her relatively short training history (international junior rower).
The very small CV^{range} values confirmed that the rowers were capable of repeating the same result for each selected variable with very little variation throughout the 250m rowing piece at SRRP, except in the boat yaw velocity (Table 1). Each variable will now be treated in turn.

<u>Boat velocity:</u> The CV^{range} for boat velocity showed the highest variation of the directly measured variables with $CV^{range}(v^{boat})$=6.6±5.0%.

<u>Oar angles:</u> The CV^{range} for oar angles showed the smallest variation of all selected variables with $CV^{range}(\alpha^{B})$=0.5±0.3% and $CV^{range}(\alpha^{ST})$=0.5±0.3%.

<u>Boat acceleration and propulsive net applied boat force:</u> The CV^{range} for boat acceleration ($CV^{range}(a^{boat})$=1.9±2.0%) showed a slightly higher level of repeatability than for net applied boat force ($CV^{range}(F^{boat})$=2.7±2.0%). The two consistent typical curve patterns revealed a highly significant positive relationship during the drive phase at race pace (r^2=0.904, p<0.000), which was also supported by all individual results.

Propulsive and transverse pin force and propulsive footstretcher force: The CV^{range} for all three forces showed a high repeatability on bow and stroke side. Transverse pin forces obtained the smallest variations ($CV^{range}(F_t^{pinST})$=2.3±2.0%, $CV^{range}(F_t^{pinB})$=2.0±1.6%), propulsive footstretcher forces the highest variations ($CV^{range}(F_p^{stretcherST})$=4.2±0.9%, $CV^{range}(F_p^{stretcherB})$=4.4±1.1%). There were only small CV^{range} differences found between bow and stroke side. The graphical displays of all three force variables supported the high consistencies of the repeated measures. Separating bow and stroke force curves revealed a range of technical differences between the two sides, which occur particularly during the drive phase (Figure 1). Propulsive pin and footstretcher force showed a similar curve trace, transverse pin force represented a *`sine-wave form´* for the drive phase.

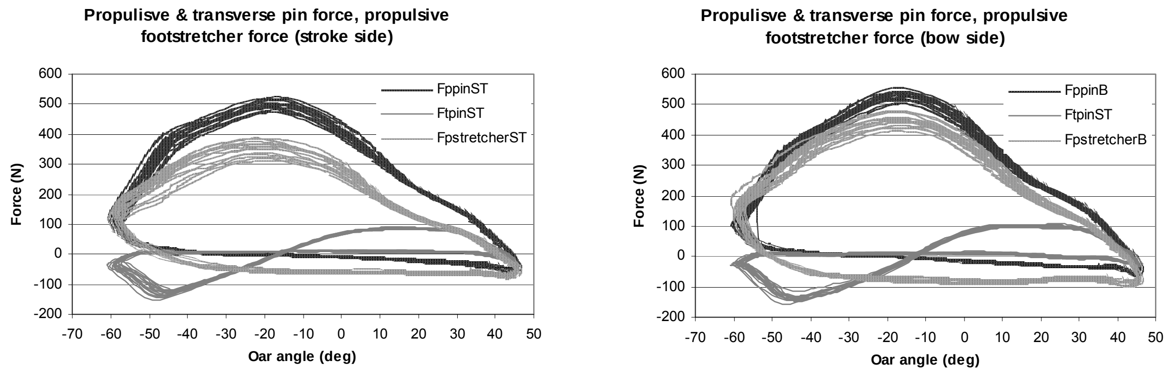

Figure 1: Propulsive and transverse pin force, propulsive footstretcher force vs. oar angle of 15 consecutive strokes at SRRP of athlete (W2) stroke side(left), bow side (right)

Net applied boat moment: At $CV^{range}(M_{applied}^{boat})$= 23±7.9%, the curve pattern for net applied boat moment revealed a relatively low consistency throughout the 15 strokes. An individual characteristic curve pattern was visible but the magnitude of the peaks varied. However, no particular similarities in the curve patterns were found between individuals (Figure 2).

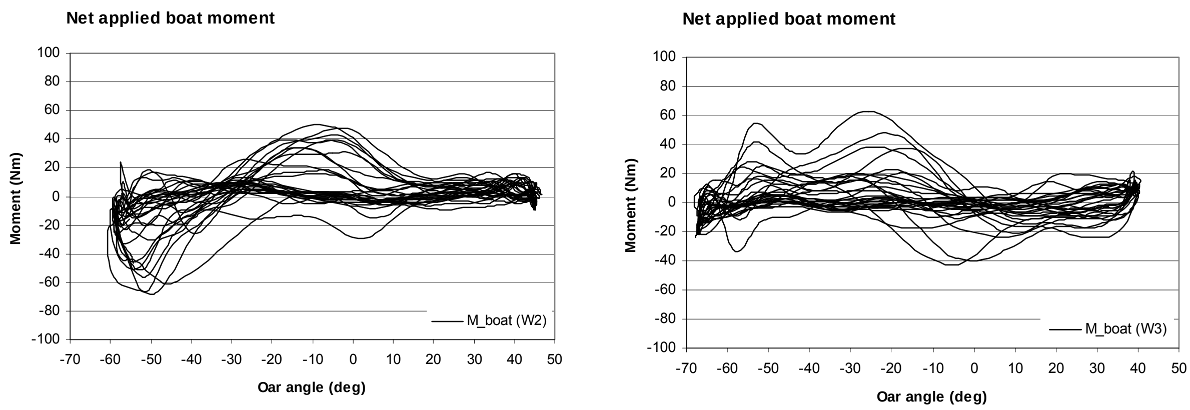

Figure 2: Net applied boat moment vs. oar angle of 15 consecutive strokes at SRRP, athlete W2 (left), W3 (right)

Net applied boat moment was calculated from the bow and stroke propulsive pin, propulsive footstretcher and transverse pin moments. Throughout the entire drive phase, propulsive pin moment was found to be the largest of the three separate moments. It had the main effect on the characteristic curve pattern of net applied boat moment. However, all three moments had a notable effect.

Yaw boat velocity: Notwithstanding the recognizable patterns for net applied boat moment, the yaw signals remained below the noise level of the instrumentation.

DISCUSSION: The small values of CV^{range}<5% confirmed that all tested rowers were capable of retaining a high repeatability for each selected technical key variable. However, the actual force application on bow and stroke side could differ substantially during single sculling. The rower is often not perfectly symmetrical in the application of force to the pins and stretcher and must correct for external perturbations (Loschner C, et al., 2000). This effect is then visible in the CV^{range} (between 13%-34%) values of the net applied boat moment as well as in the moderate consistent repeating curve patterns within the strokes. In addition, the individual curve pattern could differ substantially between athletes. A similar argument applies to boat yaw velocity, as traces showed that it did not follow any particular pattern within the strokes.

CONCLUSION: The high repeatability for each measured and derived variable indicated that:

- the selected key variables were measurable with useful levels of repeatability,
- the experienced rowers were able to repeat each stroke within the 250m with a high level of consistency.
- net applied boat moment was revealed as a technique variable which could have significant implications for training.
- boat acceleration was a qualitative indication of the propulsive net applied boat force.
- the differences in the characteristics of the individual forces underlined the need for separate bow and stroke pin and footstretcher sensors in both propulsive and transverse directions.

The results also underscored the need for a comprehensive analysis of the rowing technique to be able to assess the athlete's continuous stroke by stroke influence on boat performance. This included both the combination of the statistical and graphical analysis. The horizontal force and boat performance results, could demonstrate a need for more individualized technique analysis in the search for further improvement in rowing performance.

REFERENCES:

Loschner C, Smith R & Galloway M. (2000). Intra-stroke boat orientation during single sculling. Paper presented at the Proceedings of XVIII Internat. Symposium on Biomechanics in Sports, Hong Kong.

Loschner C & Smith R. (1999). NSWIS Rowing Assessment and Training System. Paper presented at the FISA Coaches Conference, Canberra/ Australia.

Mattes K. (2000). Untersuchungen zur Variabilität und Stabilität von Ruderleistung und Leistungstechnik in den Hauptphasen des Ruderrennens (Investigation of the variability and stability of rowing performance and performance technique in the main phases of the rowing race). Habilitation, Humboldt-Universität zu Berlin, Berlin.

Smith E. (2005). Kinematics of walking in males and females: Effects of pathological foot conditions. (PhD thesis), The University of Sydney, Sydney.

Smith R. (1996). Distribution of Mechanical Energy Fractions during Maximal Ergometer Rowing. (PhD thesis). The University of Wollongong, Wollongong.

Wagner J, Bartmus U & Demarees H. (1993). 3-Axes Gyro System Quantifying the Specific Balance of Rowing. International Journal of Sports Medicine, 14(Suppl 1), 35-38.

Zatsiorsky VM & Yakunin N. (1991). Mechanics and biomechanics of rowing: a review. International journal of sport biomechanics, 7(3), 229-281.