USE OF REAL-TIME TELEMETRY TO MONITOR INSTANTANEOUS SEAT AND BOAT VELOCITY IN PAIR OARED ROWING

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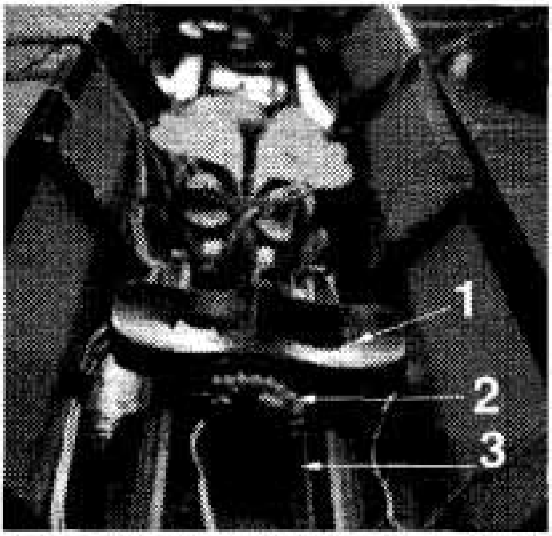
On-water instrumentation methods have been devised by several researchers to provide real time feedback of relevant biomechanical variables to rowing coaches. The principal focus of these investigations has been the measurement and interpretation of individual oar forces during the propulsive phase of the rowing stroke cycle. In an attempt to monitor rowing technique during both the drive and recovery phases of the stroke, instantaneous velocity of each sliding seat in a pair oared rowing shell was measured in conjunction with boat velocity. This also enabled links to be made between individual and combined 'crew' technique that may influence intrastroke boat velocity fluctuations during the complete stroke cycle.

KEY WORDS: rowing, biomechanics instrumentation, technique, boat velocity, seat velocity

INTRODUCTION: The design of the modern rowing shell incorporates foot stretchers and riggers fixed to the hull and a sliding, wheeled seat on tracks. This allows the athlete to utilise the strong extensor muscles of the lower limbs and trunk to generate an effective propulsive force over a greater stroke length.
Seat movement has been assessed kinematically during ergometer (Nelson and Widule, 1983) and tank rowing (Asami et al., 1978), but technological impediments have prevented the measurement of this variable during actual on-water rowing. Researchers have acknowledged that the longitudinal displacement of the rowers' centres of mass in relation to the boat must be considered when attempting to evaluate the dynamic interaction between the rowers and the impact on boat velocity fluctuations during the complete stroke cycle (Martin and Bernfield, 1980; Zatsiorsky and Yakunin, 1991). To date, there has been no known attempt to measure the movement of the rowers in the boat to determine the relationship to oscillations in boat velocity during the complete stroke cycle.

METHODS: The subjects for this study were 16 well trained, competitive male sweep rowers performing in a standard coxless pair rowing shell (mean age 21.02 $\pm$ 2.83 years, mean height 192.02 $\pm$ 5.77 cm and mean mass 90.82 $\pm$ 6.20 kg). Crews were required to perform one 500 m trial while rowing at the strictly controlled rate of 28 stroke per minute (spm). Instrumentation methods were designed and constructed using Hall effect devices to measure instantaneous velocity of the boat and each moving seat (Figure 1). All transducers were lightweight, splash-proof, robust and battery powered to provide output in the range 0-5 volts. Data were transmitted at 101.18 Hz to a remote laptop computer, presented graphically in real time and simultaneously stored for further analysis.
Analysis was performed using 15 consecutive cycles which were selected from the mid point of each 500 m trial. Individual cycles were normalised to 100 data points and data from each normalised cycle were averaged to produce a single, representative stroke cycle for each rower. All dependent variables were extracted from the ensemble average data. Results from each rower were then averaged to determine combined 'crew' results.



1: Sliding seat, 2: Hall effect transducer, 3: Magnetic track
Figure 1 - Seat velocity instrumentation installed on the boat.

RESULTS AND DISCUSSION: The focus of this study was to investigate the impact of a discrete aspect of individual and combined 'crew' technique on boat velocity. Therefore, group ensemble average data were not generated to represent generalised patterns of data for all rowers. The crew with an average boat velocity which was similar to the group mean was selected to assist with the interpretation of results. The seat and boat velocity data for crew ***8*** are provided in Figure 2. Instantaneous seat velocity in both the recovery and drive phases of the stroke are represented as positive values. Table 1 summarises the seat velocity data for the complete group, crew ***8,*** the fastest crew and the slowest crew.

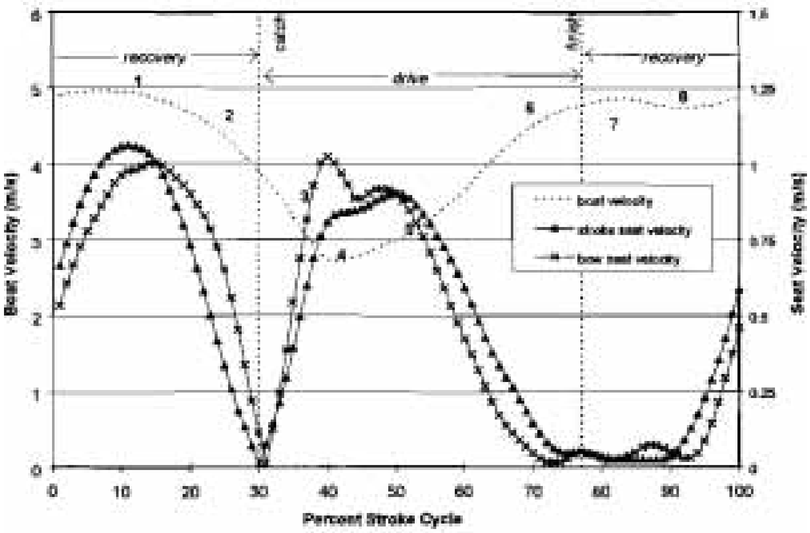


Figure 2 - Boat and seat velocity for crew 8 with specific events identified (see text).

Due to the cyclic nature of the rowing stroke, the recovery data presented in Figure ***2*** had to be divided to present the drive portion of the cycle in its entirety. Therefore, for ease of explanation, Figure 2 will be interpreted from the finish position (77% of the stroke cycle). During the early recovery phase, the seat was stationary as the lower limbs remained fully extended while the hands pushed the oar away from the body and the trunk began to pivot forward through hip flexion. This "legs down" phase was strongly influenced by crew technique and averaged ***28.56 ± 5.55*** % of the complete stroke cycle. The fastest crew extended this period to 33% of the cycle, and from a technical perspective, this may have sewed to provide a stable platform during the early recovery period which may minimise the disruption of boat balance.

Table 1 Average seat velocity details for Group (± sd), Crew 8, Fastest and Slowest Crews (15 stroke average).

	Group	Crew 8	Fastest	Slowest
Max. seat velocity in recovery (% cycle)	16.56 (4.60)	10.30	23.5	16.0
Location of rnax. seat velocity in drive (% cycle)	48.94 (3.90)	49.00	46.0	49.0
'Legs Down" phase (% cycle)	28.56 (5.55)	28.00	33.0	29.0
"Seat Arrival" to catch (% cycle)	.813 (.704)	0.5	0.0	2.0
'Seat Arrival' to 200N force (% cycle)	5.69 (1.43)	6.00	5.0	8.5
Max. boat vel. - rnax. seat vel. (recovery) (% cycle)	4.19 (1.79)	6.00	2.5	6.0
Min. boat vel. - max. seat vel. (drive) (% cycle)	6.63 (3.18)	8.00	2.0	6.0

At the end of the "legs down" phase, flexion of the knees commenced. This, in conjunction with the forward momentum of the shell and the inclination of the slanted slide rails, caused the rowers to translate towards the stern of the boat. The initiation of seat movement coincided with an increase in the boat velocity at approximately 90 % of the stroke cycle (Figure 2: Event 8). This occurred in the absence of propulsive forces from the reaction of the oars against the water.

During this phase, the acceleration of the mass of the two rowers and their oars (in a direction which was opposite to boat progression) caused a change in boat momentum. The forces resulting form rower acceleration was greater than the resistive forces acting on the boat, so boat acceleration occurred (Figure 2: Event 8 to 1). The existence of a positive boat acceleration in the early recovery period has been confirmed with accelerometers mounted in the hull of the boat (Duchesnes et al., 1989).

Martindale and Robertson (1984) conducted a comprehensive kinematic evaluation of single scull rowing to quantify and contrast the instantaneous total energy patterns of the athlete and boat. Evidence of kinetic energy exchange between the athlete and the boat was documented during the first 75% of the recovery period. During this time, the kinetic energy of the rower declined and that of the boat continually increased, "The energy causing the boat's energy to increase must have come from the subject through his connection to the boat at the feet, since the only other source of energy change in the system was the vicious (sic) drag of the water" (Martindale and Robertson, 1984, p.162).

Results of the current study reveal that each sliding seat continued to accelerate during the recovery phase to reach an average maximum velocity at 16.6 ± 4.6 % of the stroke cycle. The maximum seat velocity during the recovery phase for crew 8 coincided with the commencement of the boat deceleration period (Figure 2: Event 1). Optimal technique would logically require the initial movement of each rower's mass to occur simultaneously and the attainment of maximum seat velocity to be synchronised.

Following the maximum recovery seat velocity, a marked deceleration of the seat occurred and a simultaneous reduction in boat velocity was observed (Figure 2: Event 2). Boat deceleration occurred as the momentum of the rowers was no longer able to offset the hydrodynamic drag on the shell (Martin and Bernfield, 1980). At the end of the recovery phase, the mass of the rower moved over the feet and had to be decelerated prior to reaching the catch position. This caused an increase in the force applied to the foot stretcher and a negative impulse to the boat resulting in a decrease in boat velocity (Zatsiorsky and Yakunin, 1991). German and Russian research found that foot stretcher force was applied 0.15 to 0.22 seconds prior to the oar entering the water and was 441 to 539 N at the moment of the catch (Zatsiorsky and Yakunin, 1991).

The closer this "seat arrival" coincided with the oar reaching the catch position, the more precise the technique of the catch action. Martin and Bernfield (1980) noted that the amount of boat deceleration that occurs during the recovery is related to the time spent in the stern of the boat prior to the catch. Once the oars reach the catch position, timing of the 'leg drive' must be accurate or negative forces would be transferred to the foot stretchers before the oars are completely buried in the water. This may account for the observed boat deceleration which occurred between Events 3 and 4 (Figure 2). "If the bodies accelerate too rapidly at this stage, and the blade is only partly immersed, the 'kick back' to the hull will be increased" (Pannell, 1979, p.14). The result would be a detrimental backward impulse as the combined mass of the rowers and oars may be 4 to 7 times greater than the mass of the shell (Pannell, 1979; Martin and Bemfield, 1980).

Following the catch, the seat immediately accelerated towards the bow as the 'leg drive' was initiated. For this group, an average of 5.69 % (± 1.43) of the stroke cycle occurred between seat arrival and an oar force of 200 N. During this phase, the acceleration of the mass of the two rowers and their oars (in the same direction as boat travel) produced a proportionately rapid deceleration of the hull (Figure 2: Event 3 to 4). Martindale and Robertson (1984) found that the kinetic energy of the rower increased and that of the boat decreased during this time.

Both rowers in crew 8 demonstrated an initial seat acceleration which ended at 41 % of the stroke cycle before a secondary peak velocity occurred at approximately 53 to 55 % of the stroke cycle. The momentary period of seat deceleration coincided with the occurrence of minimum boat velocity for this crew (Figure 2: Event 4). This biphasic seat velocity pattern was evident in the data for all 16 rowers analysed in this study. It is proposed that if the rower lacked the strength to maintain the velocity of the leg drive while the hip extensors were activated to initiate the opening of the hip angle and extension of the trunk, a momentary reduction in seat velocity may result.

CONCLUSIONS: Despite acceptance that the movement of the rowers' centres of mass in relation to the boat has a dramatic influence upon instantaneous boat velocity, there has been no previous attempt to continuously measure this variable in conjunction with instantaneous boat velocity. Although measurement of individual seat velocity is only a crude indicator of the location of the rower centre of mass, results of this study are in agreement with ergometer and on-water mechanical energy assessments.

This study demonstrated how innovative technology could be used to simultaneously measure discrete aspects of rowing technique which may combine to influence instantaneous boat velocity. In analysing technique during the entire stroke cycle, greater insight into the mechanics of rowing was possible. In future, the attempt to assess individual and combined crew technique may prove to be essential in the development of optimisation strategies which address the unique requirements of each crew.

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