THE RELATIONSHIP BETWEEN SEAT MOVEMENT AND BOAT ACCELERATION DURING SCULLING

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Fluctuations in boat velocity during rowing should be minimised in achieving the shortest possible time for the **2000m** race. The aim of this study was to examine the relationship between the movement of the major body segments of a rower and the acceleration of the boat. Seat position, seat velocity, boat acceleration, and oar angle were measured for one rower for three stroke rates for at least ten consecutive strokes. Seat position was used to approximate the position of the centre of **mass** of the trunk and thighs. Maximum seat velocity increased with stroke rate. Differences in acceleration of the boat could be related to changes in the slope of the seat velocity curve.

KEY WORDS: rowing, on-water, seat velocity, boat acceleration, stroke rate, sculling

INTRODUCTION: The aim of competitive rowing is to complete the 2,000 m race distance in the shortest possible time. Considering the effects of drag only, the rower's energy expenditure will be minimised if the velocity fluctuations of the boat are also minimised. Thus, one of the goals of technique improvement will be the control of forces that cause these fluctuations. Boat velocity fluctuations are caused by the net result of drag, pin, and stretcher forces and reach about $\pm 1 m \cdot s^{-1}$, around an average velocity of about 5 $m \cdot s^{-1}$. Stretcher forces are partly a reaction to the production of propulsive pin forces by the rower during the drive phase and partly a reaction to the rower's acceleration of large body segments during both drive and recovery phases of the rowing stroke. The position of the centre of mass of three of the largest body segments relative to the boat (trunk and thighs) can be approximated by the position of the seat relative to the pins. Thus an indication of the effect of the acceleration of the large body segments on boat movement can be achieved by analysing seat position during on-water rowing. The seat position time history also indicates the proportion of the drive phase during which power is generated by leg extension.

There have been many studies of the forces the rower applies to the handle, and some more limited studies of the forces applied to the stretcher (eg Nolte, 1980; Smith and Spinks, 1998). However, there are no applied studies looking specifically at the movement of the seat in relation to the maintenance of boat velocity. Intuitively and analytically, coaches and rowers know that the accelerations of large body segments have a dramatic effect on the movement of the boat, especially during the recovery. To provide some quantitative **information** about these effects during on-water rowing, a single scull was permanently instrumented with force, position, velocity and acceleration transducers. This type of boat was chosen because in this category the accelerations are due to the effects of only one rower.

The aim of this study was to determine, within the stroke, to what extent the seat position and velocity relates to the boat acceleration at different stroke rates and how coaches and rowers can apply this information during training.

MATERIALS AND METHODS: A rower (male, international level, lightweight, single **sculler)** was directed to row at three stroke rates (20, 24, and 28 strokes per minute ($str \cdot min^{-1}$)) for two minutes each, separated by one minute of light rowing. Before the testing session the seat height and length, pin span, and stretcher position were adjusted to the individual requirements of the athlete and the transducers calibrated. Seat position, boat acceleration, and oar angle were sampled at **100Hz** and **telemetered** to the shore, where the information was graphically displayed on a laptop computer in real-time.

Measures contributing to the description of the body movement of the athlete were: (1) the bow and stroke side oar angles from an electrogoniometer **(173-580,** Radiospares, Sydney) mounted over the pin; and (2) the seat position from a cable and drum driven potentiometer

(162-3405, Space-Age Control Inc., Palmdale, California, USA). The run of the boat was measured with: (1) a magnetised impeller and coil sensor for velocity of the boat relative to the water; and (2) a micro-machined accelerometer (ADLX05, Analog Devices, Norwood, MA, USA).

The seat position transducer was calibrated as follows. The 'zero position' was where the front of the seat met the line between the pins (oars are perpendicular to the boat). A point 0.5 m towards the bow was used to scale the transducer. Distance towards the stretcher appears as a negative value; the numbers are positive when the seat moves towards the bow of the boat.

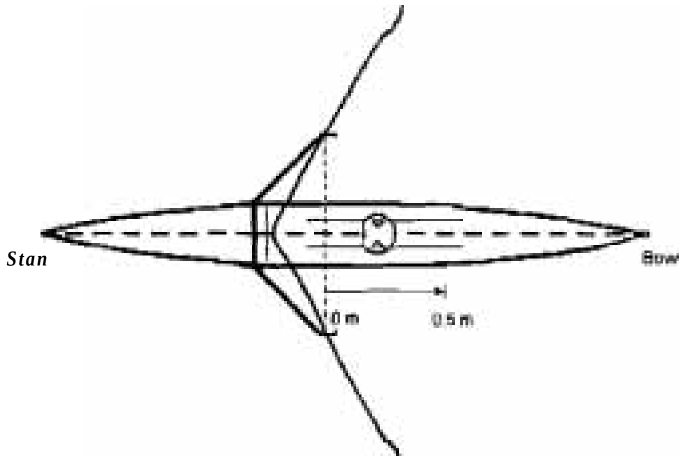

Figure 1 - Boat rigging and calibration of seat position

RESULTS:

Table 1 Mean Value of Seat Position, Seat Velocity, Oar Angle, and Boat Acceleration

Stroke Rate	Seat Position (m)		Seat Velocity ($m \cdot s^{-1}$)		Stroke Angle (deg)		Bow Angle (deg)		Acceleration ($m \cdot s^{-2}$)	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
20	0.03	0.45	0.58	0.84	-58.9	44.3	59.6	45.6	-4.96	3.72
24	-0.04	0.45	0.80	0.96	58.6	43.7	-59.5	44.5	5.52	3.83
28	-0.06	0.45	-0.90	1.14	58.1	43.5	-59.5	44.3	-6.69	3.62

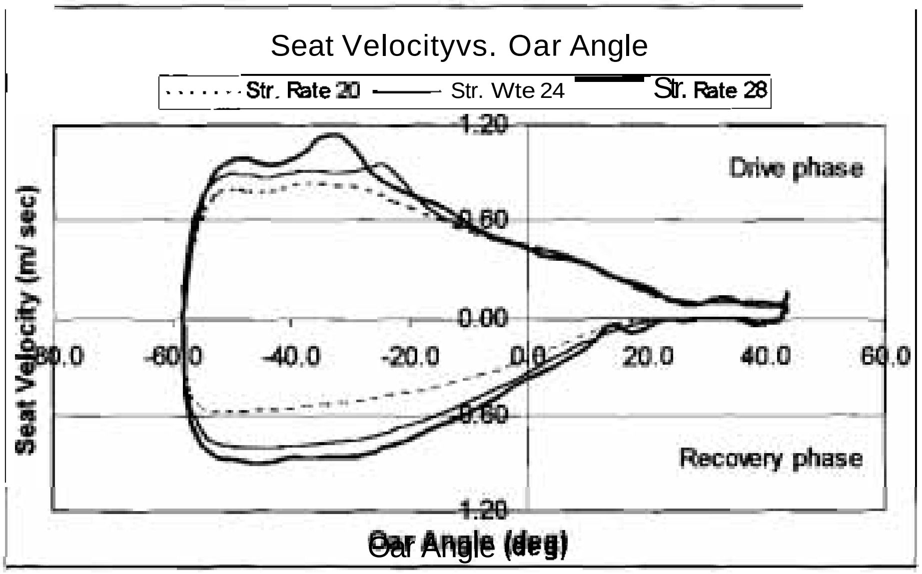

Figure 2 - Seat velocity **versus** oar angle at 20, 24, and 28 **str·min**$^{-1}$

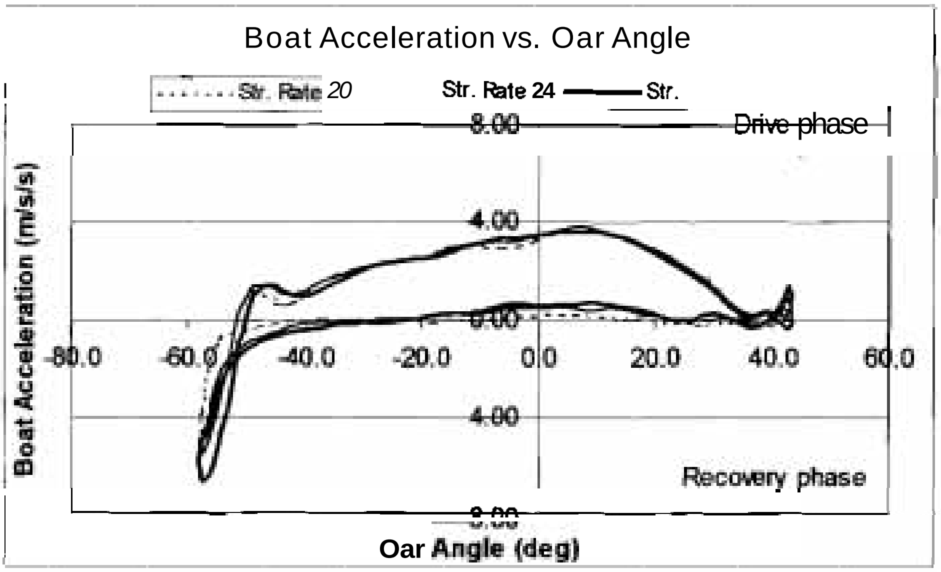

Figure 3 - Boat acceleration versus oar angle at 20, 24, and 28 **str·min⁻¹**.

DISCUSSION: The pattern of the boat acceleration was remarkably similar for the three stroke rates (Figure 3). As the stroke rating increased, a slight increase in acceleration occurred in the recovery phase while the oar was moving from 20° behind the 'zero position' to 10° past the '*zero* position' (shown as –10° on Figure 2,3) and larger decrease at the catch (near the –60° mark). With increasing stroke rate the seat velocity increases with higher rating during the drive phase but this changes by a much larger amount in the recovery phase (Figure 2). This is a natural consequence of the fact that the rower shortens the recovery time rather than the drive time in order to increase the stroke rate.
The increase in acceleration of the boat in the recovery phase starts at the same time (oar angle near 20°) as the increase in slope of the seat velocity. Similarly, the larger negative acceleration at the catch corresponds to greater changes in seat velocity. Furthermore, the boat acceleration is more sensitive to changes in the acceleration of large body segments caused by increased stroke rate during the recovery phase because there are no big external forces applied to the pins and the foot-stretcher. This underlines the importance of technique during the recovery phase and the usefulness of seat movement and velocity as technique feedback.

CONCLUSION: The connections between large body segment movements and boat acceleration have been demonstrated for just one rower over three training stroke rates. However, this test has shown that boat acceleration relates strongly to the seat velocity in the single scull, particularly during the recovery phase. Coaches and athletes will be able to use this information as a training and assessment tool to demonstrate the relationship between their seat and handle position and the changes that occur to each as well as to the boat acceleration and boat velocity with increasing stroke rates.
In the future this on-water testing procedure will be used for the technique assessment and all categories of rowers over the whole range of stroke ratings.

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