BIOMECHANICAL ANALYSIS OF TWO ELITE CANOEISTS

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INTRODUCTION

Optimization of each athlete's competitive potentialities through effective technique modification is important because the majority of the top canoeists are from northern climates, where conditions are not favourable for on-water training during the lat fall, winter, and earlier spring months. Attempts have been made (in Canada) to develop simulators to assist the conditioning of paddlers (Pelham & Holt, 1995). With limited on-water opportunity, optimizing technique is essential. Little time is available for the possible evolution of an efficient technique. That, coupled with an early emphasis on competition often leads to a technique that may not be optimum over the long term.

With this in mind, the purposes of this study were 1) to identify biomechanical parameters of elite canoeing performance, 2) to determine if on-water kinematics would closely match performance on a new C-1 simulator, and 3) measure and compare the power output of the two elite subjects (S's) on the simulator, and compare to on-water performance.

METHODOLOGY

Subjects were two males, both experienced international competitors and members of the Canadian canoe team; both left sided paddlers.

Ergometer Design: The simulator consisted of a resistance unit and a C-1 frame. The resistance unit, a Pacer 2A Biokinetics exercise (single) unit (Biokinetics, Inc., Albany, CA.) was determined to be the best duplicator of the characteristics of on-water C-1 technique by providing a semi-accommodating resistance at the #4 setting. The C-1 frame was a modified physiotherapy table. This was similar to our previous experimental set-up (Pelham & Holt, 1995).

To allow the S the opportunity to assume the proper canoeing positions, an adjustable C-1 knee and floor board with a back foot brace was fastened to the frame. Common gauge rope, 230 cm in length connected the resistance unit to the shaft by way of a hose clamp 36 cm from the bottom of a 136 cm regulation paddle with T-handle. A Macintosh Plus computer and Maclab A to D converter system (Apple Computer, Inc., Cupertino, CA.) with a hardwire connection to the resistance unit processed and analyzed the absolute force outputs of the S's. Calibration was accomplished through the use of a Chatillion scale, which was checked at selected amounts of force.

Ergometer trials: Once the S's established the correct rhythm and a stroke rate of 44 strokes per minute (80% of average racing rate of elite athletes), the camera stationed approximately 2 meters from the ergometer filmed the S's paddling for several stroke cycles. To insure the S's were maintaining the correct rate, the S's were paced by an audio signal from a metronome. Simultaneously, absolute force outputs from the computerized processing and analysis system were videotaped in sequence with the executed stroke. Force time data were recorded at a frequency of 100 Hertz.

Videographv: Video from the lateral perspective was collected both in the lab and on-water, permitting the analysis of the entire stroke cycle, including the paddle. The camera both in the lab and in the motorboat was mounted on a tripod, providing stability. On-water filming was done on a calm day, and very little unnecessary motion of either power boat or racing craft occurred during filming. In addition, the film plane was parallel to the action plane. Markings were placed on the boat and simulator; and the S's wore a minimum amount of clothing (swimsuit). In both situations the images were clear, enabling digitizing of the boat, body and both hands of the S's as well as the paddle through a complete stroke cycle. A Pentax Hi-8mm camcorder filming at the equivalent of 30 frames per second was used in both situations (calibrated).

Boat Trips: A 100 meter racing lane was constructed. Before filming, S's had a prepatory warm-up. The S's were allowed to build their rhythm and stabilize their technique prior to entering the 100m trial and filming zone. The S's were required to paddle 44 strokes per minute in the first trial (Walkman-pretaped rhythm) and in a second trial, after a period of time for recovery, at their normal racing rate for 500 meters. The camera was approximately 6 meters from the S's and stationed in a moving motor boat travelling parallel to the S's. S's used a regulation C-1 (Struer Co., Denmark) and a racing paddle of their choice.

RESULTS

Over the course of a 500 or 1000 meter race, or for a given number of strokes on the ergometer, S1 is superior (Table 1). For S2 to produce an equivalent amount of boat velocity he must compensate by increasing his stroke rate. However, any increase in the rate will be accompanied by an increase in energy expenditure. This is a less than favourable situation, which gives the mechanical and performance advantage to S1. This efficiency can be seen in the large difference over 1000 meters.

Comparisons of the movement patterns of the upper and lower hands of S2 and lower hand of S1 showed that paddling on the simulator closely resembled on-water technique (Figures 1A and 1B). Differences in both top hand and bottom hand loci of movement were noticed, but major "sticking points" causing unnecessary violent contractions were not observed. Comparison of trunk, hip and leg movements indicated strong similarity between ergometer and on-water patterns of both S's.

Table 1: A mechanical comparison of the simulated propulsive phase exerted by S1 and S2

MECHANICAL FACTOR	S1	S2
SIMULATOR:		
TIME		
Time of propulsive phase (seconds)	0.7	0.5
Time of recovery phase (seconds)	0.7	0.9
Total stroke time (seconds)	1.4	1.4
Time to maximum force (seconds)	0.46	0.3
FORCE		
Maximum force (Newtons)	190.00	214.00
IMPULSE AND POWER		
Impulse (Newton-seconds)	109.09	87.14
Length of stroke (meters)	0.98	0.64
Power (watts)	261.66	208.56
RACE TIMES:		
Personal best time for 500 meter race (minutes:seconds)	1:56	1:58
Personal best time for 1000 meter race (minutes:seconds)	3:59	4:15

As can be seen from Figures 2 and 3, the trunk and hip of S1 are clearly displaced to a much larger extent than S2. Indeed, S2 demonstrated a pattern of very small circular motions of his blade, resulting from his body only moving through a small arc (180) from deepest blade position to exit. S1 demonstrates large tear drop patterns consisting of great backward linear displacement of the blade through which his body moves from deepest blade position to exit (400).

Force dynamics of the canoe stroke: Pelham and Holt (1995) have suggested that drag forces dominate C-1 propulsion. To maximize the propulsive drag forces on the water, the most effective blade position after immersion would be accomplished by (maintaining the propulsive surface) perpendicular to the water surface. However, in both on-water and simulator trials, although each S's movement patterns were reasonably close, (to their own) both S's consistently demonstrated blade orientations that deviated from 900 throughout the propulsive phase (Figures 2 and 3). In all cases, immersion was followed by sweeping the blade through an arc, in which a perpendicular orientation was observed for a minimal period of time, and a position past the vertical was maintained for most of the propulsive phase.

S1 applies force over a greater period of time even though the blade angle is not optimum. Indeed, as illustrated in Figures 2 and 3, the total impulse during a typical stroke of S2 is 20% less than S1. Particularly meaningful are the forces produced during the latter part of the propulsive phase. At 0.5 seconds, S1 has generated a force of 190N compared to 68N for S2. At 0.6 to 0.7 seconds, S1 is still producing sizeable forces, on the ergometer whereas S2 is exiting. As expected the paddle of S1 travels a longer distance, and results in a larger total power output of S1 during the propulsive phase. However, S2 does generate a greater maximum force (214N to 190N) on the ergometer.

DISCUSSION

The primary concern in canoe racing is to maximize the effectiveness of the stroke from both a mechanical and physiological perspective. Anatomical and functional differences together with early learning experiences will dictate the particular adaptations of technique or style used. S1 and S2 have very different techniques. S1 has a longer stroke with a greater angular displacement of the trunk utilizing the musculature of the hip, trunk and lower extremities; whereas, the restrictive movement of S2 with power generated by the arms and shoulders is less powerful, more locally fatiguing and therefore less effective.

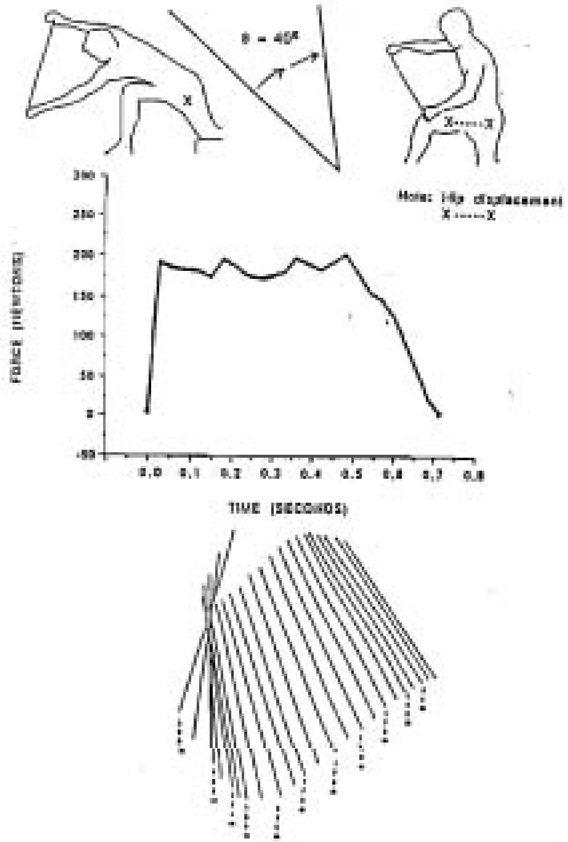

Figure 2: Top: Body motion through propulsive phase.
Middle: The impulse exerted by S1 during a simulated canoe stroke.

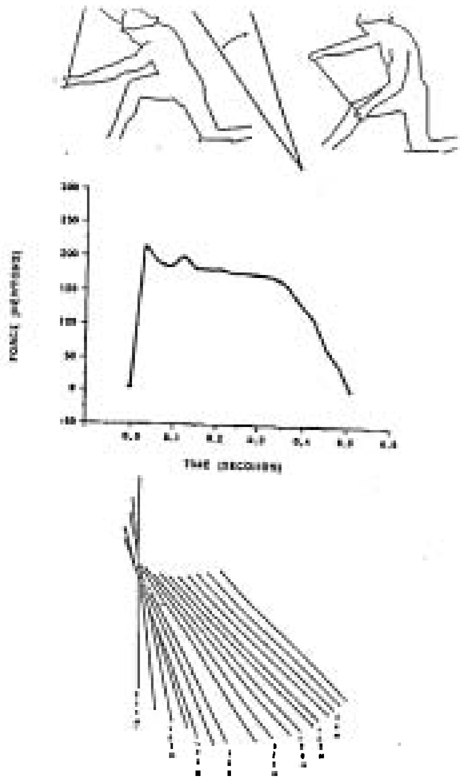

Figure 3: Top: Body motion through propulsive phase
Middle: The impulse exerted by S2 during a simulated canoe stroke.

REFERENCES

Pelham, T.W. & Holt, L.E. (1995). Testing for aerobic power in paddlers using sport-specific simulators. Journal of Strength and Conditioning Research 9(1):52-54.