BIOMECHANICAL TESTING IN ELITE CANOEING

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Top level performance in elite sport requires a sound systematic approach not only to training, but also to the sciences that support the sport. Lenz (1994) asserted that the most successful sporting associations in international sport are those that utilise a scientifically based system for research and performance analysis. The intention of this paper is to provide: 1. a brief overview of the development of biomechanical testing and research in Olympic canoeing disciplines; 2. an outline of on-water biomechanical testing in Olympic canoeing and the interpretation and application of the data; and 3. specific force and power measurements in resistance training for canoeing. The emphasis will be on the application of the testing and results and how it is used to improve performance. The information will draw on both published literature and the experience of the authors.

KEY WORDS: canoeing biomechanics, force, race analysis, kinematics, power.

INTRODUCTION: Regular systematic biomechanical measurements for Olympic canoeing disciplines began close to 30 years ago in the socialist countries and primarily East Germany and Russia. With the desire in these countries for high level Olympic performance research and testing into sprint canoeing was intensified (Issurin, 1980; Sperlich, 1986; Issurin, 1986). Sporadic research by western countries has been evident for a number of decades (Plagenhoef, 1979; Stothart, et al., 1987; Kendal & Sanders, 1992; Jackson, 1995). In Australia there has been intense biomechanical support for elite kayaking since the late 1980s. This came about primarily with the establishment of a Sprint Canoeing programme in the Australian Institute of Sport in 1988 for preparation for the Seoul Olympic Games. With Australia being awarded the 2000 Olympic Games in 1994 extra resources were put into elite sport by the government which permitted a more systematic and intensified support system for Olympic sports including canoeing. While now there probably aren't the resources available for a single country in canoeing as there were with the GDR there have been greater advancements in the biomechanical understandings of canoeing. In addition the international cooperation between Biomechanicists has increased dramatically albeit limited at this stage to a small number of professionals.

ON-WATER BIOMECHANICAL TESTING AND ITS APPLICATION TO IMPROVING PERFORMANCE: On-water testing and analysis falls into three main areas: 1. Competition Analysis, 2. On-water Force Measurements, and 3. Kinematic Analysis.

1. Competition Analysis: Competition analysis of sprint canoe races involves calculating stroke rate, boat velocity (figure 1), stroke length, and split times and provides valuable information to the athlete and coach (Sperlich, 1994; Baker, 1998; Issurin, 1998). The information is determined from video, which is ideally taken from a boat or vehicle following the race. With a time overlay and using the buoys on the course as distance measures the race data can be calculated. Race analysis information can be used not only during competition to provide feedback to the athlete in regards to their performance and possible strategies for races in a regatta, but also planning for future races. The success of the German Sprint Canoe team at the 1992 Barcelona Olympic Games can be in part attributed to the scientific support during the regatta and also in the build up to the Games. Figure 1 shows race analysis profiles from the LK1 500m semi-final of the leading contenders for the final. Through the analysis it was determined by the German coaches and scientific support team that Schmidt (Germany) would need to increase her rating towards the end of the race to achieve the necessary increase in boat velocity to win. Schmidt was able to do this in the final and achieved the desired result.

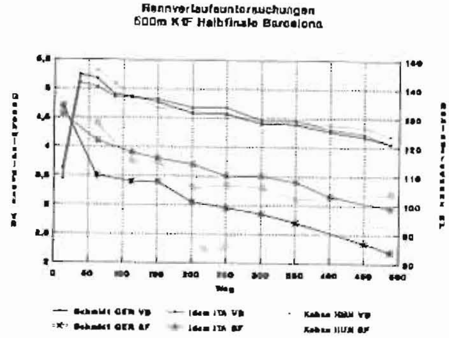

Figure 1. Stroke rate and velocity profiles of LK1 500m semi-finals at the 1992 Olympics.

Similar scientific support was provided to the Australian team particularly through the period including the 1996 and 2000 Olympic Games. Race analysis was conducted at all major domestic and international regattas where race profiles of Australian team members were produced for both during regatta performance and longer term planning. The information was used to track changes over the competitive season as well as working on race plans during the season. Race analyses however have their foundation in the athlete's ability to produce force for the duration of the race. That is the athletes ability to maintain boat speed is to a large degree dependant upon their ability to maintain force application to the paddle (Sperlich, 1994). This is where the logical link to on-water force measurements comes into place.

2. On-water Force Measurements: Biomechanical systems that measured force applied to the paddle on water were originally developed in East Germany. On-water force measuring systems have evolved from instrumented paddles tethered to data collecting boats, to force transducers mounted on the paddle and hardwired to a data logger (Sperlich & Klauck, 1992; Aitken & Neal, 1992) or a telemetry unit in the boat, to now where a system is available that permits the telemetering of the signal from the paddle to either a data collection unit in the boat or to a laptop following in a coach-boat. The force applied to the paddle is the prime variable measured with boat velocity and acceleration also being typically measured variables (figure 2). On-water force analysis has two main functions though they compliment one another (Baker, 1998). One function is concerned with the actual results that are produced, e.g. the peak force and impulse values. The data from on-water testing allows for an athlete to be compared against established norms for possible areas where improvements could be gained (table 1). In addition comparing results from test to test enables monitoring of an athlete's yearly, and year-to-year improvement. The second form of analysis uses the shape of the force curves for stroke error detection purposes and as such is qualitative. Different force curve shapes can indicate different technique faults. Figure 2 illustrates different force curve shape for paddlers in a K2. Overlaying force curves on video in real-time allows for a more thorough analysis of the underlying reason for the shape of the curve as the movement of the paddler is seen in unison with the force curve.

Table 1. Average Values of Biomechanical Variables for National Level Paddlers (Baker, 1998).

	Peak Force (N)	Impulse (N.s)	Stroke Rate	Time in Water (s)	% Time in Water	Velocity ($m.s^{-1}$)	Δ Velocity ($m.s^{-1}$)
Men	375	109	90	0.47	70	4.44	0.46
Women	290	80	99	0.44	72	4.03	0.32

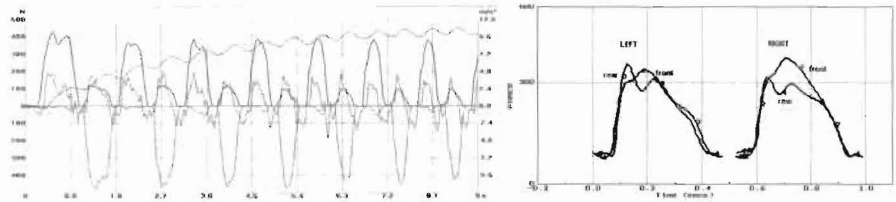

Figure 2. Force, velocity and acceleration curves from a K1 (left), and K2 force curves (right).

3: Kinematic Analysis: The third main area of canoeing performance related to biomechanics is the kinematics of the stroke. Effective application of kinematic analysis of the stroke requires knowledge and experience in stroke mechanics of canoeing. 2-D analysis particularly in the sagittal plan can provide useful kinematic information to the coach and is straightforward in its method. A camera positioned perpendicular to the boats line of travel with a field of view so as a full stroke (one side blade entry to opposite side blade entry) is needed. From this analysis important performance related information such as paddle entry and exit angles, stroke length, hand paths, and in-water times can be measured (figure 4). 3-D analysis of the stroke while providing more comprehensive information (Sanders & Kendal, 1992; Sanders & Baker, 1998; Baker et al., 1999) is very time consuming and has less application in the applied biomechanics environment.

Figure 3. 2-D Kinematics in Sprint Canoeing.

SPECIFIC FORCE AND POWER MEASUREMENTS IN RESISTANCE TRAINING FOR CANOEING: Biomechanics of canoeing first concentrated on measuring race performance and on-water parameters. It can be hypothesised that present resistance training is still not fully effective, but can be assisted by biomechanical measures. Resistance training for canoeing can be generally classified into three areas, high speed with small weights, muscular endurance using high repetitions, and maximum strength using heavy weights. However for canoeing this is not fully effective. In canoeing high forces must be applied at high stroke rates and as such power is a better indicator for resistance training. However for power training to be effective regular measurements must be available. Mounting a bench pull device on a force plate allows for such measurements. Figure 5 shows the comparison between bench pulling 35kg and 90kg. While the peak force was slightly lower with the 35kg (1219N) than the 90kg (1427N) the peak power was noticeably higher 1463W versus 837W. In addition the movement time of the 35kg pull was closer to that found in canoeing strokes.

CONCLUSION: The purpose of this paper was to provide insight to applied biomechanics servicing for canoeing from the experiences, knowledge, and testing from biomechanists who have worked extensively with the sport. It can be seen that biomechanics servicing and research has evolved dramatically since the days of the GDR. Technological developments have greatly enhanced what can be done particularly in the area of on-water testing. From once having to be tethered to a boat to collect data to now being able to transmit data from a small transducer on the paddle it is clear there have been significant advances.

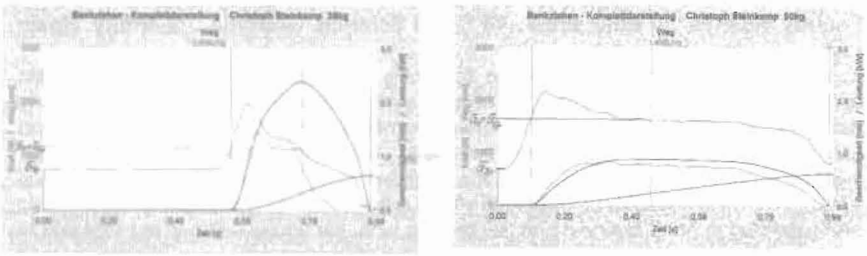

Figure 4. Bench Pull Power Measurements using 35kg & 90kg.

There is a logical link between race analysis, on-water testing, and then to resistance training measures. For testing to be effective and meaningful the sciences including biomechanics must have a sound systematic approach.

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