PERFORMANCE RELATED TECHNIQUE FACTORS IN OLYMPIC SPRINT KAYAKING

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A sprint kayaking specific deterministic model was used to identify key performance related technique factors using data from 12 international-level kayakers. There was large variability in the strength of the between-factor relationships across the group. The pull phase was split into 3 components with the 1st phase contributing the most to increases in boat velocity and the 3rd phase causing a decrease in velocity. The propulsive impulse had the largest influence on velocity, but the magnitude of the impact was moderated by blade slip. Large propulsive impulses in the 3rd phase of the pull were associated with larger decreases in velocity. The results show that the model can be used to identify key technique factors on an individual level, although the use of the model should be confirmed on additional kayakers before being used in an applied setting by practitioners.

KEYWORDS: Deterministic model, biomechanics, performance.

INTRODUCTION: There is little research on technique and style of Olympic sprint kayaking that identifies biomechanical factors that underpin performance. Previous research has described the kinematics of kayakers of different standard (e.g. Kendal & Sanders, 1992), or gender (Baker, Rath, Sanders, & Kelly, 1999), while some have started to explore the influence of equipment on performance (Jackson, 1995) and changes in kayaking proficiency (Pendergast et al., 2005). However, from a coaching and performance perspective, the underlying mechanical relationships between previously identified factors and the requirements of technique are unclear. Recently, an 8-level deterministic model was proposed that identified technique factors that determined performance in Olympic sprint kayaking (Wainwright, Cooke, & Low, 2014) (Figure 1). The purpose of this study was to populate the Wainwright et al. (2014) deterministic model with on-water performance data from a group of international-level kayakers to 1) establish whether the model could explain individual levels of performance, and 2) identify factors in the model that play a key role in determining performance.

METHODS: Data from 12 international-level kayakers completing 250m at race pace were used to create 24 individual deterministic models. Paddle forces and forwards kayak acceleration were measured using a kayaking specific measurement system (Sperlich & Sperlich, Germany) that recorded data at 100 Hz, and was calibrated prior to each trial and checked for drift post-trial. Kinematic variables were measured from video that was recorded from a moving vehicle (motor boat or car) keeping pace with the kayak using Dartfish software (Fribourg, Switzerland), with the length of the kayak (5.20 m) used as a moving calibration frame. The synchronised data were used to calculate a number of variables that were subsequently employed to calculate model factors. The pull phase was divided into three phases for more detailed analysis: Phase 1 – from paddle contact to paddle vertical; Phase 2 – from paddle vertical to maximum velocity; Phase 3 – from maximum velocity to paddle extraction (when the paddle starts to be removed from the water). The transition phase was from the position of paddle extraction to the paddle contact on the opposite side stroke. The model factors determined from the recorded data can be seen in Table 1. The values used in the deterministic models were generated from between 34 and 55 strokes (mean 42). Quadratic and linear regression models were used to establish relationships between factors on adjacent levels in the model to develop a greater understanding of how the factors in the model interact to create average stroke velocity. An important aspect of the methodology was to enable the observation of individual differences in the manipulation of

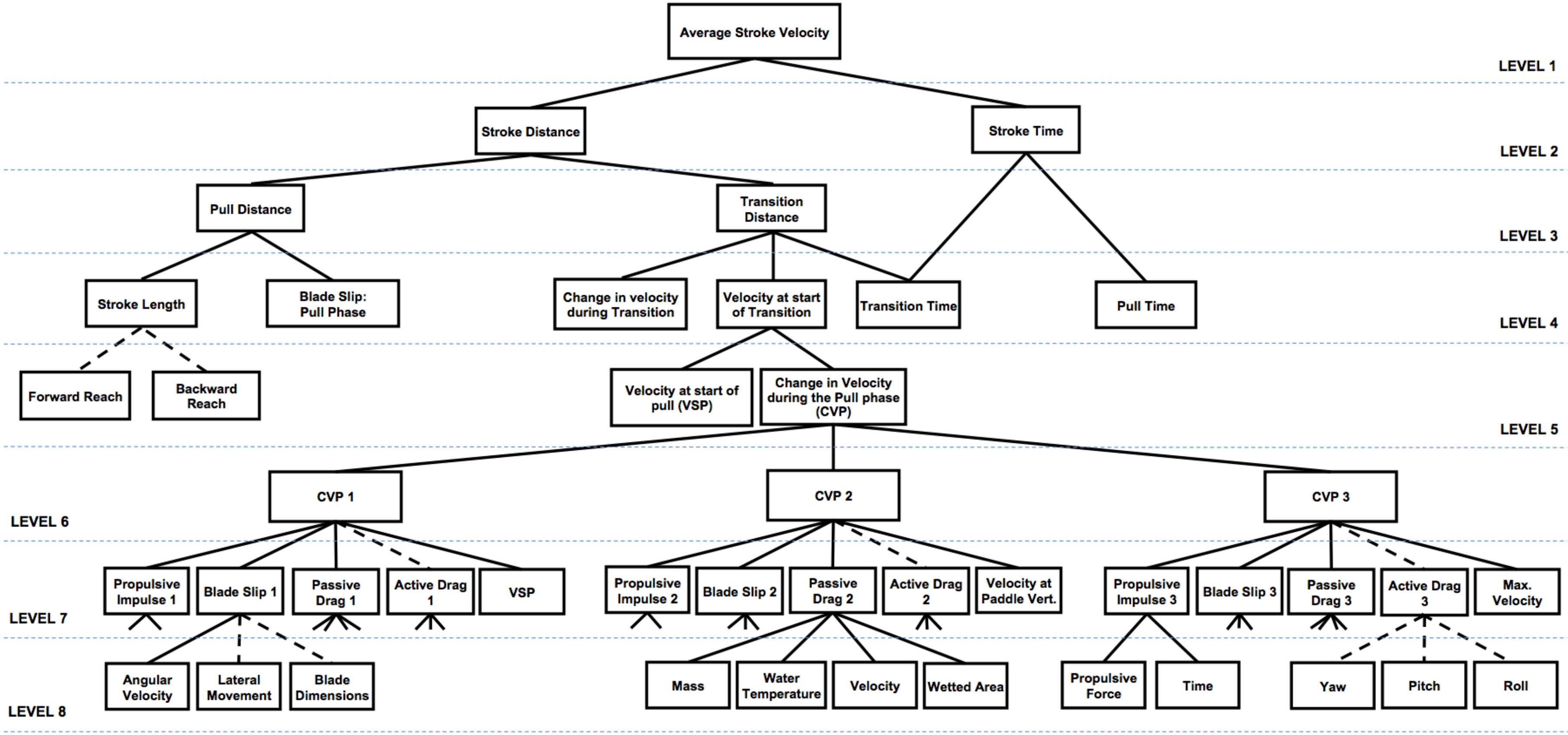

Figure 1. The Wainwright et al. (2014) sprint kayaking deterministic model.

the model factors that were used to achieve velocity. By observing differences between left and right strokes within an individual, and differences between individuals a greater understanding of the key factors that determine performance was developed.

RESULTS: The results of the regression equations between each of the model factors are shown in Table 1. Most kayakers exhibited asymmetry in their models for left and right sides, and therefore had differences in the magnitude and strength of relationships between the model factors that were used to create an average stroke velocity. When examining the change in velocity during the pull (CVP), phase 1 showed the largest change (mean increase 0.233, s = 0.077 m/s), with phase 2 increasing velocity to a smaller degree (mean increase 0.098, s = 0.063 m/s), and phase 3 experiencing a decrease in velocity (mean increase -0.138, s = 0.074 m/s). The sum of the CVP in phases 1, 2 and 3 was most strongly determined by changes in CVP 3, rather than CVP 1 or 2 as shown by the coefficients of determination. The propulsive impulse (PI) was the largest in phase 3 (average phase 1 = 17.6 n·s, phase 2 = 20.0 n·s, phase 3 = 21.3 n·s). On an individual basis increases in PI increased velocity in phases 1 and 2, but were associated with decreases in velocity in phase 3. Blade slip (BS) (average phase 1 = 0.03 m, phase 2 = -0.11 m, phase 3 = 0.10 m) was the second strongest determinant of CVP, where larger positive blade slip were associated with smaller increases in velocity. In general BS had its strongest influence on CVP in the second phase, where in 22 out of the 24 models blade sip was negative meaning that the blade had a net forwards movement, rather than in phases 1 and 3 where on average the blade moved backwards.

Table 1

The strength and range of the regressions between factors in the model. Only coefficients of determination of significant relationship ($p<0.05$) are included.

	Dependent Variable	Independent Variable	n	Av. r^2	Min. r^2	Max. r^2
Level 1	Average Stroke Velocity	Stroke Time	14	0.35	0.17	0.68
		Stroke Distance	18	0.47	0.20	0.85
Level 2	Stroke Distance	Transition Distance	23	0.54	0.17	0.85
		Pull Distance	20	0.42	0.12	0.86
	Stroke Time	Transition Time	23	0.55	0.17	0.85
		Pull Time	17	0.33	0.09	0.81
Level 3	Pull Distance	Stroke Length	23	0.37	0.07	0.80
		Blade Slip (whole pull)	13	0.39	0.12	0.75
	Transition Distance	Velocity at Start of Transition	17	0.31	0.13	0.61
		Change in Velocity during Transition	18	0.35	0.12	0.79
		Transition Time	24	0.95	0.82	0.99
Level 4	Velocity at Start of Glide	Velocity at Start of Pull	24	0.75	0.14	0.96
		Change in Velocity during Pull (whole pull)	9	0.22	0.10	0.33
Level 5	Change in Velocity during Pull (whole pull)	CVP 1	10	0.27	0.12	0.52
		CVP 2	20	0.38	0.11	0.76
		CVP 3	23	0.44	0.23	0.78
Level 6	CVP 1	Propulsive Impulse 1	20	0.49	0.17	0.89
		Blade Slip 1	9	0.24	0.13	0.36
		Passive Drag 1	3	0.21	0.33	0.09
		Velocity at Start of Pull	8	0.17	0.11	0.32
	CVP 2	Propulsive Impulse 2	23	0.57	0.26	0.80
		Blade Slip 2	18	0.28	0.10	0.61
		Passive Drag 2	6	0.24	0.12	0.38
		Velocity at Paddle Vertical	14	0.29	0.10	0.57
	CVP 3	Propulsive Impulse 3	16	0.30	0.09	0.66
		Blade Slip 3	8	0.21	0.15	0.36
		Passive Drag 3	8	0.18	0.08	0.27
		Maximum Velocity	6	0.20	0.14	0.27
Level 7	Blade Slip 1	Angular Velocity 1	14	0.34	0.11	0.72
	Blade Slip 2	Angular Velocity 2	6	0.28	0.10	0.64
	Blade Slip 3	Angular Velocity 3	6	0.17	0.08	0.25

DISCUSSION: Although many of the temporo-spatial factors are interesting and have been reported elsewhere (Baker, Rath, Sanders, & Kelly, 1999; Kendal & Sanders, 1992), the factors of most interest are those that directly influence distance the kayak moves during the stroke: the transition distance (TD) and CVP 1, 2 and 3. The most important factors that can be manipulated to maximise TD are the change in velocity during the transition (CVT), and the velocity at the start of the transition (VST). Although the strength of the relationships are variable, the regression models describe a scenario where the TD is determined by the magnitude of decrease in velocity during transition, presumably due to unwanted active drag (Pendergast et al., 2005), and by the VST that has been created during the pull phase. The CVP in each phase was most strongly determined by the magnitude of PI and BS, with the strength and nature of the relationships varying between phases. A strong relationship between the PI and CVP in each phase of the pull was expected, but it was unexpected that BS was found to play a key role in moderating the effect of the PI. While increases in CVP 1 and 2 were very important in increasing velocity during the pull, CVP 3 had the strongest influence upon the increase in velocity during the pull due to its' effect of decelerating the kayak. In general increases in PI lead to increases CVP in phases 1 and 2, but decreases in velocity in phase 3. The examination of the individual results applied to the deterministic model suggest that in general athletes should attempt to maximise the PI in phases 1 and 2, while aiming to minimise it in phase 3 once maximum velocity has been reached. The BS should be minimised where possible, and ideally be negative during phase 2. Athletes should also adopt strategies to minimise the decrease in velocity that occurs during the transition phase.

CONCLUSION: The findings demonstrate that the Wainwright, Cooke, and Low (2014) deterministic model can be used to explain individual levels of performance by examining and comparing both the relationships between factors and the magnitudes of the factors across the group. A number of novel factors have been identified that have a strong influence on other factors within the model, and determine kayak velocity. In particular was the changing role of PI in the pull phase that both increased and decreased velocity. Of additional significance was the variability and importance of BS in moderating the effectiveness of the PI on CVP. The between-athlete variation showed that each athlete used an individual style to create velocity, which suggests that standardised technique interventions used by coaches may not be equally effective in improving performance in different individuals. The approach and methods used in this study were based on a need to provide coaches and practitioners with an analysis process that would identify technique-related factors that presented opportunities to improve performance. Given the effectiveness of the model to do this, it would seem sensible to evaluate it on other high performance kayakers before recommending this approach as a valid tool for practitioners to adopt, but the findings of the present study are encouraging.

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