

INTRA- AND INTER-RATER RELIABILITY OF A VIDEO-BASED METHOD TO QUANTIFY STROKE SYNCHRONISATION IN CREW-BOAT SPRINT KAYAKING

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The purpose of this study was to assess the reliability of a method to quantify stroke synchronisation in crew-boat sprint kayaking from video analysis. One sub-elite K2 crew was recorded from a sagittal view at 120 Hz during a 200-m time trial. Video analysis identified the timing difference (termed "offset") between the front and back paddlers at four meaningful positions of the stroke (catch, immersion, extraction and release), with zero offset indicating perfect synchronisation. The analysis was performed twice by the same rater, as well as independently by two other raters. Results showed almost perfect intra-rater reliability, where intra-class correlation coefficients (ICC) ranged from .87 to 1.00, and standard error of measurement (SEM) from 0 to 5 milliseconds (ms). Inter-rater reliability was substantial to almost perfect (ICC .72 – .94, SEM 2 – 6 ms).

KEY WORDS: offset, paddling, kayak/canoe, reliability, team-boat.

INTRODUCTION: In the Olympic sport of sprint kayaking, the smallest unit of a crew-boat is the two-seater (K2) and the largest unit is the four-seater (K4). There are complexities associated with competitive crew-boat sprint kayaking that are not found in the single boat, such as a need for paddling stroke synchronisation due to the close seating proximity. Research on sprint kayaking has mostly focused on K1 performance (e.g. Michael, Smith & Rooney, 2009), while little has been documented about crew-boat racing. One study compared acceleration profiles and 500-m time trial performance of three different K4 crew combinations from five female sprint kayakers of the Canadian national team (Robinson, Holt, Pelham & Furneaux, 2011). Crew 3 was the best performer and described as more synchronised than Crews 1 and 2, but no further information on stroke synchronisation was provided. Another study examined the pacing characteristics of the different boat classes (K1, K2 and K4) at the 2004 to 2011 World Championships (Borges, Bullock & Coutts, 2009). Compared to the K1s, the crew-boats had more even 250-m split timings for the 500- and 1000-m events. The purpose of this study was to assess the reliability of a video-based method to quantify stroke synchronisation in crew-boat sprint kayaking. It was hypothesised that the proposed method would demonstrate sufficient intra-rater and inter-rater reliability.

METHODS: This study received ethical approval from the Nanyang Technological University Institutional Review Board, and written consent was obtained from all participants. Two male sub-elite sprint kayakers from the Singapore national team participated in this study (Participant A age 25.0 years old, height 1.68 m, mass 76.0 kg; Participant B 23 years old, height 1.71 m, mass 76.9 kg). The participants had 12 and 10 years of competitive paddling experience respectively.

Performance of the 200-m time trial from the right hand side sagittal view of each K2 crew was recorded at 120 Hz using a high-speed digital video camera (Casio EX-FH 100, Casio, Shibuya, Tokyo, Japan). The camera was operated by a researcher on a power boat accompanying alongside the K2 crew from about 9 m away. The capture space was about 8.5 m wide, and was fitted to encompass both the tip of the boat (bow) approaching the buoy markers, and the release position of the back paddler's blade. No calibration was necessary as the variables of interest were related to time and not spatial.

Video analyses of stroke synchronisation were performed in the open source freeware Kinovea (Version 0.8.15, Joan Charmant & contributors). Stroke synchronisation was identified from a four-position stroke model based on the contact area of the paddle blade relative to the water (McDonnell, Hume & Nolte, 2012). The four positions (catch, immersion, extraction and release) separate the phases of the stroke (entry, pull, exit and aerial), where

the entry, pull and exit are collectively the water phase duration (Figure 1). The catch was the first contact between the paddle blade and water, immersion occurred when the blade was maximally submerged, extraction was the last instance where the blade was maximally submerged, and release was the last contact between the blade and water. In sprint kayaking terminology, a complete stroke cycle beginning and ending on one side (e.g. from right catch to the next right catch) is commonly considered as two strokes (Szanto, 2010).

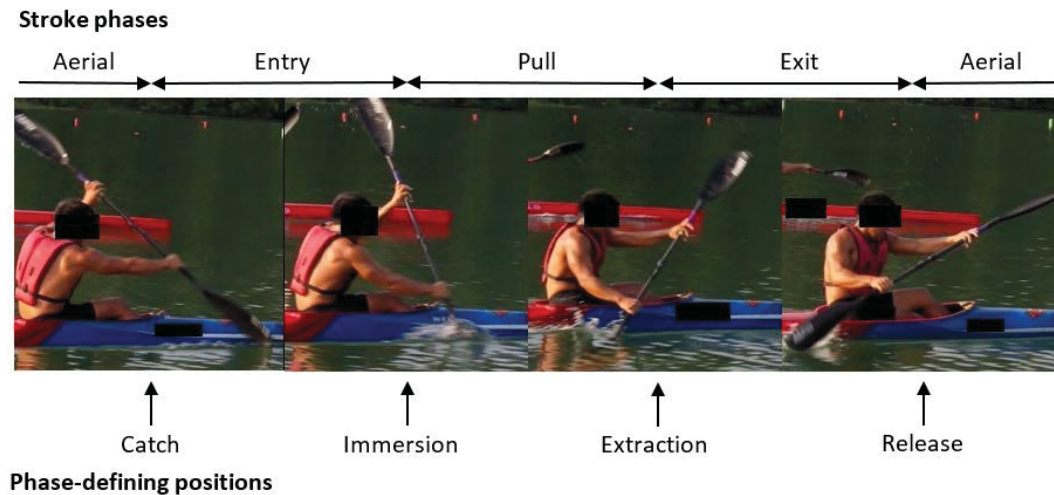


Figure 1: Phases of the kayaking stroke (entry, pull, exit and aerial) separated by phase-defining positions (catch, immersion, extraction and release) based on the contact area of the paddle blade relative to the water.

To quantify stroke synchronisation within a K2 crew, an offset variable was defined as the timing difference of the back paddler with reference to the front paddler. The offset was measured for each of the four phase-defining positions (catch, immersion, extraction and release) of every right stroke for both paddlers, beginning from the 4th right stroke. The first three strokes on the right were excluded as there were large differences in the water phase duration compared to the subsequent strokes. The offset of the back paddler could be negative, zero or positive (Figure 2).



Figure 2: Examples of offset types within a sprint kayak K2 crew at the catch position. The catch occurs when the paddle blade first contact the water. (a) A negative offset is where the back paddler's blade contacts the water before the front paddler's. (b) A positive offset, where the front paddler's blade contacts the water before the back paddler's. A zero offset (not shown) is when both paddle blades contact the water at the same time.

To assess the intra-rater reliability, a pilot 200-m trial comprising 40 strokes was analysed twice by the same rater (Rater 1) with an interval of 5 days apart. To compare between raters, this trial was also analysed independently by Raters 2 and 3. Raters 1 and 2 had ten years of experience in competitive sprint kayaking and were former national team paddlers, while Rater 3 had two years of experience. All three raters had previous undertaken basic training in biomechanical video analysis. Reliability statistics were performed using IBM SPSS Statistics for Windows Version 23.0 (Armonk, NY). Inter-rater and intra-rater reliability were evaluated using intra-class correlation coefficients (ICC) and standard errors of measurement (SEM). The ICCs were interpreted as slight ($< .20$), fair (.21-.40), moderate (.41-.60), substantial (.61-.80) and almost perfect ($> .80$) according to guidelines (Altman, 1991). After determining the intra- and inter- reliability of this method, Rater 1 then performed all analyses for the present study.

RESULTS: The performance time of the 200-m trial was 33.8 s. Table 1 summarises the stroke synchronisation offset of the crew, and the intra- and inter-rater reliability statistics. Intra-rater reliability of Rater 1 was almost perfect, where ICC ranged from .87 to 1.00, and SEM from 0 to 5 ms. Inter-rater reliability was substantial to almost perfect, where ICC ranged from .72 to .94, and SEM from 2 to 6 ms. When inter-rater reliability was substantial (i.e. ICC between .61-.80), further analysis revealed higher reliability between Raters 1 and 2 as compared to between Raters 1 and 3. At the immersion position, inter-rater reliability was higher for Raters 1 and 2 (ICC .89 [.80, .94]) than Raters 1 and 3 (ICC .73 [.55, .85]). At the extraction, inter-rater reliability was also higher for Raters 1 and 2 (ICC .87 [.78, .93]) than Raters 1 and 3 (ICC .72 [.53, .84]).

Table 1
Stroke Synchronisation Offset and Intra- and Inter-Rater Reliability

	Offset (ms)		Intra-rater		Inter-rater	
	Mean	SD	ICC (95% CI)	SEM (ms)	ICC (95% CI)	SEM (ms)
Catch	-25	16	.97 (.95, .99)	2	.85 (.77, .91)	5
Immersion	-31	13	.87 (.76, .93)	5	.74 (.61, .84)	6
Extraction	1	20	.93 (.85, .96)	3	.72 (.58, .83)	6
Release	0	14	1.00 (1.00, 1.00)	0	.94 (.90, .96)	2

Note. SD = standard deviation, ICC = intra-class correlation coefficient, CI = confidence interval (lower bound, upper bound), SEM = standard error of measurement.

DISCUSSION: This study utilised a video-based method to quantify the timing difference in stroke synchronisation of crew-boats. The analysis method was performed on a pilot K2 200-m trial, where the 200-m is the shortest distance for sprint kayaking, while the K2 is the most basic unit of a crew-boat. Stroke synchronisation was identified from a four-position stroke model (McDonnell, Hume & Nolte, 2012), which previously had only been used to identify technique parameters in individual (K1) paddling performance.

Results showed almost perfect intra-rater reliability and substantial to almost perfect inter-rater reliability (Table 1). Our findings also showed an increase in reliability with raters who have more years of competitive experience in sprint kayaking. Given that the proposed method did not require expensive equipment or complex procedures (e.g. no calibration required, free software), this is practical for coaches and sport scientists working with sub-elite sprint kayakers. One limitation of the study is that the reliability of this analysis method is not known for raters who do not have experience in sprint kayaking. Nonetheless, in a high performance setup working with sub-elite sprint kayakers, it should not be difficult to engage raters with the requisite experience. Thus, we recommended to engage raters with some years of competitive paddling experience.

CONCLUSION: This study presented on the reliability of a video-based method to quantify stroke synchronisation in crew-boat sprint kayaking. Intra-rater reliability was almost perfect

and inter-rater reliability was substantial to almost perfect. There was improved reliability for raters with more competitive experience in sprint kayaking. The proposed method is practical for coaches and sport scientists working with sub-elite sprint kayakers as no expensive equipment or complex procedures are required.

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