A CASE STUDY OF THE START IN FLAT WATER KAYAKING COMPETITIONS

Matilde Espinosa

Institute of Anthropological Research, National University of Mexico, Mexico City, Mexico

The aim of this study was to investigate the relationship between shoulder and elbow coordination at the start of a flat-water kayaking competition. A high performance male competitor is analyzed based on the four main corporal positions and phases that the body adopts during a paddling cycle. Photogrammetric procedures were used with data extracted from the movements registered by three video cameras. The amplitude of the 3D angular displacement at the shoulders and elbows was calculated. Non-parametric statistical tests were applied to analyze the angular displacement in the phases of the stroke cycle. Results showed that there are significant differences between angular displacements due to the first stroke kinematic characteristics, but left and right shoulder - elbow are highly correlated. The movements performed in the stroke cycle visually reflect bilateral asymmetries.

KEY WORDS: sprint kayaking, coordination, start paddling cycle.

INTRODUCTION: In performing movements, the different body segments are mechanically related to each other. In sports activities, body coordination is a fitness component which describes the movement patterns of sports tasks. The process of coordination and the timing of such actions are fundamental for effective movement (Laczko and Latash, 2016). The movement of paddling in flat water kayaking is a complex pattern of movements and coordination in which the trunk rotates from a seated base of support involving trunk rotation and stabilization (Mann, et al., 1980). The coordination of several segments (trunk, arms and forearms) allows athletes to control an implement (the paddle) and at the same time achieve high velocities. Then, the technique in kayaking is a determinant factor to obtain the maximum displacement velocity of the boat. The athlete’s efficiency of movements, through postural control, requires a combined relationship of posture and coordination (McKean, 2009). One characteristic of coordinated movement is that variability is structured, and it is possible to find systematic correlations between the actions of different effectors that work together to achieve a goal. (Davids, et al., 2006).

The paddling technique - the stroke cycle - consisting of the transfer of the paddle's blade in the water and in the air. There are four main corporal postures and blade positions in space on both sides of the boat, right and left: (1) Input: the blade of the paddle contacts water. (2) Vertical: the blade is in the water and the longitudinal axis of the paddle is vertical. (3) Output: the blade begins to leave the water. (4) Extension: the entire paddle is in the air. Among paddle positions, there are four motion sequences or phases: (1) Preparation: from the position 4 to the position 1, the paddler is prepared to achieve the greatest distance forward, rotating the trunk, shoulder forward and extending the elbow before contact with the blade in the water. (2) Pull: between the position 1 and the position 2, the blade enters the water and the paddler rotates the trunk and the shoulder back. (3) Power: from the position 2 to the position 3, the blade is in the water and the paddler extends this orientation of the blade to carry a more powerful stroke. At this moment, the propulsion forces applied by the paddler must be at their maximum. (4) Recovery: among the position 3 and the position 4, the paddler stops pulling the paddle with a quick off the water, recovers and carries the blade that side forward.

Even when the stroke cycle is repeated throughout the course, at the time of starting the competition, the first strokes are generally different in length, duration and strength.

The aim of this case study was to compare the angle displacements during the first stroke cycle performed at the start of a competition and get useful information to make a proposal for a coordinated movement pattern.

METHODS: Three camcorders (Panasonic AG-EZ30DV) fixed on tripods, recorded simultaneously at 60 Hz an elite male athlete (age = 24 years, height = 187 cm, mass = 83 kg) paddling in a single kayak from three different view points on the artifitial Olympic course in Mexico City. Three trials were recorded in video, for this study the first and the last were discarded. The data that were extracted from each video image represent the projected axes of rotation corresponding to the articular joints of the shoulders, elbows and wrists, and the line representing the trunk. No attached marks were used to identify anatomical landmarks. The movements were reconstructed to three-dimensional (3D) using the method of DLT (Abdel-Aziz and Karara, 1971; Woltring, 1980). The data were interpolated and smoothed using a Beta-cubic Splines method, and cleaned by a Low Pass Filter (Espinosa, 2011). The body postures that limit the four movement phases, right and left sides, in the stroke cycle were identified. The amplitude of the angle between arm and forearm (elbow), and the apparent angle between trunk and arm (shoulder) were calculated (θ). The angular velocity (ω) and angular acceleration (α) were also calculated. The beginning and ending of the cycle is when the left blade of the paddle contacts water. An angle–angle diagram (cyclogram method commonly used in the coordination study of lower limbs), was used to observe the movement cycle characteristics (Goswami, 1998). This cyclic loop graph is a visual representation for recognition of the technique shape. For the statistical analysis, nonparametric statistical tests were applied using the IBM SPSS Statistics 21, the significance level was set at $\alpha < 0.05$. The angular displacement of shoulders and elbows were tested to see their differences and to compare right and left movements symmetry.

RESULTS: The calculations indicate that the boat velocity at the end of the stroke of the first cycle at the start is 1.3 m/s, the time in which the athlete performed the stroke cycle is 1.54 s and the paddling frequency is 38.9 cycles/min. Figure 1 shows angular kinematics: angles (a), angular velocity (b) and angular acceleration (c).

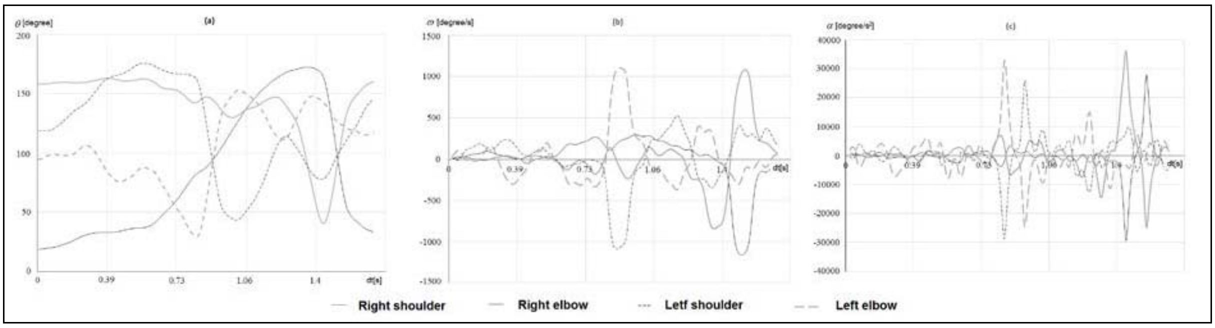

Figure 1. Start cycle angular kinematics. Each y-coordinate corresponds to (a) angle displacement θ [degrees], (b) angular velocities ω [degree/s], (c) angular accelerations α [degree/s^2]. The x-coordinate corresponds to time dt [s].

Descriptive statistics of the angular characteristics in stroke cycle [degree], timing (dt [s]), dt percentages (%), mean values and standard deviations for the right and left side cycle phases are shown in Table 1. The angle-angle diagram in Figure 2 show the shape and bilateral degree of symmetry deviations of both sides at the start.

The variables are not normally distributed, so to measure the strength of association of the variables the Spearman Rank Correlations (ρ) have been calculated. Results show there are strong negative associations: between right shoulder and right elbow $\rho = -0.677$, left shoulder and left elbow $\rho = -0.838$, right shoulder and left shoulder $\rho = -0.7$, and right elbow and left elbow $\rho = -0.536$. The Kruskal-Wallis One-Way test has been applied to determine if there are statistically significant differences between the four angle amplitude displacements of the stroke cycle. It was found high significant differences (p = 0.001*), this is there are differences between at least two of the medians.

Table 1. Characteristics of the stroke cycle phases at the start. Phases time (dt), time porcentage (%), mean and standard deviation of the angle amplitude (θ) of shoulders and elbows.

Phases	dt [s]	cycle dt %	θ [degree], mean±SD right shoulder	right elbow	left shoulder	left elbow
Left pull	0.193	13.13	22.2±2.7	158.8±0.6	125.0±6.5	98.0±1.6
Left power	0.2	13.58	32.3±1.5	161.0±1.3	154.0±9.8	93.2±11.4
Left recovery	0.213	14.48	38.8±4.0	160.0±2.3	172.1±2.9	81.5±4.9
Right preparation	0.167	11.31	67.0±11.0	148.7±4.7	165.8±2.6	46.5±13.1
Right pull	0.167	11.31	100.4±11.7	139.2±6.7	82.4±37.3	104.6±39.7
Right power	0.213	14.48	146.6±12.5	139.8±5.3	68.8±21.2	138.0±13.6
Right recovery	0.147	9.96	169.7±2.3	123.1±19.4	104.0±9.3	126.8±13.0
Left preparation	0.173	11.77	132.7±40.0	71.2±27.7	88.4±10.7	136.3±9.6
		MAX	172.32	162.62	175.64	153.25
		MIN	19.15	40.37	43.10	29.4
		RANGE	153.17	122.25	132.54	123.85
		MEAN	85.57	139.32	121.03	103.03
		STD DEV	55.20	29.95	41.67	32.81

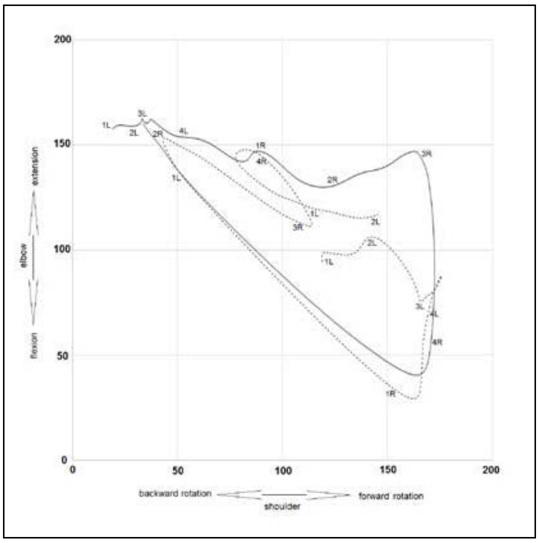

Figure 2. Start cycle Angle - angle diagram. The y-coordinate corresponds to the elbow angle and x-coordinate to shoulder angle [degree]. The solid line represents right side movements and the dotted line represents left side movements (1,2,3,4: blade positions, L: left, R: right).

DISCUSSION: The apparent angle between trunk and arm includes the activation in different articulations at shoulder area that cause different movements (flexion-extension, abduction-adduction, internal and external rotation, etc.), which have been simplified with a single data. Then, the sum of the variation of these movements is shown in Figures and Table 1.

The results (dt, dt %, θ) of this analysis show some lateral asymmetries this is, that movements performed by this athlete at the left side are not the same as right movements. It could be a logical situation since the boat is static at the beginning of the first (left side) stroke and there is already a boat displacement at the right stroke. Angular velocities and accelerations, however, reflect symmetry. The range of motion is higher in shoulder angles.

The greatest amplitude is in shoulder at both recovery phases, when the arms are raising. There is great variability in the angles, mainly in the right pull and the left preparation. The smallest amplitude exists in the pull and power of the left side, which is when the cycle starts. Angle-angle diagrams show shape asymmetries, mainly at forward shoulder rotation left elbow is not as extended as right elbow. The cycle on the left side does not begin and end with the same width of angles as on the right side, this can also be logical. The statistical analysis results show that even when there is a strong inverse correlation between shoulder and elbow right and left angle displacement, there are significant differences between the angular displacements.
The information of the angular displacements is not enough to describe the rotation of the trunk. It would necessary to consider the spatial displacements of the points which represent the shoulders. To get enough information to suggest a movement pattern it would be necessary to analyse two or three trials for each participant and to study the second and the third subsequent cycles to prove effectiveness: the boat velocity.

CONCLUSION: The analysis results of the start stroke cycle performed by the studied athlete indicate some of the angular kinematic of his technique and movement coordination. They also show the differences between the first and the second strokes of the first cycle. These results are important because they show the feasibility of carrying out a similar study in a group of athletes, with the appropriate adjustments. Further research could focus on finding a movement pattern, analysing lateral symmetries deviations based in effectiveness, to compare intra- and inter-subject variations which could lead to a proposal of an observation and training guide aimed at young athletes.

REFERENCES:

Abdel-Aziz Y.I. and Karara H.M. (1971). Direct linear transformation from comparator coordinates into object space coordinates in close range photogrammetry. *Proceedings of the ASP/UI Symposium on Close-Range Photogrammetry*. Urbana. Illinois. pp. 1-18.

Davids, K., Bennett, S. and Newell, K. (2006). *Movement System Variability*. Human Kinetics
Espinosa. M. (2011). Validación metodológica del análisis cinemático 3D del ciclo de palada en el piragüismo de velocidad. Un estudio piloto. *Motricidad European Journal of Human Movement*. Vol.26. 39-54.

Groswami, A. (1998). A new gait parameterization technique by means of cyclogram moments: Application to human slope walking*. Gait and Posture* 8, 15-36, Elsevier Inc.

Laczko. J. and Latash. M.L. (2016). *Progress in Motor Control.* Theories and Translations Series: Advances in Experimental Medicine and Biology. Vol. 957. Springer.

Mann. R. V. and Kearney. J.T. (1980). A biomechanical analysis of the Olympic stile flatwaterkayak Strokes. *Medicine and Science in Sport and Exercise*. Vol.12. No.3. pp.183-188.

McKean. M. (2009). *Postural Movement – Quantifying Timing of Joint and Segment Coordination. Structural Muscle Balance. and Joint Range of Motion.* PhD Thesis. University of Sunshine Coast. Queensland. Australia.

Woltring. H.J. (1980). Planar control in multi-camera calibration for 3-D gait studies. *Journal of Biomechanics.Vol. 13. pp. 39-48.*

Acknowledgement

The author wishes to thank Luis Ramirez and Veronica Garcia for their help in recording. Bernardo Escalona by the LPF program and particularly to Branislav Jrámek, the Czech paddler who once trained in Mexico City.