200 METRE AND 1000 METRE SPRINT KAYAKING BIOMECHANICAL ANALYSIS COMPARISON USING FIXED AND SWIVEL SEAT: A PILOT STUDY

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The purpose of the present study was to investigate the effects of using the standard fixed and swivel seat on the selected kinematic and kinetic parameters. It is conducted on a simulated 200 m and 1000 m race in the laboratory setting. One elite sprint kayaker participated in this study, performing both events and seat conditions on separate days. Paired sample t-tests and Pearson product-moment correlations were performed to compare seat conditions and relations between the parameters. High correlations were observed in paddle force with foot force, paddle power and paddle velocity. Significantly increased results were found in paddle force, paddle power and stroke rate using the swivel seat especially in the 1000 m test. Further research with more subjects is required for comparison to obtain important information of an efficient paddling execution.

KEYWORDS: flatwater kayak, performance, simulator, forces, stroke

INTRODUCTION: Sprint kayaking is a very competitive racing discipline in canoeing, especially at the World Championships and Olympic Games. The competition has become more exciting and tense with the introduction of 200-metre event in the women's category and replacing the 500-metre event in the men's category during the 2012 Summer Olympic Games in London. The kayakers are facing a more challenging competition, as they need to apply a blend of optimal biomechanical and physiological efficiency apart from the best strategy and technique of paddling to finish the race in the shortest time possible. On the other hand, development and improvement of equipment also aides in enhancing the performance, with the most recent use of swivel seat in 2005 . To the best of our knowledge, there were only three previous studies that have conducted performance comparison based on the physiological and biomechanical parameters using the fixed and swivel seat in a laboratory setting and none comparing 200 m with 1000 m.

first published the study of using fixed and swivel seat focusing on symmetry analysis of kinematic and kinetic data. They measured the foot forces using their own developed dynamometric footpad that yielded a result of increased footpad forces and knee range of motion on the swivel seat. Then, a physiological comparison study between fixed and swivel seat usage was conducted by in a 2-minute maximal ergometer testing. They reported a significantly greater mean power output produced with no increase in metabolic cost using the swivel seat, especially in the final 20 seconds of the simulation test. Lastly in 2011, a study was performed using the two types of seats where an increase of pelvis and thorax rotation were observed which, in turn, also produced a higher blade tip's mediolateral displacements and velocities for an enhanced performance using the swivel seat .

The present study aimed to investigate the biomechanical effects on the kinematic and kinetic variables that are related to the paddle force production in the 200 m and 1000 m simulated race and which parameters show significant difference on the swivel seat usage.

METHODS: The kayak simulator system was set up in the laboratory and performed using an air-braked rowing ergometer (Concept II; Morrisville, VT, USA) with modified seat and footrest platform connected with a kayak paddling adaptor to simulate kayak paddling . The seat and footrest platform were attached onto the Kistler force platforms (type 9281A, Kistler Instruments AG, Winterhur, Switzerland) that measured ground reaction forces. Each end of the paddle rope connection to the ergometer was connected with strain gauge load cells. The kinematic data was collected using a 14-camera motion capture system (Eagle, Motion

Analysis Corporation, Santa Rosa, CA, USA) at a frame rate of 100 Hz. Seven reflective markers were placed on the paddle and ergometer rope system to collect the three-dimensional coordinates of the motion.

The subject was an elite flatwater sprint kayaker, required to perform at a maximal effort without changing the normal paddling technique. After a warm up session, the subject rested for 15 minutes before performing the simulated on-water race (i.e. 40 seconds for 200 m event and 3 minutes 30 seconds for 1000 m event). The subject was required to perform the 200 m simulation race first, with a one-hour rest period thereafter, and followed by the 1000 m simulation race to avoid fatigue. This same subject repeated the same test protocol using different seat type on two separate testing days with at least twenty four hours apart. Type of seat was randomly assigned (i.e. only fixed or swivel seat on each testing day).

The data obtained was analysed using technical computing software (MatLab 7, Mathworks, USA) for stroke detection in determining the stroke time, stroke length, stroke rate, paddle velocity, paddle power, paddle force, and foot force. The variables were also time normalised to 100% of the pull phase. Ten left and right strokes with the highest paddle force value, during the first 20 seconds, in both seat conditions of the simulation test were selected for analysis. Statistical analyses for each variable were performed (SPSS version 20, SPSS Inc., Chicago, USA), all set at the alpha level of 0.05 for analysis. Paired sample t-tests were used to test for differences on the kinematic and kinetic variables between the fixed and swivel seat condition in 200 m and 1000 m simulated race. Pearson product-moment correlation coefficients were determined between all the variables in the left and right strokes for each simulated race distance and seat condition.

RESULTS: The values of mean left and right peak paddle force, peak foot force, peak paddle power, peak paddle velocity, stroke time, stroke length, and stroke rate for both 200 m and 1000 m race simulation using both seat conditions are presented in Table 1 and Table 2. Only the paddle force, foot force, and stroke length showed significant difference ($p<0.01$) during the 200 m test using the swivel seat (Table 1). All the variables in 1000 m were statistically different ($p<0.05$) across seat conditions except for stroke length (Table 2).

Table 1
Kinematic and kinetic variables in 200 m race simulation for fixed and swivel seat (mean ± standard deviation)

Event	200 m	
Seat type	Fixed	Swivel
Left		
Paddle force (N)	449.04 ± 13.58	429.63 ± 13.12**
Foot force (N)	444.85 ± 29.19	565.15 ± 24.82**
Paddle power (W)	1549.53 ± 213.65	1499.48 ± 89.67
Paddle velocity (m/s)	3.83 ± 0.44	3.89 ± 0.37
Stroke time (s)	0.82 ± 0.02	0.83 ± 0.03
Stroke length (m)	1.16 ± 0.04	1.22 ± 0.02**
Stroke rate (spm)	73.22 ± 1.98	72.11 ± 2.58
Right		
Paddle force (N)	278.17 ± 6.94	280.90 ± 6.01**
Foot force (N)	629.83 ± 27.98	546.95 ± 42.37**
Paddle power (W)	945.71 ± 59.80	938.91 ± 73.04
Paddle velocity (m/s)	3.63 ± 0.15	3.68 ± 0.46
Stroke time (s)	0.83 ± 0.01	0.83 ± 0.03
Stroke length (m)	1.28 ± 0.03	1.23 ± 0.04**
Stroke rate (spm)	72.65 ± 1.11	72.72 ± 2.45

Asterisk (**) denotes significant difference between fixed and swivel seat ($p<0.01$)

Table 2

Kinematic and kinetic variables in 1000 m race simulation for fixed and swivel seat (mean ± standard deviation)

Event	1000 m	
Seat type	Fixed	Swivel
Left		
Paddle force (N)	355.68 ± 4.60	422.52 ± 4.87**
Foot force (N)	591.27 ± 12.75	548.31 ± 21.40**
Paddle power (W)	1304.10 ± 77.86	1453.38 ± 128.93**
Paddle velocity (m/s)	3.92 ± 0.18	3.70 ± 0.27**
Stroke time (s)	1.34 ± 0.05	1.09 ± 0.04**
Stroke length (m)	1.26 ± 0.04	1.21 ± 0.05
Stroke rate (spm)	44.93 ± 1.57	55.37 ± 2.12**
Right		
Paddle force (N)	242.57 ± 7.45	273.74 ± 5.86**
Foot force (N)	652.50 ± 21.29	685.66 ± 17.28**
Paddle power (W)	979.39 ± 83.88	1076.45 ± 37.09**
Paddle velocity (m/s)	4.27 ± 0.29	4.09 ± 0.11*
Stroke time (s)	1.36 ± 0.07	1.11 ± 0.02**
Stroke length (m)	1.35 ± 0.02	1.34 ± 0.01
Stroke rate (spm)	44.11 ± 2.13	54.22 ± 1.17**

Asterisk (*) denotes significant difference between fixed and swivel seat (p<0.05)
Asterisks (**) denote significant difference between fixed and swivel seat (p<0.01)

High correlations were found on some of the variables across the 200 m and 1000 m events in both seat conditions. We focused on variables that were highly correlated with paddle force and those with significant difference between the fixed and swivel seat for further discussion. The mean peak paddle force in 200 m had higher correlation on the right side with peak foot force for both fixed (r=0.99; p<0.01) and swivel seat (r=0.94; p<0.01). In the 1000 m test on the fixed seat, peak paddle force was highly correlated with peak foot force on the right side (r=0.95; p<0.01) and on the left side with peak paddle power (r=0.98; p<0.01) and peak paddle velocity (r=0.98; p<0.01). Higher correlations of the peak paddle force with peak foot force (r=0.97; p<0.01), peak paddle power (r=0.96; p<0.01) and peak paddle velocity (r=0.88; p<0.05) were all found on the right side for swivel seat in 1000 m.

DISCUSSION: This study presents a comparison of biomechanical analysis of kayak paddling between using the standard fixed and swivel seat in 200 m and 1000 m event based on the selected strokes. The results of the performance determinants between 200 m and 1000 m race simulation for both seat conditions showed quite a different outcome (see Table 1 and 2). Our results showed that paddle force increased significantly using the swivel seat for both distances with the exception of left strokes in 200 m. In relation to paddle force and the significant correlation found with paddle power and paddle velocity is expected due to the kinetic relationship between the variables. Hence, this showed the significant increase of paddle force in the 1000 m was in relation to the decreased paddle velocity and an increased paddle power. Such finding is in accordance with the greater power output achieved when using the swivel seat in the study of . We only found a greater paddle velocity on the swivel seat in the 200 m test in our study which is not statistically significant as compared to the results of blade tip’s velocity obtained by .
Foot force data, on the other hand, provided a varied outcome between both seat conditions and across the simulation test of 200 m and 1000 m. During the usage of swivel seat, the foot force increased either only on the left or right side regardless of the race distance. This result supported the outcomes in the study done by . They concluded that there is a significant performance and efficiency achieved with a 6% increment despite the asymmetrical lower limbs pedalling motion. The leg pedalling motion or “leg drive” plays an important role to produce an efficient powerful dynamic paddling through the co-ordination

with upper body as a whole. Use of the swivel seat may help to enhance the degree of rotation on the trunk and pelvis as reported by . As such, more power can be transferred from the larger muscle groups and not only relying fully on the arm strength alone especially for longer distance race.

Other observations found on the present study were the decrease of stroke time and increased stroke rate using the swivel seat in the 1000 m test. These findings are in line with the recommendation of where they suggested for an emphasis on decreasing the stroke time in order to increase the stroke rate that had a high relation with kayak velocity. Statistical difference was found in the stroke length for the 200 m test only in this study. The length increased for the left side while decreasing for the right side using the swivel seat. This will require further investigation to address the concern raised by some of the researches previously. commented that precaution should be taken not to execute too long a stroke with a lack of energy transfer as it will slows down the kayak movement. There is still a lack of research and data availability in relation of stroke length and average kayak velocity .

The variable outcome across 200 m and 1000 m test on this single subject pilot study might be due to the individuality of this subject, the fact that only ten strokes were analysed but also may reflect important differences in the performance requirements of the two distances. Data collection from more subjects will be required for the future larger study for a better data analysis and inclusion of trunk and hip rotation data will be more meaningful. An inclusion of data analysis of all the strokes throughout the test will provide a better overview from the beginning to the end for a better understanding on the connection of the whole process for an efficient kayak paddling and into the implementation of coach education tool.

CONCLUSION: The results of the present study showed that there were some effects which might improve the kayak paddling execution with the usage of swivel seat but is only limited to this single subject study. There were increases of stroke force, stroke power and stroke rate which contributed towards a more dynamic and efficient paddling with a proper coupling action of foot force exertion. There were also important differences between the 200 m and 1000 m trials for this subject. A further thorough and complete research with bigger pool of participants is required to ascertain the finding of this initial study to also facilitate coach feedback and kayak performance with useful information.

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