A THREE-DIMENSIONAL ANALYSIS OF MALE AND FEMALE ELITE SPRINT KAYAK PADDLERS

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The purpose of this study was to investigate whether there were technique differences between national level male (n=6) and female sprint kayak paddlers (n=4) to indicate whether the same coaching strategies could be used for men and women. It was found that, despite different boat velocities, male and female paddlers were not very different in some important technique variables. It was concluded that, until distinct differences are found in technique between men and women, these groups could be coached the same way.

KEY WORDS: 3D kinematics, sprint kayaking

INTRODUCTION: The issue of whether male and female kayak paddlers use the same technique is an important one for coaches. If males and females do use the same technique the same coaching strategies can be employed. However, if males and females use different techniques, it is important to identify the differences so the respective sexes can be coached in the correct manner.

One of the major problems in attempting to answer the question from existing literature is the paucity of published studies examining the biomechanics of modem paddling technique.

Since the introduction of the wing paddle in the mid-1980s sprint kayaking has undergone an evolution in technique. Prior to this time paddlers used a flat blade. As with any evolutionary process technique continues to be modified with the on-going design alterations to the kayak blade. Whereas the original wing blade was a typical airfoil in appearance the blades currently used by international competitors are more like a propeller in shape. That is the blade shape is a wing with a twist down the longitudinal axis of the blade.

While a number of studies have examined paddling technique using the flat blade (Mann, Kearney, & Kauffman, 1978; Plagenhoef, 1978; Kearney, Klein, & Mann, 1979; Mann & Kearney, 1980) there has been little research conducted into the technique of using the wing blades. Sanders and Kendal (1992a), Sanders and Kendal (1992b), and Kendal and Sanders (1992) investigated the technique of New Zealand paddlers using the wing blade. Jackson (1995) mathematically modelled the wing blade to discover that the wing blade had a 15% higher efficiency than the conventional flat blade (wing blade 89%; flat blade 74%). In addition Sanders and Baker (1998) provided a theoretical perspective on why the wing blade is superior to the flat blade.

Furthermore, there is very limited recent research on technique with the propeller blade. This is partly due to the difficulty of measuring the motion of the blade when it is underwater. Hay and Yanai (1995) investigated the ability to predict under-water motion of a blade fmm above water movement of the shaft. Gilhome and Danaher (1996) investigated the hydrodynamic characteristics of the propeller blade using a flow tank. Due to the limited amount of published research using the current blade shape the present study will provide a valuable pool of data for future comparison.

The purpose of this study was to compare body, paddle and boat 3D kinematics of male and female sprint kayak paddlers to determine where differences may lie. This comparison was undertaken to indicate whether male and female paddlers can be coached in the same manner. Due to the size of the subject pool the study was designed as a preliminary investigation.

METHODS: Six male and four female sprint kayak paddlers aged between 18 and 25 years were subjects for the study. All paddlers had competed at the previous Australian National

Sprint Kayak Championships and three of the paddlers had been in the previous Australian Sprint Kayak team that had competed at the World Sprint Canoe Championships.

All subjects performed three trials to ensure that two full stroke cycles (paddle entry to same side paddle entry) were achieved in the calibrated area. Subjects were requested to paddle at race pace of the winner of the K1 1000m for men and K1 500m for women from the previous Australian National Championships. Having competed in the Championships subjects had a good feel for reproducing that speed over the test distance. However it eventuated that the males paddled on average faster than the required speed (4.98 $m.s^{-1}$) and the women marginally slower (4.50 $m.s^{-1}$).

Subjects were permitted a length of 200m to paddle up to the required speed before reaching the calibrated space. The calibrated space was an area of dimensions 6m X 2m X 2m with the 6m length being in the direction of travel. Two buoys were secured equivalent to the middle of both ends of the calibrated space i.e. parallel to the direction of travel, as a line of reference for the paddlers.

Two stationary gen-locked S-VHS video cameras were used to video each trial at a rate of 50 Hz. Each camera was electronically shuttered for an effective exposure time of 1.1000^{-1} s. One camera was set at 40° to the left of the line of travel and the other camera was 15° to the right of the line of travel.

Eight body parts were digitised using the APAS digitising system. The body parts digitised were the middle knuckle of the left and right hands, the left and right wrists, left and right elbows, and the left and right shoulders. Two points on the paddle shaft were also digitised. A marked point on the shaft between the hand and the neck of the blade were digitised at both ends of the paddle shaft. In addition two points on the kayak were digitised with one being a bow marker and the other a stem marker. The calculated midpoint of these two markers was used to represent kayak movement. Paddle tip data were obtained by using a 3D extrapolation of the shaft markers to the paddle tip.

The DLT method was used to convert the digitised points to real 3D coordinates. A quintic spline (Wood and Jennings, 1979) was used to smooth the data. Ten frames before first blade entry to ten frames after the next same side blade entry were digitised to ensure no end effects.

A number of key kinematic variables were chosen for analysis based upon the opinion of two elite coaches and the findings from previous literature (Sanders and Kendal, 1992a; Hay and Yanai, 1996) of what parameters would best represent the stroke.

Total stroke and intra-stroke boat velocity measures were chosen for analysis as previous work by Hay and Yanai (1996) and Sanders and Kendal (1992a) showed that the various components of these measures are indicative of high level performers. Intricately tied in with the various velocity measures are the timing and displacement measures. Entry and exit 2D and 3D shaft angles were chosen for analysis as paddle orientation during the stroke has been suggested as a characteristic of highly skilled kayakers (Sanders and Baker, 1998). Shephard (1987) identified the value that trunk rotation played in the kayak stroke which for this study was chosen to be represented by shoulder rotation.

The left and right sides were chosen for separate analysis rather than being combined because it was felt that there could be side effects between the males and females. All paddlers in the study were right side dominant.

RESULTS AND DISCUSSION: Table 1 shows the variables that had significant differences between male and female groups. The variables where there were no significant differences are presented in Table 2.

As was expected there was a significant difference ($p<0.01$) in boat speed (Table 1) between the males (4.98 $m.s^{-1}$) and females (4.50 $m.s^{-1}$). This is a logical finding and doesn't impinge on the aim of the study. In addition there were significant differences in the intra-stroke velocity results between males and females. That is during both the left and right pull phases i.e. when the blade was in the water, the average boat speed was significantly higher for the men when compared to the women. Similarly for the run phase, which is defined as when both blades are out of the water, the average boat speed was significantly higher for the men than the women. Further to this there were significant differences in the distance the boat travelled during the recovery phases for both the left (men = **1.02** m, women = **0.90** m; $p<0.05$) and right sides (men = 1.05 m, women = 0.95m; $p<0.02$)

There were no significant differences between men and women in the total stroke length or the distance covered in the pull phase. However, it should be noted that total stroke length did approach significance on both sides (right - men = **2.66** m, women = **2.48** m; $p=0.08$: left - men = **2.65** m, women = **2.46** m; $p=0.06$). The sample size may have influenced the results for stroke length and it wouldn't be unreasonable to conclude that there was a difference in the total stroke lengths between males and females. In fact if the left/right data is pooled for the one sex then a significant difference is evident in the total stroke length and the tun phase length, but still not the pull length (Table **1).**

Table 1 Key Kinematic Variables with Significant Differences

	MALES		FEMALES		P
	Mean	Std Dev	Mean	Std Dev	
Velocity ($m.s^{-1}$)	**4.94**	**0.17**	**4.50**	**0.33**	0.01
Right Pull Velocity ($m.s^{-1}$)	**5.05**	**0.15**	**4.58**	**0.32**	0.004
Right Run Velocity ($m.s^{-1}$)	**4.88**	**0.21**	**4.43**	**0.31**	0.01
Right Stroke Velocity ($m.s^{-1}$)	**4.98**	**0.17**	**4.52**	**0.32**	0.01
Left Pull Velocity ($m.s^{-1}$)	**4.99**	**0.18**	**4.59**	**0.36**	0.02
Left Run Velocity ($m.s^{-1}$)	**4.84**	**0.16**	**4.42**	**0.32**	0.01
Left Stroke Velocity ($m.s^{-1}$)	**4.93**	**0.17**	**4.52**	**0.34**	0.01
Right Run Length (m)	**1.08**	**0.07**	**0.95**	**0.10**	0.02
Left Run Length (m)	**1.06**	**0.11**	**0.90**	**0.10**	0.03
Pooled Stroke Length (m)	**2.66**	**0.19**	**2.47**	**0.16**	**0.03**
Pooled Run Length (m)	1.04	0.06	0.93	0.09	0.01

Given the significant difference in tun length it would appear that the distance in the total stroke lengths between males and females is mainly attributable to the run phase as there were no differences in the pull phase lengths. This view would link in with the finding that the pull phase times were slightly lower for men (see Table 2), but the run phase times were the same. As the men had a higher velocity during the run phase for left and right strokes and the run times were the same then a significantly greater distance covered in the tun phase is not unexpected. Despite the higher boat velocity of men during the pull phase due to their slightly lower pull phase time the distance covered during this phase did not display a significant difference.

Table 2 Key Kinematic Variables with No Significant Difference

	MALES		FEMALES		P
	Mean	Std Dev	Mean	Std Dev	
Stroke Rate (Strokes.s^{-1})	**113.2**	**9.73**	**110.2**	**9.00**	**0.52**
2D Shaft Angle Entry (Sagittal plane) (°)	**132.5**	**7.49**	**135.1**	**5.30**	**0.41**
2D Shaft Angle Exit (Sagittal plane) (°)	**25.7**	**3.33**	**26.7**	**1.92**	**0.45**
3D Shaft Angle Entry (0)	**38.2**	**4.32**	**37.3**	**4.83**	**0.67**
3D Shaft Angle Exit (0)	**23.4**	**2.78**	**23.8**	**1.21**	**0.68**
Shoulder ROM (Vertical axis) (°)	**65.3**	**5.99**	**68.7**	**5.70**	**0.19**
Elbow Angle Entry (°)	**148.4**	**9.72**	**144.0**	**10.64**	**0.33**
Elbow Angle Exit (°)	**120.4**	**12.60**	**108.0**	**10.28**	**0.18**
Pooled Pull Length (m)	**1.62**	**0.16**	**1.54**	**0.08**	**0.23**
Pull Time (s)	**0.32**	**0.03**	**0.34**	**0.02**	**0.15**
Run Time (s)	**0.21**	**0.01**	**0.21**	**0.03**	**0.86**
Stroke Time (s)	**0.53**	**0.03**	**0.55**	**0.05**	**0.35**

NB. For ease of reading the left and right data for this table have been combined

Apart from the boat velocity, run length, and pooled stroke length differences, there were no other differences evident between the male and female paddlers for the selected biomechanical variables. Table 2 shows a summary of the selected kinematic variables where no significant differences existed. The paddle entry and exit angles were similar, elbow angles were similar, shoulder ranges of movement were similar, and stroke rates were similar. From the findings of this preliminary study it can be concluded that the men and women paddlers who participated in this study showed some technique similarities.

CONCLUSION: The aim of this preliminary study was to investigate whether men and women elite sprint kayak paddlers used similar techniques. It must be kept in mind that this was a preliminary investigation and as such the small sample size would have influenced the power of the statistical findings.

Differences between males and females were evident in boat velocity parameters and run lengths as well as pooled data for total stroke length. The difference in the total stroke length can be accounted for primarily by the run length differences.

On the basis of the findings it would be reasonable to conclude that there were some technique similarities between male and female sprint kayakers. Therefore coaches should not adopt different coaching strategies at this time until further studies show that there are differences that warrant a change in particular coaching strategies. Further investigation is warranted with a larger group of elite sprint kayak paddlers.

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