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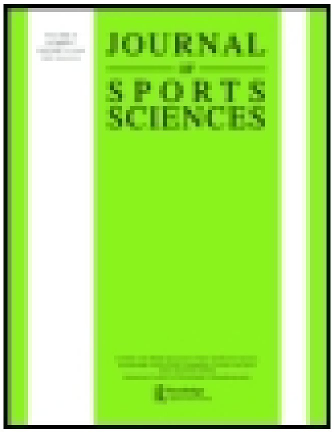

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Improving paddling efficiency through raising sitting height in female white water kayakers

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Abstract

The study compared female white water paddlers over two conditions: with seat raise and with no seat raise. The aim was to determine whether raising the sitting height would improve paddling efficiency. Sitting height of each participant was recorded in order to calculate the seat raise height required and three-dimensional kinematic data was collected for six participants over both conditions. Twelve measures of efficiency were utilised. The efficiency of all participants improved on the seat condition for ≥4 of the measures, with three participants showing improvement for ≥6 of the measures. The stern snaking measure had the highest value of significance ($P = 0.1455$) and showed an average of 11.98% reduction in movement between no seat and seat conditions. The results indicate that improvements were seen although these were individualistic. Therefore it can be concluded that it is worth experimenting with a seat raise for a female kayaker who is lacking efficiency, noting, however, that improvements might depend on anthropometrics and the seat height selected, and therefore could elicit differing results.

Keywords: *biomechanics, technology, sport, ergonomics*

Introduction

Kayaking originated from the indigenous Inuit tribe. The male members of the tribe utilised the skills of kayaking for hunting on rough seas (Heath & Arima, 2004; Mattos, 2009; Petersen, 1985; Winning, 2002). In Britain, John MacGregor, also known as Rob Roy, was the man who can be credited for making the sport more popular, writing a bestselling book about his first voyage (Winning, 2002). This initiation of kayaking has resulted in males dominating the sport throughout its history (Winning, 2002).

In a kayak, the participant is in a seated position with their legs inside the cockpit and extended in an anterior position (Michael, Smith, & Rooney, 2009). White water kayaking is one of the many kayaking disciplines. It is recreational rather than a performance paddlesport under the guidance of the British Canoe Union (BCU) definitions (Taylor, 2009). The aim of white water kayaking is to navigate a river whilst descending rapids (BCU, 2012), with the forward stroke being the primary stroke used (Wassinger et al., 2011).

The Active People Survey indicates that the participation in kayaking remains overwhelmingly towards the male demographic, with 35,400 males participating at least once per week in the sport over the October 2012 to October 2013 period, compared to 7600 females (Sport England, 2013). Participation in canoeing and kayaking has risen in both the male and female demographics over the past two years, however female participation has risen significantly and more so than males (Sport England, 2013). This largely male dominated history of the sport has resulted in kayaks being designed around the male specification (Levesque, 2008a, 2008b; Manchester, 2008). Therefore females have struggled to find suitably fitting boats (Levesque, 2008a); white water boats tend to be too big to be comfortable for women and smaller people (Manchester, 2008).

Although females have utilised the equipment available to them, it is clear from previous research that there is a large difference between male and female anthropometry in kayaking. Ridge, Broad, Kerr, and Ackland (2007) investigated the anthropometry of male and female slalom paddlers. Slalom paddling is similar in its aims to white water kayaking but with a

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competitive element, thus allowing a clear comparison. Ridge et al. (2007) discovered that for all but the skinfold tests and thigh girth measurement, males recorded larger measurements than their female colleagues across all anthropometric tests carried out. It was also identified that although females tend to have a longer trunk than their male counterparts when comparing their sitting height to their stature (53.5% to 52.4% respectively), the average sitting height for females remains shorter than their male colleagues (89.7 to 92.5 cm respectively). Ridge et al. (2007) identified, within the paper, that the anthropometrics measured for the elite slalom paddlers did not differ largely from a non-athlete reference population. This contradicts the findings of Ackland, Ong, Kerr and Ridge's (2003) investigation into Olympic sprint canoe and kayak paddlers in which it was identified that this group of kayakers displayed characteristics not often observed in the general population. This finding suggests that larger sample sizes (Ridge et al., 2007) or other kayaking populations might also display measurements further from the non-athlete reference population. This is important to appreciate when discussing white water kayakers because there is no data available on the anthropometrics of the population in this recreational sport. Therefore, it is unclear from where the measurements utilised to design kayaks were obtained and how these relate to the population as a whole, particularly how the male measurements relate to their female counterparts. This lack of knowledge has increased importance when it comes to utilising male anthropometrics to design kayaks that females must use (Levesque, 2008b). Despite this lack of information on what measurements are used by the manufacturers of kayaks, the findings of Ridge et al. (2007) suggest that, if general population anthropometrics are used, there is still a large difference between male and female sitting height, as seen in the results of their slalom paddlers who did not differ from a general population reference sample. Although the manufacturers of kayaks will not provide their sources of measurements due to rival companies potentially utilising their data, it is evident from a number of sources that boats are designed around the male specification (Levesque, 2008a, 2008b; Manchester, 2008).

The measurements the kayak design is based upon and how this relates to the paddlers themselves is important because the internal structure of the kayak must fit the paddler's body dimensions (Ong et al., 2005). It is identified in other sports that equipment setup is imperative for both comfort and efficient performance (Burke & Pruitt, 2003) and also that due to anatomical differences seen between males and females, that equipment is becoming more comfortable with more specific function (Jinhua & Yun, 2006). This separation of male and female equipment is becoming more common place in sports (Swedan, 2001), but has not yet reached the white water kayaking domain.

For a kayaker to fit their boat effectively a number of contact points within the boat are necessary in order to aid control. These are the lumbar back, gluteal region, hips, thighs, knees, and toes (Whiting & Varette, 2004). The design of the boat with respect to the paddler will affect these contact points and therefore the ability to apply a propulsive force to the boat (Ong et al., 2005). Ong et al. (2005) also noted that many slalom paddlers set their boats up based on comfort rather than the mechanical advantage that the boat setup may afford them. With this in mind, boat manufacturers must make their boats as mechanically efficient as possible allowing paddlers to focus on comfort. Paddler efficiency can be identified through consistent boat velocity (Michael et al., 2009) and four key boat movements:

- Boat-centre bouncing – centre of the boat moving up and down (Kemecsey & Lauder, 1998).
- Boat-end bouncing – either end of the boat moving up and down (Kemecsey & Lauder, 1998).
- Boat rocking – simultaneous submerging and rising of the boat sides about a longitudinal axis (Lauder & Kemecsey, 1999; Loschner, Smith, & Galloway, 2000).
- Boat snaking – sideways boat movement about a vertical axis through the centre of the boat (Lauder & Kemecsey, 1999).

Reduction of these movements would indicate an improvement in efficiency (Kemecsey & Lauder, 1998) due to the work done increasing in relation to the energy cost (Stainsby, Gladden, Barclay, & Wilson, 1980; Whipp & Wasserman, 1969) as a result of the decrease in drag forces.

In order to improve efficiency, the paddler requires boat control via the contact points previously mentioned (Whiting & Varette, 2004). Within boats that are too big for females (Manchester, 2008), it can be hypothesised that by raising the sitting height to better reflect male measurements (Ridge et al., 2007) and consequently altering the subsequent contact points, the paddler contact with the boat and thus the paddler's boat control should be improved. This in turn should improve the mechanical efficiency of the paddler. However, centre of gravity must be considered when raising the sitting height. If a seat height increase is too much, then the paddler's centre of gravity will be too high, putting the paddler off balance and therefore they will have less control over the boat (Levesque, 2008b) and therefore, the efficiency measures previously stated will be impacted, thus if the seat raise is not an appropriate height for the individual, either not enough or too much then the paddler will be measured as being inefficient.

Therefore the aims of this study were to identify the sitting height of the female white water paddlers and to use three-dimensional kinematics and performance measures to identify differences in paddle stroke efficiency when the seat was raised for female white water paddlers. It was hypothesised that the seat raise would result in a more efficient forward paddle stroke.

Methods

Participants

With institutional ethical approval, six female white water kayakers from a UK, south coast kayak club consented to participate in the investigation. The participants were required to have at least two years paddling experience on a variety of rivers and to be over 18 years of age (35.6 ± 9.7 years).

Data collection

The data capture space was calibrated prior to data collection using a 31 point floating calibration frame. The calibration frame was 5 m by 1.8 m by 2.5 m giving a capture space of 22.5 m^2. Direct linear transform reconstruction of the calibration frame showed less than 1% error of the calibrated volume for all of the resultant errors (Brown, 2009). Two Peak high speed cameras (Peak Performance technologies Inc., Colorado, USA) were placed 14.5 m apart filming at an angle greater than 100° to each other and recording at 200 Hz. After capturing the calibration frame, the area was marked with buoys and the frame removed.

On arrival, the participant's anthropometric measures were taken (Table I) and specifically sitting height was measured to enable their seat raise to be made out of high density foam, and designed to fit the participant's own boat. The seat raise height was 3.5% of the participant's sitting height to the nearest 0.5 cm. The required seat raise height was determined using a combination of research and empirical evidence. Research identified that the average sitting height of female slalom kayakers was 89.7 cm (Ridge et al., 2007), and the empirical evidence from the Canadian Freestyle Champion suggests that females should raise their seat height by "one to one and a half inches" (Manchester, 2008). Therefore 3.5% of 89.7 cm is 3.14 cm which equates to 1.24 inches, a value within Manchester's (2008) recommendations. The participants were randomly assigned to start with one of the two conditions; either with seat or no seat, and then prepared for analysis.

Participant's major visible joints, left and right trunk, head and hands were marked using black fabric markers with a white centre circle. The boats were marked on the bow, stern, and behind the cockpit on the left and right side using black markers with yellow tips. The paddle was marked at the point of shaft meeting blade with contrasting coloured tape. These comprised a 17 point system for digitisation. After warming up, the participants paddled at a comfortable pace over 50 m through the data capture area, the capture area was between 35 and 40 m of the 50 m paddle stretch. Each participant carried out five trials under each of the two conditions.

Data analysis

The kinematic data was analysed at 100 Hz using Vicon Motus Video v9.2. A Butterworth filter with a cut-off of 6 Hz was applied to the data. One full stroke cycle (left paddle entry to left paddle entry) was analysed for each participant under each condition. The reach was measured by taking the paddle at its furthest point forward and measured to the marker on the trunk on the same side of the body. There were two left reach measures ("L Reach" and "L Reach 2") and one right reach measure due to the nature of the stroke cycle analysed. Stroke length of the participants was measured from paddle entering the water to paddle exit from the water. Consistency of boat velocity (Michael et al., 2009) was measured from the marker on the bow of the boat. The four boat movements were analysed using the following methods:

- Centre bouncing: For each time point, the vertical movement at the stern was added to the vertical movement at the bow and a scatter graph was plotted. Maximum deviation from regression line was calculated.
- End bouncing: Scatter graph for bow movement in the vertical plane against time was translated onto the graph for vertical movement of the stern. Maximum difference between bow and stern was recorded.
- Rocking: The vertical movements of the left and right cockpit markers against time were plotted on a scatter graph, and the maximum difference between the two markers was calculated.
- Snaking: Lateral movement of the bow and stern were plotted on a scatter graph against time. Maximum deviation from the regression line for each marker was calculated.

The measures of efficiency: four boat movements, reach, stroke length, average velocity, and velocity standard deviation, were statistically analysed utilising Statistics Package for the Social Sciences (v18.0). A paired samples *t*-test was carried out for each measure of efficiency, comparing the mean of the seat condition to the mean of the no seat condition.

Results

The results from the sitting height of the female white water paddlers (Table I) show that on average they sit at 84.1 cm, shorter than the female slalom paddlers (89.7 cm) measured by Ridge et al. (2007).

A positive change due to introduction of seat raise was observed for all participants in at least four of the 12 efficiency measures (Table II), for three participants there was an improvement for ≥6 of the measures. The seat raise also displayed an improvement

Table I. Anthropometric data for participants and a comparison to slalom paddlers.

	Participant						Female white water kayakers (*n* = 6)			Female slalom kayakers (*n* = 12)⋆		
	1	2	3	4	5	6	Mean	*s*	Range	Mean	*s*	Range
Age	54	23	37	34	37	28	35.5	10.6	23.0–54.0	26.3	4.8	20.0–35.0
Weight (kg)	60	63.5	65.4	63.5	54	63	61.6	4.1	54.0–65.4	59.0	4.5	53.3–68.6
Height (cm)	166.1	162.2	164.9	165.4	152.6	154.6	161.0	5.9	152.6–166.1	168.0	0.05	158.0–176.0
Sitting height (cm)	85	87.7	84.9	85.2	79.8	82	84.1	2.8	79.8–87.7	89.7	3.3	84.7–95.1
Arm span (cm)	177	163.5	168.3	165	161	157	165.3	6.9	157.0–177.0	167.6	4.8	161.6–177.1
Upper arm length (cm)	34.5	30	31.5	29.2	27.4	31	30.6	2.4	27.4–34.5	31.5	1.0	30.3–33.6
Forearm length (cm)	27.3	23.3	24.2	22.3	24.1	22.5	24.0	1.8	22.3–27.3	24.0	0.7	22.6–24.6
Thigh length (cm)	44	38.5	43.5	35.4	37.6	36	39.2	3.7	35.4–44.0	44.1	2.4	40.3–48.5
Lower leg length (cm)	43.7	36.6	37.4	37.9	36.8	36.6	38.2	2.8	36.6–43.7	43.8	1.3	42.1–46.1
Shoulder breadth (cm)	43.1	45.3	45.3	39.1	37	45.8	42.6	3.7	37.0–45.8	37.4	1.2	35.9–39.4
Flexed upper arm girth (cm)	30.6	29.6	30.6	29	28	29	29.5	1.0	28.0–30.6	30.1	1.0	28.1–31.9
Chest girth (cm)	94.8	83.9	89.1	93.6	90.6	89	90.2	3.9	83.9–94.8	91.0	3.6	84.1–96.1
Waist girth (cm)	71.8	72.2	74.1	77.3	69	73.6	73.0	2.8	69.0–77.3	69.9	2.6	65.8–73.4
Hip girth (cm)	95.9	94.1	94.7	93.8	80	92	91.8	5.9	80.0–95.9	89.7	2.7	85.3–93.5
Thigh girth (cm)	48.5	51.3	52.5	50.8	43.5	51	49.6	3.3	43.5–52.5	52.9	2.1	49.9–56.6
Calf girth (cm)	36.6	37.6	36.6	36.7	31.9	35.5	35.8	2.0	31.9–37.6	34.1	1.2	32.3–36.4

Note: ⋆Data taken from adapted table in Ridge et al. (2007, p. 110).

Table II. Efficiency data for each participant.

Participant	1	2	3	4	5	6	Mean	*P*-value (effect size)	Confidence intervals (lower/upper)
NS centre bounce (m)	0.019	**0.018**	**0.021**	**0.024**	0.023	0.019	**0.021**	0.347	−0.003
S centre bounce (m)	**0.025**	0.014	⋆0.017	⋆0.022	**0.023**	**0.020**	⋆0.020	(0.18)	0.005
NS end bounce (m)	0.028	**0.020**	**0.065**	**0.027**	0.017	0.026	**0.030**	0.274	−0.008
S end bounce (m)	**0.036**	⋆0.015	⋆0.045	⋆0.024	**0.020**	**0.027**	⋆0.028	(0.28)	0.013
NS rock (m)	0.017	xxx	xxx	0.058	**0.030**	**0.036**	0.035	0.335	−0.023
S rock (m)	**0.023**	xxx	xxx	**0.077**	⋆0.028	⋆0.025	**0.038**	(0.21)	0.017
NS snake stern (m)	0.164	**0.171**	**0.214**	**0.263**	0.107	**0.154**	**0.179**	0.146	−0.025
S snake stern (m)	**0.220**	⋆0.135	⋆0.165	⋆0.196	**0.110**	⋆0.118	⋆0.157	(0.47)	0.068
NS snake bow (m)	0.090	**0.127**	**0.113**	0.160	0.053	**0.120**	0.111	0.475	−0.031
S snake bow (m)	**0.111**	⋆0.081	⋆0.104	**0.175**	**0.089**	⋆0.109	0.111	(0.03)	0.030
NS L stroke length (m)	0.720	0.792	0.654	**1.026**	**0.782**	**0.713**	**0.781**	0.479	−0.074
S L stroke length (m)	**⋆0.781**	**⋆0.872**	**⋆0.693**	0.925	0.726	0.680	0.780	(0.25)	0.077
NS R stroke length (m)	**0.722**	0.672	**0.883**	**0.962**	0.693	0.727	**0.777**	0.395	−0.052
S R stroke length (m)	0.716	**⋆0.708**	0.771	0.927	**⋆0.745**	**⋆0.733**	0.767	(0.18)	0.072
NS mean velocity ($m \cdot s^{-1}$)	1.310	1.360	**1.550**	1.640	1.360	**1.400**	**1.437**	0.483	−0.341
S mean velocity ($m \cdot s^{-1}$)	1.310	**⋆1.404**	1.510	**⋆1.680**	**⋆1.400**	1.310	1.436	(0.42)	0.804
NS SD velocity ($m \cdot s^{-1}$)	0.060	**0.070**	**0.160**	**0.120**	0.060	0.070	**0.090**	0.283	−0.267
S SD velocity ($m \cdot s^{-1}$)	**0.080**	⋆0.069	⋆0.11	⋆0.09	**0.070**	**0.080**	⋆0.083	(0.37)	0.130
NS L reach (m)	1.487	1.712	**1.682**	1.602	**1.682**	**1.666**	**1.639**	0.369	−0.061
S L reach (m)	**⋆1.506**	**⋆1.732**	1.606	**⋆1.682**	1.681	1.566	1.629	(0.16)	0.080
NS R reach (m)	1.533	**1.780**	**1.785**	**1.728**	1.714	**1.669**	1.702	0.382	−0.047
S R reach (m)	**⋆1.577**	1.770	1.739	1.724	**⋆1.775**	1.655	**⋆1.707**	(0.14)	0.037
NS L reach 2 (m)	1.428	1.663	**1.602**	**1.587**	1.572	**1.596**	**1.575**	0.322	−0.053
S L reach 2 (m)	**⋆1.465**	**⋆1.694**	1.578	1.572	**⋆1.597**	1.467	1.562	(0.21)	0.078

Notes: **Bold text** indicates larger number for each participant in each measure comparing no seat (NS) and seat (S) conditions. Left (L) right (R). ⋆denotes a positive result for the seat condition. xxx indicates no available measure for this participant in this condition.

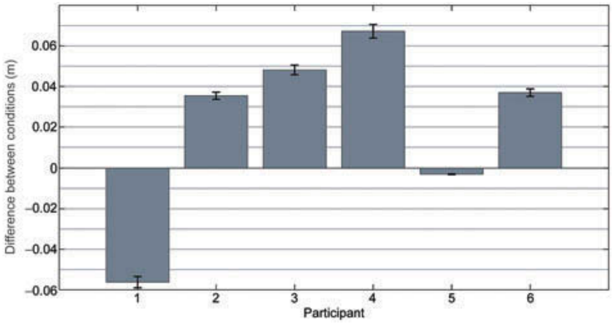

Figure 1. Difference between no seat and seat conditions for stern snaking for each participant. A positive result denotes a decrease in stern snaking with the raised seat condition. A negative result denotes a decrease in stern snaking for the no seat condition.

for each efficiency measure for at least two participants. However, there was limited consistent improvement for either the individual participants or for each measure, with some individuals showing a decrease in efficiency with the seat raise.

There was no statistically significant ($P < .05$) difference between the conditions for any of the measures (Table II). However, the result with the highest value of significance ($P = 0.146$ one-tailed) was for the snaking stern pair where there was a decrease in stern snaking from the no seat condition (M = 0.1788, $s = 0.053$) to the seat condition (M = 0.1574, $s = 0.044$). The means for each of the no seat and seat conditions (0.1788 and 0.1574, respectively) can be used to calculate an average of 11.98% reduction in movement at the stern for the seat condition. The largest difference between the two conditions was seen in participant 4 with a positive result (Figure 1). These results indicate that the seat raise reduced the amount of snaking at the stern on average for the participants. However, two participants (participants 1 and 5) showed a negative result, which explained the lack of a significant result in this measure. These two participants (1 and 5) that showed a decrease in efficiency in the seat raise condition were also the lightest paddlers in the sample (Table I).

Discussion

When looking at the impact of the seat raise on paddling efficiency, it is clear there have been improvements although these are not consistent across the measures or the participants. However for the stern snaking efficiency measure, the paired *t*-test returned a result with the highest value of significance ($P = 0.1455$) for the difference between the two conditions. To offer an improvement in efficiency, the forward propulsion of the kayak and paddler must increase in relation to the energy cost (Stainsby et al., 1980; Whipp & Wasserman, 1969) this can be achieved partly through a reduction in drag. The results show that stern snaking values were higher than the bow snaking values, for all participants, across both conditions. However, with the seat raised, there was an average of 11.98% reduction in the stern movement for all participants. This reduction in stern movement should lead to a reduction in drag at the stern, therefore improving efficiency (Lauder & Kemecsey, 1999).

This result for the stern snaking suggests a positive result for introducing the seat raise, however the subsequent findings have proven to be more individualistic. There are several possible reasons these results have been obtained. The first reason centres on the height of the seat raise. The height of each participant's seat raise was based on experiential evidence, recommending that females should raise their seat height by "one to one and a half inches" (Manchester, 2008). This was further supported by the average sitting height data gathered for slalom paddlers (Ridge et al., 2007). Having since determined the average sitting height of the white water paddlers as shorter than that of the female slalom paddlers, it may be that the seat raise was not sufficiently high to display the changes expected for some participants or to affect the measures used. Further to this, the female slalom paddlers (89.7 cm sitting height) are still shorter than their male slalom colleagues at 92.8 cm sitting height (Ridge et al., 2007) and also the male general population (91.5 cm sitting height) (Pheasant, 1996). Although the data used to design current white water kayaks was unavailable due to being proprietary information, it can be assumed that this would closer reflect either the male general population or the male slalom population rather than either the female slalom paddlers or female white water kayakers (Levesque, 2008a, 2008b; Manchester, 2008). If this was the case then it can be suggested that the seat raise should have been increased further, whilst not sacrificing balance (Burkett, 2010) due to a raised centre of gravity, to be more representative of the male sitting height.

It is also the case that the empirical evidence provided by Manchester (2008) could be incorrect as no scientific research has been carried out in this area. Despite the possibility that the seat raise height was insufficient, three of the participants in the study did show improvements for ≥6 of the 12 efficiency measures when paddling with the seat raise, showing that this seat raise height was more effective for some participants than others. This is key when looking at some of the boat movements; it is clear that for some participants there was an efficiency reduction with the introduction of a seat raise, whereas for others there is an efficiency improvement. This could be, as discussed above, due to an insufficient seat raise, or alternatively it could be due to the seat raise being too high. This would cause the centre of gravity to be too high and then the paddler would become off balance (Burkett, 2010) this lack of balance and control of the boat (Whiting & Varette, 2004) would result in a lower measure of efficiency from the boat movements. It is also important to note that Ridge et al. (2007) also identified that female slalom paddlers had shorter upper limb lengths than their male counterparts, therefore in order to interact with water they would have to lean towards the stroke side causing a moment around the longitudinal axis of the boat if the seat raise was too high, therefore reducing the efficiency measures seen in the boat movements.

If the boat movements alone are examined (Table II) then it can be seen that for participant 1 (the tallest participant) there is no improvement in efficiency seen for any of the boat movements. It can also be seen that for participant 5 (the shortest participant) there is only one improvement in efficiency for boat movements. This would suggest that participant 1 was possibly sitting too high, impacting the centre of gravity and therefore balance (Burkett, 2010), whereas participant 5 was sitting too low, suggesting that the seat raise was not enough to elicit an improvement in the efficiency and control over the boat movements (Whiting & Varette, 2004). This leads to the question as to which of the anthropometric measures would determine the correct sitting height for each individual. The current methodology used a percentage of sitting height, but it is possible that other elements such as upper limb length may be a contributing factor and therefore this would warrant further investigation.

A second reason for the result inconsistencies across both efficiency measures and participants could be due to comfort. Ong et al. (2005) suggested that many paddlers arrange their boat cockpit more for comfort than the mechanical advantage it might confer. The introduction of the seat raise was designed to afford the participants in this study with a mechanical improvement. However, this might have been at the cost of comfort as the participants did not rearrange their cockpits between the conditions. This would have had an impact on subsequent contact points in the kinetic chain because an altered gluteal region position would have altered the position of the hips, thighs, knees, and toes (Whiting & Varette, 2004). Without adjusting the boat setup for these contact points, adding the seat raise could have resulted in full contact not being made at each contact point. This would impact the mechanical improvement provided by the seat raise and affect the ability of the participants to apply propulsive forces to the boat (Ong et al., 2005).

The final reason for these potential inconsistencies could be due to the familiarisation with the seat. It has been found that technique can adapt due to the task constraints placed upon it, such as a change in equipment (Haywood & Getchell, 2009). However, due to the belief that it takes 10,000 h of practice to become an expert at a skill (Baker & Cobley, 2008), it can be assumed that technique adaptations will not fully occur in one session and therefore with a longer familiarisation period the results may have shown further differences between the two conditions, due to technique having adapted to the new task constraints.

It is important to note that despite a lack of consistency amongst the results, patterns were beginning to emerge within this sample of six participants. These patterns can be seen in the fact that all participants improved on at least one third of all of the efficiency measures and each measure showed an improvement for at least two participants. This suggests that although the effects may be individualistic, if a female paddler has had a plateau in performance or is not progressing as quickly as their peers, it is worth introducing a seat raise and using the trial and error method suggested by Ong et al. (2005) to determine whether efficiency can be improved. The improvements seen may only be small in terms of the numbers calculated in this study, but when focusing on the most used stroke in white water kayaking (Wassinger et al., 2011), and when rapids can be potentially fatal (Berry, 2002) those small improvements could be the difference between life and death.

In conclusion, the introduction of seat raise did return some positive results for each of the participants although these were not consistent. This suggests that a seat raise could have a potential positive impact on efficiency if utilised for female kayakers, however the question of how big the seat raise should be remains. For taller participants, having too big a seat raise may unbalance them due to the centre of gravity being too high and for smaller paddlers, the seat raise may need to be larger in order to elicit better control over the boat. Therefore the results seen through using a seat raise will potentially be different for all individuals, dependent on their anthropometric make up and the height of the seat raise selected, and to differing degrees of effectiveness.

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