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Selecting Kayak and Canoe Paddlers based on Morphology and Boat Set-up

Pemilihan Atlet Kayak dan Kanu Berdasarkan Morfologi dan Persiapan Peralatan Bot

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Abstract

Athletes and coaches in the sport of sprint kayaking and canoeing face contradicting philosophies about the optimum physical structure of the paddler and equipment set-up characteristics. There exists however, little normative data in the scientific literature for the current physical size and proportionality characteristics as well as equipment set-up of World-class or Asian sprint paddlers. These data and basic understanding of paddlers' morphology and boat set-up would be useful for Malaysian coaches when initially selecting talented individuals for development programs as well as in determining their specialist events. Ackland et al. (2003) found that participants in Olympic sprint paddling events considered to be homogeneous in shape and physical size, male and female paddlers have SAMs of 1.1 and 1.0 respectively. Compared to other athlete groups the variance in stature and body mass of paddlers is generally low. Whilst sprint paddlers are not athletes with extreme proportionality profiles, they do possess unique characteristics not commonly observed in the general population. Whereas in equipment set-up, Ong et al. (2005) found that there are consistent differences for both male and female athletes among sprint and slalom kayak paddlers who competed at the 2000 Olympic Games in Sydney. The sprint paddlers seated higher and using longer paddles with longer, though narrower blades ($p>0.0001$). But, among male sprint paddlers, only minor differences in equipment set-up were found between competitors ranked in the top 10 places to the rest of the field. Significant ($p<0.0001$) regression equations were developed for the prediction of foot bar distance ($r^2=.482$) and hand grip distance ($r^3=.400$). The morphology of elite paddlers appears to have altered during the past 25 years toward a more compact and robust physique. This trend is especially noticeable for the female competitors.

Keywords morphology, sprint paddlers, boat set-up

Abstrak

Atlet dan jurulatih dalam sukan kayak pecut dan kanu menghadapi percanggahan falsafah tentang struktur fizikal yang optimum pendayung dan ciri-ciri persiapan peralatan bot. Walau bagaimanpun, hanya segelintir data normatif wujud dalam literatur saintifik tentang ciri-ciri saiz fizikal dan persiapan peralatan dalam kalangan atlet kayak di dunia atau di Asia. Data dan pemahaman asas morfologi dan persiapan peralatan bot akan berguna kepada jurulatih Malaysia untuk memilih individu berbakat bagi program pembangunan, atau ketika menentukan acara khusus atlet mereka. Ackland et al. (2003) mendapati bahawa peserta dalam acara berkayuh pecut Olimpik dianggap bersifat seragam dalam bentuk dan saiz fizikal, pendayung lelaki dan wanita masing-masing mempunyai SAM sebanyak 1.1 dan 1.0. Berbanding dengan kumpulan atlet lain, varians ketinggian dan jisim badan pendayung pecut amnya adalah rendah. Manakala pendayung pecut bukan merupakan atlet berprofil berkadaran melampau, mereka hanya memiliki ciri-ciri unik yang tidak biasa terdapat dalam populasi umum. Dalam persiapan peralatan bot pula, Ong et al. (2005) mendapati bahawa terdapat perbezaan yang konsisten untuk kedua-dua atlet lelaki dan wanita dalam kalangan pecut dan pendayung Slalom yang bertanding pada Sukan Olimpik 2000 di Sydney. Pendayung pecut duduk lebih tinggi dan menggunakan pendayung lebih panjang, meskipun tirus mata dayungnya ($p > 0.0001$). Tetapi, dalam kalangan pendayung pecut lelaki, hanya terdapat sedikit perbezaan dalam persiapan peralatan bot dalam kalangan pesaing yang disenaraikan 10 teratas. Persamaan regresi yang signifikan ($p < 0.0001$) telah dibangunkan untuk meramalkan jarak bar kaki ($r2 = 0,482$) dan jarak genggaman tangan ($r3 = 0,400$). Morfologi pendayung elit nampaknya telah berubah dalam tempoh 25 tahun ke belakangan ini ke arah susuk tubuh yang lebih padat dan mantap. Trend ini amat ketara khususnya bagi pesaing wanita.

Kata kunci: morfologi, pendayung pecut, persiapan peralatan bot

INTRODUCTION

There is a lack of research pertaining to optimising human morphology and equipment set-up required for success in sprint kayaking. Blade and paddle sports require frictional forces on the boat to be minimized; however, the maximization of propulsion forces on the paddle is also essential. The 2000 Sydney Olympic Games research on kayak and canoe events were undertaken to examine factors which may assist elite coaches and sport scientist to understand the relationships between body proportions and equipment set-up characteristics and successful performance in sprint kayaking.

In the sport of sprint canoeing and kayaking, professional coaches and sport scientists have brought about many changes with respect to hull shape, paddle and blade design and athlete preparation. However, little normative data exist in the scientific literature pertaining to optimising human morphology and equipment set-up required for success in sprint kayaking. No study has simultaneously measured body size and proportions and reported their relationship with equipment set-up for elite sprint kayakers. Finally no published research has ever tested the many equipment set-up theories (Broze, 1992; Zumerchik, 1997) through a controlled intervention study.

There exists however, little normative data in the scientific literature for the current physical size and proportionality characteristics of elite sprint paddlers. These data are useful for coaches when initially selecting talented individuals for development programs, as well as in determining their specialist events.

Both kayaking and canoeing are sports whereby propulsion of the craft is derived predominantly from muscle actions of the upper body (Shephard, 1987). Distinctiveness in human morphology that could lead to a competitive advantage may be determined by two criteria:

a. homogeneity of physical structure among elite paddlers; and
b. possession of unique physical characteristics, not commonly observed in the general population.

If the populations of elite performers do not exhibit homogeneity in physical structure, an advantageous physical structure may be observed if the finalists or medalists can be shown to differ from the remaining competitors.

With respect to improved performances, too often the focus is placed on the influence of technical/equipment advances. The evolution of elite performers has also played a significant role in the establishment of recent sporting records (Norton & Olds, 1996). The data gathered in here will provide timely information about the physique of elite competitors of the 21st Century.

Absolute Body Size and Somatotype

Descriptive statistics for absolute size parameters are presented in Table 1.1. Male paddlers were similar in mean age and stature to canoeists at the Montreal Olympics (Carter, 1982), but were approximately 5 kg heavier on average. With similar skinfold values, this suggests the present sample have a higher proportional lean body mass, which is perhaps a consequence of modern practices in athlete preparation. Associated with these results, mean scores for the paddlers at the Sydney Olympics were higher on shoulder breadth (+1.7 cm), flexed arm girth (+2.3 cm), chest girth (+8.2 cm) and waist girth (+5.3 cm) than the 1976 Olympians.

Female paddlers were similar in stature, but generally older than the Montreal Olympic sample (mean = 20.6 years) and, like their male counterparts, were heavier by approximately 5 kg. The mean sum of skinfolds for the present sample is substantially lower than that for the Montreal canoeists. As the increased weight is not related to increased body fat, it suggests the current Olympic paddlers are more muscular than the Montreal females. This is supported by differences in mean segmental data between the two samples, with Sydney Olympic paddlers displaying greater shoulder breadth (+2.5 cm), flexed arm girth (+2.5 cm), chest girth (+8.2 cm) and waist girth (+6.0 cm) than the Montreal canoeists.

Table 1.1 Absolute size characteristics of Olympic sprint paddlers

Variable	Female Paddlers (n=20)			Male Paddlers (n=50)		
	Mean	**SD**	**Range**	**Mean**	**SD**	**Range**
Age (y)	26.4	5.1	19.0 – 36.0	24.8	3.0	20.0 – 31.0

Body Mass (kg)	67.7	5.7	59.1 – 80.7	85.2	6.2	73.6 – 99.8
Sum 8 Skinfolds‡ (mm)	80.0	16.9	52.9 – 103.7	55.4	15.2	30.9 – 116.1
Height (cm)	170.4	6.3	159.2 – 184.2	184.3	5.8	169.7 – 195.8
Sitting Height (cm)	90.4	2.6	84.8 – 98.0	96.9	3.0	91.6 – 103.1
Arm Span (cm)	172.8	7.5	161.4 – 184.3	190.6	7.3	175.8 – 210.4
Arm Length (cm)	33.1	1.7	30.3 – 35.7	35.9	1.7	32.2 – 39.7
Forearm Length (cm)	24.4	1.3	22.2 – 26.6	27.3	1.2	25.0 – 37.7
Thigh Length (cm)	43.8	2.2	39.9 – 48.1	46.8	2.5	41.7 – 51.3
Leg Length (cm)	44.8	3.0	39.4 – 51.2	49.6	2.4	43.2 – 54.3
Shoulder Breadth (cm)	39.3	1.2	37.0 – 41.4	43.1	1.9	38.4 – 48.1
A-P Chest Depth (cm)	18.7	1.4	16.2 – 21.1	21.5	1.4	18.8 – 25.3
Humerus Breadth (cm)	6.6	0.2	6.3 – 7.0	7.5	0.3	7.1 – 8.2
Femur Breadth (cm)	9.1	0.4	8.5 – 10.1	10.0	0.4	9.2 – 10.7
Flexed Arm Girth (cm)	32.1	1.5	29.8 – 35.3	37.6	1.9	32.8 – 43.2
Chest Girth (cm)	98.1	2.4	95.0 – 104.0	110.8	3.8	102.7 – 120.7
Waist Girth (cm)	75.8	3.4	68.8 – 85.2	85.9	3.9	77.6 – 93.8
Hip Girth (cm)	94.3	4.0	88.6 – 102.1	97.7	2.8	90.7 – 103.0
Thigh Girth (cm)	56.1	3.1	49.5 – 60.8	57.1	2.3	50.9 – 61.2
Calf Girth (cm)	35.9	1.8	31.6 – 39.2	37.8	1.6	33.6 – 40.7

‡ Sum of triceps, subscapular, biceps, iliac crest, supraspinale, abdominal, thigh, and medial calf skinfolds.

Relative Body Size

Proportionality characteristics of male and female paddlers are displayed in Figure 1.1. Clearly, the profiles for paddlers of both genders are similar in appearance. This indicates that, whether through training or self-selection, certain proportionality characteristics dominate the preferred morphology for elite performers. Olympic paddlers do not possess unusually long arms with respect to stature as one might expect, however, their unique physical characteristics include:

a. a greater than average proportional thigh length;
b. greater than average shoulder and chest breadths;
c. proportionally large upper body girths (z-arm girth and z-chest girth);
d. proportionally narrow hips for the male paddlers;
e. very low skinfold scores, thereby indicating a very lean physique.

Coaches in the sport of kayaking face contradictory philosophies about the optimum boat and paddle set-up for an athlete's physical structure. Furthermore, on what basis do coaches decide the optimum boat set-up for sprint or slalom paddlers? Clearly, the internal structure of the kayak must be designed to fit the participant's body dimensions. An incorrect equipment set-up will affect comfort as well as the ability to function at optimal levels, thereby having a detrimental effect on performance (Burke & Pruitt, 1996). Regardless of the kayak event, knowledge of an individual's body segment dimensions may provide important information to assist coaches and athletes to adjust certain aspects of the boat and paddle to maximize comfort and performance, yet minimize the potential for injury.

Athletes and coaches involved with kayak paddling are faced with a number of equipment set-up decisions that affect the ability of the athlete to apply propulsive force to their respective craft. Often the process of fine tuning equipment set-up requires hours of practice with subjective feedback from the performer driving this trial-and-error approach. For many performers though, the equipment is set more for comfort than on any consideration of the mechanical advantage it may afford.

Optimum set-up factors may become apparent when one takes account of absolute size and proportionality characteristics of the athlete. However, Ackland et al. (2003) reported that Olympic sprint paddlers exhibited little variability in absolute or relative body dimensions. We may, therefore, expect little variability in boat set up for paddlers within the sprint or slalom categories at the elite level, though set-up differences between these sports might be great.

In sprint kayaking the contestant is seated, and force is transmitted from the paddle to the boat through the seat and foot bar. Shephard (1987) reported that the successful sprint paddler is of slightly above-average stature, although excessive height leads to difficulties in balancing the vessel. Thus, sitting height may be less than the population average (Gedda et al., 1968). Alternatively, the tall paddler may adjust the seat height and foot bar distance to accommodate their particular body dimensions.

Selecting a suitable paddle is vital for success in this sport to ensure that the kayaker can optimally propel the boat efficiently with power. The selected paddle should allow the paddler to maintain an efficient cadence at their maximum cruising speed. Though a long paddle may provide an advantage for generating forward propulsion, the increased inertia could limit the ability to recover for the next stroke, thereby increasing the energy cost of the action. Choosing an appropriate length of shaft, hand position and length of blade depends on the length, width and mass of the kayak, as well as the height and reach of the paddler (Zumerchik, 1997).

For a given paddle length, the paddler may alter the mechanical advantage of the propulsive system by changing the position of the hands when gripping the paddle shaft. As a general rule, Rademaker (1977) suggested the correct hand spacing is determined by holding the paddle shaft above the head with the arms horizontal and forearms held vertical with a right angle formed at the elbow. This should divide the paddle into three equal lengths, such that the distance between the third digits of the left and right hands represents the middle third of the paddle length.

The 2000 Sydney Olympic sprint paddlers displayed few differences in equipment set-up for those ranked in the top 10 places compared with the rest of the field. A significant ($p=.017$), though small increase in the vertical distance from the seat to the top of the skirt lip (seat height-2) figure 1 for the best performers, was accompanied by a trend ($p=.082$) toward greater hand grip distance (Ackland et al., 2003). This trend was not unexpected, as Ackland et al. (2003) reported no significant difference in physical size between the ‘best’ paddlers and the remaining Olympic competitors.

Mean values for equipment set-up parameters of the sprint and slalom kayak paddlers are presented in Table 2, with paddlers separated by gender. Among sprint paddlers, sizeable differences were noted for the setting of FBD, and the selection of paddle and blade length, as well as the optimum PGW. Since the pooled data included paddlers in K1, K2 and K4 events the athletes' body size, as well as their position within the craft, generally influence these set up parameters. For example, paddlers in position four (seated aft) have to contend with a greater gunwale width than those seated forward in the kayak and, consequently, are bigger in physical size and tend to use longer paddles. However, little variation was observed for seat height and blade width.

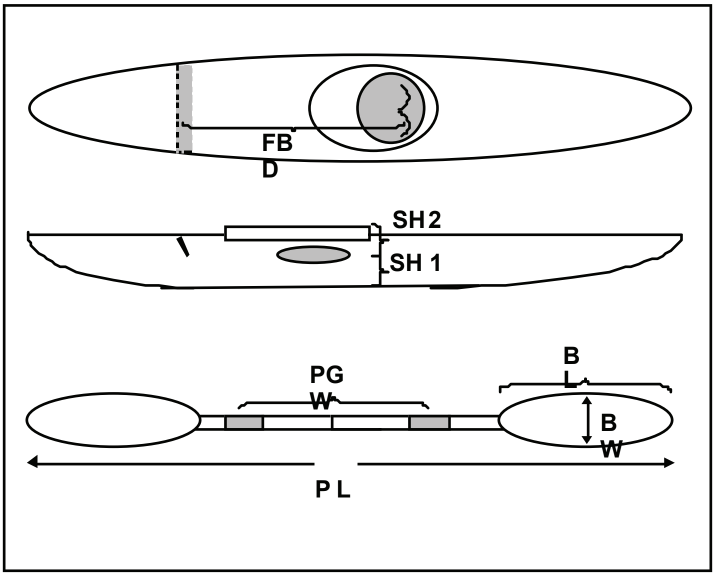

Figure 1 Equipment set-up dimensions

Table 2 Average data for body size and equipment set-up parameters for female and male sprint and slalom paddlers.

VARIABLE [1]	SPRINT (n = 11)			SLALOM (n = 12)		
	Mean	SD	Range	Mean	SD	Range
Female Paddlers						
Age (year)	26.5	5.1	19.0 – 36.0	26.3	4.8	20.0 – 35.0
Height	168.6	6.0	159.2 – 184.2	167.7	5.2	158.3 – 176.2
Weight (kg)	64.4	6.7	59.1 – 80.7	59.0	4.5	53.3 – 68.6
Seat height-1	7.6	1.3	4.8 – 10.0	0.6	0.5	0.0 – 1.7
Seat height-2	20.5	1.3	18.7 – 22.8	20.9	0.7	19.2 – 21.7
Foot bar distance	87.2	6.0	77.5 – 94.9	84.7	3.7	76.5 – 89.5
Grip distance	67.9	4.7	59.4 – 73.5	66.3	6.0	56.8 – 74.6

Paddle length	215.3	1.7	212.3 – 217.5	199.5	1.8	196.8 – 202.8
Blade length	50.4	1.7	47.6 – 53.5	47.0	0.9	46.0 – 49.0
Blade width	16.5	0.6	15.8 – 17.5	19.3	0.4	18.7 – 20.0
	SPRINT (n = 31)			**SLALOM (n = 12)**		
Male Paddlers						
Age (year)	24.7	2.9	20.0 – 31.0	27.7	5.4	19.0 – 43.0
Height	184.5	6.0	169.7 – 195.8	177.1	6.6	158.9 – 193.9
Weight (kg)	84.8	6.2	73.6 – 99.8	72.5	5.8	59.0 – 84.3
Seat height-1	8.2	1.2	5.0 – 9.9	0.8	0.6	0.0 – 2.1
Seat height-2	20.8	1.4	17.5 – 23.0	21.7	1.2	19.2 – 23.0
Foot bar distance	94.9	6.1	82.5 – 105.0	88.1	2.8	85.5 – 95.5
Grip distance	72.8	3.7	65.0 – 79.8	70.3	6.3	65.0 – 86.2
Paddle length	220.2	1.7	216.5 – 223.0	203.0	1.6	198.9 – 205.9
Blade length	51.5	1.1	47.8 – 53.0	47.0	1.2	45.5 – 49.2
Blade width	17.0	0.4	15.8 – 17.6	20.0	0.6	19.1 – 20.8

[1] All variables measured in cm unless otherwise indicated.

Similar findings were noted among slalom paddlers, except that the position of the hands on the paddle shaft (females = 56.8 – 74.6cm; males = 65.0 – 86.2cm) varied to an even greater extent than that for the sprint competitors. This variation was observed despite there being only one event for slalom kayak paddlers (K1) and competitors were not, therefore, constrained by imposed variations in the width of their craft.

Best Versus Rest – Male Sprint Paddlers

Sizeable differences were noted in the range of values for preferred FBD and PGW, however, little variation was observed for seat height and paddle dimensions. Few differences in equipment set-up were recorded for sprint paddlers ranked in the top 10 places compared with the rest of the field (Table 3). A significant ($p = .017$), though small increase in seat height-2 for the best performers, was accompanied by a trend ($p = .082$) toward greater PGW. This result was not unexpected, as Ackland et al. (2003) reported no difference in physical size between the best paddlers and the remainder using the same sample.

Table 3 Descriptive statistics and ANOVA summary of equipment set-up among male sprint paddlers ranked in the top 10 (n=16) versus the rest (n=15)

VARIABLE	GROUP	MEAN	SD	df	MS	F	Sig
Seat height-1	Best	8.3	0.7	1	0.6	0.42	.524
	Rest	8.0	1.5				
Seat height-2	Best	21.4	1.0	1	10.9	6.37	.017
	Rest	20.2	1.6				
Foot bar distance	Best	94.9	6.4	1	0.2	0.01	.945
	Rest	94.8	6.0				
Hand grip distance	Best	73.9	4.0	1	41.9	3.24	.082
	Rest	71.6	3.0				
Paddle length	Best	220.3	2.0	1	0.5	0.16	.690
	Rest	220.1	1.2				
Blade length	Best	51.6	1.2	1	0.3	0.34	.567
	Rest	51.4	0.9				
Blade width	Best	17.0	0.5	1	0.4	0.53	.534
	Rest	16.9	0.2				

The Relationship Between Body Size and Equipment Set-up

The associations between body size and equipment set-up were determined via a Pearson correlation matrix, and these data were subsequently used to facilitate the logical selection of independent variables as inputs for regression analyses. Of the seven equipment set-up variables recorded, only PGW and FBD had significant associations ($p < 0.01$) with anthropometric variables. Stepwise regression analyses using the backward elimination approach (SPSS 10.0) were then structured to identify the best morphological predictors of FBD and PGW. These two equipment set-up variables had been shown to have greatest association with measures of body size (Ackland et al., 2003).

The relationship between body size and FBD was clearly described using linear regression analysis. Variables selected for inclusion in this analysis demonstrated at least moderate ($r > .40$) association with FBD and included height, thigh length, leg length and foot length. The following significant prediction equation ($p < 0.001$) accounted for almost half the variance ($R^2 = 0.589$, SEE=4.48) in FBD among male sprint paddlers (Equation 1):

$$FBD = - 15.975 + (0.603*Ht) \quad \text{-------------} \quad \textit{Equation 1}$$

Similarly, paddle grip width PGW was predicted ($p < 0.01$) by measures of upper body size. Once again, stature accounted for over half the variance ($R^2 = 0.541$, SEE=3.08) in PGW among the sprint paddlers (Equation 2):

$$PGW = 3.557 + (0.376 * Ht) \quad \text{------------} \quad \textit{Equation 2}$$

The wrist girth measure was also included in this analysis due to its moderate association with the dependent variable, however, was excluded from the final equation.

Other regression analyses showed significant ($p<0.05$) relationships between measures of body size (height, biacromial breadth, chest firth, arm length and arm span) and both paddle length (PL) and blade length (BL). Though only accounting for 20 – 25% of the variance in the dependent variables, the positive relationship between these set-up parameters and height, biacromial breadth, chest girth, arm length and arm span is noteworthy.

Conclusions

The normative data presented emphasizing the need for critical consideration of these factors when selecting kayak and canoe paddlers. Clear differences in rigging and paddle dimensions are evident between sprint and slalom kayak paddlers, which presumably occur as a result of differences in the biomechanical demands of the two sports. Only minor equipment differences were recorded between the best and rest male competitors in the sprint events, but this was not surprising given their homogeneity in physical structure. The process of fine tuning equipment set-up often requires hours of practice with subjective feedback from the athlete. The normative data presented in this paper show a spread of values for each set-up parameter, thereby emphasizing the need for critical consideration of these factors by coaches when selecting them prior to competition. Though no greater than 50% of the variance was accounted for based on the paddler's physical structure, therefore factors such as comfort, variations in technique, or simply a paddler's unwillingness to adjust and experiment with their set-up, may contribute to the remainder of this variance. Humans demonstrate considerable anatomical differences; hence it is vital for coaches and sports scientists to have a set of morphological preferences that would eventually assist the identification of potentially successful kayak paddlers. The morphology of elite paddlers appears to have altered during the past 25 years toward a more compact, robust physique. This change is especially noticeable for the female competitors.

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