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ORIGINAL ARTICLE

Effect of paddle grip on segmental fluid distribution in elite slalom paddlers

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Abstract

Issues of high levels of muscular asymmetry have been associated with injury risk, and therefore have potential implications for decremental performance at the elite sport level. The aim of this current study was to assess the relationship between the segmental fluid distribution and the paddle grip in elite male and female slalom kayakers and canoeists. Eighty-four world-cup competitors (61 males and 23 females) took part in the study. Impedance analysis was used to assess segmental fluid asymmetry. The effect of paddle grip (loose/fixed hand in kayakers, lower/upper hand in canoeists), morphological dominance (dominant/non-dominant) and discipline (canoe/kayak) were evaluated by repeated measures ANOVA. The findings indicated a significant effect of paddle grip in canoeists on morphological asymmetry in upper limbs (arm of lower paddle hand mean fluid distribution 3.28, $s = 0.43$ litres; arm of upper paddle hand mean fluid distribution 3.19, $s = 0.41$ litres; $P = 0.000$, $\omega_p^2 = 0.33$). The sternmen demonstrated higher asymmetry between the arms of upper and lower paddle hand (mean 0.11, $s = 0.04$ litres, $P = 0.000$, $\omega_p^2 = 0.80$) than the bowmen (mean 0.04, $s = 0.06$ litres, $P = 0.015$, $\omega_p^2 = 0.44$) in double-canoes. Significant morphological asymmetry was found also in kayakers but the effect of paddle grip was not substantial. The use of segmental impedance analysis may be a suitable diagnostic tool for assessing morphological changes, which can be related to paddling training. Likewise muscular asymmetry is associated with injury risk; the evaluation of morphological changes during the training process may be considered by sport trainers and physical therapists.

Keywords: *Canoeing, kayaking, impedance analysis, asymmetry*

Introduction

White water slalom is a sport that is based on using cyclic and acyclic skills. The aim is to navigate a decked canoe or kayak through a course of hanging gates on river rapids in the fastest time possible. Most slalom courses take 80–120 seconds to complete for the fastest paddlers, depending on the level of competition, difficulty of course, degree of water turbulence and ability of the other paddlers. Arm movements with accompanying trunk and whole upper body actions create the necessary boat speed to navigate the canoe or kayak in and out of gates. The lower limbs provide support for stabilising the boat during turning and negotiating the various gates.

Canoe and kayak flat and white water paddling require significant aerobic and anaerobic capacities and upper body strength (Akca & Muniroglu, 2008; Bishop, 2000; Heller, Bily, Pultera, & Sadilova, 1994; Tesch, 1983). Early research reported that slalom paddlers had a substantial standing height and lean body mass, good general muscle development with particular emphasis on the leg muscles (Sidney & Shephard, 1973). Recently Ridge, Broad, Kerr and Ackland (2007) stated that elite male slalom paddlers had similar height and weight to a reference population of non-athletes and that male slalom paddlers were older, lighter, shorter, and had similar body fat compared with Olympic sprint paddlers. Contrary, female slalom paddlers were taller and lighter than the reference population of non-athletes and were of similar age and height but lighter and leaner than the Olympic sprint paddlers.

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The kayak paddle is composed of a pole and two blades. The blades are opposite to each other at an angle of about 60–80 degrees. The right and left side of the paddle are distinguished according to the turning direction of the blades, therefore the grip requires, one hand to be firmly fixed while the other hand is loosely fixed, when holding a paddle. Canoeists paddle on the left or right side of the boat using a paddle composed from a t-grip pole and a blade. One hand is lower and the other one is above the t-grip, and the boat is led by strokes on the preferred side or by crossbow-strokes (the arm of the bottom hand crosses in front of the bowman's body to insert the paddle in the water on the opposite side of the canoe some distance from the gunwale, facing towards the canoe, and is then pulled inward while the top hand pushes outward). For double-canoeists (two person canoe), crossbow-strokes are used only by the bowmen.

Due to the nature of the activity, white water kayaking and especially canoeing may lead to asymmetrical loading resulting from different demands of the motor tasks (fixed/loose grip in kayakers, and left/right side paddle in canoeists). High level of asymmetry has been associated with injury risk (Bak & Magnusson, 1997; Knapik, Bauman, Jones, Harris, & Vaughan, 1991). Few studies have documented the relationship between strength asymmetries and injuries in paddlers. Lovell and Lauder (2001) observed elevated bilateral peak-force strength imbalance between the upper limb of injured and non-injured competitive flat-water kayakers. du Toit, Sole, Bowerbank and Noakes (1999) stated a 23% occurrence of tenosynovitis in long distance canoeists. The incidence was significantly higher in the dominant (69%) than the non-dominant hand (24%). Schoen and Stano (2002) estimated the occurrence of 4.5 injuries per 1000 days paddled, predominantly on the shoulder, wrist/hand or elbow/forearm. In Olympic canoe and kayak paddlers, the most frequent injuries were sprains (32%), tendonitis (20%) and chronic musculoskeletal pain (14%). Of the injuries noted, 70% were reported as recurrent or chronic (Krupnick, Cox, & Summers, 1998). Regular kayaking appears to reduce shoulder joint range of motion (McKean & Burkett).

The asymmetry between the dominant and non-dominant sides or left and right sides has often been evaluated on the basis of strength properties (Demura, Miyaguchi, & Aoki, 2010; Fousekis, Tsepis, & Vagenas, 2010; Markou & Vagenas, 2006). However, muscle balance consideration should not be limited to analysis of strength parameters, since strength measurements may not accurately reflect muscle performance characteristics (Schlumberger et al., 2006). Bioelectrical impedance is a valid method to estimate the limb fluid or muscle volume (Fuller et al., 1999; Janssen, Heymsfield, Baumgartner, & Ross, 2000; Lukaski, 2000; Miyatani, Kanehisa, Masuo, Ito, & Fukunaga, 2001; Pietrobelli et al., 1998), and could be used to assess the segmental muscle distribution and, therefore, morphological asymmetry.

To our knowledge there are no studies that have evaluated the effect of paddle grip or limb-dominance on morphological aspects in slalom paddlers. As indicated earlier, issues of high levels of asymmetry are associated with injury risk, and therefore have potential implications for decremental performance at the elite level. The aim of this current study was to assess the relationship between the segmental fluid distribution and the paddle grip in elite male and female slalom paddlers.

Methods

Participants

Eighty-four competitors who took part in the first World Cup event in white water slalom from 18th to 20th June 2010 in Prague, Czech Republic, volunteered to participate in the study and provided written consent. The number of competitors, age, sex and anthropometric characteristics are reported in Table I. The study was approved by the Ethics Committee of the Faculty of Sports and Physical Education, Charles University Prague.

Body composition measurement

Body composition was evaluated using the multi-frequency device In.Body 3.0 (Biospace Co., Ltd., Korea), which measured whole-body bio-impedance. Participants were asked not to eat for 2

Table I. Anthropometric characteristics of kayakers (K1), single and double canoeists (C1, C2). Values are reported as mean $\pm$ standard deviation

Category	*N*	Age (years)	Height (cm)	Body mass (kg)	Body fat (%)
K1 male	29	25.0 $\pm$ 4.7	176.8 $\pm$ 6.0	74.0 $\pm$ 6.7	10.0 $\pm$ 2.7
K1 female	23	25.0 $\pm$ 6.6	166.1 $\pm$ 5.7	59.5 $\pm$ 4.9	17.0 $\pm$ 4.6
C1 + C2 male	32	24.2 $\pm$ 4.9	178.8 $\pm$ 6.3	75.9 $\pm$ 7.2	10.8 $\pm$ 3.7
C1	17	25.2 $\pm$ 5.2	181.6 $\pm$ 6.4	77.4 $\pm$ 7.5	10.1 $\pm$ 3.5
C2 bowmen	7	22.7 $\pm$ 5.4	175.4 $\pm$ 5.6	73.7 $\pm$ 4.4	11.6 $\pm$ 2.6
C2 sternmen	8	23.4 $\pm$ 3.5	175.9 $\pm$ 3.6	74.5 $\pm$ 8.4	11.8 $\pm$ 4.9

hours and drink 1 hour before the measurement. Testing was performed in a standing position with arms extended down. The calculation of body fat percentage was determined from prediction equation supplied by the manufacturer (Biospace Co., Ltd., Korea). The device provided fluid distribution of five body segments (left and right arm, trunk, left and right leg).

Assessment of dominance and paddle grip

Dominance was determined on the basis of the segmental fluid distribution from the impedance analysis. The limb with a higher volume of fluid was considered as dominant (D) and with a lower volume as non-dominant (ND). Assuming that the fluid distribution in healthy subjects is stable (45% extracellular water in total body water and 73% of total body water in fat free mass) (DeLorenzo, Andreoli, Matthie, & Withers, 1997), the fluid distribution in limbs is closely related to the muscle mass distribution. We refer to this fluid asymmetry as the morphological dominance.

All the kayak slalom paddlers stated their paddle grip preference (loose hand/fixed hand) and slalom canoeists their upper/lower hand preference, which was verified afterwards during the World Cup race. The level of asymmetry was evaluated in slalom kayakers and canoeists. Among canoeists, the asymmetry was also highlighted between the sternmen ($n = 7$) and bowmen ($n = 8$) in the double-canoes.

Data analysis

Descriptive statistics (mean and standard deviation) were used for the anthropometric variables. To assess lateral fluid distribution between D and ND limbs in kayak and canoe paddlers, repeated measures ANOVA ($2 \times 2 \times 2$) was used with the within-subject factor dominance and between subject factors discipline (canoe/kayak) and sex. The factor sex was insignificant in this model and was excluded from further analysis. The influence of age on the fluid distribution was also tested by adding the age as the covariate in the analysis, but no effect of age was found.

The effect of paddle grip in kayak and canoe paddlers on lateral fluid distribution was assessed by $2 \times 2 \times 2$ repeated measures ANOVA with the within-subject factor grip and the between-subject factors discipline and sex. The factor sex was again insignificant in this model and was excluded from further analysis. Furthermore, the effect of paddle grip in separate groups (C1, C2-sternmen, C2-bowmen, ...) was verified by simple repeated measures ANOVAs.

To control Type-I error, the significance level was set as 0.05. The coefficient partial omega squared (ω_p^2) was used to assess the effect size. Its value indicates the percentage of explained variance accounted for by an independent variable. The ω_p^2 is a conservative parameter of estimate of effect size, and should be used especially in small samples (Olejnik & Algina, 2003). Ferguson (2009) proposed the following interpretation of squared coefficients: 0.04 minimum practical effect, 0.25 moderate effect and 0.64 strong effect. All analyses were performed by the statistical software SPSS for Windows Version 19 (Chicago, IL, USA).

Results

There was a significant effect of morphological dominance on fluid distribution in all paddlers arms, $P = 0.000$, $\omega_p^2 = 0.50$ and legs, $P = 0.000$, $\omega_p^2 = 0.48$ (Figure 1). A significant interaction of discipline (canoe/kayak) and morphological dominance was found for arms $P = 0.001$, $\omega_p^2 = 0.11$ and legs $P = 0.003$, $\omega_p^2 = 0.09$. Slalom canoeists had greater fluid volume in lower limbs than slalom kayakers, which corresponded to a greater muscle mass in canoeists (Figure 1).

In slalom canoeists, significant differences were found in fluid distribution between the arms of the upper and lower paddle hand, (Figure 2 and Table II).

In slalom kayakers, there were no significant differences in fluid distribution between the arms with firmly fixed and loosely fixed grip, $P = 0.855$, $\omega_p^2 = -0.02$, neither were there differences between the legs corresponding to the firmly fixed and the loosely fixed hand $P = 0.404$, $\omega_p^2 = -0.01$ (Figure 2).

Sternmen in double-canoes had higher fluid volume differences between the arms of their upper and lower paddle hand (mean difference 0.11, $s = 0.04$ litres $P = 0.000$, $\omega_p^2 = 0.80$) than the bowmen (mean difference 0.04, $s = 0.06$ litres, $P = 0.015$, $\omega_p^2 = 0.44$) (Table II).

Discussion

The main aim of the study was to evaluate the relationship between the segmental fluid distribution and the paddle grip in elite male and female slalom paddlers. The sample consisted of top slalom paddlers regularly participating in World Cup races. The anthropometric characteristics of the male slalom kayak paddlers were similar to that reported by Ridge et al. (2007) and Sklad, Krawczyk and Majle (1994). Likewise, the anthropometric characteristics of the current male slalom canoeists also corresponded to that reported by Ridge et al. (2007),

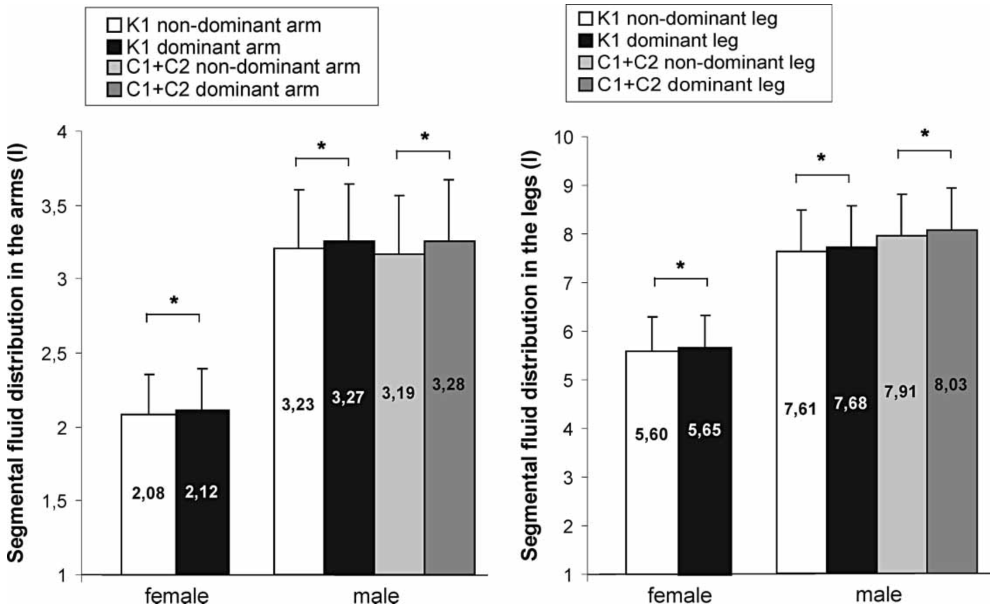

Figure 1. Average (± standard deviation) segmental fluid distribution for dominant and non-dominant arm and leg in slalom paddlers (C, canoeists; K, kayakers); *Significant effect of dominance.

suggesting a similar cohort of slalom paddlers were assessed. The body composition in the aforementioned studies was measured by two components model (body fat and fat free mass) using callipers.

To our knowledge, only one study has assessed body composition and muscle mass distribution in advanced kayakers where the body composition and muscle mass distribution were determined using bioelectrical impedance analysis (Rynkiewicz & Rynkiewicz, 2010). The investigators found that the kayak paddlers had large muscle mass and average fat mass. Additionally, they observed that percentage of body fat mass increased with age and percentage of muscle mass decreased, with the exception of the upper and lower limbs. Although, it was not discussed by the authors, their results showed a muscle asymmetry between the left and the right legs of the kayakers (mean age 20.3, $s = 1.4$ year; mean weight 6.3, $s = 1.5$ kg; 5.4, $s = 1.4$ kg for the left and right leg, respectively), but muscle mass values cannot be compared with our data because there were different diagnostics used.

Bioelectrical impedance has been proved to provide a valid estimation of total (Janssen et al., 2000)

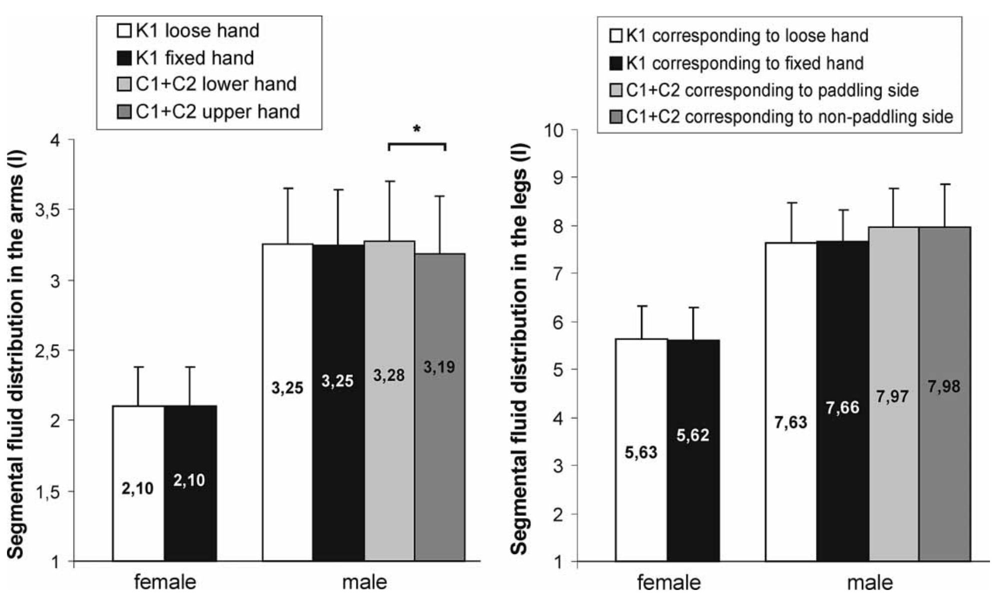

Figure 2. Average (± standard deviation) segmental fluid distribution in the arms and legs according to paddle grip in slalom paddlers (C, canoeists; K, kayakers); *Significant effect of paddle grip.

Table II. Average segmental fluid distribution ($\pm$standard deviation) between dominant and non-dominant limbs and the effect of paddle grip in single (C1) and double (C2) canoeists

		Dominant limb (L)	Non-dominant limb (L)	P	ω_p^2	Limb corresponding to lower hand on paddle (L)	Limb corresponding to upper hand on paddle (L)	P	ω_p^2
C1	Arm	3.40 $\pm$ 0.46	3.32 $\pm$ 0.43	**0.006**	0.21	3.40 $\pm$ 0.46	3.32 $\pm$ 0.43	**0.006**	0.21
	Leg	8.30 $\pm$ 0.94	8.18 $\pm$ 0.93	**0.000**	**0.36**	8.25 $\pm$ 0.43	8.22 $\pm$ 0.46	0.531	−0.03
C2 sternmen	Arm	3.22 $\pm$ 0.44	3.11 $\pm$ 0.43	**0.000**	**0.80**	3.22 $\pm$ 0.44	3.11 $\pm$ 0.43	**0.000**	**0.80**
	Leg	7.83 $\pm$ 0.75	7.72 $\pm$ 0.71	0.066	0.19	7.75 $\pm$ 0.67	7.80 $\pm$ 0.79	0.509	−0.03
C2 bowmen	Arm	3.03 $\pm$ 0.18	2.96 $\pm$ 0.19	**0.015**	**0.44**	3.03 $\pm$ 0.18	2.96 $\pm$ 0.19	**0.015**	**0.44**
	Leg	7.61 $\pm$ 0.50	7.49 $\pm$ 0.56	0.16	0.10	7.52 $\pm$ 0.55	7.58 $\pm$ 0.51	0.566	−0.05
C1 + C2	Arm	3.28 $\pm$ 0.43	3.19 $\pm$ 0.41	**0.000**	**0.33**	3.28 $\pm$ 0.43	3.19 $\pm$ 0.41	**0.000**	**0.33**
	Leg	8.03 $\pm$ 0.85	7.91 $\pm$ 0.84	**0.000**	**0.27**	7.97 $\pm$ 0.82	7.98 $\pm$ 0.87	0.787	−0.01

or segmental limb muscle volume (Fuller et al., 1999; Lukaski, 2000; Miyatani et al., 2001), but very few articles have evaluated limb asymmetry according to morphological or functional dominance. We found significant differences in fluid distribution between D and ND limbs in all paddlers. Although kayaking is a symmetrical activity, there was a morphological asymmetry in both male and female kayakers. As expected, significantly larger asymmetry between D and ND limbs was found in canoeists than in kayakers. This asymmetry was consequently related to the paddle grip. We have not observed any differences in fluid distribution between the arms of the loosely and firmly fixed hand in kayakers. Furthermore, there were no significant differences in asymmetry between the legs. The current results showed that the paddle grip in kayakers does not affect the segmental fluid distribution in the arms or the legs and, therefore, morphological asymmetry.

Significant differences in fluid distribution were noted between the arms of the lower and upper paddle hand in slalom canoeists which corresponded to the differences between morphological dominant and non-dominant arms in the same paddlers. Therefore, we propose that the paddle grip affects the morphological asymmetry in elite slalom canoeists. This asymmetry is probably caused by one side paddling and the fact that the dominant arm corresponded to the lower arm when holding a paddle. Asymmetrical loading in the long term leads to differences between D and ND arm in bone mineral composition and density, as reported in racquet players (Kannus & Haapasalo, 1995). Calbet, Moysi, Dorado and Rodriguez (1998) also showed arm asymmetry in professional tennis players due to the existence of approximately 20% more bone mineral content and muscle mass in the dominant arm. However, we have not found any differences in fluid distribution in the legs corresponding to the paddling and non-paddling side.

The fluid volume in the arms of the lower and upper paddle hand was compared between the sternmen and bowmen in double-canoes. Higher fluid volume in the sternmen's arms may be explained by the different demands during the course. The sternman is required to keep the paddle in the water on one side and uses more of an isometric stroke to keep the boat on course. The bowman uses crossbow-strokes.

Conclusion

In conclusion, the results showed a significant relationship between paddle grip in slalom canoeists and morphological asymmetry in upper limbs. The sternmen demonstrated higher asymmetry than bowmen in the double-canoe. A significant morphological asymmetry was found also in slalom kayakers but the effect of the paddle grip was not substantial. The use of segmental impedance analysis may be a suitable diagnostic tool for assessing morphological changes, which can be related to paddling training. Likewise muscle asymmetry is associated with injury risk; the evaluation of morphological changes during the training process may be considered by sport trainers and physical therapists.

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