

Morphological Characteristics of European Slalom Canoe and Kayak Paddlers

Características Morfológicas de los Remeros de Canoa y Kayak de Slalom Europeos

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SUMMARY: The primary aim of this study was to determine the morphology of elite canoe slalom paddlers and to identify if morphology differences existed between kayak and canoe paddlers. The survey included a total of 74 canoe slalom paddlers who competed in the 2018 European Championship. These competitors were assessed using a battery of anthropometric dimensions according to standardized anthropometric techniques and bioimpedance analysis using the multifrequency octopolar device Tanita MC-980. Elite slalom male competitors can be characterized to having average body height (~180 cm), average weight (~75 kg), with ectomorphic mesomorph somatotype (1.3 – 5.5 – 2.7), well developed trunk and arm muscles (biceps girth: 35.4 ± 1.8), low hypertrophy of legs and low body fat (8 ± 3.2 %). In addition, there are no significant differences between canoe (C1) and kayak (K1) paddlers. For female competitors we can conclude, there has been little change in anthropometric values through the decades. However, C1 competitors are younger, more mesomorphic and less ectomorphic.

KEY WORDS: Anthropometry; Bioelectrical impedance; Somatotype; Kayak slalom; Canoe slalom.

INTRODUCTION

Canoe slalom is a timed event where competitors navigate a whitewater course by passing through a combination of upstream and downstream ‘gates’ consist of two poles suspended above the water. Each course varies up to a maximum of 300 m in length and a maximum of 25 gates, with a minimum of six upstream gates. Depending on the course design international athletes will complete racing in 90 to 110 seconds. Overall race performance is determined by the time to complete plus penalties gained for touching (2 seconds) or missing a gate (50 seconds). Canoe slalom is contested in two types of boat, canoe and kayak. In canoe slalom the athlete uses a single-blade paddle and is strapped into the boat with their knees bent and tucked under their body. In contrast, in kayak slalom the athlete is seated and uses a double-bladed paddle. Male and female athletes compete in individual kayak (K1) and individual canoe (C1) races.

Canoe slalom relies on the muscles of the upper limbs and trunk to create the necessary boat propulsion and to navigate it in and out of gates, which requires an appropriate level of muscular strength and power. Anthropometric

measures of Olympic paddlers revealed body height and body weight were average for male (177 ± 7 cm; 72.5 ± 5.8 kg) in comparison to a reference population of non-athletes and above average for females (168 ± 5 cm; 59 ± 4.5 kg) (Ridge *et al.*, 2007). Chest girth measurement for males and females have been recorded at 102.9 ± 4.1 cm, 91.0 ± 3.6 , respectively and were 35.0 ± 1.6 cm and 30.1 ± 1.0 cm for flexed arm girth in males and females, respectively (Ridge *et al.*). Male and female slalom athletes are considered predominantly mesomorphic (Ridge *et al.*). A recent study, however, reported that international male canoeists body weight (76.2 ± 4.4), somatotype (1.4 – 5.6 – 2.3) and girth of flexed arm (35.6 ± 1.5) (Busta *et al.*, 2018) were different to that of earlier research (Ridge *et al.*).

The difference between the above two studies suggest that the morphology of competitors may have changed over the last 11 years. Due to the development of canoe slalom in the last quarter century (shortening of courses, improvement of materials and boats, improved physical conditioning and coaching) it is likely that the athletes’ morphology has

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changed. It is plausible that morphology changes in the body parameters may be related to strength, speed and power attributes for canoe slalom. To determine possible changes a similar representative research sample is required to compare Ridge *et al.* data with current slalom athletes. The primary objective of this study was to determine the morphology of canoe slalom paddlers that competed in the 2018 European Championship. A secondary objective, was to identify if morphology differences existed between kayak and canoe paddlers, which included an assessment of body composition analysis to determine body fat percentage.

MATERIAL AND METHOD

Participants. Seventy-four competitors from the 2018 Canoe Slalom European Championship were assessed using a battery of anthropometric dimensions and bioimpedance analysis. From 48 male paddlers, 23 competed in canoe events and 25 in kayak events. From 26 female paddlers, 11 competed in canoe events and 15 in kayak events. According to the rules for canoe slalom international events, only 3 competitors of the same country for each category can start at the European Championship. Therefore, the sample population verifies an elite or sub-elite level of competitors. Athletes were contacted and invited to take a part in this study through team officials during a team leaders meeting. Specific rules for measurements were given. All participants read and signed a consent form before testing and the study was approved by the university ethical committee.

Data collection. Two days prior to the European Championship event, paddlers were assessed on consecutive days. To eliminate inter-rater variability, all measurements were conducted by a single experienced examiner. Licensed anthropometric instruments were used for data collection and anthropometric measurements were performed according to techniques suggested by the Anthropometric Standardization Reference Manual (Lohman *et al.*, 1988). Arm span was measured in standing position with the arms fully extended. The distance between the tips of the stretched middle fingers was taken. Sitting height is a measurement of the distance from the highest point on the head to the base sitting surface when the subject sits with both feet on the floor, the lower back and shoulders against the wall, looking straight ahead. Shoulder breadth, the distance between the lateral margins of the acromion processes, was measured using breadth caliper. Other breadth measurements were made by a specific breadth measurement calipers. Other anthropometric parameters (forearm girth, flexed arm girth, chest, thigh, calf girth) were measured according to techniques suggested by the

Anthropometric Standardization Reference Manual. We measured skinfold thicknesses (triceps, subscapular, suprailiac, thigh and calf skinfold) to determine somatotype. We used caliper type BEST K-501 (Trystom, CZE). Measurement of skinfold thicknesses were completed once on the right site of the body. Somatotypes were calculated according to Heath & Carter (1990). Body fat was evaluated using the multifrequency octopolar device Tanita MC-980 (Tanita Co., Tokyo, Japan) using 1, 5, 50, 250, 500 and 1000 kHz, which measured whole-body bioimpedance. The participant's age, sex and height were entered into the device. Participants were asked not to eat for 2 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 the prediction equation supplied by the manufacturer (Biospace Co., Ltd., Korea).

Data analysis. Descriptive statistics of male and female data were used to compare canoe and kayak paddlers. To determine differences between the groups an independent student's T-test was used. Statistical significance was set at $p < 0.05$ and to determine practical differences between canoe and kayak paddlers Cohen's d was calculated. Effect sizes were classified as trivial (0–0.2), small (0.2–0.6), moderate (0.6–1.2), large (1.2–2.0) and very large (>2.0) (Hopkins, 2006).

RESULTS

Table I illustrates the age, body mass, height, body mass index, anthropometric dimensions, bioimpedance analysis of male ($n=48$) and female ($m=26$) European canoe slalom athletes. Table II shows the comparison between male and female canoe and kayak athletes. For male canoe and kayak paddlers there was no significant difference ($p > 0.05$) in age, body mass, height, body mass index, anthropometric dimensions and bioimpedance analysis. Similarly, for females there was no significant difference ($p > 0.05$) between canoe and kayak paddlers in body mass, height, body mass index and bioimpedance analysis. There was a significant difference in age ($p=0.04$, $d = 0.83$), morphological categories of mesomorphy ($p=0.02$, $d = 0.93$), and ectomorphy ($p=0.03$, $d = 0.80$).

Figures 1 and 2 show somatographs of individual canoe (C1) and kayak (K1) men paddlers, the individual somatotypes and also average somatotype. Figures 3 and 4 show somatographs of individual canoe (C1) and kayak (K1) women paddlers, the individual somatotypes and also average somatotype.

Table I. Morphology of male and female European paddlers.

Variable	Male paddlers (n=48)		Female paddlers (n=26)	
	Mean ± SD	Range	Mean ± SD	Range
Age (years)	24.3 ± 4.8	15 – 36	23.7 ± 6.9	16 – 46
Body mass (kg)	74.8 ± 6.2	56.5 – 85.3	58.8 ± 4.6	51.4 – 68.4
Height (cm)	179.8 ± 5.1	167.1 – 193.5	164.2 ± 5.4	154.2 – 173.1
Body mass index	23.1 ± 1.5	19.4 – 26.2	21.8 ± 1.4	19.6 – 25.1
Sitting height (cm)	94.7 ± 3.9	83.5 – 103	88.4 ± 3.0	83.2 – 95
Arm span (cm)	184.5 ± 6.3	170 – 195.6	165.0 ± 6.9	152 – 180
Sitting height/body height (%)	51.5 ± 1.5	46.2 – 55.8	53.5 ± 1.9	0.47 – 0.59
Arm span/body height (%)	102.6 ± 2.8	94.3 – 111.1	100.5 ± 1.9	96.5 – 104.0
Shoulder breadth (cm)	36.0 ± 2.1	32 – 39.7	30.8 ± 1.1	29.2 – 33.9
Humerus breadth (cm)	7.2 ± 0.4	6.3 – 8.7	6.2 ± 0.4	5.5 – 6.9
Femur breadth (cm)	10.1 ± 0.6	8.7 – 12	9.1 ± 0.4	8.5 – 10.2
Forearm girth (cm)	28.9 ± 1.3	25.5 – 31.4	25.0 ± 0.9	23.2 – 26.8
Flexed arm girth (cm)	35.4 ± 1.8	31.5 – 38.4	30.6 ± 2.1	28.3 – 38.0
Chest girth (cm)	101.6 ± 5.2	85.5 – 110.3	90.9 ± 3.7	81 – 99
Thigh girth (cm)	50.3 ± 3.5	40.9 – 50.6	49.9 ± 3.3	43.1 – 54.9
Calf girth (cm)	36.1 ± 1.8	32 – 41.5	34.9 ± 2.2	30.4 – 40.1
Sum of 5 skinfolds (mm)	32.8 ± 7.1	20 – 47	54.0 ± 13.0	39 – 95
Body fat (%)	8.0 ± 3.2	3 – 16.2	17.0 ± 4.3	10 – 26.6
Endomorphy	1.3 ± 0.3	0.6 – 2.1	2.5 ± 0.8	1.3 – 4.8
Mesomorphy	5.5 ± 0.9	3.9 – 7.8	4.8 ± 0.9	3.3 – 6.6
Ectomorphy	2.7 ± 0.8	1.3 – 4.6	2.4 ± 0.8	0.9 – 3.8

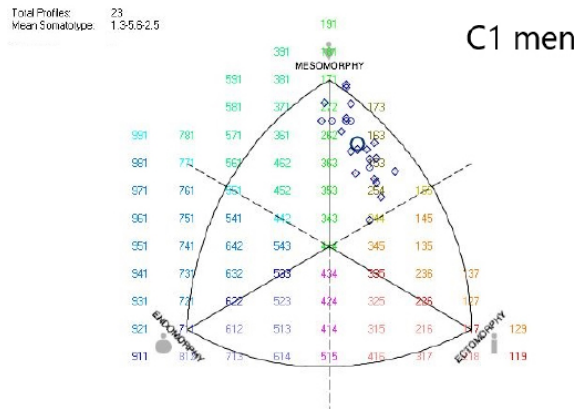


Fig. 1. Somatograph of C1 men paddlers: \diamond individual somatotype; ? average somatotype.

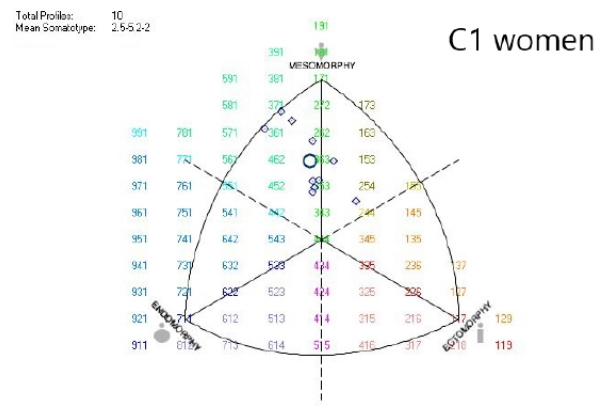


Fig. 3. Somatograph of C1 women paddlers: \diamond individual somatotype; ? average somatotype.

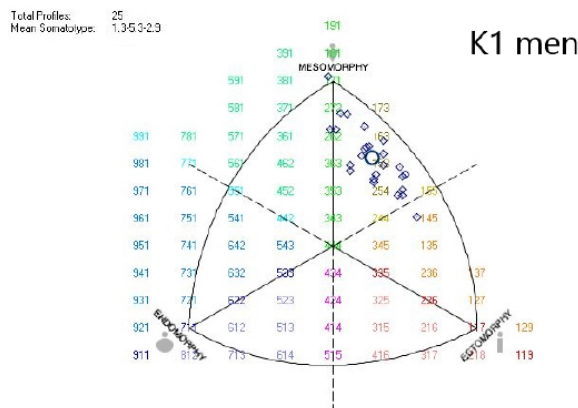


Fig. 2. Somatograph of K1 men paddlers: \diamond individual somatotype; ? average somatotype.

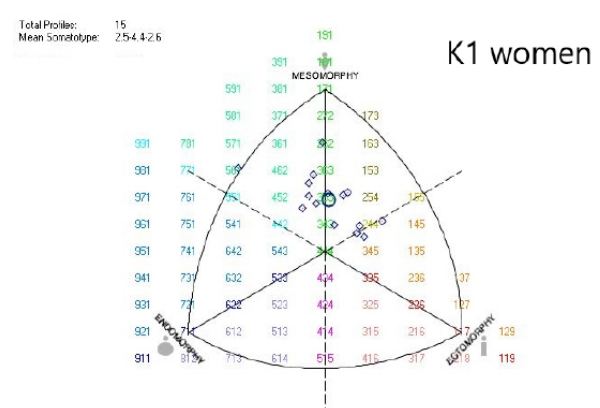


Fig. 4. Somatograph of K1 women paddlers: \diamond individual somatotype; ? average somatotype.

Table II. Comparison between male and female canoe and kayak European paddlers.

Variable	Male paddlers (n=48)				Female paddlers (n=26)			
	Canoe	Kayak	Difference		Canoe	Kayak	Difference	
	(n=23)	(n=25)	p	d	(n=11)	(n=15)	p	d
Age (years)	24.5 ± 4.7	24.2 ± 5.8	0.85	0.06	20.9 ± 3.6	25.9 ± 7.7	0.04	0.83
range	18 – 35	15 – 36			17 – 30	16 – 46		
Body mass (kg)	75.6 ± 6.2	74.0 ± 6.2	0.40	0.25	59.4 ± 4.0	58.4 ± 4.9	0.60	0.22
range	56.5 – 84	63.1 – 85.3			54.1 – 68.4	51.4 – 65.8		
Height (cm)	179.2 ± 5.3	180.3 ± 4.8	0.44	0.21	163.7 ± 6.2	164.4 ± 4.5	0.77	0.12
	167.1 – 191.5	172.1 – 193.5			154.2 – 173.1	157.4 – 171.7		
Body mass index	23.5 ± 1.4	22.8 ± 1.6	0.10	0.46	22.3 ± 1.2	21.6 ± 1.7	0.27	0.47
	20.2 – 25.9	19.4 – 26.2			20.2 – 24.1	19.6 – 25.1		
Sitting height (cm)	94.9 ± 3.7	94.5 ± 3.9	0.71	0.10	88.7 ± 3.1	88.2 ± 2.8	0.65	0.16
	88.5 – 103	83.5 – 102.9			84.4 – 93.0	83.2 – 95		
Arm span (cm)	184.5 ± 5.8	184.6 ± 6.8	0.96	0.01	165.2 ± 7.6	164.6 ± 6.3	0.82	0.08
	172.0 – 193.5	170.0 – 195.6			155.3 – 180	152 – 174.1		
Sitting height/body height (%)	52.9 ± 1.2	52.3 ± 1.7	0.14	0.40	54.2 ± 1.7	53.6 ± 1.1	0.35	0.41
	50.9 – 55.4	46.2 – 55.8			52.5 – 59.1	51.2 – 55.3		
Arm span/body height (%)	103.0 ± 2.7	102.4 ± 2.9	0.46	0.21	100.9 ± 1.8	100.0 ± 1.9	0.30	0.48
	97.8 – 111.1	94.3 – 109.4			92 – 103.9	96.5 – 103.3		
Shoulder breadth (cm)	36.5 ± 1.9	35.5 ± 2.1	0.10	0.49	30.9 ± 1.3	30.7 ± 0.9	0.76	0.17
	32.5 – 39.7	32.0 – 39.5			29.2 – 33.9	29.3 – 33		
Humerus breadth (cm)	7.2 ± 0.5	7.2 ± 0.3	0.90	0	6.3 ± 0.3	6.2 ± 0.3	0.26	0.33
	6.3 – 8.7	6.8 – 7.6			5.5 – 6.7	5.7 – 6.9		
Femur breadth (cm)	10.2 ± 0.6	10.1 ± 0.5	0.54	0.18	9.3 ± 0.3	9.1 ± 0.5	0.18	0.48
	8.7 – 12.0	9.0 – 11.3			8.7 – 9.8	8.5 – 10.2		
Forearm girth (cm)	28.8 ± 1.4	28.9 ± 1.1	0.64	0.07	25.2 ± 0.7	24.8 ± 1.0	0.21	0.46
	25.5 – 31.4	26.1 – 30.4			24.5 – 26.8	23.2 – 26.4		
Flexed arm girth (cm)	35.7 ± 1.9	35.1 ± 1.6	0.28	0.34	30.7 ± 1.2	30.1 ± 1.6	0.32	0.42
	31.5 – 38.4	31.8 – 38.0			28.4 – 33.2	28.3 – 32.6		
Chest girth (cm)	102.0 ± 6.2	101.2 ± 3.9	0.61	0.15	92.3 ± 3.2	90.1 ± 3.7	0.15	0.63
	85.5 – 110.3	91.0 – 107.3			87.7 – 99.0	81.0 – 97.0		
Thigh girth (cm)	50.4 ± 3.6	50.2 ± 3.4	0.79	0.05	51.0 ± 2.6	49.5 ± 3.5	0.26	0.48
	40.9 – 56.0	43.2 – 55.1			47.0 – 54.9	43.1 – 54.2		
Calf girth (cm)	36.0 ± 1.9	36.2 ± 1.8	0.63	0.10	35.5 ± 1.9	34.8 ± 2.6	0.48	0.30
	32 – 38.6	33 – 41.5			32.6 – 38.6	30.4 – 40.1		
Sum of 5 skinfolds (mm)	33.1 ± 7.6	32.6 ± 6.6	0.80	0.07	55 ± 9.5	57.2 ± 17.4	0.69	0.15
	20 – 47	22 – 43			40 – 70	39 – 95		
Body fat (%)	8.6 ± 3.4	7.5 ± 2.8	0.24		17.4 ± 3.2	16.8 ± 5.0	0.70	0.14
	4 – 16.2	3 – 13.3			12.5 – 22.1	10.0 – 26.6		
Endomorphy	1.3 ± 0.3	1.3 ± 0.3	0.32	0	2.5 ± 0.6	2.5 ± 0.9	0.40	0
	0.8 – 2.1	0.6 – 1.8			1.7 – 3.6	1.3 – 4.8		
Mesomorphy	5.6 ± 0.9	5.3 ± 0.9	0.14	0.33	5.2 ± 0.9	4.4 ± 0.8	0.02	0.93
	3.9 – 7.8	3.9 – 7.6			3.9 – 6.6	3.3 – 6.0		
Ectomorphy	2.5 ± 0.7	2.9 ± 0.8	0.04	0.53	2.0 ± 0.7	2.6 ± 0.8	0.03	0.80
	1.3 – 3.8	1.3 – 4.6			0.9 – 3.2	1.0 – 3.8		

DISCUSSION

The primary aim of this study was to determine the morphology of elite canoe slalom paddlers and to identify if morphology differences existed between kayak and canoe paddlers.

Male athletes. In comparing our results with previous research (Ridge *et al.*; Bílý *et al.*, 2011; Vedat, 2012; Bílý *et al.*, 2013), the morphology of canoe slalom male athletes has not changed in the last 2 or 5 decades (Sidney &

Shephard, 1973; Vaccaro *et al.*, 1984; Sklad *et al.*, 1994). The somatotype of elite USA male canoe slalom paddlers revealed a classification of ectomorphic-mesomorphy (2.9 – 5.2 – 2.4), which is similar to the current results except that the endomorphy component is lower. This is probably due to a reduction in fat contribution of contemporary paddlers. In the present study elite slalom athletes were characterized as average in body height (~180cm) and weight (~75kg), with predominantly mesomorphic somatotype, average body ratios, low body fat and specific muscularity developed mainly in the upper limbs and chest. However, there were no statistical and practical significant differences between C1 and K1 paddlers illustrating the physiognomy of C1 and K1 paddlers were similar.

In comparison with flat water canoeing (canoe sprint) athletes (Sitkowski, 2002; Ackland *et al.*, 2003), canoe slalom athletes are smaller in height and weight. In canoe sprint athletes, Ackland *et al.* reported body height and body mass weight of 185±6.0 cm and 84.8±6.2 kg, respectively, which is similar to that reported by Sitkowski of 185.3±1.9 cm and 87.0±4.6 kg. Canoe slalom paddlers have different somatotype in comparison to Olympic canoe sprint paddlers (1.6 – 5.7 – 2.2) (Ackland *et al.*) and elite Lithuanian canoe sprint kayakers (3.5 – 6.2 – 2.8) (Gutnik *et al.*, 2015). Larger differences exist between elite slalom paddlers and elite rowers in body height 191.1 ± 5.7 cm and body weight 87.7 ± 8.0 kg (Sklad *et al.*) and in junior World Championship rowers (body height 187.4 ± 5.8 and weight 82.2 ± 7.4 kg) (Bourgeois *et al.*, 2000). However, in comparison with rowers (Sklad *et al.*; Bourgeois) canoe slalom paddlers have larger biceps girth (35.4 ± 1.8 cm vs. 31.9 ± 2.1; resp. 32.9 ± 1.9 cm). In comparison to other water sports that are characterized by upper limb movement, such as, international canoe polo players, have similar anthropometric measures to canoe slalom athletes (Alves *et al.*, 2012).

From the current results, large competitive canoe slalom males are rare. Body height and weight greater than 190 cm and 80 kg, respectively is uncommon and may be an important aspect for talent identification. Greater body height is often associated with additional weight, which is likely to be detrimental to paddling performance especially when in 2005 international regulations shortened boats from 4.0 m to 3.5m (www.canoeicf.com). Larger competitors are likely to have a disadvantage in optimizing boat hydrodynamic properties. Similar to canoe sprint performance canoe slalom paddlers have large biceps girth (~35 cm) and low body fat (~8 %) (Van Someren & Palmer; 2003; Akca & Muniorglu, 2008), that may correlate to slalom performance.

Female athletes. In comparing the current female K1 competitors to the 2000 Olympic canoe slalom K1

competitors (Ridge *et al.*), body weight (58.4 ± 4.9 vs. 59.0±4.5kg), somatotype (2.5 – 4.4 – 2.6 vs 2.4 - 4.1 – 3) and biceps girth (30.1 ± 1.6 vs. 30.1 ± 1.0) were similar, but current competitors were shorter in body height (164.4 ± 4.9 vs. 168 ± 5). However, they were of similar body height to Australian ranked paddlers (164.4 ± 4.9 vs. 163.0 ± 5.0) (Freeman *et al.*, 1987).

We observed two significant differences between female canoe and kayak paddlers. Firstly, the age was significantly different ($p = 0.04$; $d = 0.83$) with the canoe paddlers being approximately 5 years younger than kayak paddlers. The difference in age probably reflects the female canoe category being a new discipline. The first world championship was scheduled in 2011 (www.canoeicf.com) and it will be held for the first time at the Tokyo Olympic Games, which may have attracted a younger cohort. Secondly, there were significant differences in mesomorphy ($p = 0.02$; $d = 0.93$) and ectomorphy ($p = 0.03$; $d = 0.80$) somatotype values. Canoe paddlers were more mesomorphic and less ectomorphic in comparison with kayak paddlers, and may be explained by different demands of strength abilities.

In comparison to canoe sprint competitors (Ackland *et al.*) the current canoe slalom competitors were of similar height, but had lower body weight (58.8 ± 4.6 vs. 67.3±5.9). Differences between canoe slalom and canoe sprint paddlers are noticeable as early as 15 years of age (Alacid *et al.*, 2012). In addition, when comparing canoe slalom competitors to female rowers (Sklad *et al.*) they were smaller in stature (164.2 ± 5.4 vs. 176.7 ± 6.4), lower body mass (58.8 ± 4.6 vs. 73.4 ± 5.2), and similar biceps girth (30.6 ± 2.1 vs. 30.5 ± 2.9) and chest girth (90.9 ± 3.7 vs. 86.9 ± 3.9). Despite lower body weight, this suggests that canoe slalom female competitors have well developed trunk and arm muscles, which are important physical attributes for canoe slalom.

CONCLUSION

Canoe slalom has evolved with the advancement in technology, course design, coaching, nutrition, physical and psychological training. With a greater emphasis placed on strength, speed and stability we can conclude, that anthropometric parameters of male canoe slalom paddlers have not changed through the preceding decades. Elite slalom male competitors can be characterized to having average body height (~180 cm), average weight (~75kg), with ectomorphic mesomorph somatotype (1.3 – 5.5 – 2.7), well developed trunk and arm muscles (biceps girth: 35.4 ± 1.8), low hypertrophy of legs and low body fat (8 ± 3.2 %). In addition, there are no significant differences between canoe

(C1) and kayak (K1) paddlers. For female competitors we can conclude, there has been little change in anthropometric values through the decades. However, C1 competitors are younger, more mesomorphic and less ectomorphic.

Generally, canoe slalom performance is likely to be disadvantaged, if the athlete has large physiognomy. Body weight over 80 kg in male elite paddlers is rare, similarly body height greater than 190 cm is equivalent for a female of greater than 70 kg and 180 cm. For male and female, K1 and C1 we suggest developing strength without excessive leg hypertrophy. On the contrary, it is probably necessary in canoe slalom to have very well developed muscles of the chest and arms and keep body fat contribution very low.

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RESUMEN: El objetivo de este estudio fue determinar la morfología de los remeros de canoa de slalom de élite e identificar si existían diferencias morfológicas entre los remeros de kayak y canoa. El análisis incluyó un total de 74 remeros de canoa slalom que compitieron en el Campeonato de Europa de 2018. Los competidores fueron evaluados mediante una batería de dimensiones antropométricas según técnicas antropométricas estandarizadas y análisis de bioimpedancia utilizando el dispositivo octopolar multifrecuencia Tanita MC-980. Los competidores masculinos de slalom de élite se pueden caracterizar por tener una estatura corporal promedio (~ 180 cm), un peso promedio (~ 75 kg), con somatotipo mesomorfo ectomorfo (1,3 - 5,5 - 2,7), músculos del tronco y del brazo bien desarrollados (circunferencia del bíceps: 35,4 ± 1,8), baja hipertrofia de piernas y baja grasa corporal (8 ± 3,2 %). Además, no existen diferencias significativas entre los remeros en canoa (C1) y kayak (K1). Para las competidoras, podemos concluir que se han observado pocos cambios en los valores antropométricos a lo largo de las décadas. Sin embargo, los competidores de C1 son más jóvenes, más mesomórficos y menos ectomórficos.

PALABRAS CLAVE: Antropometría; Impedancia bioeléctrica; Somatotipo; Kayak slalom; Slalom en canoa.

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