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Strength and Strength-Related Anthropometric Parameters of the International Level Canoe Slalom Male Paddlers

Fuerza y Parámetros Antropométricos Relacionados con la Fuerza de los Hombres Remeros de Canotaje Slalom de Nivel Internacional

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SUMMARY: The aim of the study was to determine the differences in hand-grip strength and strength-related anthropometric parameters between the highest-performance international paddlers (HILP) and other international paddlers (ILP) in canoe slalom. In male competitors (n=48; 23 canoeists and 25 kayakers) who took part in the 2018 European championship event in canoe slalom in Prague, Czech Republic representing 15 European countries were measured hand-grip strength and strength-related anthropometric parameters two days prior the event. Differences between the group of HILP (medallists from Olympic Games, world championship and European championship in the previous three years and European championship finalists at the same time) and ILP were found. HILP have significantly higher forearm, arm and chest girths than ILP. Moderate or high practical differences and margin statistic differences were found also for hand-grip strength, body weight, body mass index and age. The consistently high-performing paddlers are heavier, have more muscular upper body and are stronger than the other group, while keeping their lower body lean. Therefore, regular upper-body strength training to all canoe slalom paddlers is important but caution is required because body weight over 80 kg may be a limiting factor.

KEY WORDS: Water sport; Training; Handgrip; Whitewater; Canoe slalom.

INTRODUCTION

Canoe slalom is a timed event where competitors navigate a white-water course by passing through a combination of upstream and downstream gates. There are two boat categories: kayakers (K1) have two paddle blades and are seated in their boat; canoeists (C1) have a single blade and kneel in their boat.

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 (Nibali *et al*., 2011). 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. The major role in the propulsive phase of a canoe/kayak stroke requires latissimus dorsi (Trevithick *et al*., 2007) and the forearm muscles to transmit muscular power generated that are not phylogenetically adapted (Kracmar *et al*., 2016). Additionally, canoe slalom paddlers use narrower hand grips, which results in shorter, more powerful strokes with increased elbow flexion compared to that of a top-level sprint. According to Kracˇmar *et al*. (2016) the forearm muscles are very often the weakest part of the muscle chain and for this reason wrist and elbow tendinitis is very common injury in white water slalom (Fiore & Houston, 2001). Therefore, forearm strength and endurance are known to be important performance factors in canoeing (Hamano *et al*., 2015). Hamano *et al*. (2015) reported a strong correlation between handgrip strength and performance in canoeing ($r=0.745$; $p<0.01$) and kayaking ($r=0.636$; $p<0.01$).

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Slalom tasks require great physical fitness and precise technical skills (Messias *et al*., 2014). Over the last 40 years canoe slalom has evolved and strength training has gained higher importance, which is a feature of other sports (Messias *et al*., 2021). Canoe slalom competition preserves the unpredictability (Nibali *et al*., 2011) and therefore it is difficult to find strong performance predictors. Previous research showed significant and medium high correlations between strength tests (e.g., 1-RM bench-press, 30 seconds peak power in arm-crank Wingate test) (Busta *et al*., 2018) and significant differences between the athletes who were and were not selected to the national team in strength-related anthropometric parameters such as, flexed arm girth, forearm girth, and chest girth (Busta *et al*., 2018). Significant strong correlations have been observed between upper arm girth and short distance performance in canoe sprint (Akca & Muniorglu, 2008) and between upper and forearm girth in canoe/kayak ergometer performance test (Hamano *et al*., 2015).

Anthropometric parameters are well known in canoe slalom (Ridge *et al*., 2007) where there are no significant differences between C1 and K1 category (Coufalová *et al*., 2021). However, differences in strength-related anthropometric parameters between the highest-performance international paddlers and other international paddlers in canoe slalom are still unclear, further it is unknown if differences exist in hand-grip strength within an elite group of paddlers. Therefore, the aim of the study was to determine the differences in hand-grip strength and strength-related anthropometric parameters between the highest-performance international paddlers and other international paddlers in canoe slalom. It was hypothesised that the highest-performance international paddlers will have significantly higher hand-grip strength and strength-related anthropometric parameters such are forearm, arm and chest girths or mesomorphy component of the somatotype.

MATERIAL AND METHOD

Participants. Male competitors (n=48; 23 canoeists and 25 kayakers) who took part in the 2018 European championship event in canoe slalom in Prague, Czech Republic representing 15 European countries volunteered to participate in the study and provided written consent. The study was approved by the university ethical committee. There were no significant differences in hand-grip strength and strength-related anthropometric parameters between canoe and kayak paddlers and therefore both groups were combined. However, the training status of the competitors was divided into two sub-groups according to their long-term performance:

- Highest international performance level paddlers (HILP), which included medallists from Olympic games, World championships and European championships in previous 3 years and at the same time finalists from the European championship 2018 (n=6),
- International performance level paddlers (ILP), participants of the European championship 2018 (n=42).

Data collection

Anthropometric measurements. 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. Other anthropometric parameters (forearm, flexed arm, chest, thigh and calf girths) were measured according to techniques suggested by the Anthropometric Standardization Reference Manual. Skinfold thicknesses (triceps, subscapular, suprailiac, thigh and calf skinfold) were measured by a caliper BEST K-501, Trystom, CZE) to determine the somatotype that were calculated according to equations of Heath & Carter (1990).

Grip strength. Handgrip isometric strength was assessed with a conventional dynamometer (Takei TKK 5401, Takei Scientific Instruments, Tokyo, Japan) according to Balás *et al*. (2015). In a sitting position, the paddlers grasped the hand dynamometer by the dominant hand with elbow in full extension, arm near the body and gradually applied maximal pressure for at least for 2-s. The best of three consecutive trials with the dominant arm was considered for data analysis. A 30-s recovery was allowed between trials. During the grasp the stretched hand was not allowed to touch any part of the body. The moveable part of the handle was adjusted to reach the first phalanx of the ring-finger.

Data analysis. Descriptive statistics of data were used to compare highest international performance level paddlers and international performance level paddlers. To determine differences between the groups an independent student´s T-test was used. All statistical calculations were performed using IBM SPSS for Windows (version 24, Chicago, Il., USA). Statistical significance was set at $p<0.05$. To determine practical differences between the groups 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). Mean and standard deviation were calculated for all variables.

RESULTS

Table I illustrates differences between highest international performance level (n=6) and international performance level (n=42) in male competitors. Significant statistic differences between the performance groups were found in dominant forearm girth, dominant flexed biceps girth and chest girth. For these parameters were also found moderate or large practical difference. Moderate or large practical differences with low p-value in the same time were found in hand-grip strength of right and dominant hand, body weight, body mass index (BMI) and age.

Table I. Differences between highest international performance level and international performance level in male competitors

Men	HILP (n=6)		ILP (n=42)		Differences	
	Mean ± SD	Range	Mean ± SD	Range	p	d
Age	28.7 ± 4.6	21 - 35	23.7 ± 5.1	15 - 36	0.06	1.02
Body height (cm)	180.8 ± 4.8	172 – 186	179.6 ± 5.1	167 – 193.5	0.64	0.24
Body weight (kg)	79.0 ± 4.6	71.9 – 85.3	74 ± 6.2	56.5 – 84.1	0.06	0.91
BMI	24.2 ± 1.1	22.5 – 25.9	23.0 ± 1.5	19.4 – 26.2	0.06	0.91
Endomorphy	1.3 ± 0.3	0.9 – 1.9	1.3 ± 0.3	0.6 – 2.1	0.73	0
Mesomorphy	5.5 ± 0.7	4.5 – 6.5	5.4 ± 0.9	3.9 – 7.8	0.82	0.12
Ectomorphy	2.3 ± 0.7	1.5 – 3.2	2.8 ± 0.8	1.3 – 4.6	0.14	0.66
Arm span (cm)	187.9 ± 3.8	181 - 193	184.1 ± 6.4	170 – 195,6	0.086	0.72
Hand-grip right (kgf)	63.8 ± 6.6	55.3 – 73.7	57.0 ± 6.5	43.7 – 69.0	0.07	1.03
Hand-grip left (kgf)	60.9 ± 6.3	54.9 – 70.8	55.9 ± 5.9	43.6 – 66.9	0.14	0.81
Hand-grip dominant (kgf)	63.7 ± 6.7	55.1 – 73.7	56.2 ± 6.8	43.6 – 68.9	0.05	1.11
Dominant forearm girth (cm)	30.3 ± 0.6	29.5 – 31.4	28.7 ± 1.2	25.5 – 31.0	0.00	1.68
Dominant flexed biceps girth (cm)	36.9 ± 0.9	35.6 – 38.0	35.2 ± 1.8	31.5 – 38.4	0.00	1.19
Chest girth (cm)	106.1 ± 3.3	101.1 – 110.3	101.0 ± 5.1	85.5 – 110.0	0.01	1.18
Thigh girth (cm)	52.3 ± 2.0	48.8 – 55.1	50.0 ± 3.6	40.9 – 56.0	0.06	0.78
Calf girth (cm)	35.5 ± 1.6	32.2 – 37.0	36.2 ± 1.9	32.0 – 41.5	0.39	0.40

DISCUSSION

The main finding of this study indicates that HILP have significantly higher forearm (p=0.00), arm (p=0.00) and chest (p=0.01) girths than ILP. Moderate or high practical differences and margin statistic difference were found also for hand-grip strength and indicates that there is a difference in strength between HILP and ILP. Our hypothesis was therefore accepted.

In the current study the hand-grip strength between HILP (63.8 ± 6.6 kg) and ILP: 57.0 ± 6.5) was the same, however the right-hand grip strength in both HILP and ILP (63.8 and 57.0 kg, respectively) was superior to previously reported in moderately-trained canoe slalom athletes (47 ± 9.5 kg) (Massy-Westropp *et al*., 2011). In canoe sport disciplines similar values of handgrip strength was observed in Iranian male Canoe Polo Team (61.6 ± 9.6 kg) (Sheykhlouvand *et al*., 2015). A similar level of hand-grip strength was observed in male adult canoe slalom paddlers (C1 category) of 55.1 and 54.1 kg (Ferreira *et al*., 2008; Busta & Suchy, 2016). In contrast, lower hand-grip strength was observed in junior paddlers (Dokumaci & Çakir-Atabek, 2015) for national level canoe sprint paddlers (38.1 kg), national level canoe (42.5 kg), kayak (44.7 kg) sprint paddlers (Tamoghni & Adhikari, 2018), and international level junior canoe slalom paddlers (44.9 kg) (Busta & Suchy, 2016). Additionally, lower hand-grip was also observed for university level canoe (50.0 kg) and kayak (50.6 kg) sprint paddlers of Japan. Ferreira *et al*. (2008) reported that in kayaking, hand-grip strength level was significantly smaller compared to canoeing (K1: 46.2 kg, C1: 55.1 kg), however, in the current study there was no statistical or practical difference between C1 (57.1 ± 7.9) and K1 paddlers (57.2 ± 6.4). In supporting this Hamano *et al*. (2015) did not observe any difference between C1 and K1 paddlers in the hand-grip strength. Differences between C1 and K1 are unlikely to be significant in canoe sport disciplines. The current study shows that practical differences were found between HILP and ILP in right handgrip (d=1.03; p=0.07), left hand-grip (d=0.81; p=0.14) and dominant hand-grip strength (d=1.11; p=0.05). Based on the moderate practical differences and threshold statistic differences it is possible that HILP are stronger (dominant hand-grip strength: 63.7 vs 56.2 kg) than less successful ILP.

Anthropometric parameters and somatotype of European championship competitors were very similar to parameters and somatotype of Ridge *et al*. (2007) for competitors at the Sydney 2000 Olympic Games. Anthropometric parameters of elite canoe slalom paddlers have not change fundamentally during the last 20 years. We observed several moderate practical differences in anthropometric parameters between HILP and ILP. Moderate practical differences were found in age (d=1.02; p=0.06), body weight (d=0.91; p=0.06) and BMI (d=0.91; p=0.06). In addition, three statistic and moderate or large practical differences were found in forearm girth (d=1.68; p=0.00), flexed biceps girth (d=1.19; p=0.00) and chest girth (d=1.18; p=0.01). Based on the moderate practical differences and threshold statistic differences this may infer that HILP are heavier (weight: 79 vs. 74 kg) and more muscular (BMI: 24.2 vs. 23.0; forearm girth: 30.3 vs 28.7 cm; flexed biceps girth: 36.9 vs 35.2 cm; chest girth: (106.1 vs. 101.0 cm). However, no significant difference was found in the circumferences of the lower limb. HILP have more developed trunk and arm muscles but not lower limb muscles. Therefore, this is indicative that their physique is better adapted to canoe slalom because they can maximize upper-body muscle hypertrophy while at the same time they can maintain low hypertrophy of the lower body. In supporting this Busta *et al*. (2018) reported body weight should not exceed 80 kg for all international level canoe slalom paddlers. Body weight over 80 kg for international level paddlers is very rare, from the current sample population (n=48) only 5 competitors exceeded 80 kg, with a maximum weight was 85.3 kg. The group of HILP were approximately 5 years older (d=1.02; p=0.06). The age of HILP (28.7 years) was similar as the age of Olympic participants in Sydney (28.1 years) (Ridge *et al*., 2007) and illustrates a high influence of experiences on the canoe slalom performance.

CONCLUSION

Several differences were found between highest international performance level paddlers (medallists from Olympic Games, world championship and European championship in previous 3 years and European championship finalists at the same time) and other international performance level paddlers. The consistently high-performing paddlers are heavier, have more muscular upper body and stronger than the other group, while keeping their lower body lean. Therefore, regular upper body strength training to all canoe slalom paddlers is important but caution is required because body weight over 80 kg may be a limiting factor. Thus, a well-constructed periodized resistance programme that can build the appropriate muscular and neural adaptations for strength and power is encouraged. The consistently high performing paddlers are also approximately five years older, illustrating that there is a large influence of sport age and experiences in canoe slalom.

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RESUMEN: El objetivo del estudio fue determinar las diferencias en la fuerza de prensión manual y los parámetros antropométricos relacionados con la fuerza entre los remeros internacionales de alto rendimiento (RIAR) y otros remeros internacionales de canotaje en slalom. En hombres competidores (n=48; 23 piragüistas y 25 kayakistas) que participaron en el campeonato europeo de slalom en canoa de 2018, en Praga, República Checa, que representa a 15 países europeos, se midió la fuerza de agarre manual y los parámetros antropométricos relacionados con la fuerza dos días antes del evento. Se encontraron diferencias entre el grupo de RIAR (medallistas de Juegos Olímpicos, campeonatos del mundo y campeonatos de Europa en los tres años anteriores y finalistas del campeonato de Europa al mismo tiempo) y remeros internacionales. Los RIAR presentaban circunferencias de antebrazo, brazo y pecho significativamente más altas que los remeros internacionales. Además, se encontraron diferencias prácticas moderadas o altas y diferencias estadísticas en el límite para la fuerza de prensión manual, el peso corporal, el índice de masa corporal y la edad. Los remeros de alto rendimiento son más pesados, tienen la parte superior del cuerpo más musculosa y son más fuertes que el otro grupo, mientras mantienen la parte inferior del cuerpo esbelta. Por lo tanto, es importante el entrenamiento regular de fuerza de la parte superior del cuerpo para todos los remeros de piragüismo, sin embargo se requiere precaución debido a que el peso corporal superior a 80 kg puede ser un factor limitante.

PALABRAS CLAVE: Deporte acuático; Capacitación; Empuñadura; Agua Blanca; Eslalon en canoa.

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