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# Physical Fitness Parameters of Elite Chinese Male Canoe Slalom Paddlers

## Parámetros de Aptitud Física de los Remeros Masculinos Chinos de Élite en Canoa Slalom

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**SUMMARY:** This study aimed to investigate the physical fitness parameters of elite Chinese male canoe slalom athletes and explore the corresponding training strategies. Eight elite male slalom kayakers from the Chinese national team were selected as research subjects. The following parameters were measured: age, height, weight, body mass index (BMI), arm span, upper arm circumference, body fat percentage, maximum oxygen uptake, heart rate, blood lactic acid level, upper limb strength, and 300-m linear speed in flat water. Compared with elite international male slalom athletes, elite Chinese male slalom athletes had lower values for age, height, weight, BMI, arm span, and upper arm circumference, while body fat percentage, bench push, and bench pull values were greater, and the 300 m straight-line speed in flat water was slower. From an athlete development and physical training perspective, elite Chinese male slalom athletes should prioritize the accumulation of competitive experience instead of increasing training years in order to swiftly reach top international standards. Additionally, these athletes should manage their body fat percentage and improve their aerobic capacity, paddling skills, mechanical work, and linear speed in flat water.

**KEY WORDS: Canoe slalom; Physical fitness; Anthropometry; Strength; Speed.**

## INTRODUCTION

The canoe slalom is a timed event where competitors navigate a whitewater course by passing through a combination of upstream and downstream gates (width 1.2-4.0 meters). Each course is different, to a maximum of 300 m in length, containing a maximum of 25 gates and a minimum of six upstream gates. Courses are designed such that are completed by leading athletes in 90-110 s, although time penalties for touching a gate (2 s) and missing a gate (50 s) are incurred.

The Olympic canoe slalom competition includes four events: women's kayak (WK1), men's kayak (MK1), women's canoe (WC1), and men's canoe (MC1). Competition characteristics place high demands on athletes' physical, technical, cognitive, and psychological abilities (Macdermid *et al*., 2019); with physical fitness being an important foundation for an athletes' competitive abilities. Literature reveals that most studies have analyzed the physical fitness and paddling techniques of elite canoe slalom paddlers from an anthropometric, exercise physiology, and exercise biomechanics perspectives, and that there are more studies on male athletes than female athletes.

Athletic physical fitness includes three major elements: body shape, physiological function, and physical quality, each of which contains a large number of specific parameters that comprehensively reflect fitness status. An athlete's body shape is predominantly controlled by genetic factors and, with the exception of body weight, there is limited change affected by sports training. Elite athletes often exhibit body shapes that conform to the characteristics of their sport (Ren *et al*., 2019). Presently, only a few studies have specifically focused on the anthropometric parameters of elite canoe slalom paddlers, and some studies have only categorized them according to sex without distinguishing event categories (Vedat, 2012; Bielik *et al*., 2019).

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Busta *et al*. (2018a) showed that when selecting athletes for the Czech national team for the MC1 event at the Rio 2016 Olympic Games, there was no statistically significant difference in somatotype between those selected and those not selected; however, forearm (27.8 ± 0.6 cm vs. 26.8 ± 1.4 cm), upper arm (35.60 ± 1.5 cm vs. 33.5 ± 1.7 cm), and chest circumference (98.3 ± 2.4 cm vs. 93.9 ± 2.3 cm) were significantly larger among those selected ($p < 0.05$), and this was considered to be directly related to higher strength levels of the athlete. Additionally, the total skinfold thickness and body fat percentage were lower in the selected athletes (Busta *et al*., 2018a). Bily *et al*. (2011) suggested that a longer arm span facilitates better performance of specific paddling skills and is one of the most important physical characteristics to enable slalom kayakers to reach the highest level of competition.

Similar to canoe sprint and rowing athletes, canoe slalom athletes require a good metabolic capacity for both anaerobic and aerobic energy systems. Zamparo *et al*. (2006) arrived at a similar conclusion. In a simulated competition, the proportions of phosphonic, glycolytic, and aerobic energy systems in Italian MK1 players were 24.9 %, 29.9 %, and 45.2 %, respectively. Therefore, if the upper-body strength of an athlete is increased and the paddling technique is optimized, a reduction in energy expenditure and an increased efficiency in energy metabolism should be prioritized (Zamparo *et al*., 2006).

The load intensity of canoe slalom races is high. Messias *et al*. (2015) showed that the highest and average heart rates of elite slalom athletes were 184 ± 8 and 173 ± 14 bpm, respectively. Gao *et al*. (2018) stated that elite Chinese slalom athletes had an average heart rate of 171.4 ± 4.9 bpm in simulated competitions, and blood lactate values on the 3rd min of simulation tests of 13.8 ± 3.4 mmol/L in MK1, 13.3 ± 1.8 mmol/L in WK1, and 13.6 ± 1.8 mmol/L in MC1. Baker (1982) showed that the mean blood lactate levels in British elite slalom athletes 4-5 min after the World Championships were 16.18 ± 1.20 mmol/L in MK1, 12.20 ± 1.77 mmol/L in WK1, and 13.10 ± 1.75 mmol/L in MC1. Zamparo *et al*. (2006) found that the blood lactate value of Italian men's kayakers after a simulated slalom race was 12.9 ± 1.2 mmol/L (the average of the 3rd and 5th min).

Existing studies have predominantly used cardiopulmonary function tests combined with treadmills or paddling ergometers, standardized arm crank ergometry, or graded functional tests. Busta *et al*. (2018b) stated that the maximum oxygen uptake of a slalom athlete is also referred to as the peak oxygen uptake ($VO_{2peak}$) because of the difficulty in achieving maximum oxygen uptake in a water rowing test or upper body ergometer test at the equivalent level of the lower body or whole-body exercise test. Busta & Bily (2014) tested the cardiopulmonary function of eight elite Czech male slalom athletes under extreme load conditions using arm crank ergometry and the paddling ergometer, with reported values for $VO_{2peak/kg}$ of 66.29 ± 3.16 ml/kg/min and 38.49 ± 7.92 ml/kg/min, respectively. The $VO_{2peak}$ measured using the paddling ergometer was 41.93 % lower than that measured using the arm-crank ergometry test. However, the heart rate index was relatively similar (183.0 ± 6.02 vs 181.88 ± 4.99 beats/min), so it is proposed that the test method that replicates the specific technique is more conducive to evaluating the physiological function of the athletes (Busta & Bily, 2014).

Canoeists require superior upper body strength, strength endurance, explosive power, and trunk stability (Rynkiewicz *et al*., 2019). Absolute strength is the foundation, strength endurance is beneficial for maintaining speed advantage, whereas explosive power is effective for improving sprinting during the acceleration phase (Liow & Hopkins, 2003). The bench press and pull exercises are often used for upper-body strength training and testing (McKean & Burkett, 2013; Busta & Suchy, 2016). In addition, because athletes in rowing sports need to counteract their body weight, weight must also be considered when evaluating the strength level of athletes, that is, the evaluation of relative strength (Busta & Suchy, 2016). The muscle strength of the upper body forms the basis of slalom kayaker paddling efficacy. However, the specific strength characteristics of slalom kayakers should not only examine the muscle strength level but also the mechanical stroke parameters.

Existing studies have often used kayak power meters or tethered test methods to test the peak paddle force, paddle time, power, impulse, and other mechanical parameters (Ferrari *et al*., 2017; Messias *et al*., 2018). The peak stroke power largely reflects the explosive power of athlete paddling. These can be used as essential indicators to evaluate the specific strength levels of slalom athletes. Messias *et al*. (2015) used an all-out 30 s test to determine the mechanical parameters of 12 elite male kayakers of the Brazilian national team and found that the absolute peak paddling force of the athletes was 170.29 ± 35.36 N and the absolute paddling impulse was 3634.73 ± 707.26 N•s.

The best result for Chinese canoe slalom athletes at the Olympic Games was sixth place in MC1. There is a gap between the overall level of Chinese competition and that of top international athletes. Currently, the lack of research on physical fitness parameters and training strategies for canoe slalom athletes in China has restricted the development of this sport. Therefore, this study tested the physical fitness parameters of elite Chinese male slalom athletes, including anthropometric, physiological, and physical qualities; compared them with the related indicators of elite international male slalom athletes in the relevant literature; analyzed the characteristics of the parameters and their training concerns; and provided references for the research and application for physical training of these athletes.

## MATERIAL AND METHOD

**Participants and study design.** Eight elite male canoe slalom players from the Chinese national team (age: 24.5 ± 2 years; four male kayakers and four male canoeists), who had participated in the canoe slalom world championships, were recruited for the study. Informed consent was obtained from all the participants, and the study protocol was reviewed and approved by the Scientific Research Ethics Committee of Wuhan Sports University.

**Data collection and instruments.** Anthropometric parameters including height, weight, body mass index (BMI), arm span, upper arm circumference, and body fat percentage were measured using a tape measure, scale Martin ruler, and a skinfold caliper. The physiological indicators included $VO_{2peak/kg}$, heart rate, and blood lactate levels. An Italian Cosmed K4b2 cardiorespiratory fitness tester was used to test the $VO_{2peak/kg}$ using a running platform (treadmill) with an incremental exercise program at a constant speed of 11.2 km/h and a gradual incline of 2.5 %/ 2 min to exhaustion (Modified Astrand, 1978). A Finnish POLAR V800 heart rate meter was used to measure the heart rate. Blood lactate levels were measured using a German EKF portable blood lactate meter with a range of 0.5 to 25.0 mmol/l and a high precision coefficient of variation (C.V.) of 3 % in 15 s.

The physical quality indicators included bench press and bench pull absolute strength, relative strength, and 300 m straight-line speed in flat water. Kayak bench press and bench pull trainers were used to test the muscle strength of the athletes. A complete warm-up was performed, and the starting load for absolute strength test is based on the best result from the previous test, it was divided into three incremental loads until the strength limit of 1RM was reached, with the best result obtained as the final result. The standard canoe sprint course tests a 300 m straight-line speed. The 300 m straight-line course was marked, and staff were assigned to give the order and time at the start and finish, respectively. Athletes started individually and two groups were measured with a 20-minute interval between groups; the best result was obtained from the two groups, and the heart rate and lactate levels were measured 3 min after completion of the test.

**Statistical analyses.** SPSS (version 25.0, Armonk, NY, IBM Corp.) was used to analyze descriptive statistics (anthropometric, physiological, and physical parameters), and data were expressed as means ± standard deviation (means ± SD).

Table I. Physical fitness parameters of elite Chinese and international slalom male paddlers.

| Parameters | Best Chinese male slalom athletes (n=8) | | Elite international male slalom athletes |
|---|---|---|---|
| | Mean ± SD | Range | Mean ± SD |
| Age (years) | 24.5 ± 2.0 | 22 - 27 | 28.7 ± 4.6 (Busta *et al.*, 2022, n=6) |
| Height (cm) | 176.8±5.3 | 168.0 - 181.0 | 180.8 ± 4.8 (Busta *et al.*, 2022, n=6) |
| Weight (kg) | 74.4±3.7 | 68.1 - 77.7 | 79.0 ± 4.6 (Busta *et al.*, 2022, n=6) |
| BMI | 23.8 ± 1.0 | 22.5 - 25.7 | 24.2 ± 1.1 (Busta *et al.*, 2022, n=6) |
| Arm span (cm) | 181.5±1.6 | 178.6 -185.3 | 187.9 ± 3.8 (Busta *et al.*, 2022, n=6) |
| Upper arm circumference (cm) | 36.1±0.9 | 34.5 - 37.0 | 36.9 ± 0.9 (Busta *et al.*, 2022, n=6) |
| Body fat percentage (%) | 9.6±0.4 | 8.8 - 10.2 | 7.5 ± 2.3 (Busta *et al.*, 2018, n=5) |
| $VO_{2max/kg}$ (ml/kg/min) | 57.3±3.1 | 53.1 - 60.7 | 60.4 ± 6.2 (Bielik et al., 2019, n=6) |
| Absolute strength of bench press (kg) | 131.9±13.4 | 115.0 - 155.0 | 114.0 ± 14.5 (Busta *et al.,* 2016, n=6) |
| Absolute strength of bench pull (kg) | 111.6±4.8 | 105.0 - 120.0 | 98.0 ± 8.5 (Busta *et al.,* 2016, n=3) |
| Relative strength of bench press | 1.8±0.2 | 1.5 - 2.0 | 1.5 ± 0.1 (Busta *et al.,* 2016, n=3) |
| Relative strength of bench pull | 1.5±0.1 | 1.34 - 1.7 | 1.3 ± 0.1 (Busta *et al.,* 2016, n=3) |
| 300-m linear speed (seconds) | 107.3±8.1(MK1:99.7±0.5, n=4) | 99.1 - 116.0 | 88.1 ± 7.7 (Zamparo *et al.,* 2006, n=8) |
| Heart rate after 300-m test (beats/min) | 178.0±3.0 | 172.6 - 182.1 | 184.0 ± 7.0 (Zamparo *et al.,* 2006, n=8) |
| Blood lactic after 300-m test (mmol/ L) | 12.3±1.9 | 9.0 - 15.3 | 11.9 ± 1.5 (Zamparo *et al.,* 2006, n=8) |

The research subjects of Busta *et al*. (2022) were the highest international performance level male slalom competitors (n=6), which included medalists from Olympic games, world championships, and European championships in the previous 3 years, and concurrent finalists from the European championship of 2018. The research subjects of Busta *et al*. (2018) were five MC1 players on the Czech national team. The research subjects of Bielik (2019) were six male slalom athletes from the Slovak national team. The research subjects of Busta *et al*. (2016) were three MC1 players from senior national teams in the Czech Republic, and those of Zamparo *et al*. (2006) were eight middle- to high-class MK1 players, all but two belonging to the Italian national white water team.

## RESULTS

Table I shows the physical fitness parameters of elite Chinese male slalom athletes and comparative parameters of elite international male slalom athletes from the relevant literature. The age, height, weight, BMI, arm span, and upper arm circumference of elite international male slalom athletes were obtained from Busta *et al*. (2022). Body fat percentages of elite international male slalom athletes were obtained from Busta *et al*. (2018a,b). The $VO_{2max/kg}$ index of elite international male slalom athletes was obtained from a study by Bielik *et al*. (2019). The absolute and relative strength parameters for the bench press and pull in elite international male slalom athletes were obtained from Busta & Suchy (2016). The results of the 300 m straight-line speed test in flat water of elite international male kayakers were obtained from Zamparo *et al*. (2006). The data for comparison with the relevant indicators of the elite Chinese male slalom athletes were based on the same test method to ensure objectivity.

## DISCUSSION

Busta *et al*. (2022) pointed out that elite international male slalom athletes are generally older (28.7 years), which was similar to the age of Olympic participants in Sydney (28.1 years) and illustrates a high influence of canoe slalom experience (Busta *et al*., 2018a,b). Compared with the average international athlete, the highest-performance international paddlers 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, respectively). MC1 players are relatively tall approximately ≥180 cm; and male kayakers typically weigh <80 kg. Previous studies have reached similar conclusions (Bily *et al*., 2011; Vedat, 2012; Busta *et al*., 2018a,b; Bielik *et al*., 2019).

Table I and Figure 1 (A to G) show that, compared with elite international male slalom athletes, their Chinese counterparts are younger (24.5 ± 2.0 vs. 28.7 ± 4.6 years, respectively), shorter (176.8 ± 5.3 vs. 180.8 ± 4.8 cm, respectively), leaner (74.4±3.7 vs. 79.0 ± 4.6 kg, respectively), have a lower BMI (23.8 ± 1.0 vs. 24.2 ± 1.1, respectively), shorter arm span (181.5 ± 1.6 vs. 187.9 ± 3.8 cm, respectively), lower upper arm circumference (36.1 ± 0.9 vs. 36.9 ± 0.9 cm, respectively), and higher body fat percentage (9.6 ± 0.4 % vs. 7.5 ± 2.3 %, respectively). To improve the physical performance of Chinese male slalom athletes, from the perspective of athlete development and physical training, it is recommended that the national team preferentially select athletes with greater height, longer arm span, larger upper arm circumference, and greater muscle mass for training; moreover, the athletes should improve control of their body fat percentage.

According to the slalom competition protocol, the time between two rounds of heats is approximately 1 h, and the time between heats and finals is approximately 24 h. Full-race athletes have good anaerobic and aerobic metabolisms, and multi-round competitions require athletes to have an outstanding aerobic capacity to improve fatigue recovery. Bielik *et al*. (2019) found a $VO_{2max/kg}$ of 60.4 ± 6.2 ml/kg/min (n=6) for elite Slovakian male kayakers in the 2016 Rio Olympic cycle and suggested that slalom kayakers may benefit from the oxidative system during rest or intervals between trials, acting indirectly on performance. Using the same treadmill test, the $VO_{2max/kg}$ of elite Chinese male slalom athletes was found to be 57.3 ± 3.1 ml/kg/min, lower than the Slovakians (Fig. 1H, Table I). Nonetheless, judging from the decreasing speed of Chinese male slalom athletes in the latter part of the race and their lack of ability to compete continuously, these athletes need to improve their aerobic capacity (Gao *et al*., 2021).

Figure 1 (I and J) and Table I show that the Chinese male kayakers and canoeists outperformed the Czech National Team male canoeists in both absolute and relative values of the bench press and bench pull tests. However, muscle strength is not the only physical quality that affects slalom performance. The actual paddling efficacy must be analyzed in terms of an athlete's mechanical paddling parameters, particularly peak paddling force, power, and impulse, as well as their ability to maintain these parameters throughout the race. Macdermid *et al*. (2020) tested the mechanical paddling parameters of competitors in a continental-championship race and found that elite competitors exhibited fewer propulsive strokes and more turning strokes (11 vs. 3, paddle time between 1.0 and 1.2 s) in the faster run on the same course, and that turning strokes had greater impulse (208 vs. 94 N•s), and peak force (362 vs. 321 N), but a lower rate of peak force development (810 vs. 1925 N•s-1). To the best of our knowledge, there is a lack of research on the biomechanical stroke parameters in elite Chinese slalom athletes, which should be analyzed to determine the specific technical performance of these athletes. In particular, the upper body strength of elite Chinese male slalom athletes was better than that of the elite international male slalom athletes; however, their paddling speed was lower.

Unlike the general human displacement speed, the canoe slalom speed is a reflection of the speed at which an athlete can row forward and successfully cross the gate. On the one hand, athletes need to have a good flat water paddling speed. However, athletes require reasonable line awareness, excellent boat control skills, and a stable mentality to complete an entire race in white water. Few studies have been conducted on the paddling speeds of slalom athletes in flat waters, which are typically tested in the context of paddle mechanics. Zamparo *et al*. (2006) tested Italian male kayakers (n=8) with a hydrostatic 300 m race time of 88.1 ± 7.7 s, and found that they had a heart rate of 184 ± 7 beats/min and a lactate level of 11.9 ± 1.5 mmol/L (3rd and 5th-min averages). In comparison elite Chinese male slalom athletes had significantly slower straight-line speeds 107.3 ± 8.1 s (KM1: 99.7 ± 0.5 vs. 88.1 ± 7.7 s) in flat water, lower heart rates (178.0 ± 3.0 vs. 184 ± 7 beats/min) and higher lactate levels (12.3 ± 1.9 vs. 11.9 ± 1.5 beats/min) than the Italian KM1 players (Figs. 1K-M, Table I). KM1 was the fastest of the four Olympic Canoe Slalom events. However, elite Chinese male kayakers are significantly slower in flat water than international paddlers, and Gao *et al*. (2021) pointed out in previous studies that the performance of elite Chinese slalom athletes in the Olympic Games is approximately 10 s slower that of top international competitors. In addition to strengthening specific technical training, elite male Chinese slalom athletes should improve their paddling speed in flat water.

## CONCLUSION

The physical fitness parameters reported in this study indicated that the age, height, weight, BMI, arm span, and upper arm circumference of elite Chinese male slalom athletes were lower than those of elite international male slalom athletes. However, the values of body fat percentage, bench push, and bench pull of elite Chinese male slalom athletes were greater, and their 300 m straight-line speeds in flat water were slower. To reach the top international standards of athletic development and physical training, elite

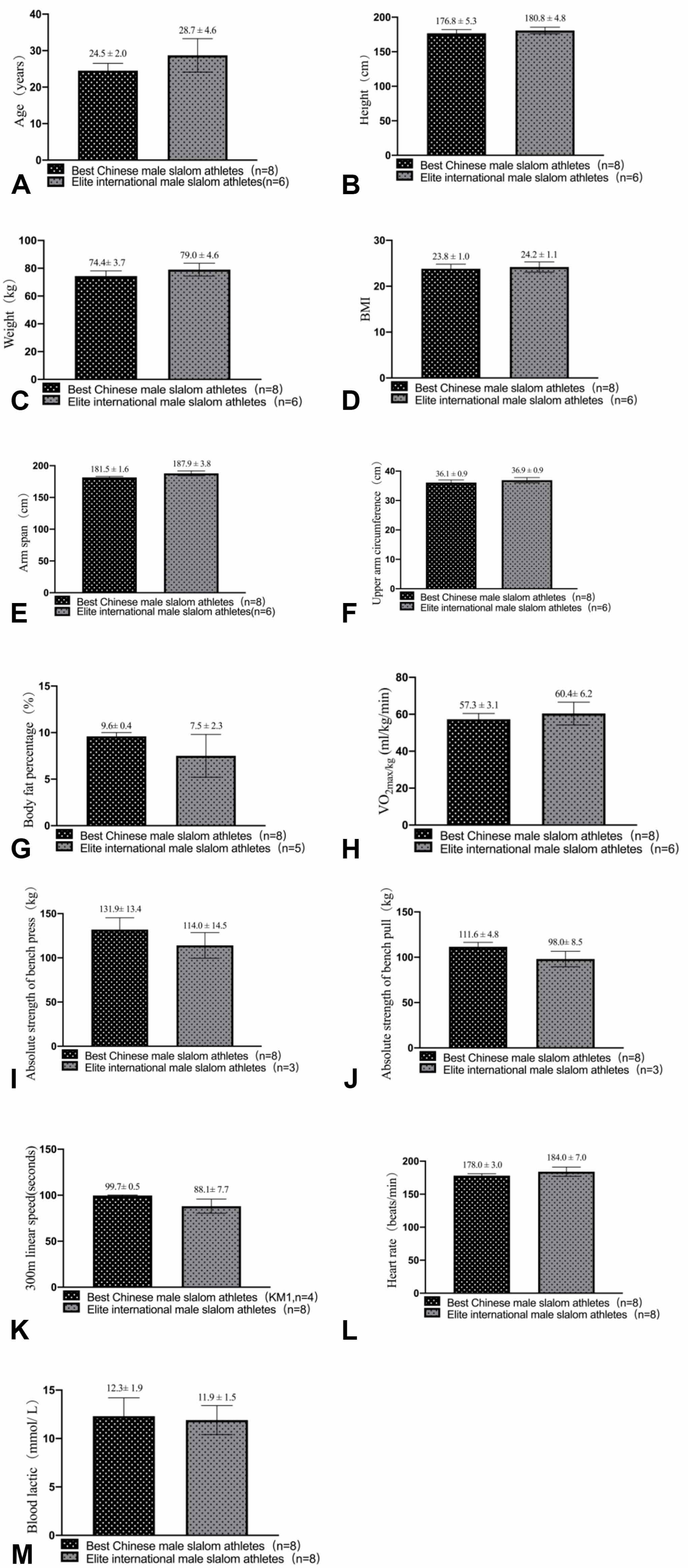


Fig. 1. A. Comparison of age of elite slalom kayakers. B. Comparison of heigtht of elite slalom Kayakers. C. Comparison of weight of elite slalom Kayakers. D. Comparison of BMI of elite slalom Kayakers. E. Comparison of arm span of elite slalom Kayakers. F. Comparison of upper arm circumference of elite slalom Kayakers. G. Comparison of Body fat percentage of elite slalom Kayakers. H. Comparison of the VO2max/kg of elite slalom Kayakers. I. Comparison of bench push of elite slalom Kayakers. J. Comparison of bench pull of elite slalom Kayakers. K. Comparison of 300 m of elite slalom Kayakers. L. Comparison of heart rate of elite slalom Kayakers. M. Comparison of blood lactic acid values of elite slalom Kayakers.

Chinese male slalom athletes should accumulate competitive experience over a longer training period. The national team should preferentially select athletes with an increased height, longer arm span, larger upper arm circumference, and greater muscle mass for training; moreover, the athletes should control their body fat percentage and improve their aerobic capacity, paddling skills, mechanical work, and linear speed in flat water.

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**RESUMEN:** Este estudio tuvo como objetivo investigar los parámetros de aptitud física de los atletas masculinos chinos de élite de canoa slalom y explorar las estrategias de entrenamiento correspondientes. Ocho hombres kayakistas de élite de slalom del equipo nacional chino fueron seleccionados como sujetos de investigación. Se midieron los siguientes parámetros: edad, talla, peso, índice de masa corporal (IMC), envergadura, perímetro braquial, porcentaje de grasa corporal, consumo máximo de oxígeno, frecuencia cardiaca, nivel de ácido láctico en sangre, fuerza de los miembros superiores y carrera de 300 m y velocidad lineal en agua plana. En comparación con los atletas internacionales masculinos de slalom de élite, los atletas chinos de slalom masculinos de élite tenían valores más bajos para la edad, la altura, el peso, el IMC, la envergadura del brazo y la circunferencia del brazo superior, mientras que los valores de porcentaje de grasa corporal, empuje de banco y tirón de banco eran mayores y la velocidad en línea recta de 300 m en aguas planas fue más lenta. Desde la perspectiva del desarrollo del atleta y el entrenamiento físico, los atletas de slalom masculinos chinos de élite deberían priorizar la acumulación de experiencia competitiva en lugar de aumentar los años de entrenamiento para alcanzar rápidamente los más altos estándares internacionales. Además, estos atletas deben controlar su porcentaje de grasa corporal y mejorar su capacidad aeróbica, habilidades de remo, trabajo mecánico y velocidad lineal en aguas tranquilas.

**PALABRAS CLAVE: Canoa slalo; Condición física; Antropometría; Fuerza; Velocidad.**

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