

Physical Fitness Parameters of Elite Chinese Wheelchair Curlers

Parámetros de Aptitud Física de Curlers en Silla de Ruedas Chinos de Élite

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SUMMARY: Few international studies have analyzed the characteristics of elite wheelchair curlers competing on the international stage. This study aims to investigate the physical fitness parameters of elite Chinese wheelchair curlers and explore the corresponding training enlightenment. Sixteen wheelchair curlers from the Chinese national team, including six male and two female Winter Paralympic gold medalists, were selected as research participants. The following parameters were measured: age, training age, height, weight, body fat percentage, grip strength, absolute bench press strength, and 5-km wheelchair push-timing test. Compared with ordinary curlers of the Chinese wheelchair curling team, elite curlers were older in age and training age; male curlers were shorter, whereas female curlers were taller. However, their weight and body fat percentage were lower, and their grip strength, absolute strength in the bench press, and 5-km wheelchair push-timing test were better. From an athlete development and physical training perspective, wheelchair curlers should increase training years in order to accumulate competition experience. Additionally, these athletes should manage their body weight and fat percentage, and improve their upper limb strength and aerobic capacity.

KEY WORDS: Wheelchair curling; Physical fitness; Anthropometric; Physical; Parameters.

INTRODUCTION

Curling is a competitive game without direct physical confrontation, and requires high skill levels. The sport tests the participants' tacit understanding, intelligence, endurance, and judgment and is known as "chess on ice" and "the winter gentleman's sport". Wheelchair curling evolved from a discipline that was common in Scotland in the late 1990s and was introduced to Canada in 2002, where it rapidly became popular. In 2006, the Turin Winter Paralympics included wheelchair curling as an official event. Since then, it has been a leading developer of winter sports for individuals with disabilities (Park *et al.*, 2013).

Classification rules for wheelchair curling were defined based on the athlete's degree of disability. Specifically, the most intuitive criteria are that there must be significant lower limb impairment, the athlete must be wheelchair-dependent for daily living, and the athlete cannot walk independently or can only walk for short distances. International classification is undertaken before an athlete participates in an international competition, and is the responsibility of the classification panel appointed by the World Curling Federation. The purpose of

classification in Paralympic sports is to minimize the impact of impairment on the outcome of competition so that the athletes who succeed are those with the best anthropometry, physiology, and psychology and who have enhanced their abilities to the best effect through consistent training and quality coaching. Studies have shown that disabilities in elite wheelchair curlers include spinal cord injuries, as well as polio and double-leg amputations (Bernardi *et al.*, 2012; Laschowski *et al.*, 2017, 2018; Li *et al.*, 2022).

According to the rules of wheelchair curling, winter Paralympians will participate in a mixed curling competition; each team must have four players (lead, second, third, and skip) delivering stones and comprise both genders. Each game is divided into the first and second half, with a total of eight games and a time limit of 68 min, with a 60-s timeout for each team in each game. Each player delivers two consecutive stones at each end alternating with the opponent. When the game ends, a team scores one point for each stone located in or touching houses closer to the tee than for any stone of the opposition.

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With the rapid development of the Winter Paralympic Games, wheelchair curling is becoming popular in different regions and countries, and the competitive level of athletes is constantly improving. To objectively understand the essential characteristics of wheelchair curling and improve the performance of elite wheelchair curlers, it is beneficial to systematically analyze their physical fitness. However, few international studies have investigated the physical fitness parameters of elite wheelchair curlers competing on the international stage.

Bernardi *et al.* (2012), reported that the effects of comprehensive physical fitness assessments on performance in winter sports have not been investigated in sitting athletes, including wheelchair curlers. Lee *et al.* (2022), revealed that the contents of technical, tactical, and physical training currently conducted to improve performance in wheelchair curling use most of the methods from non-disabled curling, and there are no independent training theories designed for wheelchair curling. Beak & Han (2022) revealed that key factors affecting the performance improvement of elite wheelchair curlers are preconditions for various studies on wheelchair curling performance.

Wheelchair curling is a dominant Paralympic winter sport in China; the Chinese wheelchair curling team won two gold medals in the Pyeongchang 2018 Winter Paralympics and the Beijing 2022 Winter Paralympics. However, limited research has been conducted on the physical fitness characteristics of elite Chinese wheelchair curlers. Therefore, this study tested the anthropometric and physical parameters of elite Chinese wheelchair curlers and compared them with related indicators of elite international wheelchair curlers in the relevant literature and those of ordinary Chinese wheelchair curlers, identified the physical fitness components that can be considered fundamental requisites for successful performance, and provided references for the research and application of physical training in these athletes.

MATERIAL AND METHOD

Participants and study design. Sixteen wheelchair curlers from the Chinese national team (age: 33.6 ± 4.2 years; twelve male and four female curlers), including six male and two female Winter Paralympic gold medalists, were recruited for the study (Six curlers with poliomyelitis, four curlers with spinal cord injury, two curlers with spina bifida, four curlers with lower limb amputation). Eight Winter Paralympic gold medalists were selected as elite curlers, whereas the remaining eight were selected as ordinary curlers. 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, and body fat percentage, were measured using a size and weight meter and a skinfold thickness meter. The physical quality indicators included the absolute strength of the bench press, grip, and a 5-km wheelchair push timing test. Bench-press trainers and grip dynamometers were used to test the muscular strength of the athletes. A complete warm-up was performed and the starting load for the absolute strength test was based on the best result from the previous test. It was divided into three incremental loads until the strength limit of 1 RM was reached, with the best result being obtained as the final result. The grip strength was the maximum of the three tests. Self-propelled wheelchairs for 5-km were used to test aerobic capacity of athletes. The staff was assigned to give the order and time at the start and finish, respectively. Athletes started individually and two curlers were measured with a 10-second interval.

Statistical analyses. SPSS (version 25.0, IBM Corp Armonk, NY, USA.) was used to analyze descriptive statistics (anthropometric and physical parameters), and data were expressed as means \pm standard deviation (SD). A t-test for independent samples was conducted to compare the physical fitness parameters of elite and ordinary Chinese wheelchair curlers. Statistical significance was set at $p \leq 0.05$.

RESULTS

Table I and Figure 1 (A to H) show that, compared with ordinary Chinese wheelchair curlers, elite Chinese wheelchair curlers are older, have longer training age (male: 11.3 ± 3.7 years vs. 7.7 ± 4.2 years, $p=0.14$; female: 5.8 ± 4.2 vs. 3.5 ± 0.7 years, $p=0.21$, respectively), leaner, and lower body fat percentage (male: 20.4 ± 5.3 vs. 23.3 ± 2.6 %, $p=0.45$; female: 28.7 ± 6.3 vs. 30.3 ± 3.2 %, $p=0.33$, respectively), elite male wheelchair curlers are relatively short, whereas elite female wheelchair curlers are relatively tall.

The test values of bench press absolute strength (male: 108.3 ± 35.8 vs. 89.0 ± 10.6 kg, $p=0.41$; female: 56.5 ± 0.7 vs. 51.0 ± 1.4 kg, $p=0.04$, respectively), grip strength (male: 52.3 ± 11.2 vs. 51.7 ± 8.7 kg, $p=0.92$; female: 41.5 ± 0.7 vs. 30.0 ± 0.0 kg, $p=0.00$, respectively) and 5-km wheelchair push-timing test (male: 26.3 ± 2.2 vs. 27.4 ± 3.1 Min, $p=0.60$; female: 28.5 ± 0.7 vs. 31.5 ± 0.7 Min, $p=0.05$, respectively) of elite wheelchair curlers are better.

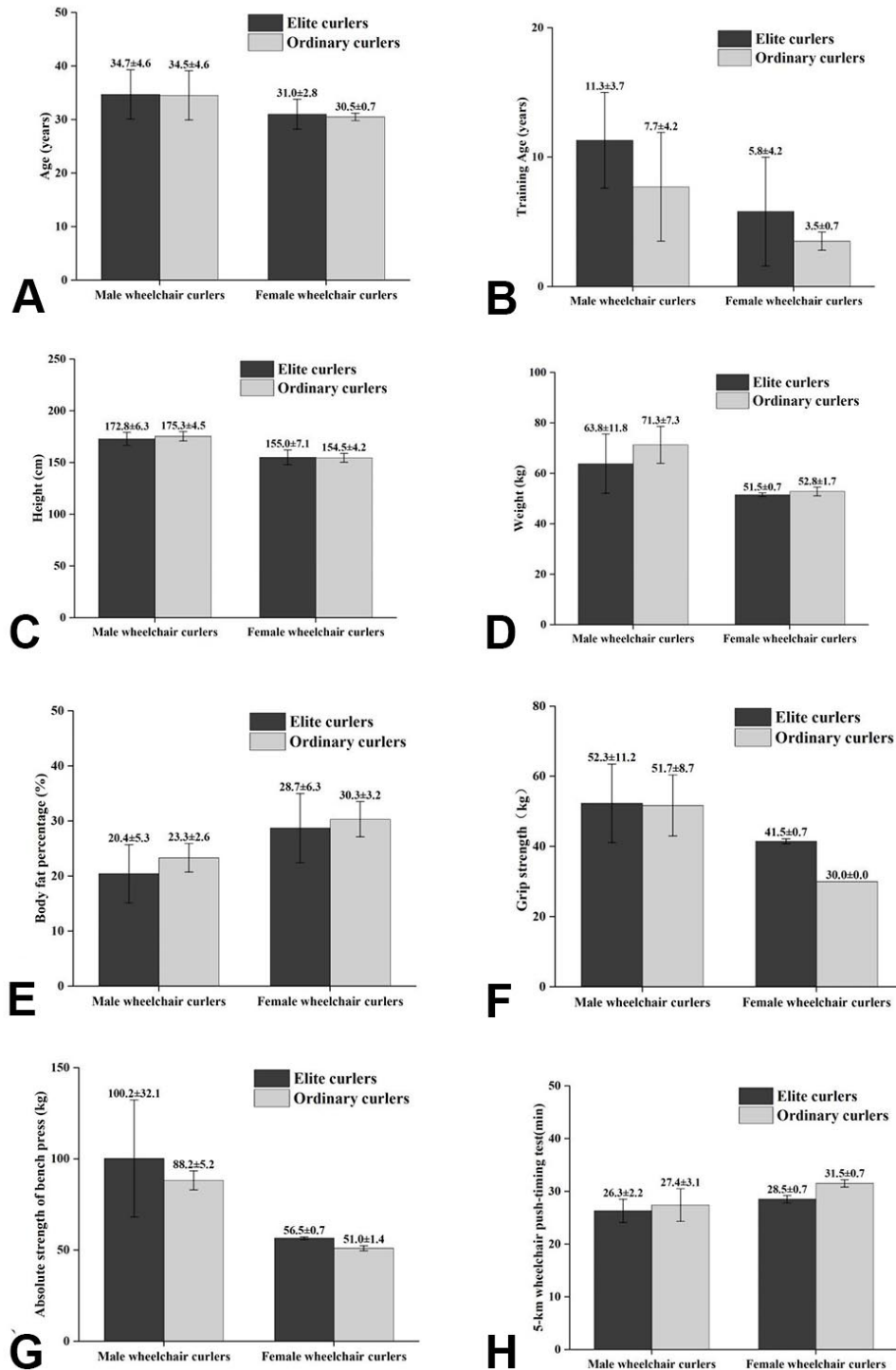


Fig. 1. **A.** Comparison between age of elite and ordinary Chinese wheelchair curlers. **B.** Comparison between training age of elite and ordinary Chinese wheelchair curlers. **C.** Comparison between height of elite and ordinary Chinese wheelchair curlers. **D.** Comparison between weight of elite and ordinary Chinese wheelchair curlers. **E.** Comparison between body fat percentage of elite and ordinary Chinese wheelchair curlers. **F.** Comparison between grip strength of elite and ordinary Chinese wheelchair curlers. **G.** Comparison between absolute strength of bench press of elite and ordinary Chinese wheelchair curlers. **H.** Comparison between 5-km wheelchair push-timing test of elite and ordinary Chinese wheelchair curlers.

Table I. Physical fitness parameters of elite and ordinary Chinese wheelchair curlers.

	Male curlers			Female curlers		
	Elite (n=6)	Ordinary (n=6)	p	Elite (n=2)	Ordinary (n=2)	p
Age (years)	34.7±4.6	34.5±4.6	0.95	31.0±2.8	30.5±0.7	0.84
Training age (years)	11.3±3.7	7.7±4.2	0.14	5.8±4.2	3.5±0.7	0.21
Height (cm)	172.8±6.3	175.3±4.5	0.45	155.0±7.1	154.5±4.2	0.82
Weight (kg)	63.8±11.8	71.3±7.3	0.22	51.5±0.7	52.8±1.7	0.81
Body fat percentage (%)	20.4±5.3	23.3±2.6	0.45	28.7±6.3	30.3±3.2	0.33
Grip strength (kg)	52.3±11.2	51.7±8.7	0.92	41.5±0.7	30.0±0.0	0.00**
Absolute strength of bench press (kg)	100.2±32.1	88.2±5.2	0.41	56.5±0.7	51.0±1.4	0.04*
5-km wheelchair push-timing test (min)	26.3±2.2	27.4±3.1	0.60	28.5±0.7	31.5±0.7	0.05*

** , P<0.01, Very significant difference; * , P<0.05, Significant difference.

DISCUSSION

Bernardi *et al.* (2012), analyzed the anthropometric indicators of 75 elite seated athletes in four sports, wheelchair curling, alpine skiing, cross-country skiing, and Paralympic ice hockey, from four Winter Paralympic Games between 1998 to 2010, and found that wheelchair curlers (n=10) had a higher mean age (42.0 ± 8.6 years), weight (82.3 ± 29.3 kg), and body fat percentage (26.2 ± 7.74 %, skinfold thickness test) compared with athletes in other sports. Their height (180.0 ± 9.0 cm) was comparable to that of alpine skiers, but higher than that of cross-country skiers and Paralympic ice hockey athletes. Wheelchair athletes cannot walk and sitting in a wheelchair for a long time reduces the range of movement of the limbs, slows down energy metabolism, and easily degenerates muscle function, which increases the probability of converting energy into fat (Jones *et al.*, 1998).

Flueck (2020) studied the age, weight, height, and body fat percentage (Dual X-ray Absorptiometry [DXA] test) of six athletes from the Swiss national wheelchair curling team, and the results were 51.0 ± 2.0 years, 74.9 ± 8.9 kg, 172.7 ± 3.6 cm, and 25.3 ± 4.9 %, indicating that the Swiss elite wheelchair curlers had similar age and body fat percentages, but significantly lower weight and height values than those of the athletes assessed in the Bernardi's study. Another investigation (Lee *et al.*, 2022) reported the average age, total mass, and body fat percentage (DXA test) of six wheelchair curling players from the Korea Wheelchair Curling Association as 51.8 ± 7.4 years, 71.4 ± 7.8 kg, and 39.9 ± 6.6 %, respectively.

Compared to Bernardi *et al.* (2012), Flueck (2020), and Lee *et al.* (2022) anthropometric parameters for elite wheelchair curlers, elite Chinese wheelchair curlers are younger, shorter, leaner, and have lower body fat percentages. Table I and Figure 1 (A to F) show that, compared with the general athletes of the Chinese wheelchair curling team, the elite curlers were older and had more training years,

indicating that wheelchair curlers need longer training time to accumulate competition experience. Elite male curlers were shorter, whereas elite female curlers were taller. However, the weight and body fat percentages of elite male and female curlers were lower than those of ordinary curlers, which is related to the Chinese wheelchair curling team's emphasis on athlete strength and aerobic training.

Current research has shown differences in age, height, weight, and body fat percentage among international elite wheelchair curlers; however, compared with other elite Winter Paralympic-seated athletes, wheelchair curlers are generally older and have higher body fat percentages (Bernardi *et al.*, 2012). However, the elite Chinese curlers who won the gold medal for wheelchair curling in the Winter Paralympics twice are younger, shorter, and lighter than the elite international wheelchair curlers. Since previous studies did not distinguish between the sexes of elite wheelchair curlers, there are certain limitations when comparing the anthropometric parameters of elite Chinese and international wheelchair curlers.

According to Bernardi *et al.* (2012), the absolute and relative peak oxygen uptake (1.8 ± 0.35 L.min⁻¹, 23.4 ± 7.60 mL.kg⁻¹.min⁻¹) of wheelchair curlers was the lowest among the four events. The authors also found that the absolute and relative value of peak anaerobic work (11.4 ± 2.40 KJ, 145.8 ± 43.76 J.kg⁻¹) and the average power of the upper limbs (251.1 ± 67.16 W, 3.6 ± 1.13 W.kg⁻¹) of wheelchair curlers were the lowest in the four events. However, the relative strength of the upper limbs of a wheelchair curler was 12.1 ± 2.08 N.kg⁻¹, which was also the lowest in the four events. Meanwhile, the absolute upper body strength of elite wheelchair curlers (1005.48 N, n=2) surpassed that of ordinary players (826.3 ± 205.30 N, n=8).

There has been no research on the physiological parameters of elite wheelchair curlers in China; however,

Chinese wheelchair curling teams have paid more attention to athletes' aerobic training and have typically used self-propelled wheelchairs for long-distance training to develop their aerobic capacity. Table I and Figure 1 (E) show that in the standard track and field 5-km wheelchair push-timing test, the elite Chinese wheelchair curler test results were better than those of ordinary athletes. In particular, the results of elite and ordinary female wheelchair curlers were significantly different, suggesting that elite athletes have a better aerobic capacity to maintain their physical fitness over long periods of competition.

The Chinese wheelchair curling team attached great importance to strength training of the upper limbs of athletes, usually using bench press training and wheelchair climbing training to develop upper limb strength. Table I and Figure 1 (F and G) show that the grip strength and absolute bench press strength test values of elite Chinese wheelchair curlers were greater than those of ordinary athletes, especially the results of elite and ordinary female wheelchair curlers which are significantly different, indicating that elite curlers need to have better upper limb strength to help them improve their accurate control of delivery.

The coordination ability of human movement is composed of various elements, such as response, spatial orientation, and proprioceptive abilities. Under the comprehensive control of the nervous system, movement coordination can be divided into motor and muscle coordination. In a wheelchair curling competition, one or two players from each team wear a stopwatch, which is used to measure the sliding time of the curler between the two hog lines to accurately control the power and state of delivery. According to Laschowski *et al.* (2017), elite wheelchair curlers must be able to finely control the joint angle and strength of the delivery technique and strengthen the coordination ability of their brain, eyes, hands, and body to work together. Another study (Wang *et al.*, 2022) indicated that the most common wheelchair curling technique involves the trunk supplying a stable base for accurate control of the curling arm and hand, that is, dynamic chain control coordination related to the trunk, upper arm, lower arm, hand, and curling delivery stick.

LIMITATIONS. Few studies have examined the physical fitness parameters of elite wheelchair curlers. Since previous studies not only had a small sample size, but also did not distinguish between the sexes of elite wheelchair curlers, and the physical fitness test parameters were not uniform, there are certain limitations when comparing the physical fitness parameters of elite Chinese and international wheelchair curlers. Although this study tested the physical fitness parameters of Chinese wheelchair curlers who had

won two Winter Paralympics championships, and compared the differences between the physical fitness parameters of gold medalists and ordinary curlers of different sexes, the parameters tested were relatively few, and the analysis of physical fitness characteristics of elite wheelchair curlers was limited due to the physical disability of wheelchair curlers.

CONCLUSION

Compared with the general curlers of the Chinese wheelchair curling team, elite Chinese curlers were older in age and training age; male curlers were shorter, whereas female curlers were taller. The weight and body fat percentage of elite curlers were lower, and the grip strength, absolute bench press strength, and 5-km wheelchair push-timing test were better. From an athlete development and physical training perspective, wheelchair curlers should increase training years in order to accumulate competition experience. Additionally, these athletes should manage their body weight and fat percentage, and improve their upper limb strength and aerobic capacity. Future studies should be carried out to test and analyze the physical fitness parameters of elite wheelchair curlers in different countries, distinguish between the sexes of curlers, and further expand the sample size of the investigation.

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RESUMEN: Pocos estudios internacionales han analizado las características de los curlers en silla de ruedas de élite que compiten en el escenario internacional. Este estudio tiene como objetivo investigar los parámetros de aptitud física de los bigudíes chinos en silla de ruedas de élite y explorar la iluminación del entrenamiento correspondiente. Se seleccionaron como participantes de la investigación dieciséis curlers en silla de ruedas del equipo nacional chino, incluidos seis medallistas de oro masculinos y dos femeninos de los Juegos Paralímpicos de Invierno. Se midieron los siguientes parámetros: edad, edad de entrenamiento, altura, peso, porcentaje de grasa corporal, fuerza de agarre, fuerza absoluta en press de banca y prueba de sincronización de empuje en silla de ruedas de 5 km. En comparación con los curlers ordinarios del equipo chino de curling en silla de ruedas, los curlers de élite eran mayores en edad y tiempo de entrenamiento; Los curlers masculinos eran más bajos, mientras que las mujeres eran más altas. Sin embargo, su peso y porcentaje de grasa corporal fueron menores, y su fuerza de agarre, fuerza absoluta en press de banca y prueba de sincronización de empuje en silla de ruedas de 5-k fueron mejo-

res. Desde la perspectiva del desarrollo del atleta y del entrenamiento físico, los curlers en silla de ruedas deberían aumentar los años de entrenamiento para acumular experiencia en competencia. Además, estos deportistas deben controlar su peso corporal y porcentaje de grasa, y mejorar la fuerza de sus miembros superiores y su capacidad aeróbica.

PALABRAS CLAVE: Curling en silla de ruedas; Aptitud física; Antropométrico; Físico; Parámetros.

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