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ORIGINAL RESEARCH

Construction of a sport-specific strength and conditioning evaluation index system for elite male wheelchair badminton athletes by the Delphi method

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Abstract

In this study, the Delphi method was used to construct the evaluation index system of the specific physical fitness of Chinese wheelchair badminton players. The Delphi method was used in the first two rounds to determine sport-specific strength and conditioning evaluation indexes for wheelchair badminton athletes. The Analytic Hierarchy Process was used in the third round to determine the weighting of each index. The results indicate that the recovery rate of questionnaires in the first two rounds was higher than 90%, the degree of expert authority was >80%, the degree of expert coordination in the second round was 0.350 and was greater than that in the first round (0.298), and significance testing of the coordination coefficient was significant ($p < 0.001$), thus indicating that expert opinions were consistent. Results during construction of the evaluation system were credible. Ultimately, we identified four primary indicators, 12 secondary indicators, and 30 tertiary indicators. The order of the four primary indices in terms of weighting was as follows: sport-specific skills (0.4406), sports qualities (0.2928), cardiorespiratory function (0.1828), and body shape (0.0838). We used the Delphi method to construct an evaluation index system for the sport-specific physical ability of elite male wheelchair badminton athletes. The index system exhibited high credibility and specificity for wheelchair badminton.

Keywords

Wheelchair badminton; Sport-specific strength and conditioning; Evaluation system; Delphi method

1. Introduction

Wheelchair badminton is a vital component of para-badminton sport in which athletes suffering from paralysis or amputation of the waist and lower limbs complete a badminton match on a specialized badminton court with the assistance of a sports wheelchair. The Chinese wheelchair badminton team has achieved significant success on the international arena. A total of seven athletes participated in the wheelchair badminton competition at the recently concluded Tokyo Paralympic Games, including three male athletes and four female athletes. These athletes won a total of five gold, three silver, and two bronze medals. The three male athletes have achieved outstanding results. However, considering non-optimized training plans and the physical limitations of the athletes, sport-specific strength and conditioning training has a certain ceiling, under which wheelchair badminton athletes are not able to accomplish their true potential in competitive arenas. Therefore, it is vital that we establish a sport-specific strength and conditioning strategy to improve the performance of athletes in competitive games.

Sport-specific strength and conditioning is based on the specific needs of special competitions and is based on the physical activity of an athlete's body shape, cardiorespiratory function, and sporting qualities that are different from those of other sports. The core of this strategy is to meet the physical needs of the competition, followed by the maintenance of continuous movement capacity that is appropriate to the competition. Due to their own physiological limitations, wheelchair athletes are associated with significant difficulties with regards to the selection of test indicators and the determination of testing methods. Furthermore, the test indicators acquired are highly specific and are difficult to study. Few previous studies have specifically investigated wheelchair badminton athletes; thus, the selection of appropriate indicators would require reference guidelines based on the sport of badminton and other wheelchair sporting events.

In a previous study of badminton, Fernandez *et al.* [1] found that the ability of athletes to change their direction of movement is one of the most important athletic abilities required by successful badminton players at any level. However, due to the limitations of wheelchairs and the smaller court used for wheelchair badminton in comparison with a regular badminton court, the ability to move in a straight line is more in line with the sport-specific requirements of wheelchair badminton players. Zhang identified the long throw as an important indicator of upper limb strength for badminton players [2]. However, the long throw in badminton needs to be performed under the action of a player's swing, which is not only a reflection of upper limb strength, but also requires sport-specific technique. In another study, Ayuningtyas *et al*. [3] found that a suitable body shape can influence key biomechanical characteristics and the sporting performance of badminton athletes, thus resulting in better levels of physical ability. Tomaszewski *et al*. [4] investigated the physical characteristics of elite and sub-elite badminton players by applying several key indicators, including body height, arm span, body weight, body fat percentage, defatted mass, and body mass index (BMI), to investigate the influence of an athlete's physical characteristics on sporting performance. When selecting appropriate indicators for the body shape of wheelchair badminton athletes, body height, body weight, body fat percentage, and BMI, are not informative due to the different degrees of lower limb atrophy or amputation. Instead, sitting height and body fat percentage, as calculated from skinfold thickness, are more suitable physical characteristics to consider. In a previous study, Samsir *et al*. [5] used the four-point on-court test and the 20 m sprint as test indicators to verify the effect of high-intensity interval training on the sporting performance of badminton athletes. The four-point on-court test is also a comprehensive reflection of the special ability of wheelchair badminton athletes, although the distance and direction of the sprint need to be adapted in a reasonable manner according to the specific characteristics of wheelchair badminton. Diaper *et al*. [6] tested and evaluated specific physiological indicators for other wheelchair sports, including body fat, body weight, blood pressure, blood lactate, and maximal oxygen uptake in a 33-year-old British female wheelchair tennis athlete who competed in class L1 over a two-year period prior to the Athens Paralympic Games to determine the efficacy of the athlete's training and to recommend sport-specific strength and conditioning interventions to coaches as reference guidelines. Turbanski *et al*. [7] performed upper body strength training on wheelchair athletes from different disciplines for eight weeks with a bench press load of 80% of 1 RM (Repetition maximum, which refers to the maximum number of consecutive times a person can perform a certain action under a certain weight) five sets of 10–12 repetitions twice a week with 3–5 minutes' intervals, and observed a significant improvement in upper body strength and explosive strength parameters. In another study, Stojanović *et al*. [8] tested the agility of wheelchair basketball athletes using modified T-run and 8-run wheelchair movement tests and identified significant differences in the agility of wheelchair basketball athletes in different classes. Cherif *et al*. [9] tested body shape indicators (height, weight, sitting height, arm span and skinfold thickness) and strength and conditioning indicators (vertical jump, drop jump, reverse jump, deep squat jump, fold run, and yo-yo run) in disabled track and field athletes to identify differences in physiological characteristics and athletic performance between several categories of athletes with cerebral palsy, upper arm amputation, short stature, and mental retardation. Petrigna *et al*. [10] screened and reviewed the literature related to wheelchair basketball fitness testing and found that grip strength, the 20 m sprint, maximal passing, and the Yo-Yo (modified version) test were more appropriate for the fitness testing of wheelchair basketball athletes. These findings highlight the fact that when training and testing athletes with disabilities, we can refer to the proven means and methods of able-bodied athletes but make reasonable adaptations according to the sporting level and physical condition of athletes with disabilities. The selection of these test indicators for badminton and other wheelchair sports, combined with the characteristics of wheelchair badminton sports that can be reasonably adapted, will be an important basis for the selection of appropriate indicators.

The Delphi method is a scientific method that can be applied to establish various evaluation index systems and determine the weighting of specific indicators. Few very studies have specifically investigated wheelchair badminton with the Delphi method, although several other studies have investigated other sports in the context of disability. For example, Villiere *et al*. [11] identified indicators of body shape characteristics that can affect the athletic performance of wheelchair fencers by adopting the Delphi method. Yulianto *et al*. [12] used the Delphi method to design a circuit training method for wheelchair tennis athletes. In addition, Krabben [13], Allen *et al*. [14] and Hynes *et al*. [15] all used the Delphi method to confirm standard measurements of visual acuity and how they related to athletic performance in visually impaired judo athletes, visually impaired track and field athletes, and visually impaired golfers, respectively.

In this study, we first considered the specific characteristics of wheelchair badminton events and the physiological characteristics of male wheelchair badminton players. Then, we combined this information with the specific needs of these athletes and established a targeted and systematic evaluation index system for sport-specific strength and conditioning training by applying the Delphi method, thereby providing a strategy for sport-specific strength and conditioning training. Our findings provide a basis for the development of sport-specific strength and conditioning training methods for Chinese male wheelchair badminton athletes. Our findings also provide key guidelines for the development of specific strength and conditioning strategies for training in other forms of wheelchair sports and to guide scientific preparation for the Winter Paralympic Games and Asian Paralympic Games.

2. Objects and methodologies

2.1 Objects

We aimed to construct a sport-specific strength and conditioning evaluation index system for Chinese male wheelchair badminton athletes. The survey subjects were three athletes from the Chinese male wheelchair badminton team who were preparing for the Tokyo Paralympic Games, all of whom had won championships in their respective classes in the Tokyo Paralympic Games, World Championships, or International Open tournaments. Specific information is given in Table 1.

TABLE 1. General information of the Chinese wheelchair badminton team athletes included in this study.

Name	Gender	Age	Experience (yr)	Level
Athlete 1	Male	20	8	International master
Athlete 2	Male	21	6	International master
Athlete 3	Male	32	14	International master

2.2 Methodologies

In this study, we used the expert survey method to determine a sport-specific strength and conditioning evaluation index system for male wheelchair badminton players. First, we determined preliminary selection indicators by conducting interviews with experts and by performing a literature review. Next, a total of three rounds of expert surveys were conducted to design an expert questionnaire (The Expert Consultation of the Construction of Sport-Specific Strength and conditioning Evaluation System for Male Wheelchair Badminton Athletes). The final evaluation index, calculated by the mean value method and by considering coefficients of variation, was generated from the first two rounds by the Delphi method. The Analytic Hierarchy Process (AHP) was used in the third round to determine the weighting of each index. The results of each round of questionnaire surveys were statistically summarized by mathematical statistics. The construction process of the sport-special strength and conditioning evaluation index system for male wheelchair badminton athletes is shown in Fig. 1.

The results of validity tests relating to the first two rounds of the questionnaire are shown in Table 2. The mean values of the validity test results for the questionnaires were all around 4, thus indicating that the questionnaire had a high degree of validity.

Validity was analyzed by Cronbach's alpha [16]. There were 66 indices in the first round of the questionnaire (the evaluation index had a coefficient α of 0.899) and 54 indices in the second round of the questionnaire, with a coefficient α of 0.915, thus indicating high validity.

3. Results

3.1 Initial selection of indicators

Due to limited literature relating to the sport-specific strength and conditioning of wheelchair athletes, some related literature on the strength and conditioning of non-para-athletes were reasonably and partially combined with the characteristics of wheelchair badminton and para-athletes to construct a sport-specific strength and conditioning evaluation system. Our review of relevant research identified four primary indices, 12 secondary indices, and 50 tertiary indices in the initial selection.

3.2 Re-selection indicators

3.2.1 General information acquired from experts

In this study, two rounds of questionnaires were administered to experts by applying the Delphi method; this considered the selection of experts by occupation, education, title, and research direction. This study focused on the evaluation of sport-specific strength and conditioning of wheelchair badminton athletes, and a total of 14 experts were selected. In terms of research direction, since there are few studies related to wheelchair badminton, the research directions of the experts selected for this study were all centered on sports training, strength and conditioning, badminton, and sports rehabilitation. According to the questionnaire results, we included individual experts with two research areas; thus, the sample size was larger than the actual number of experts when counting their research directions. The basic statistics of experts by frequency and percentage are given in Table 3.

3.2.1.1 Positive coefficient of the experts

The response rate of the questionnaire was used to reflect the participation and enthusiasm of the experts [17]. Two rounds of the questionnaire survey were undertaken; 14 of 14 questionnaires were completed in the first round (response rate: 100%) and 13 of 14 questionnaires were completed in the second round (response rate: 92.86%). The response rates were >90% in the two rounds of questionnaire surveys, thus indicating high levels of motivation and involvement for the experts.

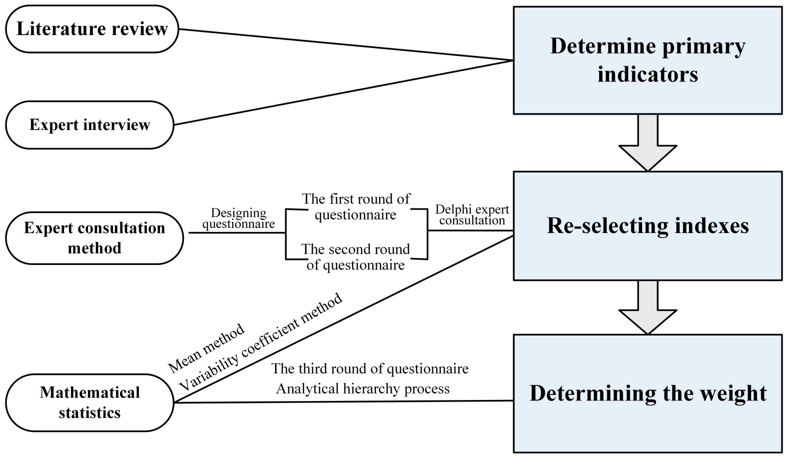
3.2.1.2 Authority coefficient (Cr) of the experts

Based on judgment (Ca) and the degree of familiarity (Cs), calculating the authority coefficient (Cr) for the experts is a good indicator for credibility. The calculation was carried out using the following algorithm: $Cr = (Ca + Cs)/2$; the greater Cr values of the experts, the higher their credibility [18]. The first two rounds of questionnaire surveys confirmed the reliability and credibility of the experts involved in the consultation, with high authority coefficients of 0.88 and 0.84, respectively, as shown in Table 4.

3.2.1.3 Coordination level of the expert opinions

In the Delphi expert consultation, we used the Kendall Harmony Coefficient (W) to reflect the coordination level of the expert opinions; the larger the W value, the better the coordination level of the expert opinions [18]. This allowed us to test the significance of the coordination coefficient; $p < 0.05$ indicated that the coordination coefficient was statistically significant and indicated that the experts had consistent opinions [17].

From Table 5, it can be seen that the results of two rounds of questionnaire surveys demonstrated that $p < 0.05$, thus indicating that the experts were consistent in terms of scoring indicators in the questionnaires. The Kendall coordination coefficient from experts in the second round of the questionnaire survey was greater than that in the first round; this means that the expert opinions were more consistent in the second round.



F I G U R E 1. Flowchart of the construction of a sport-specific strength and conditioning evaluation index system for male wheelchair badminton athletes.

T A B L E 2. Validity test results for the first two rounds of survey questionnaires.

	Very reasonable	Reasonable	General	Not very reasonable	Not reasonable	Mean value
Content validity						
First round	3	11	1	0	0	4.07
Second round	1	11	1	0	0	4.00
Utility validity						
First round	3	10	1	0	0	4.14
Second round	0	12	1	0	0	3.92
Structure validity						
First round	3	9	2	0	0	4.07
Second round	1	11	1	0	0	4.00
Total						
First round	8	30	4	0	0	4.10
Second round	2	34	3	0	0	3.97

T A B L E 3. General information of the experts participating in the consultation.

Items	The number of experts	Composition ratio (%)	The number of experts	Composition ratio (%)
	The first round (n = 14)		The second round (n = 13)	
Occupation				
Teacher	10	71.40%	9	69.20%
Coach	2	14.30%	2	15.40%
Scientific researcher	2	14.30%	2	15.40%
Others	0	0.00%	0	0.00%
Educational background				
Undergraduate	1	7.10%	1	7.70%
Master’s degree	1	7.10%	1	7.70%
Doctoral degree	12	85.80%	11	84.60%
Professional title				
Professor	6	42.90%	5	38.40%
Researcher	1	7.10%	1	7.70%
Associate Professor	4	28.60%	4	30.80%
Associate Research Fellow	1	7.10%	1	7.70%
National-class coach	1	7.10%	1	7.70%
Province-class coach	1	7.10%	1	7.70%
	The first round (n = 16)		The second round (n = 15)	
Research direction				
Strength and conditioning	7	43.80%	6	40.00%
Sports training	4	25.00%	4	26.70%
Badminton	4	25.00%	4	26.70%
Sports rehabilitation	1	6.20%	1	6.60%

TABLE 4. Authority coefficients for the experts.

Item	Ca	Cs	Cr
First round survey	0.90	0.86	0.88
Second round survey	0.90	0.77	0.84

TABLE 5. Coordination coefficient of expert opinions.

	W	X^2	D	p
First round	0.298	271.188	65	<0.001
Second round	0.350	241.121	53	<0.001

3.2.2 Construction of a sport-specific strength and conditioning evaluation system for wheelchair badminton athletes

Coefficient of variation analysis indicated the degree of coordination between the experts for each indicator; the smaller the value, the higher the degree of coordination between experts for the same index [19]. Mean value is the average value of various indicators, which indicates the importance of each indicator as determined by the experts; the greater the value, the higher the importance of the indicator [18]. This study featured two rounds of questionnaires for experts ("The Construction of Sport-Specific Strength and conditioning Evaluation System for Male Wheelchair Badminton Athletes") according to the initial selection of indicators. Experts used the Likert scale to assign values to the indicators, and the coefficient of variation and the mean value of each indicator were determined after calculation.

In the first round of indicator checks, the indicator screening standard was determined as a mean ≥3.5 and a coefficient of variation <0.35; this was because there were few studies related to wheelchair badminton, and experts had limited reference guidelines for defining indicators. Based on feedback from the experts, four primary indicators and 12 secondary indicators were identified. Of the tertiary indicators, eight non-standard indicators were modified and six indicators were adjusted. Finally, 38 third-level indicators were retained. By the second round of indicator checks, the experts had become relatively familiar with the project and the definition of indicators; thus, the screening standards were determined as a mean ≥4, and a coefficient of variation <0.25. Finally, four primary indicators, 12 secondary indicators, and 30 tertiary indicators were retained (Table 6).

3.3 Determination of indicator weighting

In this study, the relative weightings of the indicators incorporated in the evaluation system of wheelchair badminton athletes was calculated by the analytic hierarchy process. The calculation procedure was performed by YAAHP statistical software (YAAHP1.0, Shanxi Yuan Decision Software Technology Co., Ltd., Taiyuan, China) as shown in Fig. 2.

First, sport-specific strength and conditioning evaluation indicators for wheelchair badminton athletes were structured into three levels of hierarchy. The target level was sport-specific strength and conditioning for wheelchair badminton athletes. The criterion level was four primary indicators, the sub-criterion level was 12 secondary indicators, and the scheme level was 30 tertiary indicators (Fig. 3). By using a scale of 1–9 [20], each expert evaluation on the relative importance of each indicator at all levels was intuitively classified. The questionnaire ("Construction of Sport-specific Strength and conditioning Evaluation System for Wheelchair Badminton Athletes") was designed and then issued to the experts. We analyzed the data in the third questionnaire and checked the consistency of the judgment matrix through RI, which is a table of RI values calculated by statistician Thomas Saaty for first-order to ninth order matrices [21]. When the judgment matrix was not consistent, the expert matrix results were fine-tuned by the minimum change method and the maximum improvement direction method [22]. Weightings were then calculated when the judgment matrix conformed to the consistency test.

Table 7 shows the calculated weightings of the sport-specific strength and conditioning evaluation indicators for wheelchair badminton athletes.

4. Discussion

Sport-specific strength and conditioning for wheelchair athletes involves four different elements: body shape, cardiorespiratory function, sports qualities, and sport-specific skills. Of these aspects, body shape and cardiorespiratory function are key determinants of the sporting quality of the athlete. In contrast, sporting quality can exert changes in body shape and cardiorespiratory function. The performance of sport-specific skills involves the comprehensive determination of body shape, cardiorespiratory function, and sport-specific qualities, in wheelchair badminton.

With respect to body shape, athletes rely on their upper limbs and trunk to control the on-court movement of wheelchairs, and apply their technical skills within the badminton court. The sitting height and arm length of an athlete represent key factors in terms of control. Hand length, as the foundation of an athlete's hand grip strength, is a key factor affecting performance skills and movements on the court. Athletes need to have a moderate circumference of the upper limbs and trunk; a large circumference may affect muscle contraction velocity while a small circumference may not provide sufficient strength. A moderate body fat percentage is also required; this is key determinant of athletic performance [23]. An excessive amount of body fat can impose significant burden on athletes while a lower proportion of body fat can exert effects on physiological reserve.

With regards to cardiorespiratory function, wheelchair badminton is a two-win system of three games, with 21 points per game [24]. The game consists of intense confrontations and intermissions within each round, such as picking up the shuttle and wiping way sweat between rounds, as well as intermissions within the rules. The competition time is 15–30 minutes per game and 30–90 minutes per match. Each round lasts 10–40 seconds, between which the interval lasts for 15–30 seconds. A 60-second interval is allowed when the leading

TABLE 6. An evaluation indicator system for sport-specific strength and conditioning for wheelchair badminton athletes.

Primary indicator	Secondary indicator	Tertiary indicator
Body shape	Length	Sitting height
		Full arm length
		Hand length
	Girth	Upper arm tensed-relaxed girth difference
		Forearm girth index
		Chest girth
	Body composition	Body fat percentage
Cardiorespiratory function	Basic cardiorespiratory function	Resting vital capacity
		Resting heart rate
	Sport-related cardiorespiratory function	Anaerobic capacity
		Aerobic capacity
Sports qualities	Strength	Hand grip strength
		Shoulder abduction strength
		Shoulder internal rotation strength
		Shoulder external rotation strength
		Trunk flexion strength
		Trunk extension strength
		1 RM bench press
	Speed	10 m straight-line wheelchair sprint (forward)
		10 m straight-line wheelchair sprint (backward)
	Endurance	Battle rope to exhaustion
		3000 m wheelchair pushing
	Agility	Incremental straight-line shuttle wheelchair pushing
	Flexibility	Shoulder internal rotation range
		Thoracic spine rotation range
Sport-specific skills	Technical skills	Badminton long throw
		1min badminton hitting against the wall
		the landing point of backcourt long-stroke after 8 repetitions of 1 min waving battle rope
		the landing point of frontcourt net-drop after 8 repetitions of 1 min waving battle rope
	Site locomotion ability	Four-point on-court movement of wheelchair

RM: Repetition maximum.

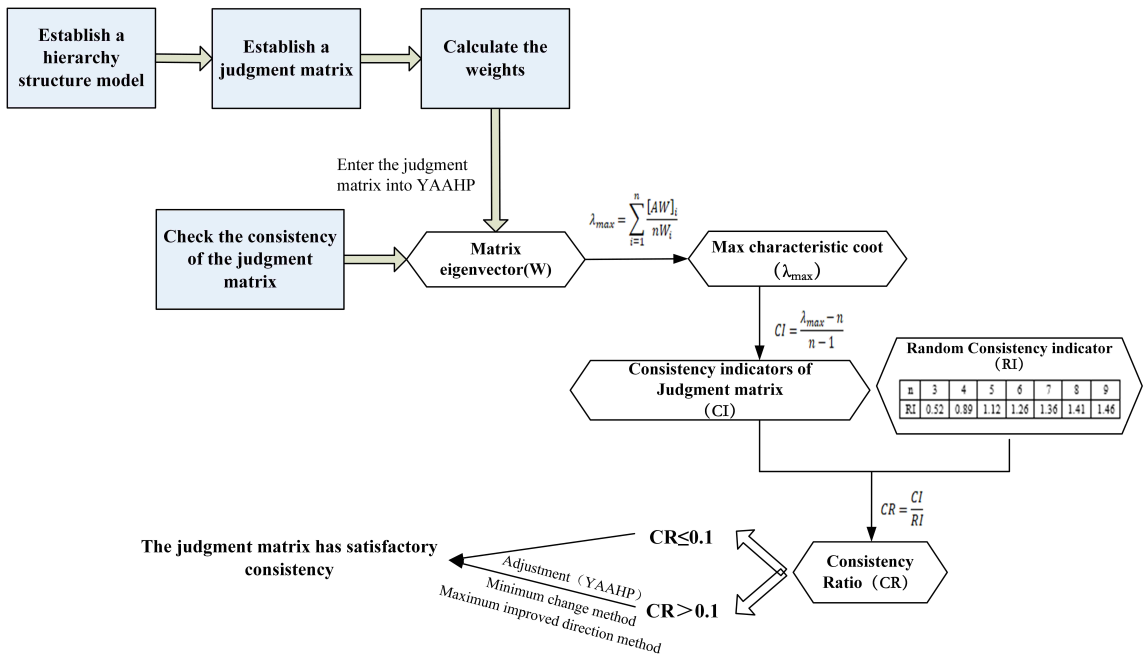


FIGURE 2. Operating procedure for weighting calculations.

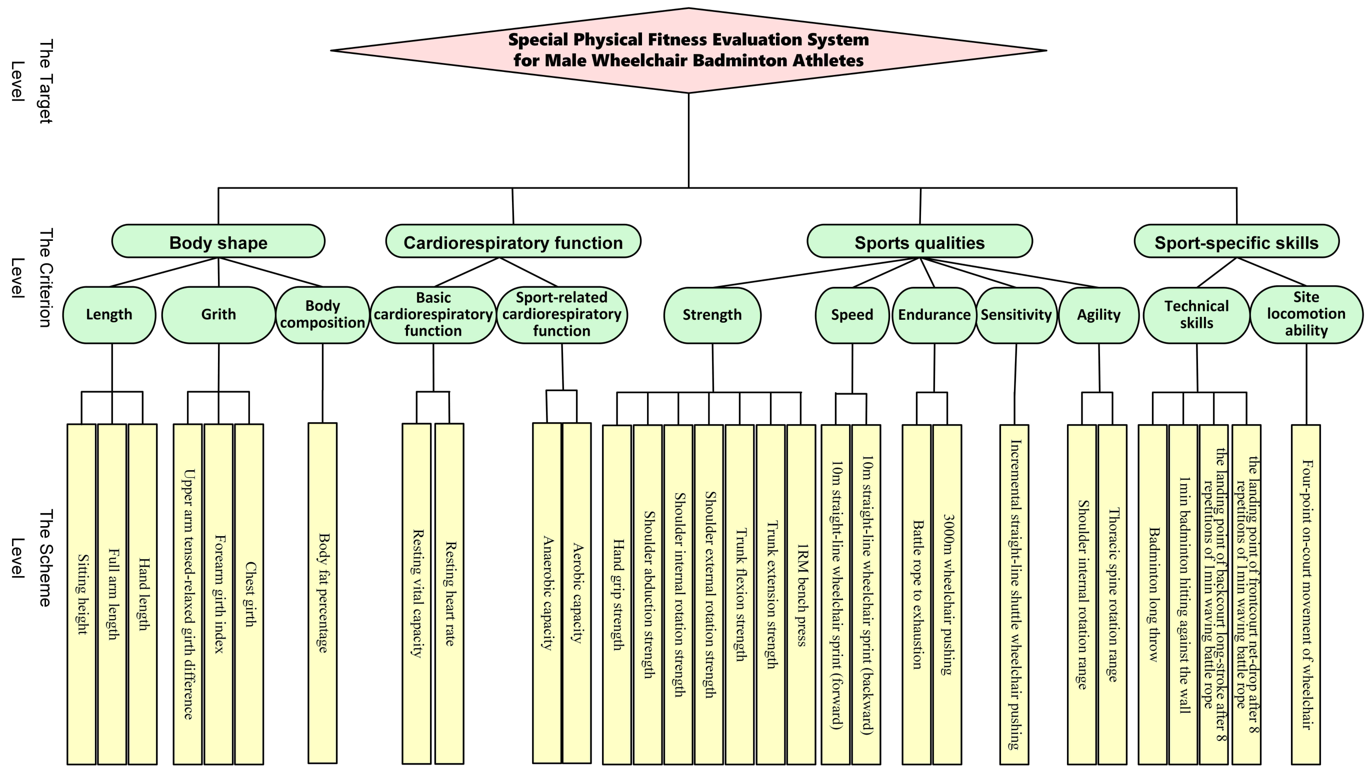


FIGURE 3. Diagram of the indicator hierarchy structural model for a "Sports-specific Strength and conditioning Evaluation System for Male Wheelchair Badminton Athletes".

TABLE 7. Weighted coefficients for sport-specific strength and conditioning evaluation indicators for wheelchair badminton athletes.

Primary indicator	Total weight	Secondary indicator	Total weight	Tertiary indicator	Total weighting
Body shape	0.084	Length	0.029	Sitting height	0.009
				Full arm length	0.016
				Hand length	0.004
		Grith	0.021	Upper arm tensed-relaxed girth difference	0.008
				Forearm girth index	0.008
				Chest girth	0.005
		Body composition	0.034	Body fat percentage	0.034
Cardiorespiratory function	0.183	Basic cardiorespiratory function	0.065	Resting vital capacity	0.030
				Resting heart rate	0.036
		Sport-related cardiorespiratory function	0.118	Anaerobic capacity	0.066
				Aerobic capacity	0.052
Sports qualities	0.293	Strength	0.065	Hand grip strength	0.008
				Shoulder abduction strength	0.010
				Shoulder internal rotation strength	0.010
				Shoulder external rotation strength	0.009
				Trunk flexion strength	0.010
				Trunk extension strength	0.010
				1 RM bench press	0.008
		Speed	0.095	10 m straight-line wheelchair sprint (forward)	0.041
				10 m straight-line wheelchair sprint (backward)	0.054
		Endurance	0.059	Battle rope to exhaustion	0.028
				3000 m wheelchair pushing	0.031
		Agility	0.052	Incremental straight-line shuttle wheelchair pushing	0.052
		Flexibility	0.021	Shoulder internal rotation range	0.009
				Thoracic spine rotation range	0.012
Sport-specific skills	0.441	Technical skills	0.257	Badminton long throw	0.032
				1min badminton hitting against the wall	0.048
				the landing point of backcourt long-stroke after 8 repetitions of 1 min waving battle rope	0.085
				the landing point of frontcourt net-drop after 8 repetitions of 1 min waving battle rope	0.091
		Site locomotion ability	0.184	Four-point on-court movement of wheelchair	0.184

RM: Repetition maximum.

score reaches 11 points, and the 120-second interval occurs between games, which occur in an alternate way between short-term heavy load and recovery. To perform well in each round, the athletes need to have good phosphocreatine capability and anaerobic energy supply. Furthermore, the constant production of aerobic energy is essential to promote recovery. The different methods of producing energy need to be based on respiration; thus, an individual athlete's vital capacity is a direct reflection of respiratory function.

In terms of sporting quality, wheelchair badminton athletes rely heavily on their trunk to support their body and complete swivel motions efficiently. They also need their upper limbs to move and execute sport-specific actions. Therefore, the development of functional strength in the muscle groups is vital, especially in the rotator cuff, wrist, fingers and trunk. For speed, wheelchair athletes predominantly move in a straight line within the court; this requires the ability to move fast over short distances. In terms of agility, athletes are expected to perform movement within the court with good acceleration and braking in their wheelchairs. In addition, repetitive efforts occur over a short period of time, thus enabling more speed endurance is available to the athletes in accordance with the requirements of wheelchair badminton. Furthermore, flexibility of the shoulder joint not only provides athletes with the transmission of strength to perform skills, but also helps them to support their bodies and exert force to move within the court. Limited by their physical impairments, wheelchair badminton athletes swivel in a manner that usually depends on the shoulder to drive the upper trunk. Therefore, flexibility in the shoulder and thoracic spine is essential; this also protects athletes against sports injuries.

In terms of sport-specific skills, the sports performance of an athlete mainly reflects his or her technical skills and site locomotion ability on the court, both of which are performed by the athlete's wheelchairs. Based on communication between athletes and their coaches, the stability to execute technical skills is very important for athletes to perform well during competition. Therefore, in terms of sport-specific skills, besides independent training of technical skills and movement, the stability and control of athlete's ability to execute technical skills needs to be trained under the conditions of muscle fatigue and increased heart rate, thus improving the ability of an athlete to hit the shuttle.

5. Conclusions

Sport-specific strength and conditioning training for wheelchair badminton athletes should be based on the sporting ability of the athletes and their different physiological characteristics. As the training system used by non-para-athletes is relatively mature, it could be used as a reference for the training of wheelchair athletes. In addition, daily monitoring and quantitative records should be maintained.

This was an exploratory study on the construction and application of a sport-specific strength and conditioning evaluation system for male wheelchair badminton athletes during a specific period. The indicators, weightings, evaluation criteria, and the target model of the system require further investigation and modification to meet development requirements over time.

This study considered male athletes of the Chinese wheelchair badminton team as the study subjects but had a small sample size and certain limitations. It is uncertain whether it can fully represent the common characteristics of male wheelchair badminton players. However, our findings highlight the importance of further research on this topic in the future. In the future research, the study subjects could be extended to female athletes and foreign athletes to investigate differences in sport-specific strength and conditioning across various sporting classes and countries. Our findings are expected to provide the basis for team selection and training for China's competitive sports for the disabled, especially for wheelchair badminton.

AVAILABILITY OF DATA AND MATERIALS

The data presented in this study are available on reasonable request from the corresponding author.

AUTHOR CONTRIBUTIONS

DTW, SWW and JHH—designed the research study and performed the research. MY—provided help and advice with regards to the vertical jump experiments. DTW—analyzed the data. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The Institutional Review Board of Capital University of Physical Education and Sports approved this study and all tests were completed prior to the start of the season (Approval number: 2021A63). All participants completed an informed permission form after being briefed about the procedures, in accordance with the Declaration of Helsinki on human experimentation.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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