CULTURA, CIENCIA Y DEPORTE

Most frequent tests in the literature for the evaluation of physical qualities in elite level Paralympic wheelchair basketball: a systematic review

Test más frecuentes en la literatura para la evaluación de las cualidades físicas en el baloncesto en silla de ruedas nivel élite: Una revisión sistemática

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Abstract

The objective was to identify the most recurrent tests in literature which are used for the evaluation of physical qualities in wheelchair basketball elite level. For this, a systematic review was carried out in PubMed, Web of Science, Scopus and ScienceDirect, involving the use of keywords athletes, wheelchair basketball and test and performance. The search strategy carried out yielded a total of 270 results where, after eliminating duplicates and applying the previously established inclusion and exclusion criteria, 39 documents were included for detailed review based on qualitative synthesis. According to the collected literature, most tests included 20m sprint as a majority, followed by 5m sprint test and dynamometer, which indicates that the most evaluated physical qualities were speed, strength, agility, and anaerobic power. According to the aforementioned, it is concluded that the tests used are tools of easy access, for the most part, since large-scale sports implements are not necessary (excluding the Wingate test, which requires a crank ergometer). They are also pertinent and valid for the evaluation of physical qualities in elite level BSR athletes.

Keywords: Adapted sports, Training, Sports Preparation, Performance, Athletes.

Resumen

El objetivo fue identificar los test más recurrentes en la literatura, utilizados para la evaluación de las cualidades físicas en el BSR nivel élite. Para ello se llevó a cabo Revisión Sistemática en PubMed, Web of Science, Scopus y ScienceDirect, combinando las siguientes palabras clave Athletes y "Wheelchair basketball" y Test y Performance. La estrategia de búsqueda realizada arrojó un total de 270 resultados donde posterior a la eliminación de duplicados y aplicando los criterios de inclusión y exclusión previamente establecidos, llegaron a ser incluidos 39 documentos para su revisión detallada de síntesis cualitativa. Los test más utilizados según la literatura recabada, señalan en primer lugar al Sprint 20m, seguido del Sprint 5m y dinamómetro, lo cual indica que las cualidades físicas más evaluadas son; velocidad, fuerza, agilidad y potencia anaeróbica. De acuerdo a lo mencionado anteriormente, se concluye que los test utilizados son herramientas de fácil acceso, en su mayoría, pues no son necesario implementos deportivos de gran envergadura, (excluyendo el test de Wingate el cual requiere un ergómetro de manivela). Además, son pertinentes y válidos para la evaluación de las cualidades físicas en atletas de BSR nivel elite.

Palabras clave: Deporte adaptado, Entrenamiento, Preparación Deportiva, Rendimiento, Atletas.

Introduction

Wheelchair basketball (WB) is one of the most well-known and attractive sports modalities in the paralympic movement (Luarte et al., 2022; Solera et al., 2021), emerging for the first time around the year 1946 in the US after the Second World War, being practiced by wounded soldiers who, for the most part, were former players without disabilities who wanted to carry on, in one way or another, practicing this sport (International Paralympic Commmittee, 2019).

This modality is regulated by the International Wheelchair Basketball Federation (IWBF) and establishes rules of play similar to the conventional sport, although with adaptations, among them, the wheelchair and sports classification. The latter is a mandatory requirement for athletes to participate in official competitions and consists of grouping athletes according to the functionality of their disability (IWBF, 2021b). According to the functionality presented, each athlete will be incorporated into a sport class ranging from 1.0 to 4.5, considering that, the lower their sport class, the greater the motor compromise presented by the athlete (Cavedon et al., 2018; dos Santos et al., 2017; IWBF, 2021b; Luarte et al., 2022). Therefore, no team may field athletes whose combined total of the five players on the court adds up to more than 14 points (IWBF, 2021b).

WB is an intermittent sport that demands athletes to possess adequate levels of strength in its various manifestations; speed and agility, aerobic and anaerobic endurance to perform high intensity actions with short recovery time intervals (Iturricastillo et al., 2016; Seron et al., 2019). In addition, technique is essential in the performance of athletes, since game situations entail having ball control and wheelchair handling in the actions proper and determinant of the modality, such as; pushing the chair, dribbling, turning, passing, throwing to the hoop and tilting the chair on a wheel (IWBF, 2021a; Soylu et al., 2020).

The wide variety of individual physical disabilities on a team makes physiological responses different for each player and considering the wheelchair which is a primordial part as the integration of the player with their chair allows for propulsion and sport movements that impact their performance (Goosey-Tolfrey & Leicht, 2013). The considerations of all these variables make a great challenge for researchers. With respect to the evaluations in WB, we have two relevant considerations which are the player and the wheelchair, since both form a single unit that gives an answer according to the athlete's sport form and the conditions of his wheelchair, in addition it should be considered that the performance not only depends on the physical condition of the athletes, but also on the skills, experiences and technical competencies of the sport (Goosey-Tolfrey & Leicht, 2013).

For athletes, complete performance evaluations should be considered that include aerobic, anaerobic and sport-specific abilities that allow the evaluation of individual parameters and the level of achievement in an indoor environment with the application of field tests (Vanlandewijck et al., 1999), in addition to specific laboratory tests such as the Wingate test with arm crank ergometers to evaluate maximal and average anaerobic power and fatigue index (Bartosz & Molik et al., 2010).

Evaluations in sport, are fundamental tools that allow knowing the physical condition of the athlete, the effects that one has with the practice of the activity and is the means by which coaches obtain objective parameters to make decisions and to be able to define the most appropriate type of training (González-Rico & Ramírez-Lechuga, 2018).

These evaluations are fundamental for the sports preparation of athletes considering the complexity of the systems that compose it; that is, competition system, training system and complementary factors (Gomes, 2009). Physical evaluations are closely related to the training system, which is related to the development and improvement of athletes considering the principles of modality specificity, individuality, overload, continuity, volume and intensity (Gomes, 2009 cited in Campos Campos et al., 2021; Fernández et al., 2021).

Therefore, the objective of this research is to identify the most recurrent tests in the literature, used for the evaluation of physical qualities in WB elite level.

Methods

Protocol

A systematic literature review was performed according to the guidelines set forth in the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) Statement (Moher et al., 2009; Page et al., 2021).

Data sources and search

A literature search was conducted between April and May 2021 in four electronic databases: PubMed, Web of Science (WOS), Scopus and ScienceDirect. Keywords in English were used in the searching process: Athletes, Wheelchair Basketball, Testing and Performance were entered. Key search terms were included and combined using the "AND", "OR" operator: [Athletes AND "Wheelchair basketball" AND Test AND Performance].

Eligibility Criteria

Eligibility criteria were determined according to the PICOS approach, which contemplates in its acronym; population (P), intervention (I), comparator (control) (C), outcome (O) and study design(s) (S), This strategy is used for the construction of research question and eligibility criteria (da Costa Santos et al., 2007).

Accordingly, studies were considered if (1) the sample consisted of elite athletes, (2) WB practitioners, (3) if the results of the studies dealt with the evaluation of physical qualities and (4) were published in English, Spanish and/or Portuguese.

Studies that corresponded to (1) thesis studies, (2) book chapters, (3) articles without full text and (4) case studies were excluded.

Selection of studies

First, all the articles obtained after the searching process from the databases were classified and registered in the Mendeley® program, in which duplicates were eliminated and those that did not meet the inclusion criterion of year of publication were excluded. Subsequently, the articles were reviewed by title and/or abstract, where one or more of the key terms were present. Finally, only articles that met all the inclusion criteria were considered. These studies were finally analyzed during the review process.

Process of data collection

The data collection process is based on the PRISMA flowchart. That is, three main filters were applied during the data collection process detailed in the previous point. The Mendeley® program was used to compile the information from all the selected databases and the results were recorded using an Excel® spreadsheet.

In the first instance, with the articles that were selected on the basis of the title and summary, the information was recorded with respect to: title and variable of the physical quality that it evaluates.

Then, the articles were read completely and those that met the inclusion criteria, an additional Excel spreadsheet was created, where the following information was identified: year of publication, title, authors, objective of the research, methodology, results, and conclusions.

Finally, based on the above information, two tables were prepared, firstly, with the characteristics of the studies: author, year, title, and objective. Secondly, with the aspects: author, year, methodology, results, and conclusions.

Results

Selection of studies

The initial search in the databases yielded a total of 270 articles, where 199 studies were registered after the elimination of duplicates. These articles were read by title and/or abstract in search of information relevant to our research topic, with 43 studies being selected for full reading. Finally, a total of 39 articles met the eligibility criteria and were selected for this systematic review.

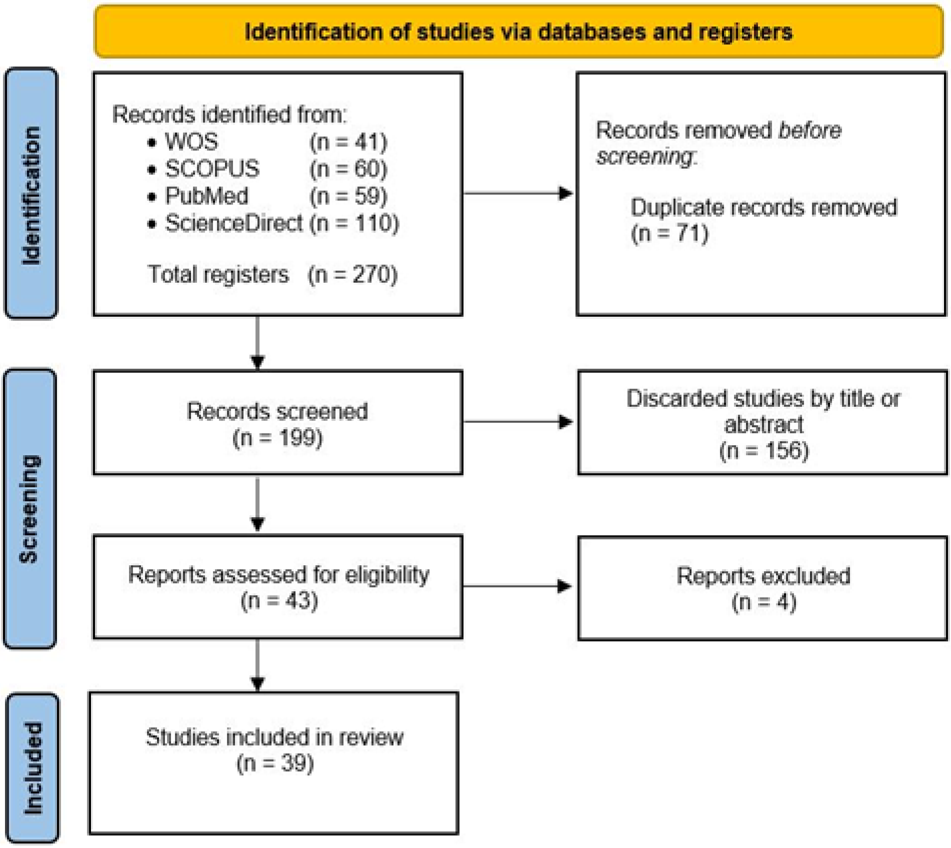

Figure 1. *PRISMA flowchart*
Page et al. (2021)

Process of data collection

Table 1 shows the identification in the original language of all the articles included in the systematic review, where the largest number of articles were between 2015 and 2020.

Table 1. Identification of selected studies

Author(s)	Year	Title
Mason et al.	2012	The Effect of Wheel Size on Mobility Performance in Wheelchair Athletes
de Groot et al.	2012	Validity and reliability of tests determining performance-related components of wheelchair basketball
Montesano et al.	2013	Improvement of the motor performance difference in athletes of wheelchair Basketball
Molik et al.	2013	Relationships between anaerobic performance, field tests, and functional level of elite female wheelchair basketball athletes
Leicht et al.	2014	Blood lactate and ventilatory thresholds in wheelchair athletes with tetraplegia and paraplegia
Ozmen et al.	2014	Explosive strength training improves speed and agility in wheelchair basketball athletes
Yanci et al.	2015	Sprint, agility, strength and endurance capacity in wheelchair basketball players
Granados et al.	2015	Anthropometry and performance in wheelchair basketball
Iturricastillo et al.	2015	Changes in Body Composition and Physical Performance in Wheelchair Basketball Players During a Competitive Season
Weissland et al.	2015	Comparison between 30-15 intermittent fitness test and multistage field test on physiological responses in wheelchair basketball players
Cavedon et al.	2015	Physique and Performance of Young Wheelchair Basketball Players in Relation with Classification.
Weissland, Faupin, Borel, Berthoin, et al.	2015	Effects of Modified Multistage Field Test on Performance and Physiological Responses in Wheelchair Basketball Players
Astier et al.	2016	Perceived exertion responses and performance of two mode of propulsion in the multistage field test with wheelchair basketball players
Pereira et al.	2016	Respiratory muscle strength and aerobic performance of wheelchair basketball players
Ferro et al.	2016	Sprint performance of elite wheelchair basketball players: Applicability of a laser system for describing the velocity curve
Vaquera et al.	2016	Validity and Test-Retest Reliability of the TIVRE-Basket Test for the Determination of Aerobic Power in Elite Male Basketball Players
Saltan & Ankarali	2017	The Role of Trunk Stabilization in Functional-Classification Levels in Wheelchair Basketball
Ferreira et al.	2017	Morphological characteristics, muscle strength, and anaerobic power performance of wheelchair basketball players
Ferro et al.	2017	Nutritional Habits and Performance in Male Elite Wheelchair Basketball Players During a Precompetitive Period
Skucas & Pokvytyte	2017	Short-term moderate intensive high volume training program provides aerobic endurance benefit in wheelchair basketball players
Molik et al.	2017	Comparison of Aerobic Performance Testing Protocols in Elite Male Wheelchair Basketball Players
de Witte et al.	2018	Development, construct validity and test–retest reliability of a field-based wheelchair mobility performance test for wheelchair basketball

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Author(s)	Year	Title
Iturricastillo et al.	2017	Neuromuscular Responses and Physiological Changes During Small-Sided Games in Wheelchair Basketball.
Cavedon et al.	2018	Anthropometry, body composition, and performance in sport-specific field test in female wheelchair basketball players
Yüksel & Sevindi	2018	Examination of Performance Levels of Wheelchair Basketball Players Playing in Different Leagues
de Witte, Sjaarda, et al.	2018	Sensitivity to change of the field-based Wheelchair Mobility Performance Test in wheelchair basketball.
Veeger et al.	2019	Improving mobility performance in wheelchair basketball
Iturricastillo et al.	2019	Velocity and Power-Load Association of Bench-Press Exercise in Wheelchair Basketball Players and their Relationships With Field-Test Performance
Tachibana et al.	2019	Influence of Functional Classification on Skill Tests in Elite Female Wheelchair Basketball Athletes
Marszałek et al.	2019	Laboratory and non-laboratory assessment of anaerobic performance of elite male wheelchair basketball athletes
Otto et al.	2019	Physiological responses at the anaerobic threshold and at peak performance during arm crank ergometer diagnostics compared to wheelchair propulsion on a treadmill in elite wheelchair basketball players
Marszalek et al.	2019	Test-retest reliability of the newly developed field-based tests focuses on short time efforts with maximal intensity for wheelchair basketball players
Antonelli et al.	2020	Effects of inspiratory muscle training with progressive loading on respiratory muscle function and sports performance in high-performance wheelchair basketball athletes: A randomized clinical trial
Weber et al.	2020	Adaptation of Anaerobic Field-Based Tests for Wheelchair Basketball Athletes
De Witte et al.	2020	Effects of seat height, wheelchair mass and additional grip on a field-based wheelchair basketball mobility performance test
Loturco et al.	2020	Relationship between power output and speed-related performance in Brazilian wheelchair basketball players
Villacieros et al.	2020	Relationship between Sprint Velocity and Peak Moment at Shoulder and Elbow in Elite Wheelchair Basketball Players
Zacharakis	2020	The effect of upper limb characteristics on palm strength, anaerobic power, and technical skills of wheelchair basketball players of varying classification
Soylu et al.	2020	The Relationship Between Athletic Performance and Physiological Characteristics in Wheelchair Basketball Athletes

Source: Own elaboration.

On the other hand, Table 2 shows a summary of the selected articles that evaluated some physical quality by means of physical tests.

Table 2. Summary of selected studies

Author(s)	Sample	Methods	Variable	Test
Astier et al. (2016)	8 athletes	Performance evaluation in synchronous and asynchronous mode (wheelchair propulsion) in multi-stage incremental field test (MFT). The number of exercise levels performed, maximal aerobic speed, rating of perceived exertion, and arm frequency were measured.	Maximal aerobic speed	Multistage Field Test (MFT)
Otto et al. (2019)	8 athletes	Physiological responses at anaerobic threshold and maximal performance in two tests were evaluated.	Oxygen uptake (VO2), heart rate (HR), energy expenditure (EE), and lactate concentration (LA)	Ergometer – Treadmill.
Cavedon, Zancanaro & Milanese (2015)	52 athletes (45 men 7 women)	Evaluation of performance in sport-specific field tests.	Speed - Explosive Force	Speed: Sprint 5m - Sprint 20m w/ball - Suicides. Explosive force: Maximum pass.
Loturco et al. (2020)	11 athletes	Verify the relationship between power output and speed-related performance.	Speed - Power	Power: Bench press, shoulder press and pull exercise on prone bench.
Villacieros et al. (2020)	12 athletes	Evaluation of the speed based on the movement of the shoulder and elbow in the propulsion.	Speed	Sprint 5m - Sprint 10m with ball and Sprint 15m with passing and braking.
Pereira et al. (2016)	19 athletes	Training sessions including stretching and resistance exercises, muscular resistance focused on the muscles of the arm, shoulder and trunk.	Respiratory Muscle Strength - Aerobic Performance	Respiratory muscle strength: analog manometer. Aerobic performance: 12-minute test in a 25x15 meter rectangle.
De Witte et al. (2018)	16 athletes	Assessment of athlete performance based on wheelchair mobility.	Mobility performance	Wheelchair Mobility Performance (WMP)
Skucas & Pokvytyte (2017)	8 athletes	Subjects participated in a two-week intervention program of mainly two types of training: wheelchair basketball and wheelchair driving resistance training.	Aerobic resistance	Ergonómetro
Ferro, Villacieros & Pérez-Tejero (2016)	12 athletes	Speed measurement through a laser system to describe the speed curve.	Speed	Sprint 20m
Yanci et al. (2015)	16 athletes	The reliability and reproducibility of an agility test and a recovery test were determined. On the other hand, the physical characteristics measured by field tests were evaluated.	Agility - Aerobic resistance - Speed - Strength	Agility: Test T. Aerobic resistance: Yo-Yo 10m. Speed: Sprint 5m and 20m with and without the ball. Strength: dynamometer and maximum pass (basketball).
Zacharakis (2020)	14 athletes	The athletes performed 8 tests of wheelchair propulsion and technical skills. Finally, their anaerobic power was evaluated.	Speed - Skill - Anaerobic Power	Speed: Sprint 5m and 20m. Ability: Dribbling, Lay-up, Passing. Anaerobic power: Ergometer.
Mason, Van der Woude, Lenton & Goosey-Tolfrey (2012)	13 athletes	They used different types of wheel sizes (0.59m, 0.61m and 0.65m) to verify mobility performance in field tests.	Speed - Mobility - Agility	Speed: Sprint 20m. Mobility: Linear acceleration and brake. Agility: Linear speed with Slalom.
Soylu et al. (2020)	26 athletes (24 men 2 women)	All BSR athletes examined underwent anthropometric measurements and took laboratory tests and three field tests in two sessions separated by 6 weeks.	Strength - Aerobic capacity - Anaerobic capacity.	Isokinetic shoulder strength: Isokinetic dynamometer. Grip strength: Manual dynamometer. Aerobic capacity: ramp protocol using a treadmill. Anaerobic capacity: Wingate test.

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Author(s)	Sample	Methods	Variable	Test
Saltan & Ankarali (2017)	113 athletes	Athletes underwent a modified wheelchair skills test to assess trunk stabilization at functional classification levels.	Skills	Modified Wheelchair Skills Test (WST) (version 4.1)
Iturricastillo et al. (2019)	9 athletes	Athletes performed power loading exercises in bench press to verify the relationship with performance in field tests.	Speed - Power Strength - Skill	Speed: Sprint 20m. Ability: 505 change of direction ability test (505 CODA), Repeated Sprint Ability Test (RSA). Power strength: Bench press isoinertial test.
Molik et al. (2013)	23 athletes (women)	Field tests and the 30-second Wingate anaerobic test were evaluated. Measures of maximal power output (PP), time to maximal power (tPP), mean power output (MP), and a fatigue index (FI) were used to assess AnP. A test battery was applied that evaluated seven wheelchair basketball skills.	Anaerobic power - Grip strength - Explosive strength - Accuracy - Speed - Agility	Anaerobic power: Wingate. Grip strength: Dynamometer. Explosive force: Maximum pass. Accuracy: Shots from different sectors of the field. Speed: Sprint 5m, 20m. Agility: Slalom with and without the ball.
Granados et al. (2015)	8 male athletes	The tests were performed in 2 different sessions separated by at least 2 days. The speed test consisted of 3 maximum sprints of 20 m (39), with a rest period of 120 seconds between each repetition.	Speed – Agility – Strength - Resistance	Speed: Sprint (5 and 20m) with and without the ball. Agility: T test and ball pick up test. Strength: Dynamometer, maximum pass and medicine ball throw (5kg). Resistance: Yo-Yo test 10 m.
Cavedon et al. (2018)	13 female athletes	Physical performance through field tests.	Speed, Skill	Speed: Sprint (5 and 20m) with and without the ball; Ability: Accurate pass; tray test.
Leicht et al. (2014)	19 athletes (2 women)	Athletes were tested on the motorized treadmill, beginning a 5- to 10-minute warm-up at speeds slower than the initial gXt speed, followed by a 10-minute passive recovery to ensure participants started the gXt from a resting state. gXt boot speed varied between 1.2 and 2.0 ms.	Resistance	Test on a motorized treadmill with a constant 1.0% incline.
Ferreira et al. (2017)	11 athletes	To provide a descriptive analysis of the morphological structure, muscle strength, and anaerobic power performance of the upper limbs of wheelchair basketball athletes.	Muscular strength -Anaerobic power	Muscle strength: right and left hand dynamometers (kg), medicine ball throw (m); Anaerobic power: Wingate test (W)
Iturricastillo et al. (2015)	8 athletes	Three accelerations were performed over 5 and 20 m in a straight line with and without the ball, with a rest period of 2 min between sprints. The T test was performed three repetitions with 3 min of rest between them. For the pick-up test, three repetitions were performed with rest periods of 3 min between them. The ball pick-up test consisted of picking up four basketballs from the ground twice with the left hand and twice with the right hand.	Speed - Agility - Pickup - Ultimate Strength - Resistance	Speed: Sprint (5 and 20 m) with and without the ball; Agility: T test and ball pick up test; Maximum strength: dynamometer and maximum pass, medicine ball throw (5kg). Resistance: Yoyo Test of 10 m.
Weissland et al. (2015)	18 athletes	The incremental continuous test MFT includes rotating around an octagon (15 × 15 m) at an initial speed of 6 km h - 1 for 1 min. Sde increases, the speed by 0.37 km. · h - 1 every minute until exhaustion. The 30-15 SI T consisted of 40-m shuttle runs for 30 s with 15 s of passive recovery. The initial speed was set at 6 km h - 1 (instead of 8 km h - 1 in the original protocol) for the first 30 s trial and was increased by 0.5 km h - 1 every 45 s.	Aerobic fitness and maximum sprint speed	Multistage Continuous Field Test (MFT) and 30-15 Intermittent Field Test (30-15 IFT).

Author(s)	Sample	Methods	Variable	Test
Molik et al. (2017)	12 athletes	For the WCT test the sports wheelchair was connected to the metal frame for safety. The speed and slope of the treadmill were increased simultaneously. The test started at 3.2 km/h 0% WCT. The speed and incline of the treadmill were increased every two minutes (0-2 min: 3.2 km/h, 0%; 2-4 min: 4.8 km/h, 1.0%; 4-6 min: 6.4 km/h, 1.5%, 6-8 min: 8 km/h, 2.0%, 8-10 min: 9.6 km/h, 2.5%, 10-12 min: 11.2 km/h, 3.0%).	Aerobic performance	Wheelchair treadmill (WCT) and crank ergometer stress test (ACE).
Antonelli et al. (2020)	17 athletes	Respiratory muscle strength is assessed using a manovacuometer, an evaluation of sports performance performed using the YoYo resistance test and intermittent recovery.	Respiratory muscle strength (MIP and MEP), aerobic PP by wheelchair yoyo test.	Intermittent Resistance Test Yoyo adapted test (10m). Respiratory muscle force manovacuometer.
Weissland, Faupin, Borel, Berthoin, et al. (2015)	16 BSR athletes (2 women)	On two separate days, all subjects performed a multistage incremental field test (MFT) and a modified MFT (MFT-8). The MFT consisted of turning around an octagonal course. For both trials, the initial rate of turn was 6 km·h −1 during the first 1-minute stage and then the rate of turn was increased by 0.37 km·h −1 every minute until exhaustion. With the same progressive speed, the MFT-8 consisted of rotating two octagons 2 meters apart to describe an 8.	Maximal aerobic speed	Octagonal incremental test MFT and modified MFT-8.
Witte et al. (2020)	21 athletes	Field-based wheelchair mobility performance (WMP) test. The participants performed the WMP test six times in their own wheelchair, of which five times with different configurations. Each WMP trial took about 6.5 minutes and was followed by a 15- to 30-minute rest period to allow for recovery. All WMP tests were videotaped from the side of the field with two video cameras.	Mobility performance	Wheelchair Mobility Performance (WMP)
Yüksel et al. (2018)	21 athletes	Specific field tests of the BSR	Agility - Speed - Aerobic resistance - Shoulder Flexibility - Skill	Balance: Modified functional scope test. A modified sit-up test and modified push-ups were implemented. Shoulder Flexibility: Back Scratch Test; Speed: Sprint 20m; Agility: slalom with and without the ball; Endurance: Endurance run 6 min; Ability: Pass by accuracy; pass by distance; zone shot.
Montesano et al. (2013)	20 athletes	Improve the percentage of shots and passes by strengthening the upper extremities through specific exercises and the use of competition balls, medicine balls and elastic bands.	Passing and shooting effectiveness	Pass registration exercises approved with one hand (5 stations) and another exercise of percentage of approval of the shot were used.
Veeger et al. (2019)	70 athletes (16 women)	The wheelchair mobility performance test (WMP test) was demonstrated with a video and a camera is used to record the performance. All lengths and angles of the athlete, wheelchair, and athlete-wheelchair interface were determined using Kinovea.	Mobility performance	Wheelchair Mobility Performance (WMP)

Author(s)	Sample	Methods	Variable	Test
Tachibana et al. (2019)	26 female athletes	Before 10 minutes of the tests, the athletes could warm up freely. The order of execution of the tasks was not specified and they were instructed to do the tests at maximum intensity, in addition to allowing them to have rest times between tests (2 min).	Speed - Agility - Resistance	Speed: Sprint 20m; Agility: T test and octagonal ball test, Endurance: Yo-Yo Test 10 m
Iturricastillo et al. (2017)	13 athletes	A battery of tests (ability to change direction, sprints, and sled towing) were performed to study neuromuscular responses. For the sled tow test, subjects performed the same 20 m wheelchair speed test, but in this case, the players pulled a resistance of 10% of their body mass. In the case of speed, two 20-meter sprints are performed.	Speed – Agility.	Agility: T test. Speed: 20m sprint. Sled towing: Subjects performed the same 20-m wheelchair speed test, but in this case, the players pulled a resistance of 10% of their body mass.
Ferro et al. (2017)	11 athletes	The players performed two sets of 20m sprints. The test began with a 15-min warm-up, and a 5-min rest was given between the two series. Players waited at the starting line with their front wheels on the line and the trunk behind. They could independently perform preparatory driving movements and pull away when ready. For the measurement, a type 1 laser sensor was used.	Speed	Sprint 20 m
Ozmen et al. (2014)	10 male athletes	The speed was determined by a speed test. The players had two attempts to cover the distance as quickly as possible in a 2-minute period. Sprint duration was measured using photocell gates at the beginning and end of the line. Agility was assessed using the Illinois wheelchair agility test. Four cones marked the beginning, the end and the two turning points. Another four cones were placed in the center at the same distance. Each cone in the center was spaced 3.3 m apart. Duration was measured by photocells located from start to finish with the best result of two recorded attempts.	Speed - Agility	Speed: Sprint 20m. Agility: Illinois

Source: Own elaboration.

Finally, Table 3 shows the 6 selected articles that were exclusively dedicated to validity and reliability of tests in wheelchair basketball, referring to several physical variables.

Table 3. Items identified from validation and/or reliability of a test

Author and year	Sample	Method	Variable	Test
Marszalek et al. (2019)	9 BSR athletes	The athletes performed 11 field tests focused on short-time effort at maximum intensity. These tests were performed twice (pre and post test) to verify the reliability of these tests.	Speed - Power - Strength - Agility	Speed: Sprint 10m, 20m, 30-second test and Sprint 10x5m. Power: Sprint 3m, 5m, Maximum Pass and Medicine Ball Throw 3kg. Grip strength: Dynamometer. Agility: Agility drill test.
De Groot et al. (2012)	19 BSR athletes	A battery of 10 tests was designed that the athletes had to perform twice to determine reliability. The validity of the tests was evaluated by relating the scores to the players' rating and the standard of competition, the coach's rating and the player's rating.	Speed - Power - Explosive Force - Agility - Skill	Ability: Precision passes, Lay-up, Free kick, Point shots. Speed: Sprint 5m, 20m, Suicides. Explosive force: Maximum pass (basketball). Agility: Slalom, Pick up balls.
Vaquera et al. (2016)	36 BSR athletes	The athletes performed a test-retest of the TIVRE-Basket test to determine aerobic power	Aerobic power	Test TIVRE-Basket
Weber et al. (2020)	11 BSR athletes	Estimation of anaerobic power through field tests. In addition, double-handed grip strength (HGS) and the medicine ball chest pass test were assessed.	Anaerobic Power – Strength - Muscular Power	Anaerobic Power: Wingate; Sprint 15m and 20m, Grip strength: dynamometer; Muscular power: medicine ball chest pass (3kg)
Marszałek et al. (2019)	61 BSR athletes	The participants were divided into two functional categories A (classes from 1.0 to 2.5; n = 29) and B (classes from 3.0 to 4.5; n = 32) according to the IWBF rules. Laboratory and field tests were carried out.	Anaerobic Performance - Speed – Skill - Agility - Strength	Anaerobic test: Wingate (ergometer). Speed: 3m sprint, 5m sprint, 10m sprint, 20m sprint, 30s sprint trial. Strength: medicine ball throw (3kg), bilateral grip, 3-6-9m mock test, Agility: agility mock test.
De Witte, Sjaarda et al. (2018)	46 BSR athletes	Wheelchair activities were assessed by systematic observation of video images of matches. Four games were recorded at the national game level and five games at the international game level. To make a translation of the match data to the test design, the result was organized in three main categories: separate activities, combined activities and ball possession activities.	Mobility performance	Wheelchair Mobility Performance (WMP)

Source: Own elaboration.

Discussion

The objective of this systematic review was to identify the most recurrent tests in the literature, used for the evaluation of physical qualities in elite level WB. A total of 39 articles related to the objective were selected.

The main findings indicate that the most used tests and instruments were: 20m sprint, with presence in 18 studies, followed by 5m sprint, used in 11 studies, dynamometer, present in 8 studies, maximum basketball pass, with presence in 7 studies, medicine ball throw, used in 6 studies, T-test, with presence in 5 studies and Wingate, used in 5 studies. This indicates that the most evaluated physical qualities are: speed, strength, agility and anaerobic power.

Table 4. Most used test according to the literature investigated

Test	Variable	Number of appearances	Studies
Sprint 20m	Speed	18	(Cavedon et al., 2015; Ferro et al., 2016; Yanci et al., 2015; Zacharakis, 2020; Iturricastillo et al., 2019; Molik et al., 2013; Granados et al., 2015; Cavedon et al., 2018; Iturricastillo et al., 2015; Yüskel et al., 2018; Tachibana et al., 2019; Iturricastillo et al., 2017; Ferro et al., 2017; Ozmen et al., 2014; Marszalek et al., 2019; De Groot et al., 2012; Weber et al., 2020; Marszalek et al., 2019)
Sprint 5m	Speed	11	(Cavedon et al., 2015; Villacieros et al., 2020; Yanci et al., 2015; Zacharakis et al., 2020; Molik et al., 2013; Granados et al., 2015; Cavedon et al., 2018; Iturricastillo et al., 2015; Marszalek et al., 2019; De Groot et al., 2012; Marszalek et al., 2019)
Dynamometer	Grip strength	8	(Yanci et al., 2015; Soylu et al., 2020; Molik et al., 2013; Granados et al., 2015; Ferreira et al., 2017; Iturricastillo et al., 2015; Marszalek et al., 2019; Weber et al., 2020)
Max pass	Explosive force	7	(Cavedon et al., 2015; Yanci et al., 2015; Molik et al., 2013; Granados et al., 2015; Iturricastillo et al., 2015; Marszalek et al., 2019; De Groot et al., 2012)
Medicine ball throw	Explosive force	6	(Granados et al., 2015; Ferreira et al., 2017; Iturricastillo et al., 2015; Marszalek et al., 2019; Weber et al., 2020; Marszalek et al., 2019)
T-Test	Agility	5	(Yanci et al., 2015; Granados et al., 2015; Iturricastillo et al., 2015; Tachibana et al., 2019; Iturricastillo et al., 2017)
Wingate	Anaerobic power	5	(Soylu et al., 2020; Molik et al., 2013; Ferreira et al., 2017; Weber et al., 2020; Marszalek et al., 2019)

Source: Own elaboration.

The 20-meter sprint test has been used to assess the speed of WB athletes in numerous studies. This test is of simple applicability and apart from obtaining speed data, it also provides certain results about factors related to performance and pushing efficiency (Brown, 2013). The protocol consists of locating, generally, a cone in the start and finish zone (20 meters in a straight line), where with a device (photocells and/or manual stopwatch) the time used is measured. Athletes must align the large wheel of their wheelchair parallel to the start line (Molik et al., 2013). Athletes have two attempts to execute the test and the best time is recorded. Authors (Cavedon et al., 2015; Cavedon et al., 2018; Granados et al., 2015; Iturricastillo et al., 2015; Yanci et al., 2014) have used this test with and without ball, finding an increase in the time used when using the ball, that is, when performing the Sprint 20m test without ball, the range of time used is between 5.16 and 5.7 seconds, but when performing the test using the ball, the range of time is between 5.76 and 9.2 seconds. On the other hand, authors (Bergamini et al., 2015) indicate the importance of an adequate propulsion symmetry as an indicator value related to sports performance and possible injuries using the 20m Sprint test with inertia measurement units. Similarly, Ferro et al. (2021) demonstrated that there is a relationship between the speed of movement of the players and the acceleration generated from the players' wrists.

The 5-meter sprint test was the second most applied test in WB athletes. This consists of the athlete starting from a stationary position and with the front of the wheel behind the starting line, the athlete must move forward as fast as possible for 5 meters. The time it takes to travel the five meters is considered, for this generally, in the studies photocells are used for the assessment, however, it is also common to use stopwatch, in this regard, authors (Cavedon et al., 2015; Cavedon, Zancano & Milanese, 2018; De groot et al., 2012) indicate that this started when the front wheels crossed the starting line and stopped when the front wheels crossed the finish line. In terms of attempts, there are studies in which athletes perform two repetitions (Molik et al., 2013; Marszalek et al., 2019) and research applying three (De groot, 2012; Granados et al., 2018; Iturricastillo, Granados & Yanci, 2015; Yanci et al., 2018). It is important to consider the dominant wrist acceleration in the test as an indicator of higher acceleration, so states Ferro et al. (2021), where it is shown that there is a significant relationship between the average acceleration of the dominant wrist and the average speed of the wheelchair player, being this relationship stronger at the beginning (0-3 m).

To measure the grip strength, the hand dynamometer is used, where the athlete from his wheelchair, holds with one hand the instrument that will be located fully extended to the side of the wheel, and without this touching it. According to Yanci et al (2015), the protocol indicates that three maximum isometric contractions are performed for 5 seconds, with a rest period of one minute, where the highest value is considered to determine the maximum grip strength. In the case of the studies by Ferreira et al. (2017) and Weber et al. (2020), they apply two attempts with one minute of rest. Authors (Oliveira et al., 2017) state that the dynamometer is a valid tool to evaluate wheelchair propulsion. It is important to consider that sports performance values in WB athletes will be related to the different classification scores (Soylu et al., 2020).

On the other hand, one of the most widely used tests to measure explosive strength in athletes was the Maximum Basketball Pass. This test consists of placing the athlete with the front wheel behind the baseline and performing an overhead pass with both arms as far as possible from a stationary position, while one of the researchers holds the wheelchair still (Granados et al., 2015; Iturricastillo et al., 2015). Athletes have a maximum of 5 attempts where the average distance between the 5 throws is taken. It is a test of easy application and helps to have parameters referred to explosive strength in athletes. The reference values considering high and low classes oscillate between 7.8 and 13.8 meters.

The medicine ball throwing test was used in several studies to evaluate explosive strength in WB athletes. The authors mainly used 3 kg (Ferreira et al., 2017; Iturricastillo et al., 2015; Marszałek, Kosmol, Morgulec-Adamowicz, Mróz, Gryko, Klavina, Skucas, Navia & Molik, 2019; Marszalek, Kosmol, Morgulec-Adamowicz, Mróz, Gryko & Molik, 2019; Weber et al., 2020) and 5 kg (Granados et al., 2015;) balls. For this test, the authors point out that the protocol consists of the athlete supporting his back firmly on the back of his chair, holding the medicine ball with both hands and performing a throw from the chest area to the front without removing his back from the back of the chair (Ferreira et al., 2017). To maintain this position, an evaluator holds with a strip of cloth (10 cm) the chest area, trying to maintain a static position of the trunk at all times of the throw. According to the selected studies, for the 3 kg ball throw and considering high and low classes, the values oscillate between 3.09 and 7.08 meters; for the 5 kg medicine ball throw, the values oscillate between 4.86 and 4.89 meters. Authors (Granados et al., 2015) have compared the maximum pass test and medicine ball throw in first and third division teams, finding significant differences between the two with an increase of 33% and 24% respectively in the results of first division teams. The aforementioned authors (Granados et al., 2015) point out that these differences between elite and lower level players have also been observed in other sports such as rugby (Baker, 2002) and handball (Gorostiaga et al., 2005), and indicate that high absolute values of muscle strength and explosiveness might be required for successful performance in high-level BSR.

Another of the most commonly used tests in this systematic review was the T-Test (Granados et al., 2015; Iturricastillo et al., 2015; Iturricastillo et al., 2017; Tachibana et al., 2019; Yanci et al., 2015). In the case of Yanci et al. (2015) and Granados et al. (2015), they built on the protocol of Sassi et al. (2009) by making modifications for the wheelchair to allow it to always be moving forward with forward movements. From this, the studies by Iturricastillo et al. (2015), Tachibana et al. (2019) and Iturricastillo et al. (2018), employ the protocol proposed by Yanci et al. (2015). The test consists of completing a T-shaped circuit composed of four cones, moving as fast as possible, where each participant must perform the test 3 times with at least 3 minutes of rest between repetitions. The values of BSR athletes range from 14.74±1.65s (Granados Domínguez et al., 2016) to 15.3±1.2s (Romarate et al., 2020). In relation to other wheelchair sports and the agility test, there is a study conducted on nine elite tennis players, where the T-test was used, whose results were 12.42±0.99s (Sánchez-Pay et al., 2021). When comparing the data presented above in relation to BSR, it can be inferred that BSR athletes present to be slower compared to tennis players. The opposite happens when compared to a study conducted to 13 wheelchair handball athletes, where it is observed that their results in the agility test were 16.5±1.5s (Borges et al., 2017), therefore, it is appreciated that BSR athletes were more agile than handball athletes.

Finally, there is the Wingate test that evaluates anaerobic power, it is characterized for being a laboratory test since a cycloergometer for upper limbs is used. The participant starts by sitting in his or her wheelchair with the cycloergometer adjusted to the level of the shoulder joint (Molik et al., 2013). According to the protocol, athletes perform a warm-up between 10 and 20 minutes consisting of three to four 5-second sprints and then rest. This test consists of performing a maximum effort for 30 seconds with a load of 5% of body weight (Ferreira et al., 2017), however, Marszalek et al. (2019) performs a load difference according to the type of athlete classification, 4% of body mass for category A participants and 5.5% for category B players. This test delivers measures such as peak power (PP), defined as the maximum 5-second value recorded during the test measured in watts (W), mean power output (MP) as mean power achieved during the 30-second test measured in watts (W), minimum maximum power output (MPP), the highest 5-second maximum power value recorded during the Wingate test measured in watts (W) and power drop (PD) (Soylu et al., 2020). This type of testing has also been employed in other Paralympic modalities, for example, wheelchair rugby (Marcolin et al., 2020), however, its application requires specific implements that may make it difficult to access.

As for the studies that focused on validating tests for the evaluation of some physical quality, six were identified. On the one hand, Marszalek et al. (2019) whose study objective was to evaluate the test-retest reliability of field tests focused on high intensity efforts, their results were that

10 out of 11 field tests are reliable for BSR athletes, since there are no statistically significant differences between test and retest (p > .05), in addition, to presenting a strong correlation for each test (r > 0.7). On the other hand, as for the study of De Groot et al. (2012), ten tests are carried out of which six showed good reliability (ICC = 0.80 - 0.97, respectively), while the accuracy pass, free throw, tray and specific throws tests, manifested moderate reliability (ICC = 0.26 - 0.67, respectively), likewise, most of the tests showed good to moderate validity (r > 0.6).

Among the limitations of the present study, we found a lack of specificity in the writing of results by the literature investigated in terms of high and low classes, which prevented us from being able to establish certain reference values discriminating between types of classes for WB athletes. On the other hand, the lack of studies focused on women's sport made it impossible to classify results according to sex.

Conclusion

The physical variables most evaluated in the literature were speed in first place, followed by strength, agility and anaerobic power. To evaluate the mentioned variables, the authors prefer to use 20m and 5m sprints, dynamometer, maximum pass, medicine ball throw, T-test and Wingate.

Finally, the articles focused on the confirmation of reliability and validity of tests for the measurement of physical variables in WB presented good results, concluding that most of the tests evaluated are reliable and valid to evaluate physical aspects in WB athletes.

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