 DOI: 10.5604/20831862.1127285 Biol. Sport 2015;32:71-78

Sprint, agility, strength and endurance capacity in wheelchair basketball players

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ABSTRACT: The aims of the present study were, firstly, to determine the reliability and reproducibility of an agility T-test and Yo-Yo 10 m recovery test; and secondly, to analyse the physical characteristics measured by sprint, agility, strength and endurance field tests in wheelchair basketball (WB) players. 16 WB players (33.06 ± 7.36 years, 71.89 ± 21.71 kg and sitting body height 86.07 ± 6.82 cm) belonging to the national WB league participated in this study. Wheelchair sprint (5 and 20 m without ball, and 5 and 20 m with ball) agility (T-test and pick-up test) strength (handgrip and maximal pass) and endurance (Yo-Yo 10 m recovery test) were performed. T-test and Yo-Yo 10 m recovery test showed good reproducibility values (intraclass correlation coefficient, ICC = 0.74-0.94). The WB players' results in 5 and 20 m sprints without a ball were 1.87 ± 0.21 s and 5.70 ± 0.43 s and with a ball 2.10 ± 0.30 s and 6.59 ± 0.61 s, being better than those reported in the literature. Regarding the pick-up test results (16.05 ± 0.52 s) and maximal pass (8.39 ± 1.77 m), players showed worse values than those obtained in elite players. The main contribution of the present study is the characterization of the physical performance profile of WB players using a field test battery. Furthermore, we demonstrated that the agility T-test and the aerobic Yo-Yo 10 m recovery test are reliable; consequently they may be appropriate instruments for measuring physical fitness in WB.

CITATION: Yanci J, Granados C, Otero M, et al. Sprint, agility, strength and endurance capacity in wheelchair basketball players. Biol Sport. 2015;32(1):71–78.

Received: 2013-09-12; Reviewed: 2014-04-15; Re-submitted: 2014-05-17; Accepted: 2014-05-24; Published: 2014-11-03.

Key words:
disability
physical characteristics
field tests
performance
reliability

INTRODUCTION

Physical capacity can be described as the capacity of the cardiovascular system, muscle groups and the respiratory system to provide a level of physical activity [1]. A low level of physical capacity is associated with a decrease in activity [2], functional status [3] and participation [4]. Boyles, Bailey, & Mossey [5] define disability as a limitation in performing certain roles and tasks that society expects an individual to perform. Thus, physical disability is the third most common major developmental disability, after autism and mental retardation [6]. It has been shown that a low level of physical capacity is associated with a high risk of medical (cardiovascular) complications, which may contribute to a reduction in quality of life [7]. On the other hand, practising physical activity has been shown to have positive health effects by lowering the risk of many prevalent chronic diseases [8]. Participation in regular physical activity is considered to be an essential part of the rehabilitation process among individuals with chronic disabilities [9]. Hence, the evaluation of physical capacity can give an indication of the potential level of activity, participation and quality of life [7].

Competitive sport for those with disabilities has been growing rapidly in recent years [9], and wheelchair basketball (WB) is probably the most popular sport for the disabled [10]. According to the estimates of the International Wheelchair Basketball Federation (IWBF), the number of players worldwide is approximately 30,000. In basketball players with different functional limitations, the players' level of trunk function directly affects the performance of different skills. In particular, trunk movement and stability during basketball are the basis for assigning a player to a particular class [10].

WB is an intermittent activity [11, 12] which combines repeated short, intense exercise bouts that include rapid sprint, acceleration, and deceleration, dynamic position changes, and maintaining or obtaining one's position on the court [13]. The game takes place over an extended time period and is characterized by numerous short periods of high or maximum intensity exercise and sprint actions interspersed with brief recovery periods [12]. Both aerobic and anaerobic energy systems must be activated to meet the energy demands of the muscles during game play [11, 12]; therefore, many studies have reported the need to assess both aerobic and anaerobic energy systems to determine the fitness level of wheelchair athletes [8, 14, 15] and WB players [16-19]. Despite aerobic metabolism being the predominant capacity in WB, it is important not to forget that anaerobic metabolism is crucial in short and high intensity actions that are decisive in a WB match [11, 12]. That is why measurements of physical fitness (sprint, agility, strength, heart rate, lactate concentrations) are usually included in test batteries when evaluating performance of WB players [12, 16-19]. Exercise testing of individuals using wheelchairs for their mobility appeared during the late 1960s and early 1970s [20]. Scientific interest in the aerobic and anaerobic exercise testing of these individuals has increased during the past decade [12, 16, 19]. The review of empirical research published so far revealed great variety in research instrumentation and procedures. Many studies published in the scientific literature analyse the physical aerobic [14, 17, 21], and anaerobic capacity [12, 17, 19], biomechanical [8, 22] and physiological variables [9, 11, 14, 21] and propulsion technique [22] of the WB athletes under laboratory conditions. In comparison to the able-bodied (AB) literature, relatively few studies have assessed the validity and reliability of field-based tests for wheelchair populations. Correlation coefficients between field and laboratory tests vary widely [23]; for example, the variability of endurance tests in wheelchair athletes has been questioned [24]. Given that those tests were developed for AB games players using a running exercise, the assumption that it can also be used for athletes with a disability using wheelchair propulsion could be erroneous [23]. Adaptations of the Cooper test (maximum distance covered within 12 min) or Leger test (maximum amount of stages of ascending intensity covered) have been validated for wheelchair exercise with contradictory results [25]. To our knowledge, nobody has reached a consensus as to the ideal field tool for assessing aerobic capacity in wheelchair players before. The Yo-Yo Intermittent Recovery Test Level 1 has been widely used in basketball [26]. However, it may require adaptations for use with WB players. That is why we have adapted a Yo-Yo intermittent recovery test of 10 m, which could be used as a measuring tool for aerobic performance in WB players. Likewise, several authors have reported that agility, in the guise of change of direction ability (CODA), was a relevant ability in WB [16]. Despite the widespread interest in CODA, a "gold standard" in testing is still to be found due to the nature of change of direction, so new tests for CODA that provide reliability and applicability are warranted.

Therefore, the aims of the present study were, firstly, to determine the reliability and reproducibility of an agility T-test and aerobic fitness Yo-Yo 10 m recovery test, and secondly, to determine the aerobic and anaerobic physical characteristics measured by sprint, agility, strength and endurance field tests in WB players.

MATERIALS AND METHODS

Sixteen wheelchair basketball players, 14 males and 2 females, belonging to the Spanish national WB third division league, participated in this study (Table 1). The inclusion criteria for the participants in the study were to have a valid license from the Spanish Federation of Sports for People with Physical Disabilities (FEDDF) and the certificate of disability that is necessary to belong to this federation. The participants were classified according to the Classification Committee of the IWBF, as well as the corresponding national classification from the FEDDF. Both requisites are compulsory for participating in official events for people in the physical disabilities category. The athletes were divided into eight groups. Category A represents wheelchair basketball players classified as level 1.0 to 2.5 and Category B

TABLE 1. Wheelchair basketball players' characteristics.

Player	Sex	Age (years)	Disability	IWBF Classification	Basketball experience (years)
P1	Male	38	Spinal cord injury	3	8
P2	Male	46	Spinal cord injury	1.5	7
P3	Female	37	Amputation	4.5	8
P4	Male	33	Spinal cord injury	1	7
P5	Male	30	Spinal cord injury	2	5
P6	Male	26	Viral disease (polio)	3	1
P7	Male	29	Dermoid cyst (embryonic origin)	1.5	7
P8	Female	39	Paraplegia	2.5	17
P9	Male	21	Legg-Calve-Perthes	3.5	.5
P10	Male	36	Amputation	3.5	.5
P11	Male	37	Dysplasia	4	5
P12	Male	26	Spina bifida	2	7
P13	Male	22	Spina bifida	2	4
P14	Male	30	Spinal cord injury	4	8
P15	Male	34	Cauda equina syndrome	4	4
P16	Male	45	Spinal cord injury + Amputation	4.5	6
Sample		33.06 ± 7.36		2.91 ± 1.14	5.94 ± 3.94

Note: Results are in means ± s; IWBF = International Wheelchair Basketball Federation; SD = standard deviation.

corresponds to levels 3.0 to 4.5 [12, 27]. None of the participants did specific sprint, strength and agility training and all did three training sessions and one match per week. Prior to involvement in the investigation, all participants gave written informed consent after a detailed written and oral explanation of the potential risks and benefits resulting from participation in this study, as outlined in the Declaration of Helsinki (2008). The participants had the option to voluntarily withdraw from the study at any time. The study was approved by the Ethics Committee of the University of the Basque Country, UPV/EHU.

Measurements

The tests were performed on a synthetic indoor court, on the usual training space and at the same time slot (between 7 and 9 pm), during the pre-season, while the team was in preparation for the WB third division league. In the prior sessions specific exercises were performed to familiarize participants with the correct execution of the tests, and explanations and specific corrections were also given to the players. The players were instructed to perform all tests at maximum intensity. No strenuous exercises were performed within the 48 h immediately prior to the tests and the study was supervised by the researchers at all times. The battery tests were performed in the first preparatory period (October, 3rd week), and the retest of T-test and aerobic fitness Yo-Yo 10 m recovery test were carried out one week later (October, 4th week). All tests were performed in the same venue and facilities. Testing was conducted over two different sessions separated by at least two days. During the first testing session each subject was subjected to sprint and agility tests. In the second testing session, players were assessed for anthropometric measurements, strength and endurance performance. In the retest session, only the agility T-test and Yo-Yo 10 m endurance test were assessed. Before each testing session a standardized warm-up consisting in 5 min self-paced low intensity wheelchair propulsion, stretching and two acceleration drills was performed. Two players could not complete the Pick-up test due to injury. Testing was conducted with each participant using his or her personal sport wheelchair and was integrated into weekly training schedules. All players performed all tests in both test and retest with the same wheelchair and the same conditions.

Physical characteristics

The anthropometric variables of sitting height (m), body mass (kg), skinfolds (mm) and arm perimeter relaxed and contracted were measured in each subject. Sitting height (cm) was measured to the nearest 0.1 cm using a stadiometer (Holtain Ltd®, Crymych, United Kingdom). Body mass was obtained to the nearest 0.1 kg using an electronic scale (Seca Instruments Ltd®, Hamburg, Germany). Skinfold thickness at 4 sites (triceps, subscapular, suprailiac and abdominal) was measured using a Harpenden caliper (Lange®, Cambridge, USA). The physical characteristics of the WB players are presented in Table 2.

Sprint

Without and with ball: The subjects undertook a wheelchair sprint test consisting of three maximal sprints of 20 m [18], with a 120 s rest period between each sprint, enough time to return to the start and wait for their next turn, as previously described by Gorostiaga et al. [28]. The participants were placed at 0.5 m from the starting point, and began when they felt ready. Time was recorded using photocell gates (Microgate, Polifemo Radio Ligth®, Bolzano, Italy) with an accuracy of ± 0.001 s. The timer was activated automatically as the volunteers passed the first gate at the 0.0 m mark and split times were then recorded at 5 m [16] and 20 m [18]. The maximal sprint test with the ball was performed using the same protocol and material. The participants started with a ball from a stationary position and pushed 20 m as fast as possible, adhering to the IWBF rules for dribbling [16]. The test consisted of 3 maximal sprints with the ball over stretches of 20 m. The domains tested were speed and ball handling [16].

TABLE 2. Participants' physical characteristics (sample, category A and B).

	Sample (1.0-4.5 pts.) (n = 16)	Category A (1.0-2.5 pts.) (n = 8)	Category B (3.0-4.5 pts.) (n = 8)
Body mass (Kg)	71.89 ± 21.71	59.63 ± 10.02	84.14 ± 23.87*
Sitting body height (cm)	86.07 ± 6.82	81.17 ± 3.88	90.97 ± 5.45**
Triceps skinfold (mm)	13.76 ± 5.70	13.20 ± 6.05	14.33 ± 5.73
Subscapular skinfold (mm)	17.11 ± 8.40	16.03 ± 4.96	18.20 ± 11.19
Suprailiac skinfold (mm)	13.14 ± 6.44	10.71 ± 2.92	15.56 ± 8.22
Abdominal skinfold (mm)	26.51 ± 10.16	21.83 ± 4.71	31.19 ± 12.27
Σ skinfold (mm)	70.52 ± 26.09	61.77 ± 15.36	79.27 ± 32.56
Arm perimeter (cm)	32.06 ± 4.04	30.46 ± 2.07	33.66 ± 5.01
Contracted arm perimeter (cm)	34.99 ± 4.77	33.61 ± 3.34	36.36 ± 5.80

Note: Results are means ± SD; SD = standard deviation. Significant differences between category A and B, * $p < 0.05$, ** $p < 0.01$.

Agility

T-test: The participants began with the wheels 0.5 m from cone A, and completed the circuit as follows (Figure 1) using the protocol by Sassi et al. [29], modified to perform with a wheelchair and always using forward movements. A-B displacement (9.14 m): At his/her own discretion, each subject moved quickly forward to cone B and touched the top with the right hand. B-C displacement (4.57 m): Facing forward they moved to the left to cone D and touched the top with the left hand. C-D displacement (9.14 m): The participants then moved to the right to cone D and touched the top. D-B displacement (4.57 m): They moved back to the left to cone B and touched the top. B-A displacement (9.14 m): Finally, the participants moved as quickly as possible and returned to line A. All participants performed the test 3 times with at least 3 min rest between trials. The total distance covered was 36.56 m and the height of the cones was 0.3 m. Seven days later, the retest was performed under the same conditions. A photocell (Migrogate Polifemo Radio Light®, Bolzano, Italy) located over cone A was used to record the time. Time measurement started and finished when the subject crossed the line between the tripods. The calculated margin of error was ± 0.001 s and the sensors were set approximately 0.40 m above the floor.

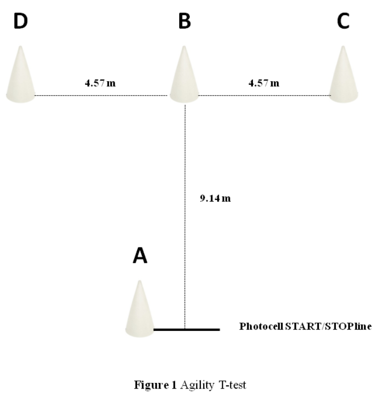

FIG. 1. Agility T-test.

Pick-up the ball: From a stationary position the participant had to start propelling and had to pick up four basketball balls from the floor as previously described by De Groot et al. [16], twice with the left hand and twice with the right hand. After picking up the ball, the ball had to be placed in the lap and the participant had to push the wheelchair once before throwing the ball [16]. The total time taken to complete the test was recorded with a photocell (Migrogate Polifemo Radio Light®, Bolzano, Italy) located over the start and finish lines. All participants performed the test 3 times with at least 3 min rest between trials. The tested domains were ball handling and speed [16].

Strength

Handgrip: Handgrip strength was measured in the dominant hand [30], with the arm in extension and in the vertical axis. The participants performed the test seated in their wheelchair with the test arm fully extended and not touching the wheelchair [27]. A portable hydraulic hand dynamometer (5030J1, Jamar®, Sammons Preston, Inc, United Kingdom), was used for handgrip strength measurement. The testing protocol consisted of three maximal isometric contractions for 5 s, with a rest period of at least 60 s, and the highest value was used to determine maximal grip strength. The subjects were instructed to squeeze the dynamometer as hard as possible. Visual feedback of the recorded strength was provided. The parameters used for analysis were: peak absolute strength (kg) and relative handgrip strength (kg/kg of body mass) [31].

Maximal pass: The participant began in the middle of the baseline, front wheels behind the line, and had to pass a basketball ball as far as possible from a stationary position [16]. The distance between the participant and where the ball hit the floor was measured (in metres). The end score was the average distance of five passes. The tested domain was passing (explosiveness) [16].

Endurance

Yo-Yo intermittent recovery test: Level 1 version of the Yo-Yo test was completed according to previously described methods [26]. The original Yo-Yo IR1 test consisted of 20 m shuttle runs performed at increasing velocities with 10 s of active recovery between runs until exhaustion [26]. Due to the differences between running and propelling the wheelchair, the distance covered in the shuttle run was reduced to 10 m. Pushing speeds were dictated in the form of audio cues broadcast by a pre-programmed computer. The test was considered to have ended when the participant failed twice to reach the front line in time (objective evaluation) or felt unable to cover another shuttle at the dictated speed (subjective evaluation). The total distance covered during the test was measured [26]. Heart rate (HR) was recorded at 5 s intervals [28] by telemetry (Polar Team Sport System®, Polar Electro Oy, Finland) during all the test. Resting conditions (pre-test) and immediately after each exercise stage (post-test) earlobe capillary blood samples were obtained for the determination of lactate concentrations (Lactate Pro LT-1710®, ArkRay Inc Ltd, Kyoto, Japan).

Statistical Analysis

Data analysis was performed using the Statistical Package for Social Sciences (version 19.0 for Windows, SPSS®, Chicago, IL, USA). Standard statistical methods were used for the calculation of the mean and standard deviations. Data were screened for normality of distribution and homogeneity of variances using a Shapiro-Wilk normality test. The intraclass correlation coefficient (ICC) was used to assess T-test and Yo-Yo 10 m endurance test reproducibility (test-retest) and coefficient of variation (CV): (SD/mean)*100 [32] was used to assess sprint, agility and strength tests. Both CV and ICC were performed using three repetitions. The best performance of each test was used for further analysis, except for the maximal pass test, in which the average of all releases was used [16]. Student t-tests for independent samples were used to compare differences between Category A and B performance. Statistical power calculations for T-test correlation ranged from 0.69 to 0.95 in this study. The $p < 0.05$ criterion was used for establishing statistical significance.

RESULTS

The T-test and Yo-Yo 10 m endurance test show good reproducibility values (ICC = 0.74-0.94), and the coefficients of variation (CV) for those tests ranged from 2.6% to 7.2%. Table 3 shows the absolute and relative reliability analysis for the T-test and Yo-Yo 10 m endurance test.

The sprint (5-20 m) with or without ball and agility, strength or endurance test values of the WB players are presented in Figure 2A, Figure 2B and Table 4, respectively. No significant differences were found between Category A and B in sprint, change of direction, strength, or endurance performance.

DISCUSSION

This study analyses anthropometric, sprint, agility, strength and endurance characteristics of WB players from a national league. The

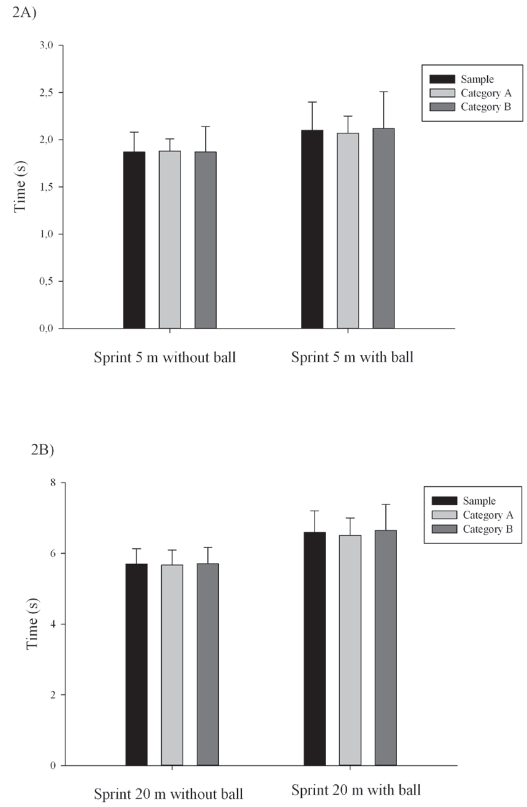

FIG. 2. 5 m (2A) and 20 m (2B) (with and without ball) sprint test results.

TABLE 3. Absolute and relative reliability measures of the T-test and Yo-Yo 10 m endurance test.

	Test (Mean ± SD)	CV (%)	Retest (Mean ± SD)	CV (%)	ICC (CI 95%)
T-test					
Time (s)	16.96 ± 1.14	2.58	16.85 ± 1.20	2.49	0.74
Yo-Yo 10 m					
LA Post (mmol·l-1)	7.21 ± 2.45	-	6.77 ± 2.67	-	0.83
HRmax (beats·min-1)	175 ± 19	-	170 ± 19	-	0.85
Distance covered (m)	1014 ± 369	-	991 ± 358	-	0.94

Note: CV = coefficient of variation, ICC = intraclass correlation coefficient, LA = lactate concentration, HR = heart rate, CI = confidence interval.

TABLE 4. Descriptive measures from wheelchair basketball agility and strength tests (Sample, Category A and B).

	Sample	CV (%)	Category A	CV (%)	Category B	CV (%)
Agility						
T-test (s)	16.96 ± 1.14	2.58	16.56 ± 0.92	2.83	17.29 ± 1.26	2.37
Pick-up the ball (s)	16.05 ± 2.52	6.61	15.82 ± 2.77	8.19	16.23 ± 2.54	5.28
Strength						
Handgrip (Kg)	44.50 ± 11.33	5.50	40.71 ± 9.95	4.94	48.29 ± 12.06	6.05
Maximal pass (m)	8.39 ± 1.77	7.17	7.56 ± 1.18	8.13	9.35 ± 1.95	6.04
Yo-Yo 10 m test						
LA Post (mmol·l-1)	7.21 ± 2.45	-	7.24 ± 3.06	-	7.17 ± 1.90	-
HRmax (beats·min-1)	175 ± 19	-	171.71 ± 24.91	-	178.43 ± 14.51	-
Distance covered (m)	1014 ± 369	-	966.43 ± 304.28	-	1062.86 ± 444.74	-

Note: Results are in means ± SD; CV = coefficient of variation; LA = lactate; HR = heart rate.

main contribution of the present study is the characterization of the physical performance profile of WB players using a field test battery. Field testing is a feasible way to get an indication of performance standard in WB [16]. However, to our knowledge no scientific articles have been published to determine the capacity to change direction using a T-design test, as well as the strength measurement through the handgrip strength test. On the other hand, it is difficult to compare the results of different studies that have measured aerobic capacity in WB players.

It is important to determine the validity and reproducibility of field tests in order to assess physical performance in WB players. In this regard, several field tests have been validated, such as 5-20 m sprint tests [16, 18], the pick-up agility test and the maximal pass [16]. Nevertheless, we have not found studies that examined the reproducibility of an agility T-test and a Yo-Yo 10 m recovery endurance test. In the present study, the T-test in WB players showed good reproducibility values (ICC = 0.74), a value which could be considered good because it was greater than 0.70 [33]. Similar findings have been observed in other T-design tests [29] and other agility tests [34]. The results in terms of reproducibility in the Yo-Yo 10 m test in WB players were also good to excellent considering the three parameters measured (ICC lactate post = 0.83, ICC HR_{max} = 0.85, and ICC distance covered = 0.94). These results indicate that both the T-test and the Yo-Yo 10 m test can be used in the evaluation of training programmes [35]. The CV values in different sport studies measured below 10% have been positively evaluated [32]. In our study, the fact that the CV of all tests were under 7.17% (CV sprint 5 m = 2.71% and 20 m = 1.41%, CV sprint 5 m with ball = 6.66% and 20 m with ball = 3.03%, CV T-test = 2.58%, CV pick up the ball = 6.61%, CV handgrip = 5.50%, CV maximal pass = 7.17%) shows an optimal assessment of reproducibility.

There are many studies that have measured sprint performance without and with the ball in WB players [16, 18, 36]. In this study, the mean velocity in 5 m without the ball (1.87 s) was better than the results obtained by De Groot et al. [16] in Premier league, Tournament A and Tournament B wheelchair players (2.4 s, 2.5 s, 2.6 s, respectively). Comparing the values obtained in the 20 m sprint without the ball, our results were also better (3.8%) than for national players [18], 0.2-5.3% worse than for international WB players [36, 37] and 22.9% for wheelchair tennis [24].

Concerning 20 m sprint performance with the ball, the values reported in our study (6.59 s) were better than those obtained by De Groot et al. [16] in Premier League (7.00 s), Tournament A (7.40 s) and Tournament B (8.70 s) players. In any case, it is difficult to compare the results of different studies that have measured sprint time in WB players because they differ in the methodology of the measurement. Possibly, the use of photocells to measure time in our study versus the use of manual lap timing in other investigations, as well as using the average of the three trials in order to analyse the best result in the statistical analysis, together with putting the starting position 0.5 m behind the line in our case, have influenced the difference in the results of the sprint tests.

Many fitness components have been analysed in basketball players, including muscular power [38], speed [39] and agility [40]. This last component has been used widely in the scientific literature with the T-design test, particularly in basketball [41], and in various sports [42]. However, this is the first study to analyse the performance of the T-test in WB players. As was expected, the results obtained in this test by the WB players were worse than those obtained in other studies by AB athletes [29]. Those differences could be due to the setup, handling and the propulsion technique of the wheelchair, which can influence the performance of an athlete substantially [43].

Regarding the pick-up test, the results in our study were worse (16.05 ± 2.52 s) than those obtained by De Groot et al. [16] in the Belgian WB premier league players (15.3 ± 1.2 s), similar to a Tournament A category (16.1 ± 1.7 s) and clearly better than the Tournament B category players (19.0 ± 2.2 s). Taking into account that in AB basketball a high number of changes of direction occur frequently [40], this suggests that it could also be important in a WB game. Therefore, agility training in WB players could be critical to improve performance in this sport.

Although the handgrip has been used in basketball players and in other sports [30, 31], to our knowledge, this is the first study that has analysed the capacity to generate force measured by a handgrip strength test in WB players. In this work, the values in the absolute (44.50 ± 11.33 kg) handgrip strength test were worse than the results obtained by Gerodimos [31] in AB basketball players (66.71 ± 9.33 kg) and Fallahi & Jadidian [30], in AB athletes (48.15 ± 7.98 kg), and slightly higher than those obtained by Gerodimos [31] in adolescent basketball players (42.10 ± 9.44 kg). In contrast, regarding the relative values, WB players [30] performed better (0.64 ± 0.12 $kg \cdot kg^{-1}$) than the group of athletes and non-athletes (0.56 and 0.54 $kg \cdot kg^{-1}$, respectively). The higher relative strength values observed in WB players compared with AB players may be related to differences in the initial fitness level, amount of training carried out during the previous pre-season period, training intensity and/or motivation, interfering effects between training modes, and the differences in the physiological adaptations to the wheelchair in WB players. Regarding the results of the maximal pass test, the result obtained by our players (8.39 ± 1.77 m) was inferior to those obtained by WB players in the Belgian league [16] in Premier League, Tournament A and Tournament B (14.6 ± 4.2 m, 13.4 ± 2.2 m, 12.1 ± 2.6 m, respectively). Taking into account that the throw and pass actions are the most common abilities in WB, and that the differences in maximal and power strength of the elbow extension can differ between sport levels [44], it may be appropriate to elicit specific training to improve performance in the WB game.

Evaluation of aerobic performance can be used to analyse the functioning of cardiovascular, respiratory and neuromuscular systems, providing a global assessment of the integrative physiological responses and probable relationship with functional capability [17]. Nevertheless, it is difficult to compare the results of different studies that have measured aerobic performance because they differ in a number of factors, including type of tests (MSFT, Cooper, Leger), or the variables measured (VO_2max, distance, HR, lactate). In this study, the WB players showed a mean HR_{max} of 175 ± 19 beats·min $^{-1}$ (89% of HR_{max}), a significant ($P < 0.01$) difference between pre- and post-test blood lactate concentration (1.03 ± 0.39 vs. 7.21 ± 2.45 mmol·l^{-1}, respectively) and a mean distance covered of 1014 ± 369 m. In any case, the mean HR_{max} and blood lactate concentration observed in our WB players are lower than those reported in the literature for international WB players [17, 21]. Therefore, it is not surprising that some physiological measures, such as HR and blood lactate concentration, are inversely related to lesion level, meaning that the higher the level of injury, the lower the peak responses, and vice versa. One explanation can be that the autonomic innervations of the HR in individuals with lesion levels at or above the fifth thoracic segment (T5) are impaired, resulting in lowered HR_{max} of about 100-135 beats·min^{-1} [23], as was the case of the subject classified in IWBF 1.0 (125 beats·min^{-1}). Regarding the distance, our players covered over 39% less than AB basketball players performing a Yo-Yo IR1 intermittent test [26]. This difference between AB and WB players could be due to the skills required in wheelchair team sports (forwards and backwards pushing, braking and acceleration, etc.), which can influence the turns and the way to go in each split.

In the present study, no significant differences were found between Category A and B in sprint (5-20 m with and without ball), agility (T-Test and pick-up), strength (handgrip and maximal pass), or endurance performance (Yo-Yo IR1). Our results are similar to those presented by Molik et al. [12], showing that the level of anaerobic performance of 1.0–2.5 point players (Category A) does not significantly differ from 3.0–4.5 point players (Category B), which may suggest that the classification system for wheelchair basketball athletes should in fact be modified. However, the contradictory results found in other studies [19, 27] highlight the need for more research, especially in the use of field tests that may help coaches and trainers to better evaluate the anaerobic performance of wheelchair basketball athletes while also taking into account the players' functional classification level [27].

CONCLUSIONS

In conclusion, the agility T-test and the Yo-Yo 10 m recovery endurance test are reliable, so both can be regarded as a useful tool in the evaluation of training programmes in wheelchair basketball. WB players showed better results in 5 and 20 m sprints without and with the ball than reported in the literature. Moreover, this is the first study to analyse performance in the T-test in WB players. As was expected, the results were worse than those obtained in other studies in AB athletes. Regarding the pick-up test results, players showed worse values than those obtained in elite [16], and we consider that this parameter could be important to differentiate levels of players. Also, this is the first study that has analysed the capacity to generate force measured by a handgrip strength test in WB players. Knowing that throwing and passing actions are the most common abilities in WB, it may be appropriate to design specific training programmes aimed at these types of exercises in order to improve performance in the WB game.

Acknowledgments

The authors would like to thank the Bera-Bera wheelchair basketball players and coaches for the opportunity to carry out this investigation. This study was partially supported by the Federación Guipuzcoana de Deporte Adaptado, the Hegalak Zabalik Fundazioa-Deporte Adaptado and the Department of Physical Education and Sport (UPV/EHU).

Conflict of interests: the authors declared no conflict of interests regarding the publication of this manuscript.

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