Anthropometry and Performance in Wheelchair Basketball

Cristina Granados,[1] Javier Yanci,[1] Aduna Badiola,[1] Aitor Iturricastillo,[1] Montse Otero,[1] Jurgi Olasagasti,[2] Iraia Bidaurrazaga-Letona,[1] and Susana M. Gil[1]

[1]Department of Physical Education and Sport, Faculty of Physical Activity and Sports Science, University of the Basque Country, UPV/EHU, Vitoria-Gasteiz, Spain; and [2]Guipuzcoa Adapted Sport Federation, San Sebastián, Spain

Abstract

Granados, C, Yanci, J, Badiola, A, Iturricastillo, A, Otero, M, Olasagasti, J, Bidaurrazaga-Letona, I, and Gil, SM. Anthropometry and performance in wheelchair basketball. *J Strength Cond Res* 29(7): 1812–1820, 2015—This study investigated whether anthropometric characteristics, generic and specific sprinting, agility, strength, and endurance capacity could differentiate between First-Division and Third-Division wheelchair basketball (WB) players. A First-Division WB team ($n = 8$; age $= 36.05 \pm 8.25$ years, sitting body height $= 91.38 \pm 4.24$ cm, body mass $= 79.80 \pm 12.63$ kg) and a Third-Division WB team ($n = 11$; age $= 31.10 \pm 6.37$ years, sitting body height $= 85.56 \pm 6.48$ cm, body mass $= 71.18 \pm 17.63$ kg) participated in the study. Wheelchair sprint, agility, strength, and endurance tests were performed. The First-Division team was faster (8.7%) in 20 m without the ball, more agile (13–22%), stronger (18–33%), covered more distance (20%) in the endurance test, and presented higher values of rate of perceived exertion for the exercise load (48%) than the Third-Division team. Moreover, the individual 20-m sprint time values correlated inversely with the individual strength/power values (from $r = -0.54$ to -0.77, $p \le 0.05$, $n = 19$). Wheelchair basketball coaches should structure strength and conditioning training to improve sprint and agility and evaluate players accordingly, so that they can receive appropriate training stimuli to match the physiological demands of their competitive level.

Key Words disability, physical characteristics, field test, exercise load

Introduction

Wheelchair basketball (WB) is one of the most popular and well-known adapted sports (11), and in 1993, the International Wheelchair Basketball Federation (IWBF) was established as its world governing body with full responsibility for its development (24). Nowadays, the main official competitions of the IWBF are the World Championships and Paralympics Games, which implies that competitiveness is increasing, and it is becoming more important to monitor the fitness characteristics and performance of WB players.

Laboratory tests have commonly been used to assess physical fitness and performance, and as a result, the literature on laboratory testing is more abundant than the literature on field-based testing (20). Many published studies analyze the anthropometric measures (31), physical aerobic (4,13) and anaerobic capacity (13,31), biomechanical or propulsion technique (40), and physiological variables (4,11) of WB athletes under laboratory conditions. The disadvantages of this approach, however, are the lack of ecological validity, the high cost, and the amount of time required (2). Hence, field-based tests have become an attractive option (20), considering that these kinds of tests are a feasible way to get an indication of performance level (12).

There is a limited volume of literature on field-based physiological testing in wheelchair sports, such as basketball, when compared with that available for individuals and team athletes in nondisabled sports (20). However, many researchers have assessed sprint performance by measuring 5- to 20-m sprints, 20-m sprint with a ball, and 35-m maximum speed tests (9,12,14,36,39), agility capacity in lay-ups, ball pick-up, and slalom tests (12,39), strength capacity in the maximal pass tests (12), anaerobic performance in repetitive 15×20-m sprints, 5×20-m consecutive sprints and 30-second sprint tests (19,37,39), and aerobic performance in the 12-minute push and 20- to 25-m shuttle run tests (15,39) in WB players.

Baseline measurements indicate the strong and weak points of an athlete and subsequent follow-ups can monitor progress, that is, the effectiveness of training (12). In this line of thought, comparative measurements might indicate the most important skills for discriminating the WB players' levels, and therefore, technical staff and players could benefit from specific training to better develop those skills. Few studies have compared these players' anthropometric and physiological characteristics. Although some studies have analyzed different performance-related components, like anaerobic and technical capacities (12), little information is

Address correspondence to Cristina Granados, cristina.granados@ehu.es.

29(7)/1812–1820

Journal of Strength and Conditioning Research

available concerning the anthropometric and physiological characteristics of players from different competitive categories. To the best of our knowledge, there are no studies that investigate the differences in endurance capacity measured by field tests in different WB competitive categories. An examination of the fitness profile could be very important for optimal design of strength/power and endurance training programs (21) to improve WB performance.

Considering that WB places emphasis on sprint, agility, endurance, and muscle power-related actions, the data were collected to test the following hypotheses, that a difference exists between WB players from different competitive levels regarding sprint, agility, endurance, and muscle power development, as well as anthropometric characteristics. Therefore, the aim of this study was to investigate what anthropometric characteristics, generic and specific sprint, agility, strength, and endurance tests could differentiate between First- and Third-Division WB players, and the associations between the wheelchair mobility tests and the strength/power tests.

Methods

Experimental Approach to the Problem

The tests were performed on a synthetic indoor court, in the usual training area and in the same time slot (between 18:00 and 21:00 hours) at the beginning of the season, when the teams were starting the First- and Third-Division WB league competition. In the previous sessions, specific exercises were performed to familiarize the participants with the correct execution of the tests, and explanations and concrete corrections were also given to the players who were instructed to perform all tests at maximum intensity. No strenuous exercises were performed within the 48 hours immediately before the tests, and the participants were also requested to maintain the same diets throughout the test procedures and to abstain from caffeine and alcohol intake the day before testing.

Subjects

Two WB teams participated in the study. According to their competitive level, the participants were divided into 2 groups: a Spanish First-Division WB team ($n = 8$; age = 36.05 ± 8.25 years) and a Spanish Third-Division WB team ($n = 11$; age = 31.10 ± 6.37 years). 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 (Table 1). Both requisites are compulsory for participating in official events for people in the physical disabilities category. None of the participants did specific sprint, strength, and agility training, and all did 3 training sessions and 1 match per week. Before involvement in the investigation, all participants gave their written informed consent after a detailed written and oral explanation of the potential risks and benefits resulting from their participation in this study. The project was approved by the Ethics Committee of the University of the Basque Country (Universidad del País Vasco/Euskal Herriko Unibertsitatea, UPV/EHU) and carried out according to the Declaration of Helsinki.

Procedures

The battery of tests was performed during the first week of the competitive period (November, first week) in the same venue and facilities. Testing was conducted over 2 different sessions separated by at least 2 days. During the first testing session, each participant performed sprint and agility tests. In the second testing session, players were assessed for anthropometric measurements, strength, and endurance performance. Before each testing session, a standardized warm-up was performed consisting in 5 minutes of self-paced low-intensity wheelchair propulsion, stretching, and 2 acceleration drills. Testing was conducted with each participant using his personal sport wheelchair and was integrated into weekly training schedules. The players were instructed to refrain from strenuous exercise on the day before testing and to avoid smoking and drinking alcohol, tea, and coffee on the day of testing. They were also asked not to exercise in the 3 hours leading up to the test and to consume their normal pretraining diet, which was standardized for each testing session.

Physical Characteristics. The anthropometric variables of sitting height (in centimeters), body mass (in kilograms), skinfolds (in millimeters), and arm perimeter relaxed (in centimeters) and contracted (in centimeters) were measured in each player. Sitting height 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, MA, USA).

Sprint. ***Without and With a Ball.*** The participants undertook a wheelchair sprint test consisting of 3 maximal sprints of 20 m (39), with a 120-second rest period between each sprint, which was enough time to return to the start and wait for their next turn. The participants were placed at 0.5 m from the starting point and began when they felt ready. Time was recorded using photocell gates (Polifemo Radio Light; Microgate, Bolzano, Italy) placed 0.4 m above the ground with an accuracy of ±0.001 seconds. 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 (12) and 20 m (39). The maximal sprint test with a 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

TABLE 1. Wheelchair basketball players' characteristics.*†

Player	Sex	Equipe	Age (y)	IWBF classification	Injury time (y)	Time of training (y)
P1	Female	Third Division	37	1	30	8
P2	Male		33	2	9	7
P3	Male		30	3	10	5
P4	Male		26	4.5	23	1
P5	Male		39	2.5	20	17
P6	Male		21	3.5	21	0.25
P7	Male		36	4	6	0.08
P8	Male		37	2	34	6
P9	Male		26	2	26	7
P10	Male		22	4	23	4
P11	Male		34	4.5	9	4
Sample ($n = 11$)		31.10 ± 6.37	3.0 ± 1.18	19.18 ± 9.38	5.39 ± 4.74	
P12	Male	First Division	40	4.5	8	8
P13	Male		42	1	17	6
P14	Male		26	3.5	0.5	0.5
P15	Male		35	4	27	14
P16	Male		35	1	33	21
P17	Male		39	4	39	20
P18	Male		23	4.5	9	3
P19	Male		48	2	43	30
Sample ($n = 8$)		36.05 ± 8.25	3.06 ± 1.49	22.06 ± 15.71	12.81 ± 10.23	

*IWBF = International Wheelchair Basketball Federation.
†Results are in mean ± *SD*.

for dribbling (12). The test consisted of 3 maximal sprints with the ball over stretches of 20 m.

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. (34), modified to perform with a wheelchair and always using forward movements. A–B distance (9.14 m): at his own discretion, each subject moved quickly forward to cone B and touched the top with the right hand. B–C distance (4.57 m): facing forward, they moved to the left to cone C and touched the top with the left hand. C–D distance (9.14 m): the participants then moved to the right to cone D and touched the top. D–B distance (4.57 m): they moved back to the left to cone B and touched the top. B–A distance (9.14 m): finally, the participants moved as quickly as possible to return to line A. All participants performed the test 3 times with at least 3 minutes rest between trials. The total distance covered was 36.56 m and the height of the cones was 0.3 m. A photocell (Polifemo Radio Light; Migrogate) located over cone A was used to record the time. Time measurements started and finished when the subject crossed the line between the tripods. The calculated margin of error was ±0.001 seconds and the sensors were set approximately 0.40 m above the floor.

Ball Pick-up. From a stationary position, the participant had to start propelling his chair and pick up 4 basketball balls from the floor (Figure 2) as previously described by De Groot et al. (12), twice with the left hand and twice with the right hand. After picking up the ball, it had to be placed in the lap and the participant had to push the wheelchair once before throwing the ball (12). The total time taken to complete the test was recorded with a photocell (Polifemo Radio Light; Migrogate) located over the start and finish

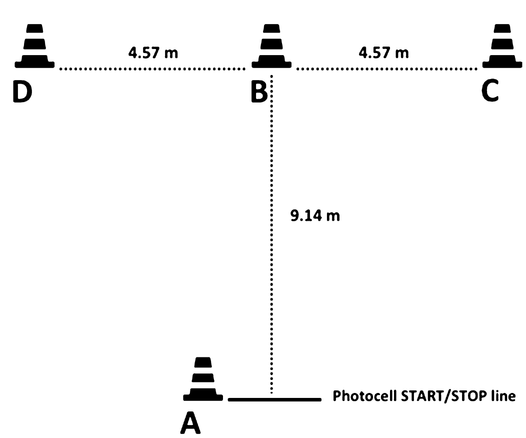

Figure 1. Agility T-test.

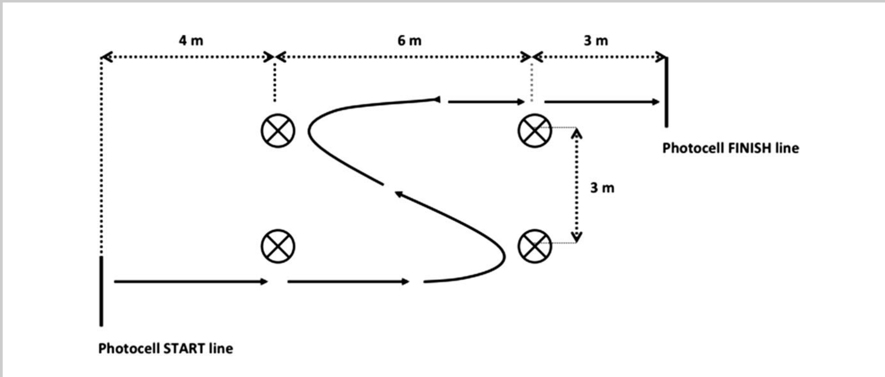

Figure 2. Ball pick-up test.

lines. All participants performed the test 3 times with at least 3 minutes rest between trials. The tested domains were ball handling and speed (12)

Strength. ***Maximal Pass.*** The participant began in the middle of the baseline, front wheels behind the line, and had to pass a basketball ball with a 2-arm overhand throw as far as possible from a stationary position, with one of the researchers holding the wheelchair still (12). The distance between the participant and where the ball hit the floor was measured (in meters). The end score was the average distance of 5 passes (12). The tested domain was passing (explosiveness) (12)

Medicine Ball Throw. Upper-limb power was examined using a 5-kg medicine ball, which they had to pass with a 2-arm overhand throw as far as possible from a stationary position, with one of the researchers holding the wheelchair still. The distance between the participant and where the ball hit the floor was measured (in meters) to the nearest 0.01 m (18).

Handgrip. Handgrip strength was measured in the dominant hand with a portable hydraulic hand dynamometer (5030J1, Jamar; Sammons Preston, Inc., Bolingbrook, IL). The test was performed in the wheelchair sitting position. The testing protocol consisted of 3 maximal isometric contractions for 5 seconds, with a rest period of at least 60 seconds and the highest value was used to determine maximal grip strength. The players 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 (in kilograms) and relative handgrip strength (kilograms per kilogram of body mass) (17).

Endurance. ***The Yo-Yo Intermittent Recovery Test.*** The level 1 version of the Yo-Yo test (Yo-Yo IR1) was completed according to previously described methods (8). The original Yo-Yo IR1 test consisted of 20-m shuttle runs performed at increasing velocities with 10 seconds of active recovery between runs until exhaustion (8). Because of the differences between running and propelling the wheelchair, the distance covered in the shuttle run was modified in this study to 10 m (Yo-Yo 10 m). Pushing speeds were dictated in the form of audio cues from a preprogrammed computer. The test was considered to have ended when the

Table 2. Physical characteristics, training experience, injury time, and classification of IWBF in total players, First-Division, and Third-Division teams.*†

	Total players (N = 19)	First Division (n = 8)	Third Division (n = 11)	Cohen's d
Age (y)	33.10 ± 7.40	36.05 ± 8.25	31.10 ± 6.37	0.68
Sitting body height (cm)	88.23 ± 6.00	91.38 ± 4.24	85.56 ± 6.48	1.06
Body mass (kg)	75.01 ± 15.80	79.80 ± 12.63	71.18 ± 17.63	0.56
Σ skinfold (mm)	65.12 ± 21.85	69.08 ± 24.97	61.97 ± 19.79	0.32
Elbow diameter (cm)	7.29 ± 0.53	7.60 ± 0.41	7.07 ± 0.51	1.15
Wrist diameter (cm)	5.73 ± 0.42	5.90 ± 0.27	5.61 ± 0.47	0.76
Arm perimeter (cm)	33.23 ± 3.27	34.65 ± 2.76	32.1 ± 3.34	0.83
Contracted arm perimeter (cm)	35.61 ± 3.39	36.45 ± 2.49	34.94 ± 3.97	0.46
Training experience (y)	8.51 ± 8.20	12.81 ± 10.23	5.39 ± 4.74	0.93
Injury time (y)	20.40 ± 12.13	22.06 ± 15.71	19.18 ± 9.39	0.22
IWBF class	2.95 ± 1.22	3.06 ± 1.50	2.91 ± 1.09	0.11

*IWBF = International Wheelchair Basketball Federation.
†Values are mean (±*SD*).

Table 3. Sprint, agility, and strength tests in total players, First-Division, and Third-Division teams.*

	Total players ($N = 19$)	First Division ($n = 8$)	Third Division ($n = 11$)	Cohen's d
Sprint (s)				
5 m	1.78 ± 0.13	1.73 ± 0.60	1.81 ± 0.15	0.69
20 m	5.43 ± 0.41	5.16 ± 0.18	5.61 ± 0.44†	0.83
5 m with ball	1.93 ± 0.16	1.89 ± 0.18	1.95 ± 0.14	0.62
20 m with ball	6.11 ± 0.59	5.76 ± 0.40	6.34 ± 0.60	0.86
Agility (s)				
T-test	15.49 ± 1.27	14.35 ± 0.62	16.26 ± 0.96‡	2.36
Pick-up the ball	13.44 ± 1.80	11.85 ± 0.78	14.51 ± 1.45‡	2.28
Strength				
Maximal pass (m)	10.08 ± 2.73	12.36 ± 2.23	8.26 ± 1.36‡	2.22
Medicine ball throw (m)	4.19 ± 0.89	4.86 ± 0.71	3.67 ± 0.65‡	1.75
Handgrip (kg)	45.41 ± 8.55	53.75 ± 6.94	44.0 ± 9.75†	1.15
Handgrip ($kg\cdot kg^{-1}$ of body mass)	0.60 ± 0.11	0.67 ± 0.11	0.61 ± 0.11	0.36

*Values are mean (±*SD*).
†Significant difference ($p \leq 0.05$) compared with First-Division team.
‡Significant difference ($p < 0.01$) compared with First-Division team.

participant failed twice to reach the front line in time (objective evaluation) or felt unable to cover another shuttle run at the dictated speed (subjective evaluation) (8). The total distance covered during the test was measured (8). Heart rate (HR) was recorded at 5-second intervals by telemetry (Polar Team Sport System; Polar Electro Oy, Kempele, Finland) during the whole test. Earlobe capillary blood samples were obtained to determine the lactate concentrations $[La]_b$ at rest (pretest) and exhaustion (posttest) (Lactate Pro LT-1710; ArkRay, Inc., Ltd., Kyoto, Japan).

Rated Perceived Exertion. At the end of the endurance test, the subjects were asked to rate their perceived exertion (RPE) on a 10-point category rating scale (16), presented on paper. They were asked separately for respiratory rate of perceived exertion (RPEres) (1) and their arm muscle rate of perceived exertion (RPEmus) (1,6). Each participant's RPE was recorded 10 minutes after completion of the Yo-Yo 10-m test, when the participants finished the stretching exercises. Each player completed the RPE scale without the presence of the other players so they could not see the values

Table 4. Endurance test (Yo-Yo 10 m) results in total players, First-Division, and Third-Division teams.*†

	Total players ($N = 19$)	First Division ($n = 8$)	Third Division ($n = 11$)	Cohen's d
Distance covered (m)	1,143.9 ± 307.8	1,297.5 ± 224.36	1,021.5 ± 319.39	1.00
Time (min)	18.47 ± 4.76	20.90 ± 3.43	16.52 ± 4.91	1.27
HR_{max} ($b\cdot min^{-1}$)	176.77 ± 19.11	184.38 ± 14.04	170.7 ± 21.09	0.76
LA pre ($mmol\cdot l^{-1}$)	1.08 ± 0.41	0.98 ± 0.25	1.16 ± 0.51	0.45
LA post ($mmol\cdot l^{-1}$)	7.24 ± 3.57‡	8.65 ± 4.21§	6.11 ± 2.67‖	0.72
RPEres	5.85 ± 2.33	6.56 ± 2.16	5.22 ± 2.43	0.58
RPEmus	5.11 ± 2.23	6.13 ± 1.87	4.22 ± 2.22	0.98
RPEres-EL (AU)	107.18 ± 52.75	139.90 ± 56.12	78.09 ± 28.05¶	1.10
RPEmus-EL (AU)	93.99 ± 46.44	126.29 ± 40.57	65.29 ± 30.07#	1.50

*HR = heart rate; LA = lactate; RPEres = respiratory rate of perceived exertion; RPEmus = muscular rate of perceived exertion; AU = arbitrary units; EL = exercise load.
†Values are mean (±*SD*).
‡Significant difference ($p < 0.001$) between Pre and Post Yo-Yo 10-m test.
§Significant difference ($p \leq 0.05$) between Pre and Post Yo-Yo 10-m test.
‖Significant difference ($p < 0.01$) between Pre and Post Yo-Yo 10-m test.
¶Significant difference ($p \leq 0.05$) compared with First-Division team.
#Significant difference ($p < 0.01$) compared with First-Division team.

given by other participants. Players were allowed to mark a plus sign (interpreted as 0.5 point) alongside the integer value if they wished (16). The subjects were trained to use the 10-point scale before the data collection for this study during a month, and it was used in all types of training sessions. The data were recorded by the same investigator on all occasions. To measure the exercise load (EL), the value of the RPE was multiplied by the test duration measured in minutes (16): respiratory RPE-EL (RPEres-EL) and muscular RPE-EL (RPEmus-EL).

Statistical Analyses

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 *SD*s. Data were screened for normality of distribution and homogeneity of variances using Levene's normality test. Because of the small sample, the Mann-Whitney *U*-test was used to determine the differences between groups in physical characteristics and sprint, agility, strength, and endurance tests. Practical significance was assessed by calculating effect size. Effect sizes (d) of above 0.8, between 0.8 and 0.5, between 0.5 and 0.2, and lower than 0.2 were considered as large, moderate, small, and trivial, respectively. 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 (12). The Wilcoxon tests were used to compare lactate between pretest and posttest. Pearson product-moment correlation coefficients (r) were used to determine correlations between strength/power and sprint values. Statistical power calculations for the t-test correlation ranged from 0.69 to 0.95 in this study. The $p \leq 0.05$ criterion was used to establish statistical significance.

Results

Physical Characteristics, Training Experience, Injury Time, and International Wheelchair Basketball Federation

The physical characteristics, training experience, injury time, and IWBF classification are presented in Table 2. No statistically significant difference was observed between groups; however, the First-Division team showed higher values in sitting height (6.4%, $p > 0.05$, $d = 1.06$), elbow diameter (7.0%, $p > 0.05$, $d = 1.15$), and arm perimeter (7.0%, $p > 0.05$, $d = 0.83$) than the Third-Division team, as well as a longer training experience (57.9%, $p > 0.05$, $d = 0.93$).

Sprint and Agility

The results of the sprint and agility tests are presented in Table 3. The 20-m sprint time without the ball in the First-Division team was 8.7% faster ($p \leq 0.05$, $d = 0.83$) than in the Third-Division team. In the rest of the sprint tests, the differences were not statistically significant; however, the First Division showed better results than the Third-Division team, and the values of Cohen's d were moderate to large in the 5-m sprint time without (4.6%, $p > 0.05$, $d = 0.69$) and with the ball (3.7%, $p > 0.05$, $d = 0.62$), and 20-m sprint time with the ball (10.1%, $p > 0.05$, $d = 0.86$).

In both agility tests, the First-Division team was significantly better than the Third-Division team (Table 3). In the T-test, the First-Division team was 13.3% faster ($p < 0.01$, $d = 2.36$) than the Third-Division team, showing a bigger difference in the pick-up test (22.4%, $p < 0.01$, $d = 2.28$).

Strength

The results of the WB players' strength tests are presented in Table 3. The First-Division team was 33.2% higher ($p < 0.01$, $d = 2.22$) in the maximal pass and 24.0% higher ($p < 0.01$, $d = 1.75$) in the medicine ball throw test than the Third-Division team.

In handgrip strength, a significant difference ($p \leq 0.05$, $d = 1.15$) was observed between groups in absolute values (53.75 ± 6.94 vs. 44.00 ± 9.75 kg, First and Third Division respectively); however, no statistically significant difference was observed in relative values (0.67 ± 0.11 vs. 0.61 ± 0.11 $kg \cdot kg^{-1}$ of body mass, First and Third Division, respectively).

Endurance

The endurance test values of both groups are presented in Table 4. Significant differences were found between 2 groups in RPEres-EL ($p \leq 0.05$, $d = 1.10$) and RPEmus-EL ($p < 0.01$, $d = 1.50$). Furthermore, the First-Division team showed higher values in distance covered (21.3%, $p > 0.05$, $d = 1.00$, large), in time (21.0%, $p > 0.05$, $d = 1.27$, large), and RPEmus (31.2%, $p > 0.05$, $d = 0.98$, large) than the Third-Division team.

Relationships Between Strength/Power and Sprint

In all players, the individual 20-m sprint time values correlated inversely with the individual values of absolute ($r = -0.64$, $p \leq 0.05$, $n = 19$) and relative handgrip strength ($r = -0.77$, $p < 0.01$, $n = 19$), maximal pass ($r = -0.54$, $p \leq 0.05$, $n = 19$), and medicine ball throw ($r = -0.60$, $p \leq 0.05$, $n = 19$).

Discussion

The main contribution of this study is the comparison of the anthropometric variables and physical performance profile (5- and 20-m sprints without and with the ball, agility T-test, pick-up, maximal pass, medicine ball throw, handgrip, and endurance Yo-Yo 10-m test) in different categories of WB players, and the associations between the wheelchair mobility tests and the strength/power tests. Moreover, to the best of our knowledge, no scientific articles have been published on RPE and RPE-EL measurements in WB players. In this study, no significant differences were observed in anthropometric variables, training experience, injury time, or IWBF classification. However, the First-Division team was faster, more agile, stronger, covered more distance, and presented higher values of RPE-EL than the Third-Division team.

Height is routinely accepted as essential for success in basketball. In this study, despite there not being significant differences between groups in sitting body height, the First-Division team tended to be taller ($d = 1.06$) than the

Third-Division team. The higher values in height compared with the Third-Division team could give the First-Division team some advantage in certain WB game actions such as blocking or throwing. However, it should not be forgotten that the player and chair are only 1 structure; therefore, not only the physical attributes and physiological performance could be important but also the configuration of the wheelchair and the mobility of the structure (29).

Wheelchair propulsion in basketball players has been studied earlier (10). In this study, no significant differences in the 5-m test (without and with the ball) were observed between groups, although over 20 m, the First-Division team was significantly faster (without the ball) or tended to be faster (with the ball) than the Third-Division team. One explanation for this could be that during the first 3 pushes, basketball players are able to maintain a higher push rhythm thanks to the force applied at the end of the first push (10).

Agility performance measured with the different tests has been used widely in the scientific literature in various sports (26,35), particularly in basketball (25) and in WB players (12). In this study, significant differences between both groups were obtained in the change of direction ability (CODA) measured by the T-test and pick-up test. Similarly, De Groot et al. (12) reported significant differences between different WB categories (Premier League, Tournament A and Tournament B). The differences found respect to agility in WB players between different competitive levels have also been shown between amateur and professional AB players (26) with respect to the positional role in AB professional soccer players (32), and between selected and nonselected AB young footballers (22). This finding suggests that agility can be used to discriminate between competitive levels of WB players. However, more studies are needed with WB players to analyze the CODA as it may be a good predictor of performance.

In most sports, general and specific strength training is a critical component of success in competition (38). Thus, it is logical to think that WB performance depends on strength and power in the upper extremities. One of the major findings of this study was that absolute strength and explosiveness of the upper-extremity muscles were higher in the First than the Third Division team in handgrip (18%), maximal pass (33%), and medicine ball throw (24%), and the associations between the wheelchair mobility tests and the strength/power tests. These strength differences between elite and lower level players have also been observed in other sports such as rugby (3) and handball (21), and indicate that high absolute values of strength and muscle explosiveness could be required for successful performance in high-level WB. In this line of thought, relationships between strength/power values and velocity were observed in this study, suggesting that the differences in explosiveness and absolute strength, in part, could account for the differences between groups in the time of the 20-m sprint. Taking into account that none of the participants did specific strength training, it may be very interesting for coaches and technical staff to structure strength and conditioning training to improve sprinting, one of the most important components of competitive WB.

Competitive basketball is an intermittent high-intensity physical activity that requires well-developed aerobic and anaerobic fitness (30). Although basketball performance is thought to be mainly dependent on players' anaerobic abilities, high aerobic fitness is also important for improved performance (5,36). Furthermore, aerobic conditioning has been suggested to be important for preparing players to be able to sustain an appropriate training load volume for basketball (36). Despite, nonsignificant differences being observed between groups, the First Division tended (large effect sizes) to cover a longer distance in the Yo-Yo 10-m test, showed higher maximum heart rate (HRmax), blood lactate concentration, as well as RPEres and RPEmus than the Third-Division team. Differences in the Yo-Yo IR1 performance have been reported to be a consequence of fitness status, the respective period of the competitive season, and the playing position within an elite soccer team (27). Taking into account that the battery of tests was performed in the same period of the competitive season for both teams, and that 2 of them had players playing in similar positions, it can be hypothesized that the First Division had a better fitness status than the Third-Division team, as was shown in the sprint, agility, and strength tests. This finding suggests that the First Division could recover faster than the Third-Division team, and therefore, achieve improved performance.

Rate of perceived exertion has been defined as the subjective intensity of effort, strain, discomfort, and fatigue that 1 feels during exercise (33). Because of its easy versatile and cheap use as an indicator of the degree of physical strain (7), it has been applied in many sports. Therefore, perceptual responses can be differentiated between the active limbs or skeletal muscle and respiratory-metabolic systems: RPEmus and RPEres, respectively (28,33). In addition, several studies performed with men's basketball players (16) and soccer players (23) have found that the RPE-EL method is a valid and reliable measure of internal global training load in these sports, based on the significant individual relationships ($r = 0.50–0.90$) observed between several HR-based ELs and RPE-EL. To the best of our knowledge, this is the first attempt to investigate the subjective RPEres, RPEmus, RPEres-EL, and RPEmus-EL methods, in WB players. In this study, significant differences were observed between the First- and Third-Division teams in RPEres-EL and RPEmus-EL. These results suggest that these differences are due to the "Yo-Yo 10-m test duration" factor, which was significantly different between the 2 teams. Therefore, the independent monitoring of RPEres-EL and quantification of RPEmus-EL in WB may be an interesting evaluation method for physical trainers and coaches. These results should be treated with caution and further studies are needed to analyze the RPE and RPE-EL, both respiratory and muscular, in WB players.

Practical Applications

This study has practical importance, because it shows that (a) higher values in sprint, agility, and strength are required in WB to play at a better divisional level and (b) agility tests could be a useful tool to discriminate between competitive levels in WB players. These significant differences observed between First- and Third-Division male WB players provide new normative sprint, agility, strength, and endurance capacity data for these populations and can contribute to talent selection and identification. Wheelchair basketball coaches should structure strength and conditioning training to improve sprint and agility and evaluate players accordingly, so that they may receive appropriate training stimuli to match the physiological demands of their competitive level.

Acknowledgments

The authors thank the Bera-Bera and Zuzenak wheelchair basketball teams 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). No known conflicts of interest are associated with this publication, and there has been no significant financial support for this work that could have influenced its outcome.

References

1. Aliverti, A, Kayser, B, Mauro, AL, Quaranta, M, Pompilio, P, Dellacà, RL, Ora, J, Biasco, L, Cavalleri, L, Pomidori, L, Cogo, A, Pellegrino, R, and Miserocchi, G. Respiratory and leg muscles perceived exertion during exercise at altitude. *Respir Physiol Neurobiol* 31: 162–168, 2011.
2. Apostolidis, N, Nassis, GP, Bolatoglou, T, and Geladas, ND. Physiological and technical characteristics of elite young basketball players. *J Sports Med Phys Fitness* 44: 157–163, 2004.
3. Baker, D. Differences in strength and power among junior-high, senior-high, college-aged, and elite professional rugby league players. *J Strength Cond Res* 16: 581–585, 2002.
4. Bernardi, ME, Guerra, B, Di Giacinto, A, Di Cesare, V, Catellano, V, and Bhambhani, Y. Field evaluation of paralympic athletes in selected sports: Implications for training. *Med Sci Sports Exerc* 42: 1200–1208, 2010.
5. Bloxham, LA, Bell, GJ, Bhambhani, Y, and Steadward, RD. Time motion analysis and physiological profile of Canadian world cup wheelchair basketball players. *Sports Med Train Rehabil* 10: 183–198, 2001.
6. Borg, E, Borg, G, Larsson, K, Letzter, M, and Sundblad, BM. An index for breathlessness and leg fatigue. *Scand J Med Sci Sports* 20: 644–650, 2010.
7. Borg, G. Psychophysical bases of perceived exertion. *Med Sci Sports Exerc* 14: 377–381, 1982.
8. Castagna, C, Impellizzeri, FM, Rampinini, E, D'Ottavio, S, and Manzi, V. The Yo-Yo intermittent recovery test in basketball players. *J Sci Med Sport* 11: 202–208, 2008.
9. Chapman, D, Fulton, S, and Gough, C. Anthropometric and physical performance characteristics of elite male wheelchair basketball athletes. *J Strength Cond Res* 24: 1, 2010.
10. Coutts, KD. Kinematics of sport wheelchair propulsion. *J Rehabil Res Dev* 27: 21–26, 1990.
11. Croft, L, Dybrus, S, Lenton, J, and Goosey-Tolfrey, VA. Comparison of the physiological demands of wheelchair basketball and wheelchair tennis. *Int J Sports Phys Perform* 5: 301–315, 2010.
12. De Groot, S, Balvers, IJ, Kouwenhoven, SM, and Janssen, TW. Validity and reliability of tests determining performance-related components of wheelchair basketball. *J Sports Sci* 30: 879–887, 2012.
13. De Lira, CA, Vancini, RL, Minozzo, FC, Sousa, BS, Dubas, JP, Andrade, MS, Steinberg, LL, and Da Silva, AC. Relationship between aerobic and anaerobic parameters and functional classification in wheelchair basketball players. *Scand J Med Sci Sports* 20: 638–643, 2010.
14. Doyle, TLA, Davis, RW, Humphries, B, Dugan, EL, Horn, BG, Kun Shim, J, and Newton, RU. Further evidence to change the medical classification system of the National Wheelchair Basketball Association. *Adapt Phys Act Q* 21: 63–70, 2004.
15. Dwyer, GB and Davis, RW. The relationship between a twelve minute wheelchair push test and VO_2peak in women wheelchair athletes. *Res Sports Med* 8: 1–11, 1997.
16. Foster, C, Florhaug, JA, Franklin, J, Gottschall, L, Hrovatin, LA, Parker, S, Doleshal, P, and Dodge, C. A new approach to monitoring exercise training. *J Strength Cond Res* 15: 109–115, 2001.
17. Gerodimos, V. Reliability of handgrip strength test in basketball players. *J Hum Kinet* 31: 25–36, 2012.
18. Gonaus, C and Müller, E. Using physiological data to predict future career progression in 14- to 17-year-old Austrian soccer academy players. *J Sports Sci* 30: 1673–1682, 2012.
19. Goosey-Tolfrey, VL, Foden, E, Perret, C, and Degens, H. Effects of inspiratory muscle training on respiratory function and repetitive sprint performance in wheelchair basketball players. *Br J Sports Med* 44: 665–668, 2010.
20. Goosey-Tolfrey, VL and Leicht, CA. Field-based physiological testing of wheelchair athletes. *Sports Med* 43: 77–91, 2013.
21. Gorostiaga, EM, Granados, C, Ibáñez, J, and Izquierdo, M. Differences in physical fitness and throwing velocity among elite and amateur male handball players. *Int J Sports Med* 26: 225–232, 2005.
22. Gravina, L, Gil, SM, Ruiz, F, Zubero, J, Gil, J, and Irazusta, J. Anthropometric and physiological differences between first team and reserve soccer players aged 10-14 years at the beginning and end of the season. *J Strength Cond Res* 22: 1308–1314, 2008.
23. Impellizzeri, FM, Rampinini, E, Coutts, A, Sassi, A, and Marcora, SM. Use of RPE-based training load in soccer. *Med Sci Sports Exerc* 36: 1042–1047, 2004.
24. International Wheelchair Basketball Federation, IWBF. History of the game [On line]. Available at: http://www.iwbf.org/index.php/the-game/history.
25. Jakovljevic, ST, Karalejic, MS, Pajic, ZB, Macura, MM, and Erculj, FF. Speed and agility of 12- and 14-year-old elite male basketball players. *J Strength Cond Res* 26: 2453–2459, 2012.
26. Kaplan, T, Erkmen, N, and Taskin, H. The evaluation of the running speed and agility performance in professional and amateur soccer players. *J Strength Cond Res* 23: 774–778, 2009.
27. Krustrup, P, Mohr, M, Amstrup, T, Rysgaard, T, Johansen, J, Steensberg, A, Pedersen, PK, and Bangsbo, J. The yo-yo intermittent recovery test: Physiological response, reliability, and validity. *Med Sci Sports Exerc* 35: 697–705, 2003.
28. Mahon, AD, Gay, JA, and Stolen, KQ. Differentiated ratings of perceived exertion at ventilatory threshold in children and adults. *Eur J Appl Physiol Occup Physiol* 78: 115–120, 1998.
29. Mason, BS, Porcellato, L, van der Woude, LH, and Goosey-Tolfrey, VL. A qualitative examination of wheelchair configuration for optimal mobility performance in wheelchair sports: A pilot study. *J Rehabil Med* 42: 141–149, 2010.

30. McInnes, SE, Carlson, JS, Jones, CJ, and McKenna, MJ. The physiological load imposed on basketball players during competition. *J Sports Sci* 13: 387–397, 1995.
31. Molik, B, Laskin, J, Kosmol, A, Skucas, K, and Bida, U. Relationship between functional classification levels and anaerobic performance of wheelchair basketball athletes. *Res Q Exerc Sport* 81: 69–73, 2010.
32. Raven, PB, Gettman, LR, Pollock, ML, and Cooper, KH. A physiological evaluation of professional soccer players. *Br J Sports Med* 10: 209–216, 1976.
33. Robertson, RJ and Noble, BJ. Perception of physical exertion: Methods, mediators and applications. *Exerc Sport Sci Rev* 25: 407–452, 1997.
34. Sassi, RH, Dardouri, W, Yahmed, MH, Gmada, N, Mahfoudhi, ME, and Gharbi, Z. Relative and absolute reliability of a modified agility T-test and its relationship with vertical jump and straight sprint. *J Strength Cond Res* 23: 1644–1651, 2009.
35. Sheppard, JM, Young, WB, Doyle, TL, Sheppard, TA, and Newton, RU. An evaluation of a new test of reactive agility and its relationship to sprint speed and change of direction speed. *J Sci Med Sport* 9: 342–349, 2006.
36. Stone, WJ and Steingard, PM. Year-round conditioning for basketball. *Clin Sports Med* 12: 173–191, 1993.
37. Traballesi, M, Averna, T, and Delussu, AS. Improvement in metabolic parameters and specific skills in an elite wheelchair basketball team: A pilot study. *Med Sport* 62: 1–16, 2009.
38. Turbanski, S and Schmidtbleicher, D. Effects of heavy resistance training on strength and power in upper extremities in wheelchair athletes. *J Strength Cond Res* 24: 8–16, 2010.
39. Vanlandewijck, YC, Daly, DJ, and Theisen, DM. Field test evaluation of aerobic, anaerobic, and wheelchair basketball skill performances. *Int J Sports Med* 20: 548–554, 1999.
40. Vanlandewijck, YC, Spaepen, AJ, and Lysens, RJ. Wheelchair propulsion: Functional ability dependent factors in wheelchair basketball players. *Scand J Rehabil Med* 26: 37–48, 1994.