

Article

Sports Performance Analysis of Wheelchair Basketball Players Considering Functional Classification

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Abstract: Wheelchair basketball (WB) is a sport modality adapted for people with disabilities who present functional classification (FC) according to their mobility, from 1.0 for players with lesser functional capacity up to 4.5 for great mobility and trunk control players. This study aimed to analyze and compare the external load (EL) and the internal load (IL) of the WB players according to their FC in 5 × 5 simulation game tasks. The main objective of this task was to develop a simulated game in which two teams of five players faced each other to resemble the physical demands of an official match. The development of these tasks allowed for the players to learn the different systems of play, and to improve tactical skills. To conduct the study, 12 (male) national professional WB players (years: 30.7 ± 4.82 and WB experience: 5 ± 1.43) participated in the study and were grouped according to FC. WIMU PRO™ devices monitored the EL manufactured by RealTrack Systems in Almería, Spain, and to measure the player's IL, Garmin™ Heart Rate (HR) bands were used (Garmin™ in Olathe, KS, USA). The EL variables were divided as kinematic (distance, explosive distance, acc, dec, max. acc, max. dec, average speed, max. speed) and neuromuscular (player load, impact). The IL variables were average HR, max. HR and %max. HR. The main results show that players with greater functional capacity (FC = 4.0) developed higher values in the IL and neuromuscular variables analyzed ($p < 0.05$), as well as in some kinematic variables like distance, dec and average speed ($p < 0.05$). This information is relevant because it helps to personalize the training load based on competitive demands and create a gradual and adaptable training program. This information helps athletes to develop better performance during training and prevent injuries caused by overexertion.

Keywords: performance; physical fitness; condition; inertial devices; quantify



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1. Introduction

In the field of sports, the rise of big data and the analysis of players' sporting performance has increased the possibilities of the coaching staff to analyze and identify the

weaknesses and strengths of players during the game, as well as to predict and improve sporting performance [1]. For this purpose, inertial devices (ID) have been used as a tool for the kinematic analysis of players to quantify the external load (EL) of players from different sports [2]. The EL is defined as the mechanical and/or locomotor movements aimed for the development of an activity, which are considered typical of a sports modality [3]. These can be quantified and measured through different kinematic variables such as speed, distance, accelerations (acc), and decelerations (dec) [4], or neuromuscular variables such as impacts, player load, or jumps [5]. This data monitoring allows for coaches to modify and structure training sessions based on variables such as volume or intensity to enhance performance and reduce the risk of injury [6]. To this end, strengthening sessions should be carried out to improve the assimilation of training loads, as well as to establish work thresholds for athletes [7].

IDs have been used in team and individual sports as a tool for the quantification and analysis of the internal load (IL) to which players are subjected [8]. IL is understood as the physiological response produced in players during physical activity, characterized by heart rate (HR) variability [9,10]. This tool is characterized by its high functionality and the information it collects to analyze the performance of professional players [11]. The analysis of players' IL through HR measurement provides insight into players' thresholds, allowing a more accurate assessment of physical fitness, training adaptations, and injury prevention [12]. This information allows for the coach and trainers to gain knowledge about the physical condition of players in real time [13]. Therefore, coaches must make decisions regarding task design and planning to produce improvements in players' fitness by developing tasks focused on performance enhancement [14]. In the same way, some biomechanical variables (eccentric utilization ratio, force–velocity relationship, reactive strength index, and bilateral deficit) must be used to analyze and optimize sports performance because they allow a complex and wide evaluation of the athlete's physical fitness [15].

Currently, IDs are used in various sports modalities to quantify and analyze the performance of athletes. This tool has been used in football to identify whether training intensity is up to competition standard in women's football, resulting in higher values of intensity in competition and volume in training [16]. Using developing tasks focused on Small Sided Games, greater neuromuscular activity is developed in those tasks with the presence of a goalkeeper [4]; in addition, the use of increasing playing field allows the development of greater speed values [17]. Due to its multidisciplinary nature, studies have been developed in different disciplines such as basketball [18], handball [19], and even parachute jumping [20].

On the contrary, few studies use IDs in sports for people with disabilities to analyze athletes' EL and IL. This tool has been used in seven-a-side football for people with cerebral palsy to investigate the motor performance of players considering functional classification (FC) [21]. The FC is a score given to athletes with disabilities according to their motor limitations based on trunk movement and technical skills (bouncing, turning, or throwing) [22]. In wheelchair basketball (WB), this rating ranges from 1.0 to 4.5, with players with higher functional ability having a higher score [23]. WB is a team invasion sport in which the FC of the players influences their performance [22,24], where players with a higher FC (4.0) have higher values in kinematics (speed, distance, or acc) variables [25]. In turn, in the present modality, HR has been used to analyze the IL to which players are subjected [26]. Following this line of inquiry, it is the players with the highest FC (3.0–4.5) who present higher values due to their greater physical and movement capacity [27].

The use of ID allows for coaches to monitor player workload, prevent overload injuries, and determine work thresholds [28]. Thus, it is important to ensure that reliable and valid variables are used to monitor EL in athletes, including the whole body and specific joints to control and optimize the player's performance. The large number of variables that the ID provides the coaching staff allows for them to record and analyze the athlete's sports performance in different situations (training and competition). Therefore, this study aimed

to analyze the EL and IL of the WB players according to their FC in 5×5 simulation game tasks.

2. Materials and Methods

2.1. Design

Using a cross-sectional design [29], the present work carries out a retrospective analysis of the data collected during the training sessions. In addition, a descriptive, associative, and inferential strategy [30] is used for data analysis. This methodology allows the evaluation of the EL and IL to which WB players are subjected during training sessions, and specifically during real game simulations (considering WB, 5×5). The primary goal of this task is to create a simulated game where two teams of 5 players compete against each other to replicate the physical challenges of a real match. Developing these exercises helps players learn various playing systems and enhance their tactical skills.

2.2. Participants

To conduct the study, a national professional WB team was carefully selected, consisting of 12 highly experienced male players. All players who participated in at least 10 tasks (5×5 simulation games) were included in the analysis, without excluding any of them. All the tasks selected conducted a 5×5 game simulated with an average of 15.04 min per task using the full court. An analysis of the participants was conducted, considering various contextual variables as well as the CF of each player. Table 1 displays sample characterization.

Table 1. Sample characterization.

FC	1.0	2.0	3.0	4.0
Number of players	2	5	2	3
Years (age)	41 ± 0	33 ± 2.16	25 ± 2.82	28.3 ± 7.57
Weight (kg)	82.0 ± 2.82	65.0 ± 5.40	57.5 ± 21.92	75.0 ± 8.88
Height (cm)	181.5 ± 4.94	160.5 ± 33.39	167.5 ± 20.50	180.0 ± 10.81
Experience (year)	6.5 ± 2.12	4.2 ± 1.56	4.0 ± 1.41	3.6 ± 1.54

kg: kilograms; cm: centimetres; FC: Functional classification.

2.3. Sample

The total number of cases in the study sample was 287. These cases were obtained from the analysis of all the exercises that aimed to simulate the competition through full game tasks (5×5). To gather as much information as possible, the data were collected at a frequency of 100 Hz, resulting in a total of 100 numerical data per second for each task and player analyzed.

2.4. Instruments

Twelve WIMU PRO™ devices manufactured by RealTrack Systems in Almería, Spain were used to evaluate the EL of the players. These devices were placed in the interscapular area using an anatomical harness (RealTrack Systems in Almería, Spain) as shown in Figure 1. For quantifying the internal load (IL) of the players, HR bands manufactured by Garmin™ in Olathe, KS, USA were used.

For collecting the data, the Ultra-Wide Band (UWB) system was used using 8 antennas (RealTrack Systems in Almería, Spain) placed around the basketball court. The measurement error underwent validation using the protocol for data quality analysis. All the perimeter lines of the court were covered with two ID together before starting the data collection. The measurement error was identified in 0.053 ± 0.03 m over the entire surface. SVIVO™ software (RealTrack Systems SL, v.2020, Almeria, Spain) was used to visualize the data in real time during sessions. SPRO™ software (RealTrack Systems SL, v. 990, Almeria, Spain) was used for data processing and analysis.



Figure 1. Placement of the ID.

2.5. Procedure

To begin the study, the managers and directors of the national team were contacted. The advantages and disadvantages of conducting the study were explained to them. After receiving their approval, a meeting was organized with the entire group of players to inform them about the data collection procedures and the materials that would be used. Subsequently, all the players signed an informed consent document before proceeding.

At the beginning of the study, all the players attended a familiarization session with the IDs and HR bands. Then, all the tasks carried out during the training sessions were recorded. The study was developed under the premises of the Declaration of Helsinki [31] and ethical standards for sports science research [32]. It was approved by the Bioethics Committee of the University of Extremadura (Registration number 79/2022).

2.6. Variables

The independent variable of the present study was player FC. In the same vein, the dependent variables were related to different indicators considering the EL and IL of the players (Table 2). To carry out a proper comparison of the data between groups, all the variables were normalized into the same unit of time (minute).

2.7. Statistical Analysis

Kolgomorov–Smirmov and Levene’s tests were performed to identify the sample characteristics [33]. The results indicated values of $p > 0.05$; therefore, normality was assumed in sample distribution. Parametric models were used to test the hypotheses of the study [34]. Subsequently, a descriptive analysis of the sample was performed to characterise the data by frequencies (mean and standard deviation) as a function of player FC. To compare and identify the differences between groups, a factor analysis using ANOVA for independent samples was used.

In addition, the Bonferroni post hoc test was used to identify differences between groups. The effect size (Cohen’s d) was interpreted through the following proposal: low effect (0–0.2), small effect (0.2–0.6), moderate effect (0.6–1.2), high effect (1.2–2.0), and very high effect (>2.0) [35]. Finally, regarding partial eta squared (η^2), the range was small (0.010–0.059), medium (0.060–0.139), and large (>0.140) [36]. In the same vein, a correlational analysis was carried out to identify a relationship between the dependent variables and some contextual items such as weight, height, and experience of the player. For this purpose, Pearson’s correlation test was used, interpreted according to Field [33]:

insignificant ($r^2 < 0.1$), small ($0.1 < r^2 < 0.3$), moderate ($0.3 < r^2 < 0.5$), large ($0.5 < r^2 < 0.7$), very large ($0.7 < r^2 < 0.9$), almost perfect ($r^2 > 0.9$), and perfect ($r^2 = 1$).

The IBM SPSS Statistics software for MAC OS (version 27, 2021, IBM Co., Ltd., Armonk, NY, USA) was used to conduct statistical analyses. Statistical significance was determined at $p < 0.05$.

Table 2. Description of selected dependent variables.

	Variable	Unit	Description
Kinematics EL	Distance	Meters (m)	Space covered
	Explosive distance	Meters (m)	Space covered with an acc higher than 1.12 m/s ²
	Acc	Number (n)	Speed change in a positive movement
	Dec	Number (n)	Speed change in a negative movement
	Max. acc	m/s ²	Maximum capacity of increased speed
	Max. dec	m/s ²	Maximum capacity of decreased speed
	Average speed	km/h	Average speed
	Max. speed	km/h	Maximum speed
Neuromuscular EL	PL	Arbitrary unit (a.u.)	Cumulative load concerning accelerations on the 3 axes
	Impact	Number (n)	Impacts received during the tasks
Objective IL	Max. HR	Beats per minute (bpm)	Highest peak pulse rate
	Average HR	Beats per minute (bpm)	Average beats per minute in a time interval
	% Max. HR	Beats per minute (bpm)	Athletes' work thresholds according to their maximum pulse rate, Z1 (50–60%), Z2 (60–70%), Z3 (70–80%), Z4 (80–90%), Z5 (90–95%), and Z6 (>95%).

EL: external load; IL: internal load; PL: player load; HR: heart rate; Acc: acceleration; Dec: deceleration.

3. Results

Table 3 shows the results of the factor analysis for the comparison between groups. The FC4.0 players present the highest values in most of the dependent variables, except for the explosive distance, maximum acc and dec, whose maximum values correspond to FC2.0 and FC1.0, respectively. Furthermore, in those variables where significant differences between groups are observed, the players of FC4.0 present the greatest number of differences from the rest of the athletes.

Table 4 shows the results related to Pearson's bivariate test considering Kinematics EL, Neuromuscular EL, and Objective IL such as the dependent variable and weight, height, and player's experience as independent variables in order to identify a correlation between those items.

Table 3. Descriptive and inferential analysis regarding FC.

Variables	FC1		FC2		FC3		FC4		F	df	p	η ²	Post-Hoc	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD						
Kinematics EL	Distance(m)/min	35.61	15.60	47.29	27.18	40.89	26.95	54.76	20.12	5.930	3	0.001 *	0.059	FC1 < FC2; FC1 < FC4; FC3 < FC4
	Explosive dist (m)/min	3.53	1.45	6.13	7.47	5.11	5.19	5.50	2.92	2.473	3	0.062	0.025	
	Acc/min (n)	27.01	6.52	27.38	7.89	26.99	6.73	29.68	5.11	1.761	3	0.155	0.018	
	Dec/min (n)	16.09	8.76	16.76	9.94	14.74	10.85	20.74	9.66	3.630	3	0.013 *	0.037	FC3 < FC4
	Max. acc (m/s ²)	5.97	1.54	5.43	2.29	5.62	2.02	5.07	1.83	1.684	3	0.171	0.017	
	Max. dec (m/s ²)	−5.24	1.60	−5.07	2.29	−5.05	2.04	−4.86	2.13	0.271	3	0.847	0.003	
	Max. speed(km/h)	16.52	6.38	16.73	7.78	16.80	8.89	16.20	2.88	0.079	3	0.972	0.001	
Avg. speed(km/h)	3.99	0.88	4.44	1.40	4.19	1.38	4.69	0.83	3.175	3	0.025 *	0.032	FC1 < FC4	
Neuromuscular EL	Player load/min	0.41	0.22	0.49	0.30	0.47	0.34	0.71	0.27	9.367	3	0.000 *	0.090	FC1 < FC4; FC2 < FC4; FC3 < FC4
	Total impacts/min	69.67	42.00	98.04	65.94	87.63	68.99	126.26	53.67	7.288	3	0.000*	0.071	FC1 < FC2; FC1 < FC4; FC2 < FC4; FC3 < FC4
Objective IL	Max. HR (bpm)	150.92	27.13	153.03	31.81	149.61	26.48	172.83	18.01	8.009	3	0.000 *	0.078	FC1 < FC4; FC2 < FC4; FC3 < FC4
	Avg. HR (bpm)	124.87	21.48	121.55	25.42	117.86	22.77	138.04	18.89	8.044	3	0.000 *	0.078	FC1 < FC4; FC2 < FC4; FC3 < FC4
	Avg. (% of max)	69.10	13.16	69.24	13.57	66.129	11.22	73.09	9.66	3.065	3	0.028 *	0.031	FC3 < FC4

EL: External load; IL: Internal load; Acc: Accelerations; Dec: Decelerations; FC: Functional classification; SD: Standard deviation; * $p < 0.05$; η²: partial eta squared.

Table 4. Bivariate correlation between the height, weight and experience and the EL and IL variables.

Variables			Height	Weight	Experience
Kinematics EL	Distance (m)/min	Pearson	0.039	0.046	0.103
		Sig.	0.51	0.437	0.082
	Explosive dist (m)/min	Pearson	0.052	0.058	0.088
		Sig.	0.376	0.325	0.135
	Acc/min (n)	Pearson	0.112	0.075	0.055
		Sig.	0.059	0.203	0.354
	Dec/min (n)	Pearson	0.073	0.082	0.160 **
		Sig.	0.214	0.167	0.006
	Max. acc (m/s ²)	Pearson	0.153 **	0.155 **	0.120 *
		Sig.	0.009	0.009	0.042
Max. dec (m/s ²)	Pearson	−0.179 **	−0.160 **	−0.131 *	
	Sig.	0.002	0.007	0.027	
Max. speed (km/h)	Pearson	0.258 **	0.021	0.225 **	
	Sig.	0	0.723	0	
Avg. speed (km/h)	Pearson	0.313 **	0.054	0.281 **	
	Sig.	0	0.358	0	
Neuromuscular EL	Total impacts/min	Pearson	0.126 *	0.019	0.089
		Sig.	0.033	0.751	0.131
	Player load/min	Pearson	0.137 *	0.041	0.116 *
		Sig.	0.02	0.493	0.049
Objective IL	Max. HR (bpm)	Pearson	0.258 **	0.021	0.225 **
		Sig.	0	0.723	0
	Avg. HR (bpm)	Pearson	0.313 **	0.054	0.281 **
		Sig.	0	0.358	0
	Avg. (% of max)	Pearson	0.208 **	0.08	0.156 **
		Sig.	0	0.176	0.008

EL: External load; IL: Internal load; Acc: Accelerations; Dec: Decelerations; ** $p < 0.01$; * $p < 0.05$.

4. Discussion

The main objective of this study was to analyze the EL and IL of WB players during 5×5 game simulation tasks, a strategy used by coaches to work on real game situations, as well as the development of technical–tactical skills that occur during competitions. Therefore, to achieve this main objective, two specific objectives were established: (i) to identify the physical demands of the players in the 5×5 tasks as a function of the players' FC and (ii) to determine whether there are differences in the players' EL and IL during these tasks as a function of FC.

After the analysis and evaluation of the data, it was observed that players with greater functional capacity, those with an FC of 4.0 points, are the ones who develop higher values in the variables analyzed due to their greater capacity for movement and physical capacity [27]. On the contrary, players with lower functional capacity (FC1.0) present a greater number of differences with the rest of the FC due to presenting lower ranges of movement, as well as greater difficulty in the development of changes in direction and speed [25]. This information is of great importance for the coaching staff, as it allows for them to know the physical demands in simulated competition situations and to improve those weak aspects of the players in attack and defensive situations. In addition, to be able to match training loads to competition, analyses of the players' EL and IL during competitions should be carried out to determine the players' maximum ranges and thresholds and to develop individualized training sessions.

The group of players with FC4.0 had the highest values in the analyzed variables and also showed the greatest difference from the rest in sporting performance. This is because the FC4.0 players have a large range of movement, as well as the ergonomics of the chair and great mobility of the trunk [37,38]. To improve physical fitness, techniques to improve propulsion and acc must be implemented [39]. These techniques allow for improving the function of the upper extremities, reducing the incidence of pain and the

probability of injury [28]. As the performance of WB players is closely linked to upper extremity muscular strength as well as aerobic and anaerobic capacity, it is important to focus on these areas [40]. This illustrates how WB players exhibit higher values in the analyzed variables due to their greater trunk range of motion. This enables them to perform better during tasks and competitions.

When analyzing the kinematic EL variables, it is evident that FC4.0 players covered the greatest distance during the tasks, averaging approximately 54 m per minute. In terms of explosive velocity, FC2.0 players covered the greatest distance, with no differences between the averages of the other FC players. The fact of presenting a high explosive distance signifies and corroborates the intermittent nature of the sport [41,42]. Therefore, explosive strength work sessions and programmes should be developed to improve and perfect the players' performance [43]. In sequence, reviewing the values of the number of acc and dec, as well as the average speed obtained, it was again the players with the highest score (4.0) who presented the highest records due to their great capacity for movement [37] and predisposition during the game to perform the main technical–tactical actions [44]. In this regard, this is the reason why the players with lower FC present values under the average—because of their limitation of movement. The coaching staff needs to design drills that enhance speed, mobility, agility, strength, and both technical and tactical abilities of players to improve their performance during matches.

The objective internal load variables are analyzed by studying the heart rate of the players. The results indicate significantly higher values for FC4.0 players compared to the rest of the categories, with maximum values of 172 bpm and working at 73% of the maximum. On the other hand, the players with a lower FC show significant differences regarding FC4.0, with a maximum of beats per minute of around 150. The players present an average pulse rate close to 140, coinciding with previous studies in the literature [45]. These values demonstrate the need for a good aerobic and anaerobic base of the players for the development of a good performance [40]. In addition, due to the different positions and FC, each player presents different physical demands, influencing cardiovascular performance [25,46].

Finally, regarding the neuromuscular variables, such as PL and the number of impacts, it is again the FC4.0 players who present the highest values. These results are due to the large number of impacts that occur during the game both during offensive and defensive actions [47]. The PL is one of the variables that is most closely related to the fatigue or load to which the player is subjected during a task, correlated with external [48] and internal load [49]. Therefore, to reduce injuries and asymmetries as well as to reduce player fatigue, the coaching staff should monitor PL values to determine when players are enduring high training loads since most of the fatigue and load are produced at low–medium intensity [50]. Basketball players need to understand the EL demands during competition and implement a proper warm-up tailored to these needs to prevent injuries [51]. Additionally, the coaching staff should consider the exercises that require players to exert a high physical load, considering the specific playing position. These exercises should be administered with adequate rest time to allow for specific adaptations that directly influence the technical and tactical development of the players.

Taking as a reference the correlational analysis of EL and IL variables according to the weight, height, and experience of the players, conclusive and practical results need to be taken into account for the development of personalized training tasks. Considering the kinematic EL variables, a positive correlation is observed between the maximum acceleration variable with height, weight, and experience, i.e., as the independent variables increase, there is a significant increase in the maximum acceleration results. The same occurs with maximum deceleration: a negative correlation is observed in the results. As the values of height, weight, or experience increase, the maximum deceleration values decrease considerably. Considering the values of average and maximum speed, it is height and experience that show the greatest relationship and positive significance. Next, the correlations with the neuromuscular EL variables such as impacts and the PL of the athletes

are observed, with height and experience having a positive influence on these results. Similarly, considering the IL variables related to heart rate, height and experience are also positively influenced; height has the greatest effect on average heart rate ($r^2 = 0.313$). These results are in line with previous studies in which the height of the player above the ground has a great influence on the performance of the player since it allows better movement of the trunk depending on the FC of the player [52]. In addition, the experience of the players is a very important factor in the development of performance, since the greater the experience, the greater the knowledge of the game and the greater the ease with which the athletes can make decisions [53]. Thus, experience can be considered as a determining factor in differentiating the performance of players according to gender [54]. Therefore, the coaching staff must take into consideration the height and experience of the players when determining their performance, as well as the playing position, since they influence player performance of the technical–tactical actions during the game [55].

One limitation of the study was the small sample size because working with a national selection is complex when it comes to scheduling collection times. Therefore, for future investigations, it is recommended to establish different time ranges to carry out the collections. It is also suggested to carry out collections at different times of the season and compare the performance depending on the time of year. In this regard, it is recommended to analyze the player load during matches to analyze the physical demands and adapt the training load to their threshold. On the other hand, it should be noted that this is one of the first studies to analyze the EL and IL of WB players using ID. This study allows us understanding of the physical demands to which the players are subjected.

5. Conclusions

It is important to assess the EL and IL experienced by players during WB training. These data help the coaching staff in the training program to meet specific competitive requirements and allows for the development of a gradual and adaptable training program. This approach ensures that athletes can perform at their peak during training, enhancing their skills and improving performance during competitive events.

In this regard, based on the results obtained in simulated matches and in real competitions, the coach and the physical trainer must adapt the physical loads to the maximum values of the players, including work using thresholds in training sessions. In this way, they will work in a specific and personalized way during the training sessions, producing the required improvements in each of the players. At the same time, the tasks must be adapted to the movement capacity of the players, using larger playing fields for players of FC3.0 to 4.5, as they are the ones who develop higher values of functionality and movement compared to players with lower FC values.

Personalizing training loads based on athlete work ranges reduces injury risk due to overload. The coaching staff should consider exercises requiring players to exert a high physical load, considering the specific playing position. These exercises should be administered with sufficient rest time to allow for specific adaptations that directly influence the technical and tactical development of the players. Based on the study's aims, some conclusions can be affirmed:

- The players with higher FC show upper values in most variables and develop significant differences between the rest of the categories.
- Identifying the maximum values of the players helps the coaching staff prepare and design the training sessions regarding their threshold.
- Acceleration, deceleration, and change in direction are the most important factors in WB influencing sports performance. In this regard, the present study shows the higher values that the player develops during the training task. Therefore, tasks based on these abilities must be completed during training sessions.

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