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Cardiac responses and load during training and competition in wheelchair-basketball players

Jurgi Olasagasti-Ibargoien[1*], Iraia Bidaurrazaga-Letona[2], Susana M. Gil[2]

[1] Health, Physical Activity and Sports Science Laboratory (HealthPASS), Department of Physical Activity and Sports, Faculty of Education and Sports, University of Deusto, Donostia, Spain.

[2] Department of Physiology, Faculty of Medicine and Nursing, University of the Basque Country (UPV/EHU), Leioa, Spain.

*Correspondence: (JOI) jurgi.olasagasti@deusto.es 0000-0001-9802-7110

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Abstract: The quantification and monitoring of training is vital to improve performance and to avoid fatigue and injuries. Heart rate and perceived exertion have been widely used to monitor load in able-bodied sports; however, concerning sports for people with disabilities, similar reasearch is limited. Moreover, the characteristics of the disability may influence the results. The aim of this study was to compare cardiac responses and load in wheelchair-basketball (WCB) players during training and matches, and to ascertain these indicators' relationship to players' functional classification. Heart rate (HR) and peripheral and central rating of perceived exertion (RPE) were recorded in a WCB team (n=15) during a season. Absolute and relative maximal and mean HR were calculated. Internal load was quantified using Edwards' summated-heart-rate-zones method. To enable comparisons, players were divided into low- and high-class groups according to the International Wheelchair Basketball Federation (IWBF) classification. Cardiac demand and load were higher in matches compared to training in both groups of players; however, RPE was only higher in high-class players. During training, low-class players displayed lower absolute maximal HR, but higher relative HR, than high-class players. The risk of underestimating the low absolute HR values of low-class players reinforces the value of relative HR values when monitoring load. On the other hand, for high-class players, coaches must ensure that they complete intense training, to generate the stimulus required for adaptations. For low-class players, RPE should be used with caution because it may not accurately reflect load and cardiac demand.

Keywords: Basketball; Wheelchair; People with disabilities; Sports performance; Load monitoring.

1. Introduction

The objective of training in sport is to generate changes and adaptations with the aim of, ultimately, improving performance. However, while moderate-to-high training loads are necessary to induce positive training-induced adaptations, these also increase the likelihood of fatigue and injuries. Thus, the quantification and monitoring of training is vital and constitutes an objective framework to support coaches' evidence-based decision-making (McLaren et al., 2018). In able-bodied sports, a wide range of methods have been described to measure the load of exercise (McLaren et al., 2018); however, concerning sports for people with disabilities, similar research is limited (Simim et al., 2017).

Wheelchair basketball (WCB) is one of the most popular sports in the Paralympic Games and for many people with disabilities it constitutes an opportunity to launch a sports career (Gustavo de Souza Pena et al., 2020). WCB players intermittently perform high-intensity activities; thus, quantifying players' loads during matches and during training is essential in order to properly plan training sessions.

The quantification of heart rate (HR) during training sessions allows basketball staff to identify whether players are adequately prepared for the physiological demands likely to be encountered during match play (Berkelmans et al., 2018). For this reason, HR monitoring is commonly used in basketball; nevertheless, studies on the typical training and game-play responses of players is lacking in the literature (Berkelmans et al., 2018). In this assertion, the authors considered only able-bodied basketball, thus highlighting the relative scarcity of research on this topic in wheelchair basketball (WCB).

Due to its simple and accessible methodology, measuring heart rate has been widely used in WCB to quantify and monitor load (Seron et al., 2019). However, a number of issues should be taken into account regarding disabled people. Athletes with injuries above the sixth thoracic vertebrae experience impaired cardiac response during physical exercise due to altered autonomic control of the cardiovascular system. Accordingly, they exhibit lower heart rates during exercise (Roberto Zamunér et al., 2013). Thus, the use of HR monitoring to quantify training load must be undertaken carefully in sportspeople with medullar impairment (Cavedon et al., 2015; Valent et al., 2007) and more research is needed.

Rate of perceived exertion (RPE), reported using Borg's established Category-Ratio 10 (CR-10) (Foster et al., 2001), has been widely employed in able-bodied sport and WCB to quantify and monitor load (Simim et al., 2017). In WCB, the high muscular demand on the upper body causes local fatigue before cardiorespiratory fatigue (Simim et al., 2017). For this reason, a differentiated RPE has been proposed, which reports both peripheral and central RPE; these can be used as indicators of physical work in the relevant musculature and the cardiorespiratory system, respectively (Hutchinson et al., 2020).

As disabled athletes live with a wide range of injuries, they do not all experience the same physical disability nor have the same capacities. To respond to these differences, an international classification system based on functionality has been established (Mann et al., 2021) which evaluates various abilities, such as pushing, pivoting, shooting, rebounding, dribbling, passing, and catching. Players are grouped into classes from the lowest functionality, class 1.0, to the highest, class 4.5, and assigned the according number of points. To avoid imbalances between competing teams, the total number of points allowed on the court at a specific time (i.e., the total points of the five players actually playing) is 14.0 (IWBF, 2022). In addition, a recalculation of points is implemented in certain circumstances, such as the participation of novice, young or female players. These rules make a player's class a factor that coaches must consider when deciding which players are going to participate in each competition match.

Previous research has shown that higher class players perform better than lower class players (de Lira et al., 2010; Gil et al., 2015; Marszałek et al., 2022; Molik et al., 2010). However, similar studies regarding training load are scarce. Mason et al. (2017) (Mason et al., 2018) observed minimal changes in physiological demand (HR and RPE) among different small-sided games (SSG) formats, despite clear changes in activity profiles. According to the authors, this could be attributed to the large individual variability in HR. However, the analysis performed did not consider the functional classification of the players. The performance of athletes with spinal cord injuries (SCI) and athletes without SCI has also been compared using SSG (Aitor Iturricastillo, Granados, et al., 2016), although no clear distinction in the functional classification of the players was drawn.

With respect to competition, during international-level WCB games, Marszalek et al. (Marszałek, Gryko, Kosmol, et al., 2019; Marszałek, Gryko, Prokopowicz, et al., 2019) observed significant differences between A-category (1.0–2.5 class) and B-category (3.0–4.5 class) players. They also observed significant differences in HR data between championship matches compared to friendly tournament matches. However, while such differences were evident for the majority of B-category players, fewer significant differences were observed for players in the A category. Therefore, monitoring HR during a match could support the creation of exercises with loads more appropriate for the physical preparation of WB players. Further, the recording of load during training and matches, and their relationship to the functional classification of players, should be investigated.

Numerous studies have been performed on high level or international WCB (Marszałek, Gryko, Kosmol, et al., 2019; Marszałek, Gryko, Prokopowicz, et al., 2019; Marszałek, Kosmol, Morgulec-Adamowicz, et al., 2019; Molik et al., 2017); however, there is a paucity of research analyzing load in lower level teams where, in fact, the vast majority of athletes participate. The unique characteristics of a specific basketball team impact the design and management of training sessions and preparation for competition matches. Thus, the aim of this study was to compare load by recording HR and RPE during training and matches throughout a season and to ascertain the relationship between this load and the functional classification of the players. Moreover, taking into account that some players' classifications are calculated differently according to certain individual traits, we aimed to explore the influence of this system on HR and load.

2. Materials and Methods

Participants - Fifteen wheelchair-basketball players from the 1st Division of the National Wheelchair Basketball League volunteered to participate in the study. Participants were classified according to the International Wheelchair Basketball Federation (IWBF) classification. This classification system was designed based on the physical ability of the player to execute specific movements made in basketball (IWBF, 2022). As such, players are grouped into categories (classes) from 1.0 (a player able to perform the fewest physical functions) to 4.5 (a player able to perform the most physical functions). In addition, the (Name of the Federation) WCB Federation applies a specific variation (recalculation) of this classification to women, new players (those who joined the federation and played for the first time less than a year ago), players under 22 years old, and First-Division players older than 50 years old. In the present study, to facilitate analysis, players were divided into two groups according to their classification: low-class (IWBF points 1.5–2.5) and high-class (IWBF points 3.0–4.5). A description of the players is shown in Tables 1 and 2.

Prior to participation, all participants were provided with a written and oral explanation of the potential risks and benefits of participation in the study, and written informed consent forms, as outlined in the Declaration of Helsinki (2013). The study was approved by the Ethics Committee of the name of the university.

Procedures - Data were collected over a 9-month competitive season (September to May). Players trained twice a week and played one match each weekend. The matches were 1 friendly in October, 10 league matches from October to January, and the cup from April to May (but was cancelled). Data were collected from 59 training sessions and 11 matches from all athletes in attendance at each session and training. A total of 376 training observations and 104 match observations were included in the analysis.

Endurance test - To obtain the peak HR (HRpeak) of each player, the participants completed an adapted version of the original Yo-Yo intermittent recovery test level 1 (YYIR1ad), which included 10-meter runs instead of the original 20 m (J Yanci et al., 2015). This test has shown good reproducibility with WB players (J Yanci et al., 2015). During the test, heart rate (HR) was continuously monitored at 1-second registration intervals by telemetry (Polar Team Sport System, Polar Electro, Kenpele, Finland). HRpeak was the highest value recorded during the YYIR1ad. The same method was used to monitor HR throughout training sessions and games.During training, data collection began at the very beginning of the session and stopped when the coach ended the session. Therefore, rest times are included in the data. From the registered data, the following variables were calculated: maximal HR attained during the training session or match (HRmax), percentage of HR attained during training sessions or matches with respect to the HRpeak obtained in the endurance test (HRpeak%), mean HR during the training session or match (HRmean), and percentage of HRmean with respect to the peak HR (HRmean%).

Following Paulson et al. (2015), HR zones were assigned to each intensity zone with respect to HRpeak (50–60% HRpeak = Z1; 61–70 % HRpeak = Z2; 71–80 % HRpeak = Z3; 81–90 % HRpeak = Z4; 91–100 % HRpeak = Z5). Time (in minutes) spent in each zone (TZ1 to TZ5) and the percentage of time spent in each zone with respect to the total time (%TZ1 to %TZ5) were calculated.

Training and matches load

Internal training load (TL) and match load (ML) were quantified for each player using Edwards' summated-heart-rate-zones (SHRZ) method (Edwards, 1993). This method includes the volume of a training session or match and considers the abovementioned five zones of intensity.

Internal load was calculated by multiplying the accumulated time (minutes) in each HR zone by a coefficient assigned to each intensity zone—which were as follows: Z1 = 5; Z2 = 4; Z3 = 3; Z4 = 2; Z5 = 1—and summating the results (in arbitrary units) (Edwards, 1993). Thus, the load corresponding to each heart-rate zone (loadEdw 1 to loadEdw 5) and total load (Total loadEdw) were determined.

Rating of perceived exertion

The 10-point scale questionnaire proposed by Foster et al. (2001) (Foster et al., 2001) was administered 10 minutes after the end of each training session/match. Players separately evaluated their perceived central exertion (RPEcent) and peripheral perceived exertion (RPEperi) (Paulson et al., 2015). All players were familiarized with the 10-point scale prior to data collection. Players were not aware of the RPE scores of their teammates.

Statistical analysis - Statistical analysis was performed using IBM SPSS statistics software (V 28). The normality of the data was analyzed using the Kolmogorov–Smirnov test. The level of significance was set to $p < 0.05$. Data were displayed as mean ± standard deviation and percentages.

Means, standard deviations, and ranges (minimum and maximum) were used as descriptive statistics for metric data. Differences between training and matches, and between low- and high-class players, were analyzed using the Student T-test or Mann–Whitney test for parametric and non-parametric data, respectively. To quantify the size of the differences, Cohen's d was calculated. Threshold values for effect-size statistics were 0.2, 0.5 and 0.8 for small, medium, and large effect sizes, respectively (Cohen, 2013).

To analyze the correlation between different variables, Pearson's correlations or Spearman's rank order were calculated for parametric and non-parametric data, respectively.

3. Results

Table 1. Players' characteristics

Pl	Sex	Age (years)	Injury	IWBF class	IWBFrecal class	WCB exp (years)	HRpeak (beats/min)
1	M	33	SCI Partial Injury C7	1	1	7	128
2	M	22	Myelomeningocele	2	2	7	196
3	M	26	Spina bifida D12-L1-L5	2	2	7	187
4	M	30	SCI total injury L2	2	2	7	173
5	M	26	Poliomielytis	3	2	1	194
6	M	38	SCI partial injury L1	3	3	9	175
7	M	37	Left hip and knee dysplasia	4	4	6	170
8	M	30	BKA	4	4	8	191
9	M	34	SCI partial injury L1-S1	4	4	5	189
10	M	46	SCI total injury D9-D10	1.5	1.5	7	185
11	F	29	SCI total injury L4	1.5	0	7	184
12	M	39	SCI partial injury L1-L5	2.5	2.5	17	177
13	M	21	Legg–Calvé–Perthes disease	3.5	2.5	0.25	189
14	M	36	BKA + other arm injury	3.5	2.5	0.08	167
15	F	37	BKA	4.5	3	8	185

Pl: player; IWBF: International Wheelchair Basketball Federation; IWBFrecal: IWBF after the recalculation was performed; WCB: wheelchair basketball; exp: experience; HRpeak: peak heart rate (HR) attained during the adapted 10-meter Yo-Yo intermittent recovery test level 1; M: male; F: female; SCI: spinal cord injury; BKA: below-knee amputation.

Table 2. Descriptive data of the players

	Mean ± SD			Range
Age (years)	32.23	±	6.60	21–46
Training experience (years)	6.24	±	4.18	0–17
IWBF (class)	2.77	±	1.06	1.0–4.5
IWBFrecalculated (class)	2.48	±	1.06	0–4
HRpeak in the YYIR1ad				
All players (beats/min)	177.44	±	17.46	128–196
Low-class (beats/min)	171.27	±	22.726	128–196
High-class (beats/min)	182.67	±	9.270	167–194
Low-classrecalculated (beats/min)	176.04	±	20.775	128–196
High-classrecalculated (beats/min)	180.36	±	7.816	170–191

IWBF: International Wheelchair Basketball Federation; YYIR1ad: adapted 10-meter Yo-Yo intermittent recovery test level 1 endurance test; HR: heart rate.

In all groups of players, HR values during matches were statistically higher than during training ($p < 0.001$) (Table 3). Regarding the comparison between classes, statistically significant differences were observed during training sessions and matches, in which low class players showed lower values of HRmax ($p<0.05$), but higher values of HRmax% ($p<0.05$) and HRmean% ($p<0.001$).

According to the IWBF classification, in comparison to low-class players, high-class players spent less time in zones 3 ($p<0.001$), 4, ($p<0.05$) and 5 ($p<0.05$), and more time in zones 1 ($p<0.001$) and 2 ($p<0.05$), during training (Table 4). Following players' gender-, experience-, or age-related recalculations, high-class players spent more time in zones 3 ($p<0.01$), 4 ($p<0.05$), and 5 ($p<0.01$), but less time in zone 2 ($p<0.001$). Almost all groups of players spent significantly more time in zones 4 and 5 ($p < 0.001$) and less time in zones 1 and 2 ($p < 0.01$-0.001) during matches in comparison to training sessions (Table 4). There were no statistically significant differences between classes during the matches.

In both groups, the total load (Total LoadEdw) in matches was statistically higher ($p<0.001$) than in training. For high-class players, loadEdw 5 ($p<0.05$) and loadEdw 3 ($p<0.05$) were lower, whereas loadEdw 1 ($p<0.001$) and loadEdw 2 ($p<0.001$) were higher. Regarding the classes with recalculations, high-class players had higher loadEdw 1 ($p<0.01$) and loadEdw 2 ($p<0.01$) values, but loadEdw 3 ($p<0.05$), loadEdw 4 ($p<0.05$), and loadEdw 5 ($p<0.01$) values which were lower than low-class players (Table 5).

In high-class players in IWBF and IWBF with the bonus, RPEcent and RPEperi were higher in matches than in training ($p<0.01$-0.001) (Table 6).. During training sessions, low-class players had higher RPEperi in IWBF ($p<0.01$) and in IWBF after recalculation ($p<0.05$).During matches, high-class players reported a higher RPEcent in WCBF ($p<0.05$) and WCBF-recalculation ($p<0.01$); and RPEperi in IWBF ($p<0.05$) and IWBF-recalculation ($p<0.05$). Correlation coefficients among RPEs, and heart-rate values and load are shown in Table 7.

Table 3. Comparison of the training and match heart rates (mean ± standard deviation) of low- and high-class players according to the IWBF classification and the classification with the recalculation

		Class	Training				Matches				
			mean	±	sd	dT	mean	±	sd	dM	d1
All players	HRmax (beats/min)		160.96	±	17.67		178.21	±	17.02***		-0.984
	HRmax% (%)		91.03	±	6.16		100.69	±	2.83***		-1.713
	HRmean (beats/min)		118.27	±	13.47		139.67	±	19.67***		-1.425
	HRmean% (%)		67.06	±	6.15		78.75	±	7.4***		-1.818
IWBF	HRmax (beats/min)	Low	156.81	±	21.14		172.76	±	22.24***		-0.747
		High	164.39	±	13.29¥	-0.438	182.52	±	9.57***	-0.595	-1.438
	HRmax% (%)	Low	91.65	±	6.78		101.27	±	3.16***		-1.545
		High	90.52	±	5.57¥	0.185	100.23	±	2.46***¥	0.371	-1.909
	HRmean (beats/min)	Low	116.49	±	15.19		135.81	±	22.59***		-1.141
		High	119.89	±	11.7	-0.254	142.79	±	16.55***	-0.358	-1.782
	HRmean% (%)	Low	68.29	±	6.28		79.46	±	7.12***		-1.729
		High	66.05	±	5.88¥¥¥	0.369	78.18	±	7.64***	0.172	-1.930
IWBF recalculated	HRmax (beats/min)	Low	160.89	±	20.4		176.96	±	20.53***		-0.787
		High	161.10	±	9.12	-0.012	180.03	±	9.95***	-0.180	-2.027
	HRmax% (%)	Low	91.56	±	6.46		100.73	±	3.19***		-1.529
		High	89.86	±	5.29¥	0.276	100.65	±	2.23***	0.028	-2.285
	HRmean (beats/min)	Low	118.54	±	14.79		139.10	±	21.77***		-1.262
		High	117.95	±	10.01	0.044	140.53	±	16.30***	-0.072	-1.901
	HRmean% (%)	Low	67.6	±	5.87		79.08	±	7.67***		-1.841
		High	65.87	±	6.63¥¥	0.281	78.26	±	6.62***	0.111	-1.838

*IWBF: International Wheelchair Basketball Federation; IWBFrecalculated: IWBF after the recalculation was performed; HRmax: session maximal heart rate; HRmax%: percentage of the maximal heart rate attained with respect to the peak heart rate obtained in adapted 10-meter Yo-Yo intermittent recovery test level 1 endurance test (YYIR1ad); HRmean: mean heart rate; HRmean%: percentage of mean heart rate attained with respect to the peak heart rate obtained in YYIR1ad. d1: Cohen's d training vs. matches; dT: Cohen's d low vs. high class during training sessions; dM: Cohen's d low vs. high class during matches; ***p<0.001 training vs. matches; ¥p<0.05, ¥¥p<0.01, ¥¥¥p<0.001 low vs. high class*

Table 4. Percentage of time spent in each heart-rate zone (mean ± standard deviation) in all players and the players divided according to their class.

		Class	Training				Matches				
			mean	±	sd	dT	mean	±	sd	dM	d1
All players	% Z5		2.13	±	3.98		21.78	±	15.06***		-2.558
	% Z4		12.79	±	11.52		27.58	±	12.79***		-1.255
	% Z3		25.52	±	12.61		27.18	±	13.31		-0.130
	% Z2		29.51	±	11.02		20.25	±	17.91***		0.727
	% Z1		30.03	±	18.87		3.86	±	11.18***		1.472
IWBF	% Z5	Low	2.67	±	4.60		22.94	±	15.67***		-2.488
		High	1.69	±	3.33¥	0.249	20.85	±	14.65***	0.138	-2.637
	% Z4	Low	14.66	±	12.17		28.64	±	13.49***		-1.123
		High	11.25	±	10.74¥	0.298	26.73	±	12.27***	0.148	-1.398
	% Z3	Low	28.08	±	12.93		27.43	±	13.81		0.050
		High	23.42	±	11.97¥¥¥	0.375	26.98	±	13.04	0.033	-0.292
	% Z2	Low	28.01	±	11.38		18.58	±	17.34***		0.743
		High	30.66	±	10.61¥	-0.233	21.60	±	18.43**	-0.168	0.719
	% Z1	Low	26.47	±	18.88		2.85	±	10.19***		1.336
		High	32.96	±	18.41¥¥¥	-0.349	4.72	±	12.01***	-0.167	1.615
IWBFrecalculated	% Z5	Low	2.48	±	4.37		21.84	±	15.47***		-2.516
		High	1.36	±	2.81¥¥	0.282	21.70	±	14.65***	0.009	-2.651
	% Z4	Low	13.52	±	11.29		29.45	±	13.55***		-1.358
		High	11.16	±	11.90¥	0.206	24.77	±	11.16***	0.370	-1.161
	% Z3	Low	26.65	±	12.72		27.26	±	13.64		-0.047
		High	23.01	±	12.04¥¥	0.291	27.07	±	13.00	0.014	-0.330
	% Z2	Low	28.65	±	10.92		17.34	±	16.38***		0.934
		High	31.41	±	11.06¥¥¥	-0.252	24.61	±	19.43	-0.412	0.499
	% Z1	Low	28.67	±	18.01		4.96	±	13.11***		1.367
		High	33.04	±	20.44	-0.232	2.21	±	7.33***	0.246	1.669

*IWBF: International Wheelchair Basketball Federation; IWBFrecalculated: IWBF after the recalculation was performed; Z: heart-rate zone; d1: Cohen's d training vs. matches; dT: Cohen's d low vs. high class during training sessions; dM: Cohen's d low vs. high class during matches; **p<0.01, ***p<0.001 training vs. matches; ¥p<0.05, ¥¥p<0.01, ¥¥¥p<0.001 low vs. high class*

Table 5. Training and match load corresponding to each heart-rate zone (1 to 5) and total load according to Edward´s summated-heart-rate-zones method.

			Training				Matches				
			mean	±	sd	dT	mean	±	sd	dM	d1
All players	LoadEdw 5		7.99	±	14.89		81.88	±	56.23***		-2.576
	LoadEdw 4		38.14	±	33.74		83.13	±	37.18***		-1.314
	LoadEdw 3		58.49	±	29.67		62.62	±	31.88		-0.137
	LoadEdw 2		46.27	±	20.65		33.65	±	33.87***		0.527
	LoadEdw 1		23.71	±	16.22		2.70	±	7.82***		1.391
	Total LoadEdw		174.63	±	47.88		263.52	±	65.12***		1.714
IWBF	LoadEdw 5	Low	9.95	±	17.63		87.45	±	61.47***		-2.440
		High	6.38	±	12.00¥	0.241	77.37	±	51.85***	0.179	-2.754
	LoadEdw 4	Low	42.66	±	36.18		84.81	±	36.24***		-1.165
		High	34.42	±	31.20	0.246	81.76	±	38.26***	0.082	-1.444
	LoadEdw 3	Low	61.75	±	30.36		62.51	±	31.23		-0.025
		High	55.82	±	28.90¥	0.201	62.72	±	32.74	-0.007	-0.232
	LoadEdw 2	Low	42.05	±	20.06		30.44	±	30.67**		0.514
		High	49.75	±	20.54¥¥¥	-0.379	36.25	±	36.37***	-0.171	-0.548
	LoadEdw 1	Low	20.01	±	15.27		1.99	±	7.13***		1.269
		High	26.75	±	16.38¥¥¥	-0.425	3.30	±	8.41***	-0.167	1.531
	Total LoadEdw	Low	176.44	±	53.48		266.91	±	64.20***		-1.621
		High	173.14	±	42.83	0.069	260.79	±	66.42***	0.093	-1.803
IWBF-recalculated	LoadEdw 5	Low	9.33	±	16.46		83.14	±	59.09***		-2.522
		High	5.03	±	10.09¥¥	0.291	79.99	±	52.47***	0.056	-2.728
	LoadEdw 4	Low	40.28	±	33.64		89.32	±	39.56***		-1.409
		High	33.39	±	33.62¥	0.205	73.83	±	31.61***	0.423	-1.220
	LoadEdw 3	Low	60.26	±	29.63		63.87	±	34.11		-0.119
		High	54.59	±	29.51¥	0.191	60.76	±	28.60	0.097	-0.210
	LoadEdw 2	Low	44.18	±	20.04		29.09	±	29.62***		0.683
		High	50.91	±	21.32¥¥	-0.329	40.50	±	38.86***	-0.340	0.389
	LoadEdw 1	Low	22.24	±	14.90		3.47	±	9.17***		1.324
		High	26.96	±	18.47¥¥	-0.293	1.55	±	5.13***	0.246	1.533
	Total LoadEdw	Low	176.31	±	49.25		268.29	±	70.68***		-1.705
		High	170.90	±	44.73	0.113	256.37	±	56.01***	0.183	-1.790

*IWBF: International Wheelchair Basketball Federation; IWBFrecalculated: IWBF after the recalculation was performed; LoadEdw: Load corresponding to each heart-rate zone; d1: Cohen's d training vs. matches; dT: Cohen's d low vs. high class during training sessions; dM: Cohen's d low vs. high class during matches; **p<0.01, ***p<0.001 training vs. matches; ¥p<0.05, ¥¥p<0.01, ¥¥¥p<0.001 low vs. high class*

Table 6. Central (RPEcent) and peripheral (RPEperi) perceived exertion during training and matches according to the classification group.

			Training				Matches				
			mean	±	sd	dT	mean	±	sd	dM	d1
IWBF	RPEcent	Low	3.25	±	1.58		3.14	±	1.57		0.072
		High	2.85	±	1.04	0.306	3.70	±	1.55***¥	-0.357	-0.725
	RPEperi	Low	3.64	±	1.45		3.25	±	1.43		0.271
		High	3.22	±	1.31¥¥	0.301	3.92	±	1.76***¥	-0.412	-0.491
IWBF-recalculated	RPEcent	Low	3.09	±	1.39		3.02	±	1.36		0.046
		High	2.92	±	1.19	0.124	4.15	±	1.65***¥¥	-0.761	-1.328
	RPEperi	Low	3.49	±	1.33		3.24	±	1.32		0.184
		High	3.25	±	1.15¥	0.168	4.25	±	1.93**¥	-0.636	-1.002

*IWBF: International Wheelchair Basketball Federation; IWBFrecalculated: IWBF after the recalculation was performed; d1: Cohen's d training vs. matches; dT: Cohen's d low vs. high class during training sessions; dM: Cohen's d low vs. high class during matches; **p<0.01, ***p<0.001 training vs. matches; ¥p<0.05, ¥¥p<0.01, low vs. high class*

Table 7. Correlations between perceived exertion and heart-related parameters and load.

IWBF	Training				Matches			
	Low-class		High-class		Low-class		High-class	
	RPEcent	RPEperi	RPEcent	RPEperi	RPEcent	RPEperi	RPEcent	RPEperi
HRmax	0.002	0.183*	-0.056	0.065	0.121	0.118	0.260	0.308*
HRmax%	0.117	0.052	0.182*	0.178*	0.555**	0.456**	0.554**	0.560**
HRmean	0.123	0.329**	-0.117	0.068	0.104	0.091	0.451**	0.507**
HRmean%	0.292**	0.227**	0.048	0.119	0.191	0.055	0.475**	0.511**
% Z5	0.157	0.055	0.168*	0.177*	0.375*	0.234	0.662**	0.671**
% Z4	0.256**	0.161	0.091	0.164*	0.131	0.033	0.431**	0.493**
% Z3	0.073	0.151	-0.081	0.063	-0.122	-0.119	-0.261	-0.456**
% Z2	-0.111	-0.061	0.034	-0.084	-0.194	-0.012	-0.397**	-0.439**
% Z1	-0.231**	-0.192*	0.012	-0.082	-0.087	-0.013	-0.377*	-0.275
LoadEdw 5	0.156	0.042	0.167*	0.178*	0.440*	0.292	0.646**	0.736**
LoadEdw 4	0.211*	0.085	0.091	0.183*	0.256	0.111	0.344*	0.516**
LoadEdw 3	0.018	0.004	-0.049	0.115	0.019	-0.006	-0.291	-0.365*
LoadEdw 2	-0.171*	-0.215*	0.083	-0.005	-0.096	0.047	-0.385*	-0.367*
LoadEdw 1	-0.271**	-0.266**	0.040	-0.052	-0.087	-0.013	-0.377*	-0.275
Total LoadEdw	0.117	-0.069	0.098	0.246**	0.412*	0.245	0.396**	0.606**
IWBF-recalculated								
HRmax	-0.440	0.128	-0.021	-0.079	0.094	0.211	0.560**	0.349
HRmax%	0.133*	0.081	0.226*	0.207*	0.478**	0.429**	0.597**	0.517**
HRmean	0.023	0.250**	-0.082	-0.041	0.171	0.263	0.608**	0.455*
HRmean%	0.218**	0.217**	0.073	0.127	0.250	0.215	0.568**	0.446*
% Z5	0.155*	0.087	0.189	0.184	0.352*	0.308*	0.774**	0.656**
% Z4	0.192**	0.167*	0.128	0.151	0.249	0.205	0.528**	0.436*
% Z3	0.012	0.129	-0.027	0.077	-0.079	-0.153	-0.438*	-0.540**
% Z2	-0.086	-0.085	0.036	-0.041	-0.221	-0.152	-0.566**	-0.410*
% Z1	-0.161*	-0.197**	-0.016	-0.088	-0.213	-0.085	-0.196	-0.143
LoadEdw 5	0.157*	0.082	0.187	0.182	0.393**	0.399**	0.789**	0.715**
LoadEdw 4	0.157*	0.121	0.135	0.163	0.300*	0.270	0.488**	0.492**
LoadEdw 3	-0.025	0.028	0.019	0.139	0.028	-0.030	-0.468**	-0.469**
LoadEdw 2	-0.124	-0.196**	0.102	0.048	-0.151	-0.086	-0.514**	-0.340
LoadEdw 1	-0.182**	-0.248**	0.032	-0.029	-0.213	-0.085	-0.196	-0.143
Total LoadEdw	0.089	0.009	0.175	0.271**	0.428**	0.365*	0.495**	0.617**

*IWBF: International Wheelchair Basketball Federation; IWBFrecalculated: IWBF after the recalculation was performed; RPE: rating of perceived exertion; cent: central; peri: peripheral; HR: heart rate; Z: zones; HRmax: session maximal HR; HRmax%: percentage of the maximal HR attained with respect to the peak heart rate obtained in adapted 10-meter Yo-Yo intermittent recovery test level 1 endurance test; HRmean: mean HR; HRmean%: percentage of mean HR attained with respect to the HRpeak obtained in YYIR1ad; LoadEdw: load according to Edward´s summated-heart-rate-zones method; *p<0.05, **p<0.01, ***p<0.001*

4. Discussion

To our knowledge, this is the first study to compare cardiac responses and load during in training to those in competitive matches in WCB. In addition, results were analysed to enable comparison between the functional classification of the players. Functionality level played a relevant role in the intensity of exercise during training sessions. Moreover, during matches, cardiac demand and load were significantly greater compared to training sessions in both high- and low-class players; however, the subjective exercise perception (RPE) did not follow this trend and differed between the two groups of players.

During training, players achieved a mean heart of 67%, a value similar to that reported for wheelchair-tennis training (68%) (Barfield et al., 2009). As this was an average value from the training sessions, it includes low-intensity periods such as warm up, cool down, resting times, and static exercises (e.g., stretching). Nevertheless, players' HR reached an average of 92% of their peak heart rate. This result is lower than values reported in other studies that specifically analyzed SSG during training sessions (Aitor Iturricastillo et al., 2017); however, it still reflects periods of high-intensity exercise during training.

The abovementioned average HR values are above the value recommended (50%) for people with disabilities (Jacobs & Nash, 2004); however, whether these values constitute stimulus sufficient to provoke adequate adaptations in order to meet the demands of competitions requires further exploration. Thus, in order to shed light on this matter, we compared HR values between training sessions and competition matches. Cardiac demand and load measured by Edwards' SHRZ demonstrated that the intensity of the matches is higher in comparison to the training sessions. Comparable results were observed in male able-bodied basketball players (Torres-Ronda et al., 2016) during 32 training sessions and 7 friendly matches. In contrast, unlike the current study, similar heart-rate responses were observed in wheelchair-tennis players with SCI (Barfield et al., 2009) during training and matches; it was suggested by the authors that this lack of differences could be explained by the similar conditions of practice and match play, which is in contrast to the competitive nature of the matches of our study.

It is interesting to note the significant cardiac demand of the matches, where peak HR even exceeded the maximal HR attained in the maximal test; these results align with those reported by other authors (Aitor Iturricastillo, Yanci, et al., 2016; Aitor Iturricastillo et al., 2018). In comparison, international WCB players, divided in low- and high- class groups, attained lower values: 95% and 97% of peak HR during matches, respectively (Marszałek, Gryko, Kosmol, et al., 2019). A reasonable explanation for the differences between these studies could be the level of the competition and the participants (international vs. non-elite); however, it is possible that our higher results are due to the difference in the methodologies used to calculate peak heart rate. Either way, we demonstrated that there are high-intensity periods during WCB competitions; therefore, training sessions should be designed to meet this high cardiac demand and load, in order to provide adequate preparation for the strain of matches.

One of our aims was to explore the relation between disability and cardiac demands and load in WCB players who differed in functionality but trained and competed together. Our findings demonstrated lower absolute HR peak and mean values in low-class players. This is most likely due to the inclusion of SCI players in this group, who are known to experience blunted HR response to exercise (Gee et al., 2020). In addition, one of the key findings of the present research was that despite their lower absolute HR values, low-class players trained at higher intensities, as evidenced by the higher relative (percentages) HR values and Edwards' SHRZ load. Accordingly, coaches' roles should be emphasized: they should pay particular attention to low-class players since their low absolute cardiac values may mask the intensity of training sessions, which results in an increased risk of overtraining, overload, and/or injuries.

It is interesting to note that, during matches, there were no differences between low- and high-class players. During matches, high-class players competed against opponents who could reasonably be expected to perform similarly, or even better, thus pushing players to higher intensities compared to training sessions, where low-class players may not have provided such strong opposition. Hence, a concern for coaches in this context is that high-class players' training load may be too low. Therefore, drills should be specifically tailored for this group of players, to ensure sufficient stimulus to induce the appropriate adaptations, improve performance and meet the demands of the matches. Such personalization could take the form of SSG which include players of higher classes, changing the number of players or the size of the court (Mason et al., 2018), and increasing the number of bouts (Javier Yanci et al., 2014) or the duration (Aitor Iturricastillo et al., 2018) of the SSG.

Our participants registered lower RPE (2.8-4.2) than other studies (Au et al., 2017; Hutchinson et al., 2020; A. Iturricastillo, Yanci, et al., 2016; Aitor Iturricastillo, Yanci, et al., 2016; Pelletier et al., 2015); however, due to the different methodologies used, drawing a comparison is not straightforward. Our values were recorded once the training session was completed, and it can be assumed that exercise of various intensities (low, medium, and high) must have been performed during the monitoring period. Conversely, the high values previously reported were obtained following specifically designed SSG and laboratory arm-crank tests performed until volitional exhaustion was reached, implying maximal effort.

Remarkably, during training, the subjective perception of effort in high-class players was the lowest; this may well reflect their lower relative heart rate during the training sessions. When these players were faced with the higher intensity and the greater demands of the matches, their perceived exertion increased together with HR. However, unexpectedly, RPE in low-class players did not follow the same trend. In this group of players, the significant increase in cardiac demand from training to competition did not correspond to a greater perceived exertion. This novel finding may be explained by the uncoupling of physiological and subjective indicators of fatigue in people with SCI (Au et al., 2017). It is well-documented that, in able-bodied people, RPE is closely related both to metabolic and cardiac intensity parameters (Scherr et al., 2013). However, in people affected with medullary lesions, there is conflicting evidence. In this regard, Au et al. (2017), in a study of participants with tetra- and paraplegia, observed that peripheral RPE develops in a nonlinear fashion despite linear increases in HR and VO2 during graded arm cycling. Thus, no correlation between RPE and HR was identified. Our study corroborates these findings. In high-class players, significant correlations were identified between both RPEs and most HR and load values, particularly during matches. On the contrary, in the low-class group, composed of participants with medullary injury, few correlations were found during training and even fewer during the matches. Thus, along with previous investigations that failed to demonstrate a clear relation between subjective measurements of perception and physiological objective values (Au et al., 2017; Lewis et al., 2007; Paulson et al., 2015) in SCI, we recommend caution when using RPE as a measurement of load in people with spinal cord lesions.

One of our aims was to explore the influence of the recalculation system on cardiac demand and load in WCB players. After applying the recalculation, small changes occurred, and the trends of the statistically significant results were mostly maintained. Nonetheless, the largest influence was observed in the subjective perception of effort during matches, where RPEs increased in high-class players, widening the difference with the low-class players. This can be explained by considering that the two players who had their class recalculated had injuries other than medullar damage; moreover, they had little experience training in WCB. Both may influence the perception of effort.

5. Practical Applications.

The results of the study are useful for coaches, athletes, and other researchers in sport physiology and sport performance by providing valuable data on how training load in wheelchair basketball can be monitored and optimized. For coaches, these findings allow for personalization of training and injury prevention through adjustments in intensity and recovery based on players' functional classification. Athletes can benefit by better understanding their own physical responses and improving their self-management.

This study has some limitations. Firstly, we grouped players according to the functional classification used in WCB; thus, comparison to other studies, where participants were divided according to their injury, was challenging. Our purpose was to explore the impact of the functional classification on cardiac demand and load in a team of WCB players with different types of disabilities training together. The reason for using this specific classification and the recalculation classification was that we intended to provide information for the coaches and technical staff involved in WC sports, who must deal with players classified according to the IWBF. Secondly, as has been carried out in previous research (Cavedon et al., 2015; Vanlandewljck et al., 1995), it would have been interesting to compare more groups of players with different levels of disability, rather than only the present two. Unfortunately, only one team participated in this study. Further studies are necessary to corroborate our findings, and, in the future, we encourage researchers to perform studies including several WC teams and larger groups of participants.

6. Conclusions

We would like to emphasize the need to individually monitor the training of WCB players and, whenever possible, matches. Firstly, we recommend performing a maximal test for each player to obtain peak HR and calculate the relative values, and, secondly, performing regular individual HR monitoring during training and adjusting training load accordingly.

There is a risk of underestimating the low absolute HR values of low-class players and, therefore, we encourage the use of relative HR values to monitor load in order to prevent overtraining, fatigue, and injuries. Conversely, in high-class players, coaches must ensure that they train at the necessary intensity to achieve sufficient stimulus to generate adaptations and improve their performance.

Finally, although the use of subjective perception has been widely recommended to monitor load, more research is needed in this subject regarding people with SCI. This assertion is based upon the present findings and, in the absence of more conclusive studies, we suggest using RPE with caution because in people with medullar damage, it may not accurately reflect load and cardiac demand.

Supplementary Materials: The following are available online at http://eurjhm.com/index.php/eurjhm, Figure S1: title, Table S1: title, Video S1: title.

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