



## Anaerobic Variables as Specific Determinants of Functional Classification in Wheelchair Basketball

by

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Every paraspport is currently encouraged to consider evidence-based classification to develop their respective classification system. Therefore, the aims of this study were to: (1) assess the relationship between trunk function and anaerobic power determining proficiency in wheelchair basketball, and (2) define “natural classes” in wheelchair basketball based on anaerobic power. Fifty-nine elite players (representing five national teams) were divided into four main functional classes: Group 1 (n=17), Group 2 (n=14), Group 3 (n=16), Group 4 (n=12). They performed the 6x10s Anaerobic Power Test using an arm crank ergometer. Average values of mean power, peak power, relative mean power, relative peak power, and power decrement were calculated for the 6x10s and 3x10s tests. The Spearman’s correlation matrix revealed significant correlations between classes and values recorded in the 6x10s test. This confirmation between anaerobic power and players’ classification endorses the division of players into different classes. Furthermore, cluster analysis (with fair quality) divided players into two “natural classes”. The first resulting class was mainly formed of participants from Group 1 (71%). An important complement to this research could be to consider wheelchair acceleration and the volume of trunk action in wheelchair basketball classification.

**Key words:** evidence-based classification, cluster, paralympics.

### Introduction

Wheelchair basketball (WB) is one of the most popular and famous Paralympic sports and was developed for people with physical impairment, i.e., leg length difference (LLD), limb deficiency (LD), impaired muscle power (MP), impaired range of motion (ROM), hypertonia (HT), athetosis (Ath), and ataxia (At) (Tweedy et al., 2017). The current classification in WB is focused on trunk function (trunk movements and stability in three planes: sagittal, frontal, and transverse), which is defined as the volume of action (VA): “The limit to which a player can move voluntarily in any direction, and with control return to the upright seated position,

without holding the wheelchair for support or using the upper extremities to aid the movement. The volume of action includes all directions and describes the position of the ball as if the player were holding it with both hands” (International Wheelchair Basketball Federation, 2014, 2021b). The active trunk movements are analyzed during different game activities, for instance wheelchair propulsion, dribbling, passing, shooting, rebounding, and wheelchair contact. There are five main classes for players with physical impairment (1.0, 2.0, 3.0, 4.0 and 4.5 points). Additionally, when a player’s trunk function demonstrates the characteristics of two neighboring classes, a classifier may assign the

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player an additional half point in classification: 1.5, 2.5, or 3.5 (International Wheelchair Basketball Federation, 2021a).

According to the International Paralympic Committee (IPC), each parasport should consider using the concept of evidence-based classification (EBC) to develop their classification system. The EBC is included in the Classification Code and some good examples have been explained in the literature (International Paralympic Committee, 2007, 2009; Tweedy et al., 2017). Generally, this concept involves four main steps and assumes a logical process of conducting research to develop the classification system in each parasport (Tweedy et al., 2014, 2017; Tweedy and Vanlandewijck, 2009). In step 1, researchers have to identify athletes' impairment type(s) in a specific parasport. In step 2, it is important to develop determinants of performance in that specific parasport. In step 3 (which can be twofold), researchers have to develop valid measurements of impairment and standardized sport-specific measurements of determinants of performance in that parasport. In step 4, researchers should check the relative strength of association between valid measurements of impairment and sport-specific measurements of performance determinants (Tweedy et al., 2014, 2017; Tweedy and Vanlandewijck, 2009). As a result, the researchers' investigation can specify a number of classes ("natural classes") (Altmann et al., 2018).

Step 1 in EBC in WB was established by analyzing the current classification system in WB and the steps in the EBC. There are seven groups of impairment in WB (LLD, LD, MP, ROM, HT, Ath, At). To establish step 2, it is necessary to consider the specificity of sport performance (Tweedy et al., 2017); WB is characterized by intermittent efforts in the game emphasizing short-term efforts at maximal intensity (Coutts, 1992; Goosey-Tolfrey, 2005; Hutzler, 1993; Hutzler et al., 2000). WB requires a high level of anaerobic fitness in players in terms of accelerations, dynamic wheelchair propulsion and maneuverability in both defensive and offensive actions. Those activities are affected by trunk limitations (Vanlandewijck et al., 2010), which is why classification in WB is based on trunk function in particular game situations as mentioned above (step 2 in EBC).

Additionally, trunk function is subject to standardized observation in selected situations on the court, when players put maximal effort into their movements (standardized observation of trunk function is carried out in three planes and is clearly described in the International Wheelchair Basketball Federation (IWBF) classification manual (International Wheelchair Basketball Federation, 2021a); step 3). Development of the standardized observation of trunk function in sport-specific activities in WB includes wheelchair activities that determine proficiency in wheelchair court sports, such as short-term efforts, i.e., power during sprints, acceleration, field ball passing tests or anaerobic performance laboratory tests. Different criteria have been used to evaluate the uniqueness of WB determinants and the classification system based on short-term efforts in WB. Anaerobic power in WB has been examined by studying athletes' anaerobic performance in a variety of laboratory tests (de Lira et al., 2010; Hutzler et al., 1998; Molik et al., 2013; Molik et al., 2010) or field-based tests (Cavedon et al., 2015; Cobanoglu et al., 2021; Doyle et al., 2004; Gil et al., 2015; Molik et al., 2013; Tachibana et al., 2019) and compared to players' classification. Sprint tests (5m, 20m), agility tests (T-test, figure eight with the ball) and ball passes (one- or two-handed ball pass tests) have often been used. Studies have reported a strong relationship between results in field-based tests and different functional classes. However, the relationship between players' functional classifications and performance in different field-based tests remains unclear. The 30-s Wingate Anaerobic Test (the 30-s WAnT) for the upper limbs, performed on an arm crank ergometer, has been used to evaluate WB athletes' mean power (MP) and peak power (PP), finding strong relationships between players' classifications and anaerobic performance variables (de Lira et al., 2010). The limitations of most of the studies are the relatively small sample size of players and the fact that, although the 30-s WAnT is a reliable and valid test, intermittent tests such as the 6x10s Anaerobic Power Test (6x10s AnT) would be more specific for WB players. Additionally, the EBC concept was not clearly included in previous WB research and the optimal margins of the scores have never been assessed (step 3 in EBC).

The relative strength of the association

between trunk function (current classes 1.0-4.5) and players' wheelchair activities (anaerobic power) that determine proficiency in WB, needs to be assessed in order to complete the development of EBC for trunk impairment in WB. Thus, the aim of this study was two-fold: (1) to assess the relationship between trunk VA standardized assessment and anaerobic power that determines proficiency in WB, and (2) to determine "natural classes" in WB based on anaerobic power.

## Methods

### Participants

Fifty-nine elite men's WB players (mean age  $28.6 \pm 6.8$  years) representing the national WB teams of Austria ( $n=8$ ), France ( $n=18$ ), Latvia ( $n=7$ ), Lithuania ( $n=9$ ), and Poland ( $n=17$ ) volunteered to participate in this study. Participants were at least 18 years of age and had a minimum of 2 year experience in WB. They were informed about the purpose of the study and all testing procedures and were asked to sign an informed consent form. All procedures were approved by the Local Bioethics Committees (KEIB-10/2016, SKE01-16/2017) and were completed in accordance with the ethical standards as described in the Declaration of Helsinki. Data collection was carried out between February 2017 and May 2019 during training camps of national WB teams.

Participants were divided into four main functional classes: Group 1 ( $n=17$ ), Group 2 ( $n=14$ ), Group 3 ( $n=16$ ), and Group 4 ( $n=12$ ). Each player's classification was evaluated by international classifiers. The date of birth, body mass and range of upper limb motion were also recorded.

### Design and Procedures

The 6x10s Anaerobic Power Test (6x10s AnT) was conducted using a manual LODE ANGIO (Groningen, Netherlands) arm crank ergometer (ACE) with the Wingate Anaerobic Software Package - Wingate v.1.07b (Groningen, Netherlands). Athletes used their own wheelchair and strapping to maximize trunk stability. The ACE was firmly affixed to a wall mounted gymnastic ladder. The axis of rotation of the ergometer was set at the level of the athlete's glenohumeral joints. The wheelchair itself was stabilized by two assistants to help minimize rotational movements while arm cranking.

Each athlete performed one 6x10s AnT

protocol. The test protocol included a warm-up consisting of cranking at 60-rpm with resistance of 50W for 2min. Then, resistance was automatically set at the predetermined testing level and the athlete was instructed to crank as fast as possible six times for 10-s with 15-s rest intervals between efforts. Verbal encouragement was given throughout the test. During the assessment of anaerobic performance, resistance of the ergometer was set on the basis of the individual profile from 4 to 5.5% of body mass.

The following variables were recorded during the test: average values of mean power (MP, Watt), peak power (PP, Watt), relative mean power (rMP, scaled to individual body mass in kilograms, Watt/kg), relative peak power (rPP, scaled to individual body mass in kilograms, Watt/kg), and power decrement (PD, %) calculated as power decrement between first and last peak power calculated in percentages. Measures were calculated for the 6x10s AnT and also for the first 3x10s trials.

The 6x10s AnT protocol was valid as the correlation matrix between the 6x10s AnT and the WANt variables demonstrated moderate and strong correlations ranging between 0.67 and 0.9,  $p < 0.001$ .

### Statistical analysis

Four groups were formed according to the main class. The normality and homogeneity of variance for each group were checked using the Shapiro-Wilk and Levene tests, respectively. Measurements were submitted to a one-way analysis of variance. The Tukey test was used for post-hoc comparisons. The Kruskal Wallis test was employed to compare distributions (ranks) when the assumption of normality was not met. The Dwass-Steel-Critchlow-Fligner test analyzed pairwise comparisons for non-parametric distributions. Effect sizes were expressed in  $\eta^2$ , with values of 0.01, 0.06 and 0.14 for small, medium and large effects, respectively (Cohen, 1988). Also, a Spearman's Rho test was used to study relationships between the main class (ordinal variable) and performance measurements. Furthermore, a two-step cluster analysis (Log-likelihood algorithm) was carried out using all the anaerobic measurements and the main class as a categorical variable for analysis. IBM SPSS (Armonk, NY: IBM Corp., USA) and R-based Jamovi (2019) programs were employed for

the statistical analysis (Jamovi, 2019).

## Results

The description of measurements and comparisons among groups are presented in Tables 1 and 2, respectively. As the post-hoc tests indicated, lower values of anaerobic power were found for participants in Group 1 with respect to players belonging to Group 3, and overall, to Group 4. The rest of the groups did not show systematic differences among them (Table 2). For instance, Groups 1 and 2 only differed in MP in the 3x10s. This measurement (MP in the 3x10s AnT), along with MP in the 6x10s AnT revealed significant differences among the groups (large

effect sizes). In contrast, and besides the anthropometric measurements, both PD% 3x10 and PD% 6x10 were similar among groups. An increase in anaerobic power performance followed an ordered pattern according to the main class (the higher the number of the main class, the better the performance); that is, the Spearman's correlation matrix revealed significant correlations between the main classes and the values of the 3x10s and the 6x10s AnT (Table 3).

**Table 1**  
*Mean and Standard Deviation of the measurements by main classes in wheelchair basketball*

	Main class											
	1 (n=17)			2 (n=14)			3 (n=16)			4 (n=12)		
	M	Med.	SD	M	Med.	SD	M	Med.	SD	M	Med.	SD
<b>Anthropometric variables</b>												
Body mass [kg]	68.01	71.00	14.01	77.36	75.00	13.09	76.68	760.00	14.61	81.42	80.50	16.22
Range of upper limbs [cm]	184.62	182.00	12.68	187.64	188.00	10.72	183.63	185.00	10.20	194.00	196.00	8.76
<b>3x10s AnP</b>												
MP [W]	316.45	327.33	70.08	376.40	379.83	53.72	404.77	407.67	53.99	443.36	430.50	46.28
PP [W]	429.20	401.33	126.71	516.26	547.33	106.25	570.52	572.67	104.66	618.56	627.50	62.57
tPP [s]	4.91	4.53	1.18	4.34	4.23	0.58	4.38	4.23	0.60	3.95	4.10	0.51
rMP [W/kg]	4.58	4.53	0.75	4.93	5.08	0.72	5.37	5.48	0.81	5.60	5.43	1.05
rPP [W/kg]	6.18	5.80	1.46	6.79	6.77	1.56	7.54	7.13	1.43	7.84	7.50	1.58
PD [%]	16.47	14.01	8.78	15.06	13.66	4.46	17.86	18.09	6.90	19.57	19.55	5.68
<b>6x10s AnP</b>												
MP [W]	287.08	290.17	67.68	348.18	358.83	50.43	366.30	363.00	44.96	398.99	396.67	22.89
PP [W]	386.29	360.17	120.51	474.58	514.58	99.83	509.55	529.25	95.52	561.56	557.17	56.53
tPP [s]	4.72	4.37	1.21	4.20	4.23	0.48	4.28	4.27	0.47	3.83	4.07	0.62
rMP [W/kg]	4.16	4.10	0.75	4.57	4.66	0.74	4.85	4.87	0.70	5.06	4.74	0.95
rPP [W/kg]	5.59	5.17	1.42	6.25	6.38	1.50	6.73	6.37	1.34	7.14	6.59	1.56
PD [%]	30.81	29.21	11.10	25.15	26.06	6.48	30.68	28.83	7.86	28.57	28.04	8.07

*Note.* MP–mean power, PP–peak power, tPP–time to achieve peak power, rMP–relative mean power, rPP–relative peak power, PD–power decrement, M–mean, Med.–median, SD–standard deviation

**Table 2**  
Comparisons between groups by main classes in wheelchair basketball

	Contrast	Value	p	$\eta^2$	Sig. post-hoc
<b>Anthropometric variables</b>					
Body mass [kg]	F(3,55)	2.13	0.086	0.04	NA
Range of upper limbs [cm]	F(3,53)	2.28	0.090	0.11	NA
<b>the 3 x 10 s AnP</b>					
MP [W]	$\chi^2(3)$	27.24	<0.001	0.44	1-2*, 1-3**, 1-4***, 2-4*
PP [W]	F(3,55)	8.85	<0.001	0.33	1-3**, 1-4***
tPP [s]	$\chi^2(3)$	10.17	0.017	0.13	1-4*
rMP [W/kg]	$\chi^2(3)$	12.57	0.006	0.17	1-3*, 1-4*
rPP [W/kg]	$\chi^2(3)$	10.99	0.012	0.15	1-3*, 1-4*
PD [%]	$\chi^2(3)$	4.84	0.184	0.03	NA
<b>the 6 x 10 s AnP</b>					
MP mean [W]	$\chi^2(3)$	26.25	<0.001	0.42	1-3**, 1-4***, 2-4*
PP mean [W]	F(3,55)	8.33	<0.001	0.31	1-3**, 1-4***
tPP mean [s]	$\chi^2(3)$	9.81	0.020	0.12	1-4*
rMP mean [W/kg]	$\chi^2(3)$	11.01	0.012	0.15	1-3*, 1-4*
rPP mean [W/kg]	$\chi^2(3)$	9.68	0.021	0.12	1-4*
PD [%]	$\chi^2(3)$	3.3	0.348	0.01	NA

Note. \* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ ;  $\eta^2$ -effect size,  
MP-mean power, PP-peak power, tPP-time to achieve peak power,  
rMP-relative mean power, rPP-relative peak power, PD-power decrement

**Table 3**  
Spearman's correlation matrix between main classes and anaerobic powers variables

	Main class	
<b>3x10s AnP</b>		
MP [W]	0.68	***
PP [W]	0.55	***
tPP [s]	-0.40	**
rMP [W/kg]	0.45	***
rPP [W/kg]	0.43	***
PD [%]	0.25	n.s.
<b>6x10s AnP</b>		
MP [W]	0.66	***
PP [W]	0.52	***
tPP [s]	-0.36	**
rMP [W/kg]	0.41	**
rPP [W/kg]	0.40	**
PD [%]	0.03	n.s.

Note. \* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ , MP-mean power, PP-peak power,  
tPP-time to achieve peak power, rMP-relative mean power, rPP-relative peak power,  
PD-power decrement, n.s.- o statistically significant differences

**Table 4**  
Cluster analysis for wheelchair basketball players divided into two groups

	Clusters		
	Importance	1	2
Size (n=59)		17	42
PP in the 6x10s AnP [W]	1	318.59	540.16
PP in the 3x10s AnP [W]	0.91	360.12	594.12
MP in the 6x10s AnP [W]	0.86	261.14	380.10
MP in the 3x10s AnP [W]	0.62	293.51	415.63

Note. Only predictors >0.5 of importance are depicted; MP-mean power; PP-peak power

**Table 5**  
Cluster analysis for wheelchair basketball players divided into four groups

	Clusters				
	Importance	1	2	3	4
Size (n=59)		17	18	20	4
PP in the 6x10s AnP [W]	1	318.59	527.28	545.79	569.92
PP in the 3x10s AnP [W]	0.92	360.12	571.98	610.55	611.58
MP in the 6x10s AnP [W]	0.90	261.14	365.09	393.73	379.50
MP in the 3x10s AnP [W]	0.71	293.51	390.81	439.82	406.33

Note. Only predictors >0.5 of importance are depicted; MP-mean power; PP-peak power

We carried out a cluster analysis to reveal underlying groups of participants from anaerobic power measurements. The first analysis with an unconstrained number of groups (Table 4) showed two clusters with a fair quality (silhouette of cohesion and separation =0.5). The first cluster was mainly formed by participants from Group 1 (71%), while the second cluster was more heterogeneous, with Group 3 being the most frequent (33.3%). When the number of clusters

was constrained to 4 (Table 5), the first cluster was similar to that of the previous analysis (Table 4). The rest of participants were divided into three remaining clusters, in which the most frequent category coincided with the main class group: cluster two with participants from Group 2 (56%), cluster 3 with participants from Group 3 (50%) and cluster 4 with participants from Group 4 (50%). Therefore, it seems clear that there was a cluster of 17 participants that behaved quite

differently from the rest.

In both models, the variables of PP in the 6x10s AnT, PP in the 3x10s, MP in the 6x10s AnT and MP in the 3x10 s were sorted first in terms of clustering importance. In other words, PP and MP were revealed as the most relevant classifying measurements.

## Discussion

The main aim of this study was to assess the relationship between trunk function standardized assessment and anaerobic power that determines proficiency in WB. In this research, two anaerobic tests were selected (6x10 and 3x10 AnP) due to the inherent specificities of WB, wherein intensive and short maximal efforts are separated by short rest intervals. In our study, strong relationships were found between classification levels (main classes) and anaerobic power variables in the 6x10s AnT and 3x10s trials. This finding suggests that anaerobic power might be one of the most significant factors describing performance in WB classification, which follows the EBC concept (step 2). In a previous study, de Lira et al. (2010) also confirmed strong relationships between the classification level and anaerobic power. However, those authors used the 30-s WAnT on the ACE. For further studies, trunk function and wheelchair acceleration should be included together with anaerobic performance to confirm the correctness of WB classification. Vanlandewijck and co-authors concluded that trunk strength (trunk impairment) is one of the main determinants in wheelchair sport performance (activity) and should be measured and quantified (Vanlandewijck et al., 2010, 2011a, 2011b). For instance, Rehm et al. (2019) confirmed that trunk strength (stability), which is significantly associated with trunk function in WB classification, assessed with the new field test with players in a sitting position pushing a force gauge against a wall, could detect differences among players and be helpful in players' classification.

The second aim of this study was to determine "natural classes" in WB based on anaerobic power. Only elite athletes who were members of national teams were chosen to minimize the impact of differences in training and the sports level between players. Differences were systematically found between players

representing the lowest (Group 1) and the highest (Group 4) functional abilities. No significant differences were recorded among the main groups: 2, 3 and 4. The results of the current study partially confirm previous analyses done by Molik et al. (2013). Those authors conducted their study using the 30-s WAnT on the ACE to prove that the anaerobic performance level for those in classes 1.0–2.5 was significantly lower than those in classes 3.0–4.5. Moreover, their study underlined similarities between players in category A (classes 1.0-2.5) and category B (classes 3.0-4.5). Garcia-Fresneda and Carmona (2021) found that short distance sprint performance (3-m, 5-m, 12-m wheeling sprints at maximum speed) showed a significantly strong association with classification in women's WB players, i.e., the higher the trunk function of players of classes 4.0 and 4.5, the lower the result in sprint tests compared to players of classes 1.0-1.5 with lower trunk function and the higher the results in sprint tests (García-Fresneda and Carmona, 2021). In our study, cluster analyses based on anaerobic variables confirmed that the division into two groups of players was correct – the first cluster group was mainly formed of participants from functional class 1, and thus it provides important scientific evidence for WB classification. Van der Slikke et al. (2018) also found two clusters confirming two main classes in WB. They used inertial sensors (xIMU for match; X-IO technologies and Shimmer3 for field tests, Shimmer Sensing) on wheels and a frame during match and field tests to measure forward acceleration as well as rotation of the frame in the horizontal plane in WB players. The first cluster in their study (n=14) showed an agreement (95%) with 1.0-1.5 class players and six 3.0-4.5 class players. The second cluster (n=33) included 3.0-4.5 class players and one 1.0-2.5 class player. Those authors proved that using inertial sensors in a field test could be sensitive enough to detect differences between WB players for classification (scientific evidence) (van der Slikke et al., 2018). Hence, current findings add evidence to the classification of WB players at two levels: A and B (Molik et al., 2013).

On the other hand, previous analyses do not provide a clear answer as to what the optimal number of classes in WB is (Gil et al., 2015; Molik et al., 2010; Rehm et al., 2019; Vanlandewijck et al.,

1995). Only, Marszalek and Molik (2021) showed, by discriminant analysis, that trunk function in all movement planes (sagittal, frontal, and transverse) clearly differentiates between WB players dividing them into four main classes. Currently, there are four main classes in WB (1.0-1.5, 2.0-2.5, 3.0-3.5 and 4.0-4.5); however, our study did not confirm the division of WB players into four main functional groups based on anaerobic variables. Analyzing the fourth cluster division of players based on anaerobic power determinants seems to be incorrect because the values of MP in the 6x10s AnT and 3x10s trials, in contrast to PP values, do not increase in relation to players' classification. That is why we suggest that WB performance needs to be described by more than one sport performance determinant. Nevertheless, the current study is one step forward in developing the EBC concept in WB classification (step 2 in EBC) indicating determinants (anaerobic variables) to differentiate between players. However, we still recommend continuing players' trunk function observation in

a real game to assign them to particular sport classes (step 3 in EBC).

### Limitations and recommendations for future studies

The limitation of this study was the division of WB players into only four main classes (because of the limited number of players in each class). In future analyses, a comparison of WB players representing eight classes is needed. It would be advisable for future studies to search for other determinants, e.g., as Zwierzchowska et al. (2015) did in wheelchair rugby. Finally, comprehensive analyses of all determinants will allow the proper number of classes to be described in WB.

In conclusion, this study confirmed a strong relationship between anaerobic power values in the 6x10s AnT and 3x10s trials, and players' WB classification. Two "natural classes" of WB players were found based on anaerobic power values in the 6x10s AnT and 3x10s trials. Future studies should consider wheelchair acceleration and trunk function.

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