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NEW METHODS FOR MOBILITY PERFORMANCE MEASUREMENT IN WHEELCHAIR BASKETBALL

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Increased professionalism in wheelchair sports demand a more precise and quantitative measure of individual wheelchair mobility performance, to allow it to be an evaluation measure of wheelchair setting or training optimization. This research describes the application of an inertial sensor based method for measuring wheelchair kinematics and a factor analysis based selection of outcomes best describing wheelchair mobility performance. This set of kinematic outcomes was analysed for sensitivity towards wheelchair performance differences due to competition level and classification of the match data of 29 wheelchair basketball athletes. The method proved sensitive and is believed to provide a solid basis for a kinematics based definition of wheelchair mobility performance in sports.

KEYWORDS: Inertial Measurement Unit; Wheelchair Sports; Wheelchair Performance

INTRODUCTION: The current level of play in wheelchair basketball requires a professional approach in optimizing performance. Overall game performance is well measured by quantitative game characteristics but the individual underlying mobility performance is mostly described in a more qualitative manner (Mason et al., 2010; Mason et al., 2013). A more detailed and objective estimation of athlete-wheelchair mobility performance is wished for, to enable the application of scientific knowledge into sports practice. A newly developed method for measuring wheelchair kinematics in sports (R M A van der Slikke et al., 2015) allows for a more quantitative estimation of individual athlete-wheelchair mobility performance during game play. The goal of this research was to select a set of wheelchair kinematics that describes key aspects of wheelchair mobility performance and to evaluate this set to differences in performance due to classification or competition level. An extensive set of wheelchair kinematics (n=33) was calculated for match performance of 29 athletes of different classifications and competition level. Principal component analysis was used to select a set of not highly correlated kinematics and these outcomes were compared for differences between athletes of different classification and competition level. Competition level is by definition expected to relate to wheelchair performance, whereas the differences in physical capacity between classification groups are known to relate to most aspects of wheelchair mobility performance (Vanlandewijck et al., 2011). The method was rated accurate if General Linear Models (GLMs) revealed classification and competition level as significant factors in kinematic outcomes during matches.

METHODS: During premier division competition and friendly international level matches, athletes own wheelchairs were equipped with three inertial sensors (x-IMU, x-io Technologies sample frequency of 256 Hz), one on each wheel axis and one on the rear frame bar (Figure 1). In 11 matches, wheelchair kinematics were measured of 29 wheelchair basketball players, with twelve male first division players (National NL), nine female internationals (NL & UK) and eight male internationals (NL, ISR & AUS), with in each group similar distributions of player classification. This study was approved by the ethical committee of the department of Human

Movement Sciences: ECB-2014-2. All participants signed an informed consent after being informed on the aims and procedures of the experiment.

With the three IMU configuration (R M A van der Slikke et al., 2015a; R.M.A. van der Slikke et al., 2015b) the following wheelchair kinematics were measured: displacement, speed, acceleration, rotation, rotational speed and rotational acceleration. All dynamic kinematics were calculated for movement time (>0.1 m/s) or rotational time (>10º/s) respectively, to rule out the effect of differences in active game time. For the kinematics, averages, best performances and frequencies were calculated. Principal component analysis with varimax rotation and Kaiser normalization was used to determine most dominant orthogonal (not highly correlating) factors in calculated kinematics (n=33). Based on these factors a set of the most dominant kinematics was made to describe wheelchair mobility performance. The kinematics of this set were used to build a multivariate General Linear Model (GLM) with classification (n=7) and competition level (n=3, see Table 1) as fixed factors, both single and combined.

Figure 1: Measurement setup, with IMUs at on wheels and frame measured during a match.

Table 1: shows the distribution of classification, age, competition level and gender for groups divided by competition level

Level group		*Min*	*Max*	*Mean*	*SD*	*N*
National Male (NM)	Class	1	4.5	2.5	1.4	12
	Age	14	46	27.9	9.4	
International Male (IM)	Class	1	4.5	2.8	1.1	8
	Age	22	42	30	6	
International Female (IF)	Class	1	4.5	2.8	1.3	9
	Age	15	39	28.3	8.8	

RESULTS: Principal component analysis revealed two main factors relating to acceleration and speed, but with limited overall explained variance (<70%). When forced to extract all factors with an eigenvalue greater than 0.5, six factors were extracted, best described by these kinematics: average speed; average of the best 5 speeds; average forward acceleration; average rotational speed with linear speed below average (turning, ≤1.5 m/s); average rotational speed with linear speed above average speed (curving, >1.5 m/s); average of best 5 rotational speeds; average rotational acceleration. Both average accelerations (linear and rotational) loaded on one factor, but were both included for conceptual considerations. Once reduced to these seven kinematic outcomes, factor analysis showed that rotational speed explained 60.5% of the overall variance and the remaining six components each 1.9 – 13.7% of the total variance (Table 2).

Table 2: Explained variance (upper half) and component matrix (lower half) for selected outcomes. Bold numbers indicate highest load per outcome on each component.

		Component	1	2	3	4	5	6	7
		Initial Eigenvalues	4.24	0.96	0.81	0.40	0.29	0.17	0.13
		% of Variance explained	60.5%	13.7%	11.6%	5.7%	4.1%	2.5%	1.9%
Component matrix	Linear	speed	0.173	0.350	0.221	0.241	0.166	**0.837**	0.110
		speed best 5	0.113	**0.948**	0.018	0.083	0.144	0.234	0.078
		acceleration	0.195	0.010	**0.854**	0.193	0.370	0.208	0.124
	Rotational	speed in turn	0.372	0.110	0.216	**0.810**	0.228	0.261	0.161
		speed in curve	**0.932**	0.111	0.147	0.240	0.095	0.128	0.118
		speed best 5	0.487	0.225	0.290	0.398	0.251	0.227	**0.596**
		acceleration	0.128	0.208	0.393	0.210	**0.838**	0.161	0.116

The mean value and standard deviation of these kinematics are displayed in Table 3, with the results per classification grouped by classification ≤ 2.5 and > 2.5.

Table 3: Average kinematic match characteristics per classification and competition level group

			Class ≤ 2.5		Class >2.5		National male		International male		International female	
Direction	**Average**		**Mean**	***SD***	**Mean**	***SD***	**Mean**	***SD***	**Mean**	***SD***	**Mean**	***SD***
Linear	speed	m/s	1.50	*0.09*	1.67	*0.11*	1.54	*0.10*	1.60	*0.17*	1.59	*0.11*
	speed best 5	m/s	2.83	*0.18*	3.11	*0.18*	2.95	*0.26*	2.94	*0.26*	2.95	*0.16*
	acceleration	m/s^2	2.04	*0.52*	2.65	*0.57*	2.09	*0.50*	2.90	*0.55*	2.01	*0.44*
Rotational	speed in turn	°/s	78	*7.7*	88	*5.2*	79	*8.5*	83	*6.3*	86	*8.3*
	speed in curve	°/s	63	*8.5*	72	*6.5*	63	*8.9*	69	*7.7*	70	*8.5*
	speed best 5	°/s	172	*22.2*	200	*18.9*	169	*22.6*	199	*25.1*	189	*17.3*
	acceleration	$°/s^2$	301	*71.3*	422	*119*	320	*106*	424	*127*	327	*77.3*

Classification appeared to be a significant factor in the GLM of all kinematic outcomes, with R^2 values between 0.43 – 0.62 and R^2 adjusted values between 0.27 – 0.51 (Table 4). Competition level as a significant factor produced a GLM for best rotational speed and forward acceleration. Combined, classification and level produced a GLM for most kinematics with R^2 values from 0.84 - 0.94 and R^2 adj. from 0.59 - 0.75.

Table 4: Significant (p<0.05) multivariate GLM R^2 values for the fixed factor Classification, Competition level and combined factor (with interaction effect).

		Classification		Level		Class. & Level	
Direction	**Average**	**R^2**	**R^2 adj.**	**R^2**	**R^2 adj.**	**R^2**	**R^2 adj.**
Linear	speed	0.58	0.47			0.84	0.59
	speed best 5	0.49	0.35				
	acceleration	0.47	0.32	0.40	0.35	0.90	0.75
Rotational	speed in turn (<1.5 m/s)	0.59	0.48			0.87	0.67
	speed in curve (> 1.5 m/s)	0.60	0.49			0.94	0.85

speed best 5	0.62	0.51	0.28	0.22	0.90	0.75
acceleration	0.43	0.27				

DISCUSSION: A new detailed and quantitative measure for wheelchair mobility performance was introduced, by factor analysis based selection of kinematic outcomes that appeared sensitive towards performances differences due to classification and competition level. Main kinematic factors were related to acceleration and speed, but based on extended extraction a set of seven kinematic outcomes was selected. Once reduced to this set, the factor best related to "average rotational speed in a curve" appeared to explain 60.5% of total variance. In this stage of development of the quantitative based definition of wheelchair performance, the set of seven outcomes was retained, but future research might reveal basis for further reduction.
All seven kinematic outcomes showed to be affected by differences in wheelchair performance due to variance in physical capacity (classification). This sensitivity towards wheelchair performance allows for the method to be used as a objective and quantitative evaluation tool, measuring all key kinematics of wheelchair performance. Although reduced to a manageble (for coach and athlete) set of seven kinematic outcomes, the outcomes still describes forward motion/roation; best/average perfromance; speed/accelerations. In that way it could be the first step in mapping wheelchair performance in court sports in a comprehensive way, allowing for groupwise comparissons and individual athlete evaluation alike.
In this analysis only classification and competition level were included as possible factors, where it is known that other factors such as field position also affect wheelchair performance characteristics. Field position is known to relate strongly to classification (Vanlandewijck et al., 2004; de Witte et al, 2016), so part of the effect assigned to classification might have been an effect of field position, but that does not affect the conclusions towards sensitivity of the method.
The ease of use of the IMU based measurement of wheelchair kinematics and the selection describing wheelchair mobility performance in a more detailed and quantitative manner enables performance estimations on an individual level. In that way it is a crucial tool in professionalizing wheelchair sports, since it supports evaluation of interventions in wheelchair settings or athlete training.

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