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SPEED PROFILES IN WHEELCHAIR COURT SPORTS; COMPARISON OF TWO METHODS FOR MEASURING WHEELCHAIR MOBILITY PERFORMANCE

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Wheelchair mobility performance is an important aspect in most wheelchair court sports, commonly measured with an indoor tracking system or wheelchair bound inertial sensors. Both methods provide key performance outcomes regarding speed. In this study, we compared speed profiles of both methods to gain insight in the level of agreement. Data were obtained from 5 players during 6x 10 min. of wheelchair basketball match play. Both systems provide similar outcomes regarding distance covered and average speed. Due to differences in sample frequency and reference position on the wheelchair (for speed calculation), minor differences show at low speeds (<2.5 m/s). Since both systems provide complementary features, a hybrid solution as proved feasible in this study, could possibly serve as the new standard for mobility performance measurement in court sports.

KEY WORDS: wheelchair basketball, activity profiles, wheelchair mobility performance, inertial sensors, indoor tracking.

INTRODUCTION: Quantitative assessment of an athlete's individual wheelchair mobility performance (WMP) is needed to evaluate game performance, improve wheelchair settings and optimize training routines (Mason et al., 2013). Most wheelchair mobility performance research is based on methods that either rely on global references, like radio frequency based indoor tracking systems (ITS), (Rhodes et al., 2014) or on wheelchair bound inertial sensors (van der Slikke et al., 2015a). Tracking systems provide position data, enabling tactical team analyses, but lack the option to calculate higher order outcomes like acceleration, due to limited sample frequencies. Inertial sensor based methods like the WMP monitor (WMPM) allow for easy and accurate measurement of wheelchair mobility performance, but provide no information on absolute field position. In this study, we compared outcomes of both methods regarding speed, to gain insight in the level of agreement between devices. This insight is needed to stipulate to what extend research outcomes from both methods are interchangeable, and if there are pointers for optimizing wheelchair mobility performance research.

METHODS: Five highly trained wheelchair basketball players (age: 20 ± 1 years; playing experience: 7 ± 2 years) volunteered to participate in the study. Their wheelchair mobility performance was monitored using an ITS (Ubisense, ~8 Hz) with a tag on the footplate and simultaneously with three inertial sensors (Shimmer3, 199.8 Hz) on wheels and frame (WMPM). Being part of a larger study on basketball game innovations, measurements (6x 10 min.) were performed during different 3 v 3 game formats. The six ITS sensors were located around the perimeter of a regulation-size wheelchair basketball court (28 x 15 m). The sensors were positioned at each of the four corners of the court, with two additional sensors positioned at the half-way line. Each sensor was mounted on an extendable tripod, elevated approximately 4 m high. Raw position data was filtered using a 3-pass sliding-average filter with a window width proportional to the tag frequency (Rhodes et al., 2014). For the wheelchair mobility profile, speed is derived from the filtered position data. For the WMPM speed calculation is based on the wheel sensors, with additional skid correction algorithm (van der Slikke 2015b). Heading direction is based on the inertial sensor mounted to the frame.
For each measurement, distance covered, speed and time in six fixed speed zones was calculated. Although the WMPM differentiates between forward and backward movements,

the absolute speed was used for outcome calculation, to allow for correct comparison with the ITS.
Additionally, WMPM outcomes were also recalculated (WMPM2) to align with the ITS, so with adjusted filter frequency and reference position (Figure 1). For this WMPM2 outcomes, the heading direction and distance between footplate - frame centre is used to recalculate distance & speed data based on a reference point close to the footplate.
Agreement between methods will be determined by compassion of the covered distance, average speed and percentage time in different speed zones used in default ITS analysis. At a more detailed level, raw speed signals will be compared by calculating the Root Mean Square Error (RMSE). Synchronisation for speed signal RMSE comparison was based on best signal cross correlation.

Figure 1: Wheelchair measurement setup, with the Ubisense tag (ITS) mounted on the footplate and the Shimmer3 inertial sensors on frame and wheels. The reference point for the ITS (R_{ITS}) is the same as the tag, whereas the reference point for the WMPM (R_{WMPM}) is the frame centre.

RESULTS: The average distance calculated per ~10 min. game time was 882.3 m for the ITS, 837.8 m for the WMPM and 883.4 m for WMPM2. Differences in calculated distance between ITS and WMPM ranged from -7.6% to 6.4% and between ITS and WMPM2 from -7.6% to 7.3%. The RMSEs between speed calculated by the ITS and the WMPM were 0.41 m/s and 0.33 m/s for WMPM2. The differences of percentage time in the six fixed speed zones varied from 0.1 – 15.7 between ITS and WMPM and 0.0 – 9.0 between ITS and WMPM2 (see Table 1).

Table 1
Speed and distance related outcomes of the indoor tracking system (ITS) in the middle, the Wheelchair Mobility Performance Monitor (WMPM) on the left and the adjusted WMPM2 on the right. Columns in-between show the differences between methods.

		WMPM	*difference*	ITS	*difference*	WMPM2
Distance per ~10 min. (m)		837.8	*-2.6% (± 3.2%)*	882.3	*0.1% (± 3.3%)*	883.4
Speed (m/s)	average	1.30	*-2.6%*	1.37	*0.1%*	1.38
	RMSE		*0.41*		*0.33*	
Speed Zone (m/s)	0 - 0.5	22.4%	*13.7*	8.7%	*5.7*	14.4%
	0.5 - 1.5	37.9%	*-15.7*	53.6%	*-9.0*	44.6%
	1.5 - 2.5	29.3%	*-0.1*	29.4%	*2.0*	31.3%
	2.5 - 3.0	6.6%	*1.0*	5.5%	*0.9*	6.4%
	3.0 - 3.5	2.8%	*0.7*	2.1%	*0.4*	2.5%
	3.5+	1.0%	*0.3*	0.7%	*0.0*	0.7%

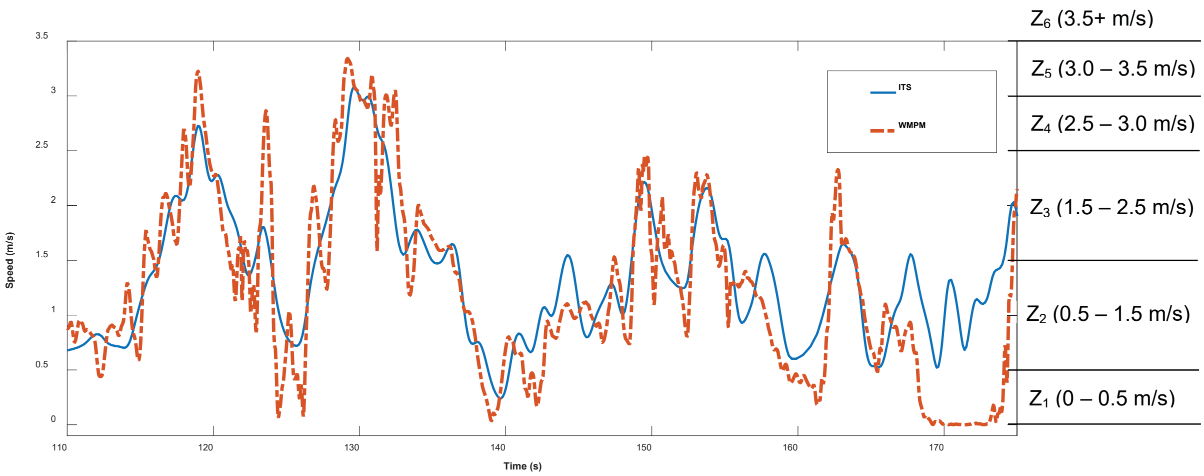

Figure 2: Typical example of the speed signal by the ITS and WMPM, showing small differences in speed pattern e.g. while pushing (112-119s) and turning on the spot (168-174s).

DISCUSSION: In general, both systems provide quite similar speed data, but the features of each method do account for some typical deviations. The difference in reference point on the wheelchair (footplate vs. frame centre) affected the calculated speed and distance slightly (≤ 2.6%), since frame rotations added to the speed in the ITS and not in the WMPM (see Figure 2, time 170-175s). Since the ITS only provides information on tag position and not on heading direction, it is impossible to calculate the speed and distance covered of a different reference point on the wheelchair. To attain a fair comparison, it is however possible to adjust the WMPM outcomes to a reference point near the footplate. Once adjusted, systems provide very similar distance and average speed data (≤ 0.1% ± 3.3%), although still individual differences up to 7.6% occur. The RMSE of 0.41 m/s for the WSPM and 0.33 m/s for the WMPM2 is acceptable for this type of measurements. The position of the reference point causes a very low percentage of time in the lowest speed zone (<0.5 m/s) for the ITS and WMPM2, because when not moving forward, often turns on the spot still cause some

speed (see Figure 2, time 168-174s). With the ITS system, the sample frequency used also acts as a low-pass filter, drawing the speed signal towards the average, so with more time assigned to the corresponding speed class (0.5 – 1.5 m/s, see Figure 2).
These results provided an insight to what extent research outcomes obtained with both methods are interchangeable. For distance, average speed, speed profiles and higher speeds zones (> 1.5 m/s), both methods provide similar outcomes. Wheelchair court sports research has typically focussed on these outcomes (Rhodes et al.,2014, van der Slikke et al., 2016b), so the method used is not believed to affect research conclusions drawn. For specific comparison of lower speed zone outcomes, a recalculation of WMPM outcomes (to WMPM2) is advisable, if source data are available.

CONCLUSION: The type of method used for future research is depending on the research question, with a focus on field position (ITS) or acceleration profiles (WMPM). The ITS provides information on field position, so enables wheelchair mobility performance analysis split by game specific characters (e.g. offence-defence, location to the bucket and heat maps). The WMPM provides more detailed kinematic data, allowing for analyses regarding e.g. accelerations, rotations and push characteristics (van der Slikke et al., 2016a). For the most comprehensive approach, this study proved the feasibility of a hybrid solution incorporating both methods, hence providing the best of both worlds and possibly serving as the new standard for mobility performance in court sports.

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Acknowledgement

We would like to thank for the Loughborough University Enterprise funding and the valuable assistance of Mike Hutchinson during the measurements.