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Short communication

Speed profiles in wheelchair court sports; comparison of two methods for measuring wheelchair mobility performance

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ABSTRACT

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 wheelchair mobility performance outcomes regarding speed. In this study, we compared speed profiles of both methods to gain insight into the level of agreement, for recommendations regarding future performance measurement.

Data were obtained from 5 male highly trained wheelchair basketball players during match play. Players were equipped simultaneously with a tag on the footplate for the indoor tracking system (~8 Hz) and inertial sensors on both wheels and frame (199.8 Hz). Being part of a larger study on 3 vs 3 player game formats, data were collected in several matches with varying field sizes, but activity profiles closely resembled regular match play. Both systems provide similar outcomes regarding distance covered and average speed. Due to differences in sampling frequency and sensor location (reference point) on the wheelchair (for speed calculation), minor differences were revealed 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 gold standard for mobility performance measurement in wheelchair basketball or wheelchair court sports in general.

1. Introduction

Quantitative assessment of an athlete's individual wheelchair mobility performance is needed to evaluate game performance, improve wheelchair settings and optimize training routines (Mason et al., 2013). Next to sport specific mobility performance outcomes, speed is one of the key performance indicators, relevant to all wheelchair sports (Burton et al., 2010; Rhodes et al., 2015; van der Slikke et al., 2016a). Based on a semi-structured interview of nine elite athletes, Mason et al. (2010) identified speed as one of the key performance indicators, important for optimizing wheelchair configuration. Fuss et al. (2012) emphasises the benefits of standard speed measurements in high-performance sports with decreasing costs of technology required. On court wheelchair mobility performance research, is often based on methods that either rely on wheelchair mounted or global reference sensors. Wheelchair bound systems essentially measure wheel rotational speed to calculate forward speed, with data loggers based on reed-switches (Tolerico et al., 2007), potentiometers (Velocometer, Moss et al., 2003) or inertial sensors (Pansiot et al., 2011;van der Slikke et al., 2015a). If sensors are placed in a fixed global position, wheelchair speed is measured with either laser technology (Ferro et al., 2016) or radio frequency based technology (Rhodes et al., 2014). This technical note describes the comparison between two common systems for performance measurement in court sports, namely the inertial sensor based wheelchair mobility performance monitor (WMPM, van der Slikke et al., 2015a) and the global reference based indoor tracking system (ITS, Rhodes et al., 2014).

Inertial sensor based methods like the WMPM allow for easy and accurate measurement of wheelchair mobility performance, but provide no information about absolute field position. Indoor tracking systems provide positional data, enabling tactical team analyses, but lack the option to calculate higher order outcomes like acceleration, due to sample frequency restrictions. In this study, we compared outcomes of both methods regarding speed, to gain insight into the level of agreement between devices.

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2. Methods

2.1. Participants & instrumentation

Five male, highly trained wheelchair basketball players (age: 20 ± 1 years; playing experience: 7 ± 2 years, IWBF classification: 1.0, 2.0, 3.0, 3.5 & 4.5) volunteered to participate in the study. Their wheelchair mobility performance was monitored using an ITS (Ubisense, ~8 Hz) with a tag positioned on the footplate and simultaneously with three inertial sensors (Shimmer3, 199.8 Hz) on wheels and frame (WMPM) of their own customised sports wheelchairs. Since the objective was to compare existing technologies, procedures and settings used for ITS and WMPM were in line with previous research.

2.2. Measurements and setup

Being part of a larger study on wheelchair basketball game innovations (Mason et al., 2017), measurements (6 times 10 min) were performed during different 3 versus 3 game formats (full court, half court and a modified court length of 22 m). Six ITS sensors were located around the perimeter of a regulation-size wheelchair basketball court (28 × 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. The digital signal processing of the ITS was originally optimised for position accuracy, using a 3-pass sliding-average filter with a window width proportional to the tag frequency (Rhodes et al., 2014). In the ITS processing for this study, a five point (~0.625 Hz) sliding average filter was applied to the raw position data of the tag. The tag was positioned at the footplate to ensure best reception by the sensors, as described by Perrat et al. (2015). For the wheelchair mobility profile, speed is derived from the filtered position data. Note that the outcomes of the ITS describe the motion of the tag mounted on the footplate, whereas the WMPM describes the movement of the wheelchair frame centre in-between both main wheels, so the reference points on the wheelchair differ (Fig. 1). For the WMPM speed calculation is based on wheel rotation derived from the wheel sensors, with additional skid correction algorithm (van der Slikke, 2015b). Heading direction is based on the inertial sensor mounted to the frame (van der Slikke, 2015a). Due to the shared frequency bandwidth between multiple player tags in the ITS, the sample frequency varied slightly around 8 Hz. Sample timestamps were utilized to resample up to the WMPM frequency (linear interpolation, Interp1, Matlab). Given the absence of hardware synchronisation options, a cross-correlation of speed signals was used for post synchronisation of systems (Li et al., 1999).

2.3. Data processing

For each of the six measurements per player (10 min match play), distance covered, speed and time in six fixed speed zones (see Table 1) was calculated. The speed zone thresholds are enclosed in the ITS method, originally based on the research regarding wheelchair rugby (Rhodes et al., 2015) and wheelchair tennis (Sindall et al., 2013).

The single tag per wheelchair for the ITS does not allow for determination of heading direction of the wheelchair, so no distinction between forward and backward movement is made. The WMPM does differentiate between directions, but to allow for proper comparison with the ITS, *absolute* values of speed were used. To gain insight in the relationship between ITS and WMPM across speeds, the average value of both systems categorised by 0.05 m/s increments, were plotted against each other.

Although the WMPM reference point at the frame centre seems preferable over a reference point at the foot plate, the ITS position outcome does not allow for recalculation of an alternative point on the wheelchair frame, since heading direction is unknown. It was however possible to re-calculate WMPM outcomes to a foot plate reference point and with filtering similar to the ITS procedure. The WMPM heading direction and the measured distance between rear axle and foot plate was used to calculate the speed of the footplate reference point (see Appendix A). This speed signal was low-pass filtered (0.5 Hz, 2nd order butterworth) and used to calculate the alternative outcomes, named WMPM2. This is not the preferred outcome of the WMPM, but does allow for the most optimal comparison of calculated displacement and speed.

Fig. 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. The WMPM2 reference point is in the middle of the footplate, so close to the R_{ITS}.

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