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Assessment of the configuration accuracy of two UWB local positioning systems, six antennae and 18 Hz vs. eight antennae and 33 Hz, to measure movement patterns in sport

Evaluación de la precisión de la configuración de dos sistemas de posicionamiento local de ultra-banda ancha, seis antenas y 18 Hz frente a ocho antenas y 33 Hz, para medir patrones de movimiento en el deporte

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Abstract

The use of valid, accurate and reliable systems is decisive for ensuring optimal data collection and correct interpretation of values. Among other factors, it seems that sampling rate and the number of nodes determine data accuracy using LPS. Thus, the aim of this study was to assess and compare the accuracy of two UWB configurations (i.e. UWB6_18HZ: 6 antennae and 18 Hz capacity vs. UWB8_33HZ: 8 antennae and 33 Hz capacity) to measure locomotion on court. A healthy and well-trained former soccer player (age: 38 years, mass: 76.34 kg, height 1.85 m) ran 9 m along the middle line of a volleyball court (n=10, samples= 424). UWB6_18HZ and UWB8_33HZ configurations have shown high accuracy in sport movement patterns monitoring (mean difference between actual measurements and UWB = 0.014±0.03m for UWB6_18HZ and 0.013±0.03m for UWB8_33HZ), although UWB8_33HZ presented higher accuracy (8.99±0.03 m) than UWB6_18HZ (8.94±0.03). Therefore, manufacturers should consider future developments based on sampling rates and number of antennae installed around the court.

Keywords: Local Positioning System; Electronic Performance and Tracking System; Technology; sampling frequency; ultra-wide band

Resumen

El uso de sistemas válidos, precisos y fiables es decisivo para garantizar una recogida de datos óptima y una interpretación correcta de los datos. Entre otros factores, parece que la frecuencia de muestreo y el número de antenas determinan la precisión de los datos utilizando sistemas de posicionamiento local (LPS). Por lo tanto, el objetivo de este estudio fue evaluar y comparar la precisión de dos configuraciones ultra banda ancha (UWB) (UWB6_18HZ: 6 antenas y 18 Hz de capacidad frente a UWB8_33HZ: 8 antenas y 33 Hz de capacidad) para medir los patrones de movimiento en los deportes. Un jugador de fútbol sano y bien entrenado (edad: 38 años, masa: 76,34 kg, altura 1,85 m) corrió 9 m a lo largo de la línea media de una cancha de voleibol (n = 10 recorridos, muestras = 424). Las configuraciones UWB6_18HZ y UWB8_33HZ han mostrado una alta precision (diferencia media entre las mediciones reales y UWB = 0.014 ± 0.03m frente a UWB6_18HZ y 0.013 ± 0.03m para UWB8_33HZ), aunque UWB8_33HZ presentó mayor precisión (8.99 ± 0.03 m_18HZ_18) que UWB6_18HZ (8,94 ± 0,03). Por lo tanto, los fabricantes deben considerar desarrollos futuros basados frecuencias de muestreo y número de antenas instaladas alrededor de la cancha.

Palabras clave: Sistema de posicionamiento local; EPTS; Tecnología; frecuencia de muestreo; ultra-banda ancha

Introduction

Since the accuracy of Electronic Performance and Tracking Systems (EPTS) (Rico-González, Pino-Ortega, et al., 2020) has gained crucial importance (Rico-González, Arcos, et al., 2020), the validity and reliability of EPTS have been widely assessed (Cummins et al., 2013; Serpiello et al., 2018) and compared (Bastida Castillo et al., 2018a; Bastida-Castillo, Gómez-Carmona, De La Cruz Sánchez, et al., 2019; Dogramaci et al., 2011; Linke et al., 2018). The higher accuracy of Local Positioning Systems (LPS) than the rest of the available tools suggests that the use of these systems will increase in the future (Rico-González,

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Pino-Ortega, et al., 2020), specifically, the LPS based on ultra-wide band (UWB) (Alarifi et al., 2016; Leser et al., 2011). Ultra-wide band (UWB) uses a set of antennae placed around the court in order to alleviate any satellite reference problems by using time-based positioning techniques (Alarifi et al., 2016).

Technology is continually improving through developments related to microprocessors, data processing, and software. In fact, new models/brands sometimes differ in terms of sampling rates, chip sets, filtering methods, and data processing algorithms (Malone et al., 2017). For these reasons, sports scientists are continuously investigating whether these improvements influence high quality measurements (Malone et al., 2017). Among others, it has been found that the sampling rate capacity influences the accuracy of the reported position of individual players on the pitch (Pons et al., 2019; Rico-González, Arcos, et al., 2020; Rico-González, Los Arcos, et al., 2020; Stevens et al., 2014), but the number of nodes has not yet been assessed in sport. Since GPS are based on quite similar principles to UWB and Jackson et al., (2018) showed significant differences ($P < 0.05$) between different amounts of reference nodes to track positioning, the authors of this study hypothesised that two different numbers of antennae and sampling rate configurations could influence the quality of the data recorded. Therefore, the aim of this study was to assess and compare the accuracy of two UWB configurations: a UWB-based system with 6 antennae and 18 Hz capacity (UWB6_18HZ), and a UWB-based system with 8 antennae and 33 Hz capacity (UWB8_33HZ).

Method

Participants

A healthy and well-trained athlete (age: 38 years, mass: 76.34 kg, height 1.85 m) volunteered to participate in the current investigation. The participant did not present any physical limitations or musculoskeletal injuries that could affect testing. Subject height was measured using a stadiometer (SECA, Hamburg, Germany). Body mass was obtained using a scale (TANITA BC-601, Tokyo, Japan). The study was conducted according to the Declaration of Helsinki and was approved by the Bioethics Commission of the University of Murcia (ID: 2061/2018). The participant was informed of the risks and provided informed written consent.

Procedure

Data acquisition in the present study was carried out on an indoor volleyball court, measuring 18 x 9 m. The participant was equipped with two light-weight (70 g) inertial devices, each measuring 81×45×16 mm, in a custom vest located on the back of the upper torso, fitted tightly to the body, as is typically used in games. The devices were placed in parallel in the custom vest, 2 cm apart and at the same height Although two devices were used simultaneously in the experimental protocol a previous study did not report any problems in UWB-based tracking system accuracy with 28 devices turned on (Bastida Castillo et al., 2018b). The participant ran along the middle line of the court ten times in each direction; with an interval of at least 5 s rest between repetitions (n = 20 trials performed and 424 samples of positioning data). All the tasks started from a standing position. The participant moved according to two criteria: (i) To run only on the lines marked on the volleyball court, and (ii) to reach a speed of >15 km/h where possible. The tests were monitored in real time by S PROTM software to verify that the devices were performing correctly and that the participant achieved the necessary speed in each trial.

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Data collection

Study methodology was written following the protocol by Rico-González, Los Arcos et al., (2020) in order to guarantee a precise description of the use of the technology, scoring 21 points out of 23 (91%). The rest of the items cannot be explained as the authors did have not this information.

Positional data on the court were recorded with a time motion tracking system using two inertial measurement units (IMU; WIMU PROTM, RealTrack Systems, Almeria, Spain). Each device had its own internal microprocessor, 2 GB flash memory and a high-speed USB interface, to record, store and upload data. The devices were powered by an internal battery with 4 h of life, had a total weight of 70 g and measured 81x45x16 mm. Each device contains, among others sensors, a 10 Hz GPS and an 18 Hz Ultra-Wide Band (UWB). This model is valid and reliable (Bastida Castillo et al., 2018b), and has International Match Standard (IMS) certification from FIFA. S PROTM software (RealTrack Systems, Almeria, Spain) was used to analyse and export the data of the x- and y- position coordinates (Bastida-Castillo, Gómez-Carmona, De la Cruz-Sánchez, et al., 2019).

Two different systems were compared:

1) A reference system composed of 6 antennae and 18 Hz UWB chipsets (UWB6_18HZ) (Figure 1). In this case, the antennae with UWB technology were fixed 1.5 m from the perimeter line in the corners and 3 m from the middle line of the court, forming a hexagon for better signal emission and reception (Bastida-Castillo, Gómez-Carmona, De la Cruz-Sánchez, et al., 2019).

2) The reference system was composed of 8 antennae and 33 Hz UWB chipsets (UWB8_33HZ) (Figure 2). The position of the antennae was equal, but an antenna was fixed 3 m behind each goal, forming an octagon with the same aim.

	UWB6_18HZ	UWB8_33HZ
Device´s characteristics (same for both configurations)		
Technology	UWB	
Weight	70 g	
Size	81×45×16 mm	
Memory	2 GB Flash memory	
Battery	4 h	
Antenna´s height	3 m	
Algorithm	TOA	
Configuration´s differences		
Hertz	18 Hz	33 Hz
Nº of antennae	6	8
Installation shape	Figure 1	Figure 2

Table 1. Configurations' characteristics

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All of the antennae were positioned at a height of 3 m and held by a tripod (Bastida-Castillo, Gómez-Carmona, De la Cruz-Sánchez, et al., 2019). The auto-start process followed the protocol suggested by Reche-Soto et al. (2019). The WIMIPROTM inertial devices were placed in a pocket in a specific custom vest placed between the scapulae at the T2-T4 level and prior to the in-field exercises following previous study protocols (Reche-Soto et al., 2019).

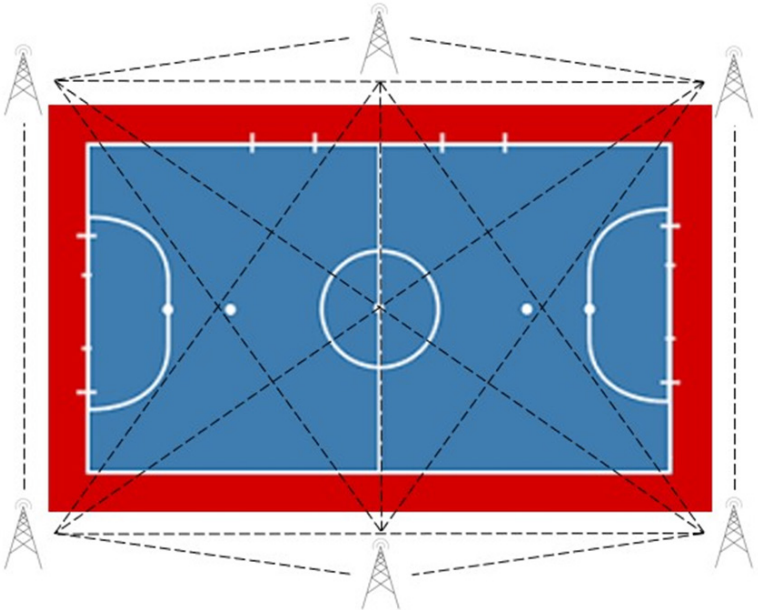

Figure 1. A system with 6 antennae and 18 Hz

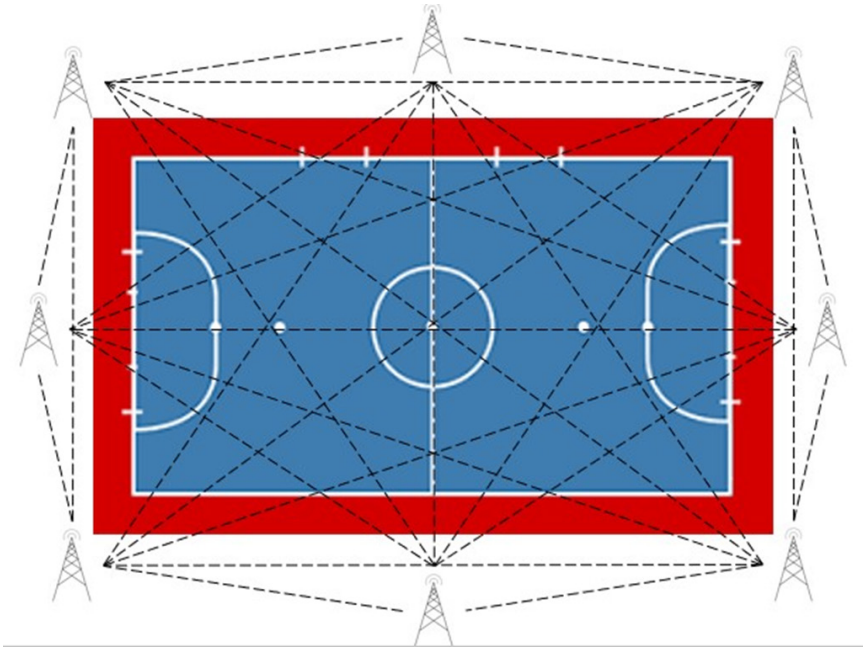

Figure 2. A system with 8 antennae and 33 Hz

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Unlike other systems, WIMIPROTM inertial devices compute the positioning data in receivers. All the antennae have a common clock and the receiving node calculates positioning data through time difference of arrival (TDOA) of the incoming signal and directly calculates its distance from the transmitter; thus, multiplying the estimated TOA by the speed of light makes it possible to draw a circle with the reference node at its centre and a radius equal to the estimated range. By collecting at least three measurements (triangulation) and intersecting the defined circles, it is possible to determine the position of the receivers with high accuracy. The UWB system was adjusted to the reference field before the start of the investigation by walking round the perimeter of the court carrying one of the devices in one hand so that it recognised this as the reference system (Bastida Castillo et al., 2018b). The number of points was 2 per second = 322 data points. The layout of the court was projected in the software S PROTM (RealTrack Systems, Almeria, Spain), and would later be the reference field in the system. This reference system was very similar to the real measurements of the court (100 x 64 m).

Data processing

To investigate the accuracy of the UWB system for monitoring the player's positions on the court, the data were transformed into raw positioning data (x and y coordinated) using software (S PRO, RealTrack Sytems, Almeria, Spain). The data were downloaded after the session because data monitored in real time have been shown to be significantly inaccurate relative to the post-session data (Rico-González, Arcos, et al., 2020). Unlike other validity and reliability studies in which optic-based systems have been used as a gold standard (Linke et al., 2018; Ogris et al., 2012), in this study a geographic information system (GIS) was proposed as the reference system (Bastida-Castillo, Gómez-Carmona, De la Cruz-Sánchez, et al., 2019), and does not require any instrument other than a device with software included. The reference system to compare the results was projected in the software using a GIS mapping application. The GIS makes representations of geometrical shapes, such as polygons or circles, with millimetre accuracy. In this way, the routes selected with their real measurements (measured by trundle wheel) were introduced into the previously created template. And then, the x and y coordinate data of the UWB system were introduced and compared. The distance error of each axis was reported. Of all the data entered, only those that corresponded to the execution of the routes were selected, according to recordings obtained using ANT+ technology and photocells at the beginning and end of each test. The protocol to record the beginning and end of the tests was described in a previous study (see study for more information) (Bastida Castillo et al., 2017).

Statistical analysis

Descriptive statistics are presented as mean values ± SD. A Shapiro-Wilk test was performed for the evaluation of normality (assumption) for statistical distribution. Error of measurement was assessed as mean difference between device data and real measures (as criterion reference). The comparison between UWB configurations (UWB6_18HZ and UWB8_33HZ) was analysed using the paired samples Wilcoxon test. Besides, an agreement analysis between the two variables was performed with the Bland & Altman test (Bland & Altman, 1986), and the coefficient of variance (%CV) was calculated as the standard deviation of difference divided by mean and multiplied by 100 (Atkinson & Nevill, 1998). The strength of the CV (<10%) was quantified in accordance with (Atkinson & Nevill, 1998). The statistical analysis was performed using SPSS (Statistics 20.0) for Mac OS Mojave.

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Results

When analysing the whole dataset (n=424 distance measures) the mean difference between the real measure and the UWB measure was 0.014±0.03m for UWB6_18HZ and 0.013±0.03m for UWB8_33HZ. Wilcoxon showed a significance difference between them (p<0.001).

Table 1 shows the difference between the raw data recorded by both UWB configurations. The paired samples Wilcoxon test revealed a systematic bias by which the values obtained with UWB6_18HZ tended to be slightly lower than those measured with UWB8_33HZ in comparison to the real values (9 meters).

	UWB6_18HZ (M±SD)	UWB8_33HZ (M±SD)	Bias ±SD (95%LOA)	Wilcoxon	Cohen d
One-way (n=106)	8.94±0.03	8.99±0.03	-0.04±0.04 (-0.14 to 0.04)	P<0.001	1.53
Return-way (n=106)	9.02±0.03	9.03±0.03	-0.007±0.04 (-0.1 to 0.08)	P<0.05	0.30
Total way (n=212)	8.98±0.03	9.01±0.03	-0.02±0.05 (-0.13 to 0.07)	P<0.001	0.62

Table 2. Bland-Altman and Wilcoxon test between raw data recorded by UWB6_18HZ and UWB8_33HZ to measure a 9-metre run. The mean ± SD of both configuration and Bland & Altman results are expressed in meters.

Cohen d revealed higher differences between UWB configuration in one-way situation (1.53). However, a high effect was found in total way (0.62). Finally, all data set reported < 1%CV.

Discussion

Due to the lack of information that studies report in their method about the use of EPTS, which makes it difficult to compare them, a fundamental survey has been published to summarise what relevant information should be reported in the methodology of studies about the use of tracking systems (Rico-González, Arcos, et al., 2020). The number of antennae and the sampling rates are two of these criteria that researchers should report on the use of UWB in their articles. For this reason, this study was aimed at assessing accuracy comparing movement pattern measurement in sport between two UWB local positioning system configurations with improvements in the amount of reference nodes and sampling rate. The results showed that both UWB6_18HZ and UWB8_33HZ had acceptable accuracy for the measurement of positioning on the court. But, UWB8_33HZ slightly outperformed UWB6_18HZ. So, sampling rate and the number of antennae as a reference of UWB systems should be considered by sport technical staff and researchers when they measure players' locomotion.

To date, low sampling frequencies have become a main reason for low quality measurement by video based semi-automatic systems and for Global Navigation Satellite Systems (Stevens et al., 2014). Duarte et al., (2010) analysed the impact of the sampling frequency on the outcomes of positional data with a camera-based system, comparing an original data set

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with different cut-off frequencies (3-Hz and 6-Hz) on the x coordinates of an attacker's locomotion in a 1vs1 football sub-phase. They found less variation using a 6-Hz than 3-Hz cut-off frequency. Thus, they used the cut-off frequency of 6 Hz to analyse player movement patterns (Duarte et al., 2010). In the same vein, we found greater accuracy in measuring locomotion on the court using UWB8_33HZ than UWB6_18HZ. This suggests that the sampling rate may be the reason for the higher quality measure. However, further studies should evaluate independently the impact of the sampling rate and the number of nodes installed around the court on the accuracy of the measurement (Rico-González, Arcos, et al., 2020). Based on the same principles for positioning calculation between global positioning systems and LPS, it seems that a greater number of reference points for calculation may also provide higher quality measurements (Jackson et al., 2018). Higher accuracy was achieved using more reference points in total distance measurements (GNSS: 997 ± 533 and GPS: 925 ± 499) (Jackson et al., 2018).

Study limits

Since the greater accuracy of a UWB system with 8 antennae and 33 Hz in comparison to a UWB system with 6 antennae and 18 Hz has only been found for linear locomotion, further studies should compare the accuracy of both systems during match conditions in different sports.

Conclusions

Both the UWB6_18HZ and UWB8_33HZ were found to have acceptable accuracy for the measurement of positioning on the court, but UWB833HZ slightly outperformed UWB618HZ. Future studies should corroborate these outcomes in different sports.

Practical Applications

Manufacturers should consider future developments based on sampling rates and number of antennae installed around the court.

Conflict of interest statement

The authors declare that they have no competing financial interests.

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