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Soccer-specific accuracy and validity of the local position measurement (LPM) system

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Abstract

Limited data is available on accuracy and validity of video-based, GPS and electronic tracking systems, particularly with reference to curved courses and short high intensity running activities. The main goal of this study was to assess soccer-specific accuracy and validity of the radio-frequency based local position measurement (LPM) system (1000 Hz) for measuring distance and speed during walking and sprinting. Three males walked and sprinted 4 soccer-specific courses 10 times each. Distance and speed recorded by LPM were compared to actual distance and speed measured by measuring tape and timing gates. In addition, accuracy was assessed. The static accuracy (SD of the mean) is 1 cm for devices put on the pitch and 2–3 cm when worn by participants. LPM underestimates actual distance (mean difference at most −1.6%). Coefficient of variation becomes larger at higher speed and increased turning angle. With regard to speed, validity correlations are high (range: 0.71–0.97). The LPM speed is significantly and systematically lower, although absolute and relative differences are small, between −0.1 km h^{-1} (−1.3%) and −0.6 km h^{-1} (−3.9%). The typical error of the estimate increases with increased speed, but does not increase with increased turning angle. Because the reported differences are small, we conclude that the LPM-system produces highly accurate position and speed data in static and dynamic conditions and is a valid tool for player tracking in soccer and ball team sports in general.

Keywords: Player tracking; Match analysis; Training analysis; Team sports; Performance analysis

1. Introduction

In sports performance analysis, many tracking technologies are used to record player positions (see Carling et al. for a recent overview of technologies).[1] Technological innovations of data acquisition systems underlie improvements with respect to type of data and data quality that become available. The majority of the data acquisition systems are video-based. However, GPS and electronic tracking systems are becoming increasingly popular. Each of these technologies have their well-described practical advantages and disadvantages when it comes to evaluating athletes' physical performance.[2–5]

Although a wealth of data in sports science is obtained through various tracking technologies, limited data is available on accuracy, validity and reliability of these technologies. The studies that have investigated validity and reliability have proven that techniques like video-tracking[6–8] and GPS-tracking[9–11] are sufficiently accurate and reliable for the evaluation and estimation of covered distance and speed in general. However, these studies also demonstrated important shortcomings of video-tracking[6] and GPS[9,11,12] when short sprints (<1 s), high intensity runs and turning movements are involved. The primary cause that has been denoted for the decreased accuracy and validity of these activities is the low sampling rate. It has therefore been suggested that an increased sampling frequency would improve both accuracy and reliability of the high intensity activities.[6,9,13]

Another important shortcoming of previous validity studies is the experimental protocol. The protocols consist

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primarily of long straight courses or continuous circular paths. Both do not adequately reflect player runs in soccer, because, players accelerate, decelerate and change direction continuously. Furthermore, these studies have only assessed athletes while moving. In terms of precision of measurement, it is also important to evaluate accuracy in static conditions.[2,14] Finally, previous studies have not assessed whether validity is affected by increased speed or turning angles, but validated technologies over a wide speed range and courses containing no turns.

So, several factors that may influence the accuracy and validity of a tracking system have not yet been evaluated. In the current study, we validate a high frequency (1000 Hz) radio-frequency based technology, the local position measurement (LPM) system (Inmotio Object Tracking BV, Amsterdam, The Netherlands), in a soccer-specific setting. We particularly aim at those issues that other studies did not include. So, the main goal of this study is to assess soccer-specific accuracy and validity of the LPM-system for measuring distance and speed during walking and sprinting. In addition, we aim to clarify to what extent turns affect accuracy and validity.

2. Methods

Three males (age: 25 ± 2 yrs; height: 1.87 ± 0.05 m; weight: 81 ± 2 kg) participated in this study. Participants wore a vest containing a transponder located on the back that was connected to two antennas, one on top of each shoulder. A further 19 transponders were put randomly across the pitch, to match the total number of 22 players in an official soccer match. The antennas received radio-frequency signals, transmitted by the main base station. This signal was tagged, transmitted back to the 10 base stations surrounding the pitch and transported by means of glass fiber technology to a server and computer in the command room where data was stored.[15] Average position of the antenna's was calculated (cm) based on timing differences.[15] Due to the reciprocal relationship between the sampling frequency and the number of transponders, the sampling frequency is 45 Hz (1000/22).

The experiment consisted of static and dynamic measurements. First, three measurements of 20 s ($45 \times 20 = 900$ samples) were performed to assess accuracy of motionless transponders ($N = 22$), when on the pitch ($N = 19$) and when worn by participants ($N = 3$). Participants were instructed not to move. In dynamic conditions, participants walked and sprinted four soccer-specific courses (Fig. 1). These courses were designed considering the most frequently occurring directional changes,[16] sprint lengths and sprint times[17] in soccer. The start, turning points and end of each course were marked by a cone. The distance between the cones was measured by means of a measuring tape. Timing gates were placed at the start and end of the course. The starting position of each trial was 3 m in front of the first timing gate. Participants had to walk and sprint each trajectory 10 times at preferred speed and were instructed to follow the course marked by the cones as closely as possible. The procedures used in this study were in accordance with the guidelines of the Medical Ethical Committee of the Medical Faculty of the University Medical Center Groningen, University of Groningen, The Netherlands.

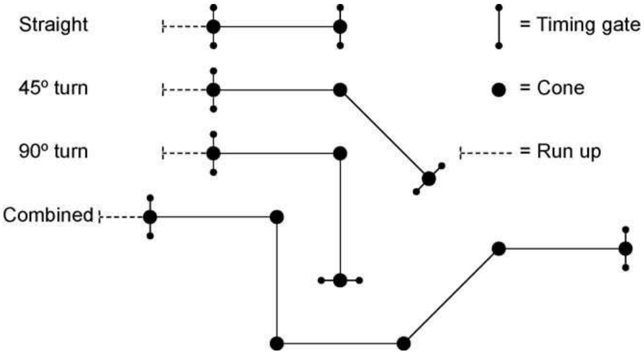

Fig. 1. Schematic representation of soccer-specific courses, the 5 m straight, 10 m 45° turn, 10 m 90° turn and the 25 m combined course. Length between adjacent cones is 5 m.

In the static condition, the accuracy of the static measurements was assessed by calculating mean distance (cm) ± SD of each sample to the average position of the transponder.[14] For all dynamic conditions, distance (cm) and average speed ($\mathrm{km\,h^{-1}}$) of LPM values (provided by the LPM-system) and actual values (measuring tape and timing gates) were calculated for all four courses, for both walking and sprinting. For distance covered, descriptive statistics and a coefficient of variation (standard deviation expressed as a percentage of the mean) were calculated. The average speed was validated by linear regression using the spreadsheet developed by Hopkins.[18] Absolute and relative (%) differences between the two measures were calculated, along with the raw typical error of the estimate (TEE) and the typical error of the estimate expressed as a coefficient of variation (TEE%). For all variables but the relative difference, 95% confidence limits were calculated. The absolute difference between actual speed and LPM speed was considered statistically significant if zero was not in the 95% confidence interval. Data were checked for heteroscedasticity by plotting residuals versus predicted values.

3. Results

In static conditions, the average positional error of the transponders on the pitch is 1 ± 0 cm for the three respective measurements. During the first measurement, one of 19 transponders had 0 cm positional error. During the second measurement, one transponder had an average positional error of 2 cm. When worn by the participants, the average positional error is 2 ± 1 cm, 2 ± 1 cm and 3 ± 1 cm for the three measurements.

Table 1
Descriptive statistics of LPM-distance of all courses for walking and sprinting (30 trials per course). Data presented in cm.

Course	Course length (cm)	Difference			Mean difference as a %	SD as CV%
		Mean ± SD	Min–max	95% CI		
Walking						
Straight	500	1 ± 2	−2 to 5	0 to 2	0.2	0.4
45° turn	1000	−8 ± 6	−9 to 4	−10 to −6	−0.8	0.6
90° turn	1000	−16 ± 10	−33 to 6	−20 to −12	−1.6	1.0
Combined	2500	−29 ± 27	−77 to 26	−40 to −19	−1.2	1.1
Sprinting						
Straight	500	0 ± 3	−6 to 10	−1 to 1	0.0	0.6
45° turn	1000	−6 ± 9	−25 to 10	−9 to −2	−0.6	0.9
90° turn	1000	−16 ± 20	−48 to 25	−24 to −9	−1.6	2.0
Combined	2500	−2 ± 42	−63 to 104	−14 to 18	−0.1	1.7

In dynamic conditions, LPM underestimates actual distance for all courses, apart from the 500 cm straight (Table 1). The mean difference between actual distance and LPM distance increases with course length and turning angle. This is also reflected by the CV%, which increases with increased course length. However, for both walking and sprinting the relative increase in CV% is larger with a sharper turning angle, 45° and 90° respectively.

Table 2 shows that the mean absolute speed differences are approximately $-0.1\,\mathrm{km\,h^{-1}}$ and $-0.4\,\mathrm{km\,h^{-1}}$ for respectively walking and sprinting. The negative values of the mean speed difference indicate that LPM speed is consistently and significantly lower compared to actual speed. The TEE% is higher in the sprinting condition compared to the walking condition for all courses apart form the 5 m straight. Pearson correlation coefficients are high, between 0.71 and 0.97. The data did not show heteroscedasticity.

4. Discussion

The aim of this study was to investigate accuracy and validity of the local position measurement (LPM) system in soccer-specific conditions for walking and sprinting. Our results demonstrated high static accuracy. The average positional error in three subsequent measurements was 1 cm for the transponders on the pitch and 2 or 3 cm for the transponders worn by the participants. The increase in positional error is most likely due to postural sway. A value of 5 mm has been reported for the sway of the centre of mass in two-legged stance under laboratory circumstances on a force plate.[19] It can be argued that the postural sway is larger in an outdoor field setting with the athlete facing the elements with postural sway being measured at the shoulders.

In dynamic conditions, we firstly compared the distance walked and distance sprinted as recorded by the LPM-system with the fixed distance on various courses. Results show that the LPM-system underestimates the actual distance, but it is well under 1.6% on average (Table 1). So, the magnitude of the difference is smaller compared to video-tracking (4.8% on average) and GPS (5.8% on average).[6,9] In previous literature, overestimates of true distance have been reported in video-tracking and GPS[6,9] as well as underestimates for GPS devices.[9] The design of the validation protocols is the most likely cause for this. In our study, the main underestimation is found in the course containing the 90° turn. This is also the course, where in both speed conditions it is most difficult for the participants to follow the marked course as closely as possible, meaning they cover less distance because turns are cut off. So, because corners are cut, distance covered by participants is likely less than official course length, partly explaining the underestimation by LPM.

Table 2
Comparison of average actual speed ($\mathrm{km\,h^{-1}}$) and average LPM speed ($\mathrm{km\,h^{-1}}$) over 30 trials for walking and sprinting four soccer-specific courses.

Course	Actual	LPM	Difference		TEE		TEE%		*r*
	Mean ± SD	Mean ± SD	Mean ± SD	95% CI	Raw	95% CI	CV%	95% CI	
Walking									
Straight	5.5 ± 0.3	5.3 ± 0.3	−0.2 ± 0.2 (−2.9 ± 3.6%)	−0.2 to −0.1	0.2	0.2–0.3	3.9	3.0–5.2	0.80
45° turn	5.7 ± 0.1	5.6 ± 0.2	−0.1 ± 0.2 (1.8 ± 2.6%)	−0.2 to −0.0	0.1	0.1–0.1	1.6	1.3–2.2	0.71
90° turn	5.5 ± 0.2	5.4 ± 0.3	−0.1 ± 0.1 (2.5 ± 2.0%)	−0.2 to −0.1	0.1	0.1–0.1	1.4	1.1–1.9	0.92
Combined	5.3 ± 0.3	5.1 ± 0.3	−0.1 ± 0.1 (2.1 ± 1.3%)	−0.1 to −0.1	0.1	0.1–0.1	1.4	1.1–1.8	0.97
Sprinting									
Straight	16.6 ± 1.2	16.0 ± 1.2	−0.6 ± 0.5 (−3.9 ± 3.1%)	−0.8 to −0.5	0.5	0.4–0.7	3.2	2.5–4.3	0.91
45° turn	17.4 ± 0.9	16.9 ± 0.8	−0.5 ± 0.4 (−3.1 ± 2.1%)	−0.7 to −0.4	0.4	0.3–0.5	2.2	1.7–2.9	0.90
90° turn	14.9 ± 0.7	14.6 ± 0.8	−0.4 ± 0.4 (−2.3 ± 2.7%)	−0.5 to −0.2	0.4	0.3–0.5	2.6	2.0–3.5	0.86
Combined	15.3 ± 0.7	15.1 ± 0.5	−0.2 ± 0.3 (−1.3 ± 2.1%)	−0.3 to −0.1	0.3	0.2–0.4	1.8	1.5–2.5	0.93

Therefore, this results in a bigger variation of covered distance for that course, which is reflected by highest CV% for this course (Table 1). So, the main finding in regard to distance is that LPM-system accurately records distance, although it slightly underestimates actual distance. Furthermore, variation becomes larger at higher speed and increased turning angle.

Secondly, we compared average course speed (LPM) to the average actual course speed. Although correlations are high ($0.71 < r < 0.97$), our results point at a systematic error since the average LPM speed is significantly and systematically lower compared to actual speed for all courses. Nevertheless, both absolute and relative differences are small, respectively between $-0.1\,\mathrm{km\,h^{-1}}$ (-1.3%) and $-0.6\,\mathrm{km\,h^{-1}}$ (-3.9%). These absolute differences are smaller than reported in previous literature on GPS.[20] However, correlations between average LPM speed and average actual speed in this study are generally lower in comparison to previous literature.[6,7,10] This is due to the homogeneity of our sample, because the speed range is approximately $0.6\,\mathrm{km\,h^{-1}}$ for all courses in the walking condition and approximately $1.7\,\mathrm{km\,h^{-1}}$ in the sprinting condition. The wider range of speed values in the sprinting condition would then on average yield higher correlations compared to the walking condition. This phenomenon is also present in our data (Table 2).

Finally, the TEE clearly shows that the magnitude of the error increases with increased speed (Table 2). During walking, the TEE is fairly stable judged by the confidence intervals, whereas more variation is present in the sprinting condition. Furthermore, TEE does not increase with increased turning angle. There is even a trend towards a better estimation of average course speed of the LPM-system with an increased number of turns. In terms of the TEE%, this trend is only present in the walking condition, which is an indication of more accurate tracking at lower speeds. So, the first main finding with regard to speed is that the LPM-system systematically underestimates actual speed, although the differences are small. Secondly, we found that the TEE increases with increased speed, but does not increase with increased turning angles.

Taken all together, we argue that the LPM-system is an accurate and valid tool for measuring distance and speed in soccer. It must be noted that the small differences we demonstrated in this study, are dependent on the current criterion measure (i.e. timing gates and measuring tape), as currently no real gold standard is available for recording distance and speed of curved courses in soccer. So, whether our reported differences are meaningful, depends on the goal of future studies. Nevertheless, we argue that because of the accuracy, small differences reported, high sampling frequency and the ability to use it both indoors and outdoors, LPM opens up new applications and types of analysis in soccer that not yet have been possible, e.g. advanced time-motion analyses or analyses of complex spatial–temporal patterns. This also implies that our findings not only apply to soccer, but extend to many other ball team sports and individual sports. In team sports with less active players, the advantage of high sampling frequency becomes larger. Also, individual players can be equipped with more devices for specific purposes.

To conclude, we have shown that the LPM-system produces highly accurate position and speed data in static and dynamic conditions. In addition, we have provided further insight in the effect of sharp turns on validity measurements during walking and sprinting short courses. Finally, we argued that technologies with high sampling frequencies open up new applications and types of analyses in sports science.

Practical implications

- The LPM-system is a valid tool to record positions of athletes in outdoor and indoor field settings. This opens up new avenues for sports scientists.
- The LPM-system provides accurate data in static and dynamic conditions at various speeds.
- Multiplayer testing in training or matches with high sampling rate is possible.

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