INNOVATIVE METHODOLOGY FOR BENCHMARKING GPS AND INERTIAL SENSORS TECHNOLOGIES FOR PERFORMANCE ANALYSIS AND INJURY PREVENTION IN SOCCER

Kostas Gianikellis[1], Santiago Gomez-Paniagua[1], María José González-Becerra[1], Miguel Rodal[1]

[1] **BioẼrgon Research Group, University of Extremadura, 10003, Cáceres, Spain**

Sports performance enhancement and injury prevention have been recurrent topics of study during the last decade. However, the lack of biomechanical criteria for the analysis of the variables obtained by the GPS technologies implemented in high performance sports pose a serious risk for both athletes and clubs. The aim of this work is to evaluate the differences found in recorded speed between a gold standard technology (Xsens) and a commercial brand of GPS. The results show significant differences ($p < 0.001$) in both average and maximum speed between the two technologies, which calls for further research in this field. Therefore, training programming, performance analysis and the design of injury prevention strategies are compromised by the deficit in the veracity of the results obtained by this type of technology.

KEYWORDS: soccer, inertial sensors, injury prevention, technical actions.

INTRODUCTION: Literature shows that the correct functioning of the neuromuscular system complex plays a key role in the control of joint stability and, therefore, reduces the risk of pathologies. This fact is essential for different fields of knowledge related to sports, such as the improvement of sports performance, injury prevention and readaptation to sports competition.

Soccer professionals need to monitor sports activity obtaining data to quantify performance during the execution of technical actions and specific movements on the field of play, and their potential influence on the health of players (Coutinho et al., 2018). This has led to the implementation of many technologies in high performance to evaluate these issues. (Almulla et al., 2020).

In order to generate reliable criteria, it should be considered that the highest number of injuries occurs in actions that are characterized by high acceleration values ("sprints", "braking", "changes of direction", "kicks" and "landings") (Harper & Kiely, 2018; Malone et al., 2018), being anterior cruciate ligament (ACL) injuries and hamstring strains the most common (Ekstrand et al., 2011; Waldén et al., 2016).

The most widely implemented technologies in this regard are wearable sensors, that monitor performance by measuring physiological effort parameters such as heart rate, metabolic parameters and muscle fatigue (Gabbett, 2016), and/or quantify effort in physical terms and magnitudes, such as distances traveled, average speed of distances traveled, and average accelerations (Castagna et al., 2017); incorporating geolocation receivers (GPS) and electromagnetic accelerometry sensors (IMUs).

However, these devices do not have adequate features or sufficient accuracy to recognize injury patterns in technical gestures in high-speed technical gestures, so current evidence suggests that there is an urgent need to implement injury prevention interventions with broad scientific support and proven efficacy (Owoeye et al., 2020). Therefore, the objective of this study is to carry out as a pilot and methodological validation one of the most widespread commercial technologies in the world of soccer, equipped with accelerometers and GPS, with a motion capture system considered as “Gold Standard”.

METHODS: 4 professional women's soccer players from the Spanish top league participated in the study. Each participant performed an outdoor protocol composed of 15 technical actions including: (1) two sprints at maximum speed; (2) four 90º changes of direction; (3) two 45º

changes of direction; (4) two 505 change of direction tests; (5) Illinois test; and (6) four runs with curvilinear trajectory.

The XSens MVN LINK system (Enschede, The Netherlands) was used to obtain the center of mass (COM) resultant velocity from the X (mediolateral) and Z (anteroposterior) axis, with a 240 Hz sample rate. As well, a commercial Global positioning system (GPS) widely used among the elite, with a sampling frequency of 10 Hz for the GNSS and 100 Hz for triaxial accelerometer, gyroscope, and magnetometer; was also used in the protocols to obtain a velocity resultant vector in all technical actions.

Once the measurement protocols have been recorded, COM velocity from X and Z axis were exported from Xsens software (MVN Analyze Pro) and resultant velocity was calculated. Similarly, GPS data was exported from the technology's own software that provided the resulting velocity vector from mediolateral and anteroposterior axis.

All data was post processed with the MATLAB (*version 9.10.0. (R2021a*). Natick, Massachusetts: The MathWorks Inc)) software, smoothing was carried out by generalized cross validation using cubic splines (Woltring, 1986) and normalized in 1001 data points (equivalent to 0-100% execution). Signal were synchronized in both technologies via global time.

The average and maximum values of the resulting speed in both technologies in each of the actions were extracted for the 4 players. Then, a parametric paired samples T-test was conducted to quantify statistical differences between technologies, for both average and maximum speed, over the diverse technical actions due to the normality values obtained by the Kolgomorov-Smirnov test in both samples and variables (p-values > 0.05).

RESULTS: Table 1 and 2 shows descriptive mean values of maximal and average speed recorded by the participants in the 15 gestures.

Table 1. Average speed mean values for all actions included in the protocol (comparison with respect to Gold Standard).

Average Speed (m/s)		Technical Actions					
		1	2	3	4	5	6
GS	Mean	4.06	3.09	3.65	3.16	2.85	2.73
Commercial	Mean	4.09	2.94	3.38	3.13	2.68	2.39
%	-5.16	0.78	-4.74	-7.41	-0.97	-0.06	-12.42

Table 2. Maximum speed mean values for all actions included in the protocol (comparison with respect to Gold Standard).

Max Speed (m/s)		Technical Actions					
		1	2	3	4	5	6
GS	Mean	7.34	5.51	6.34	6.21	5.71	4.49
Commercial	Mean	6.84	4.90	5.85	5.50	5.16	3.90
%	-9.95	-6.78	-11.07	-7.68	-11.40	-9.64	-13.13

With respect to the results of the t-test, significant differences were found in both variables: (1) p-value < 0.001 for average speed; and (2) p-value < 0.001 for maximal speed.

The analysis of the recorded data has determined statistical differences between several gestures when comparing the two technologies under the same measurement conditions, suggesting that this commercial technology underestimates maximum and average speed values to same extent along technical actions.

DISCUSSION: none of the widely employed technologies integrates in its development theoretical and mechanical models to provide information about the state of motion of the athlete's body as a whole (center of mass of the body, kinematics of the segments and kinematics of the joints, etc.), nor does it use anthropometric data and inertial parameters, therefore its functionality and the information derived from the original measurements is highly questionable and therefore, its context of application should be verified.
Despite that, soccer professionals base their actions on many variables that may well provide interesting information but lack any valid criteria, since most validity studies focus on comparing the maximum speed values obtained with these technologies with those of a radar gun (Sagiroglu et al., 2021) and/or comparing the total distance obtained by the technology with that required to complete a circuit (Beato et al., 2018). Previous studies showed that using GPS can provide useful speed accuracy (Linke et al., 2018), but recent research indicates that inertial sensors generate lower measurement errors resulting in more accurate detection (Pillitteri et al., 2021). As a result, GPS technologies underestimate the speed values in technical actions specific to the sport modality (Chambers et al., 2015). Thus, new lines of research must compare output variables obtained from GPS technologies with photogrammetry systems or inertial sensors systems that include complex correction algorithms in their data processing.
Therefore, and in view of the current situation in the world of soccer where competitions are increasing, it is essential to establish biomechanical criteria to characterize and assess the potential of these technologies through benchmarking, while evaluating their applicability to improve sports performance and injury prevention.

CONCLUSION: This study has evaluated the similarity of a widespread commercial GPS technology among professional women's soccer teams, reporting significant differences with a Gold Standard technology of similar characteristics, generating a first methodological approach that makes possible to compare the technologies used in elite soccer. Thus, the need to develop future lines of research on this subject is substantiated, taking into account the innumerable economic losses caused by sports injuries in clubs around the world.

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ACKNOWLEDGEMENTS: The BioẼrgon Research Group would like to thank Territorio Gaming SL for its invaluable confidence in economic terms and its undoubted commitment to scientific development in this field.
The study participants for their selfless collaboration in the advancement of science in this field.