Radio-Frequency Technologies and Microelectromechanical Systems

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Electronic performance and tracking systems (EPTS) and microelectromechanical systems (MEMS) allow the measurement of training load (TL) and collective behavior in team sports so that match performance can be optimized. Despite the frequent use of radio-frequency (RF) technology (i.e.,global positioning navigation systems (GNSS) global positioning systems (GPS)) and, local position systems (LPS)) and MEMS in sports research, there is no protocol that must be followed, nor are there any set guidelines for evaluating the quality of the data collection process in studies. Thus, this study aims to suggest a survey based on previously used protocols to evaluate the quality of data recorded by RF technology and MEMS in team sports.

Keywords: Electronic Performance and Tracking Systems ; Global Positioning System ; Local Positioning System ; athlete tracking ; Sensor ; MEMS ; Positioning ; Time-motion analysis

1. Introduction

Team sports coaches and scientists use technology with the expectation that it will translate into a competitive advantage [1]. Electronic performance and tracking systems (EPTS) and microelectromechanical systems (MEMS) allow training load (TL) and tactical behavior to be measured at the individual and team level during training and competition [2][3][4][5][6][7][8]. This information is then used to prescribe training sessions, adjust and individualize training programs, and prepare the competition to optimize the performance of the players and the team [9].

2. Main objective of EPTS

The main objective of EPTS is to track player (and ball) positioning on the field during training and competition. However, different forms of EPTS have different principles for their use. Global position navigation systems (GNSS)/global positioning systems (GPS) and local positioning systems (LPS) are based on radio-frequency (RF) technology [9][10]. When optic-based methods (VIDs) are used, the objects are tracked by image segmentation using different techniques of image recognition [10]. RF technologies can also be used in combination with microelectromechanical system (MEMS) devices, such as accelerometers, gyroscopes, and heart rate monitors, to measure load or physiological parameters. A chip (i.e., a reception antenna with wireless technology: Bluetooth or Adaptative Network Topology (ANT+)) is incorporated into the device; a chest strap then detects the heart's electrical signal and sends it to the device. Habitually, EPTS have been used to analyze four kinds of variables in team sports: the physiological analysis (i.e., internal training load (iTL)), time–motion analysis (external workload), neuromuscular analysis, and tactical analysis [6][11][12]. The iTL variables are those that are related to the biological stressors experienced by the player during practice [13]. As we have mentioned, the systems have the possibility of using additional devices to measure these physiological parameters (e.g., HR or oxygen saturation). External workload measures mechanical and locomotor stress during activity and is classified into two groups: kinematic load and neuromuscular load. First, those parameters related to kinematic analysis such as movement patterns, total distances covered or relative distances are obtained through location systems, both LPS and GNSS. Second, neuromuscular analysis is enabled by microelectromechanical sensors (MEMS), and includes variables such as accelerations, turns, changes of direction, jumps, player load (the sum of the three-axis acceleration), or impacts [14][15]. Finally, there are the tactical variables that differ from the rest in that, far from quantifying the load, which aim to analyze the positioning and distribution of the players on the field. Even though VIDs have been the most commonly used tool, GNSS/GPS are now widely used, with LPS being the most promising technology [10][11][16].

GNSS/GPS calculate the position of players, using a known positioning system (i.e., satellites) as a reference and an object with an unknown position through RF. There are four constellations of satellites (the European Galileo (number of satellites in operation = 22); the Russian GLONASS (number satellites in operation = 24); the US-American GPS (nº satellites in operation = 31); and the Chinese Beidou (number satellites in operation = 33)) [17]. A minimum of 24 satellites is needed to obtain useful and valid data during outdoor tracking [18]. In order to calculate the positioning of players, the satellites and receptors have to carry a high-precision synchronized atomic clock. First, a satellite sends a signal at the speed of light to indicate the moment of signal departure, thus allowing the receiver to determine how long the signal has taken to arrive and to multiply the corresponding value by the speed (distance = time × speed). In this way, and by knowing the radius (distance), a sphere is established. The position of the player can be reflected on the earth's surface at any of the points of the circle/sphere [19]. When a second circle is computed, its position can be at one of the two points where the two spheres intersect on the earth. A third satellite is needed for accurate data to be obtained. Thus, the receiver placed on the player's back (T2-T4 interscapular), using a specially designed vest, pinpoints the player's position through this technique, which is called trilateration [14][18][19][20]. Due to the high economic cost of high-precision clocks, the use of a fourth satellite was suggested [19]. The time parameter enters as an unknown variable and is calculated together with the spatial coordinates [19]. For this reason, we find discrepancies regarding the minimum number of satellites needed to calculate the position of the players [21][22].

LPS has been developed as an alternative to GNSS/GPS technology, as unlike GNSS/GPS, it can be used for indoor assessments. Although LPS are based on a unique technology, the principles of its use are quite similar to those of GNSS/GPS [11][16][20]. To compute data with this technology, a set of antennae are used as a reference system instead of satellites. The antennae are placed around the space in which the measurements are taken. The LPS could be classified into infrared, ultrasound and RF (radio-frequency identification, Wi-Fi, Bluetooth, Local Positioning measurement, and ultra-wide-band (UWB)) [16].

Most commercially available GPS/GNSS or LPS units contain microsensors that include the use of accelerometers, gyroscopes, and magnetometers, with some commercially available inertial measurement units (IMUs), such as MEMS containing one of or a combination of these sensors [10][23][24][25]. Many researchers have used GPS/GNSS and LPS to quantify the physical demands of sport [14][26], with some also using accelerometers to identify activity profiles [27]. These sensors typically sample at a higher sample rate of up to 500 Hz [20][27]. These sensors can measure the occurrence and magnitude of movement in three dimensions (anterior–posterior, medial–lateral, and vertical). As LPS, IMUs have been applied in elite sporting populations to further understand movement demands [19][26], but unlike GPS/GNSS, the IMUs have the advantage that they can be used indoors as they do not require a satellite connection [20][27]. To date, sports scientists now employ wearable sensors to identify sport-specific movements and activities in an effort to better evaluate the demands of a sport and to assist with physical preparation, injury prevention, and technical analysis of these activities [14][27]. Currently, some studies have assessed the reliability and validity of inertial sensor technology for detecting and assessing sport-specific skills [14][27].

Many recent studies have used EPTS and MEMS to assess variables, such as internal and external loads, in different individual and team sports scenarios [28][29][30][31][32]. However, only one study has highlighted the considerations that should be taken into account when utilizing GPS to collect data in a sport setting [20]. In addition, to the best of our knowledge, no study has developed a survey of the use of RF technology and MEMS in practical sports applications. The lack of a survey makes it difficult to compare the results of different studies, complicating systematic reviews and meta-analyses. Thus, this study aimed to develop the first survey for collecting, processing, and reporting GNSS/GPS, LPS, and MEMS data. We hypothesized that there would be a lack of information on the method in the articles in which RF technology was used.

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