SPORT TK-EuroAmerican Journal of Sport Sciences

https://revistas.um.es/sportk Online ISSN: 2340-8812

Received: **22/05/2025.** Accepted: **24/09/2025.** Published: **31/12/2025**

Enhancing athletic performance and well-being: The role of RFID Technology in health monitoring and sports psychology

Rabia Yıldız Öztürk[1], Metin Pekgor[2]*, Aydolu Algin[3], Turhan Toros[4], Emre Serin[4], Tolga Tek[5], Selcan Ergun[6]

[1] Mersin University, Faculty of Sport Sciences, Mersin, Türkiye.

[2] Swinburne University of Technology Melbourne, Australia.

[3] Akdeniz University Antalya, Türkiye.

[4] Mersin University, Faculty of Sport Sciences, Department of Coaching Education, Mersin, Türkiye.

[5] Selcuk University, Faculty of Sport Sciences, Department of Sport Management, Konya, Türkiye.

[6] National Defence University, School of Foreign Languages, Türkiye.

* Correspondence: Metin Pekgor; metin.pekgor@outlook.com

ABSTRACT

This study examined the integration of Radio-Frequency Identification (RFID) technology into sports psychology to enhance the monitoring and support of athletes' physical and mental performance. The review focused specifically on technologies used in sport performance and sport psychology contexts. Two groups of technologies were considered: 1) Wearable sensors. 2) RFID-based systems. Through the use of RFID-enabled wearable sensors, athletes can be tracked non-intrusively, providing real-time data on physiological markers such as heart rate, skin temperature, and muscle activity, as well as psychological indicators like stress levels and emotional states. RFID technology enables the collection of data without direct contact, offering new possibilities for understanding the complex interactions between physical exertion and mental resilience. By combining RFID with the Internet of Things (IoT), this approach allows for continuous performance monitoring and personalized feedback, thereby helping athletes optimize their training and recovery strategies. This paper highlights the potential of RFID in sports psychology, underscoring its capability to improve athlete well-being and performance through innovative monitoring and tailored interventions.

KEYWORDS

Wearable Sensors; RFID Technology; Health Monitoring; Sport Psychology; Athlete Performance

1. INTRODUCTION

In recent years, the integration of health monitoring technologies into the field of sports psychology has revolutionized the way athletes' physical and mental well-being is assessed and optimized. Health monitoring, particularly through the use of wearable sensors, provides real-time data on physiological parameters such as heart rate, muscle activity, and stress levels. In sports psychology, this data is crucial for understanding how athletes' psychological states interact with their physical performance, allowing for tailored interventions to enhance focus, resilience, and mental recovery.

By bridging the gap between physical health metrics and psychological strategies, these advanced tools provide invaluable insights for maximizing athletic potential. As a result, the use of wearable sensors in health monitoring and sports psychology has garnered significant attention in recent years, with the potential to improve both athletic performance and overall well-being (Alzahrani & Ullah, 2024; Deshmukh et al., 2022; Huifeng et al., 2020; Li et al., 2016; Subrahmannian & Behera, 2022; Seçkin et al., 2023; Seshadri et al., 2019; Waqar et al., 2021) These devices facilitate real-time data collection on various physiological and biomechanical parameters, which can be leveraged to optimize training, prevent injuries, and tailor rehabilitation programs (Li et al., 2016; Seçkin et al., 2023; Seshadri et al., 2019; Waqar et al., 2021). Interestingly, while the potential benefits of wearable sensors are widely recognized, there are challenges such as accuracy concerns, privacy issues, and the cost of technology that need to be addressed (Seçkin et al., 2023; Waqar et al., 2021). On the other hand, the integration of Internet of Things (IoT) technology and artificial intelligence (AI) models with wearable sensors is evolving, offering promising results in predicting athletic movements and monitoring health (Huifeng et al., 2020). The data generated by these sensors may be readily sent to the cloud using the Internet of Things (IoT) and 5G technologies, enabling sports experts to analyse players' status and build customized training or intervention programs. With continual improvements in data processing technologies like as cloud computing, machine learning, and artificial intelligence, raw sensor data may be converted into actionable insights to detect possible problems before they affect performance. The combination of wearable sensor-based monitoring and real-time communication technologies is critical for providing athletes with timely and effective assistance.

Wearable sensors provide substantial benefits for monitoring athletes’ health and performance, offering real-time data on physiological and biomechanical metrics. These sensors allow athletes to manage training loads, optimize recovery processes, and mitigate injury risks by providing continuous insights into physical and mental states. For example, physiological measures like heart rate (HR) and heart rate variability (HRV) are essential for assessing stress and recovery levels, and wearable HR sensors enable personalized training intensity adjustments based on these metrics (Shaffer & Ginsberg, 2017). Additionally, behavioural monitoring functions like sleep tracking offer valuable information on recovery and performance impact, as poor sleep quality is closely linked with increased injury risk and decreased performance (Fullagar et al., 2015). These data are instrumental for sports psychologists and coaches, who can develop individualized interventions that support long-term health and performance goals (Giles et al., 2020). Thus, wearable sensors represent a data-driven, innovative approach to athlete health management, facilitating precision monitoring and optimization of both physical and psychological parameters.

Wearable sensors in sports utilize diverse wireless systems, each with specific frequency ranges, power efficiencies, and communication capabilities tailored to the needs of athletic performance monitoring. Bluetooth Low Energy (BLE), operating at 2.4 GHz, provides low power consumption, making it optimal for battery-powered devices such as fitness trackers and heart rate monitors with a range of up to 100 meters (Qaim et al., 2020). Near-Field Communication (NFC), which operates at 13.56 MHz, supports energy-efficient, short-range data transfer within a few centimeters, often used in contact-based biometric devices (Song et al., 2020). Radio-Frequency Identification (RFID) offers versatile frequency ranges—low-frequency (125–134 kHz), high-frequency (13.56 MHz), and ultra-high-frequency (860–960 MHz)—which allow for non-line-of-sight data transfer ideal for tracking athletes in real time across various environments. Wi-Fi, operating on 2.4 GHz and 5 GHz bands, provides broad coverage and high data transmission rates, making it effective in controlled environments like smart gyms for real-time data streaming, although it has higher power consumption. Zigbee and Z-Wave, which operate in the 2.4 GHz and sub-1 GHz bands respectively, enable reliable mesh networking with low power requirements, supporting team tracking applications in sports facilities. Ultrawideband (UWB), covering a frequency range of 3.1–10.6 GHz, offers centimeter-level accuracy and strong interference resistance, making it ideal for indoor sports requiring precise location tracking. Finally, cellular networks, including 4G and 5G, operate across a broad spectrum (700 MHz to 6 GHz and beyond for 5G), providing extensive range suitable for outdoor sports and events like marathons, albeit with moderate to high power consumption.

Among them, RFID, in particular, offers numerous benefits for wearable sensor applications in sports. Its capability to track athletes non-intrusively, collect real-time movement data, and operate without direct line of sight has proven invaluable in diverse athletic settings. Additionally, the low power demands of passive RFID configurations support extended monitoring periods, making it cost-effective and reliable. Its adaptability and compatibility with existing sports monitoring systems further enhance RFID’s value in sports science, optimizing athlete performance, safety, and efficiency. This study examines the integration of RFID technology into sports psychology to enhance the monitoring and support of athletes' physical and mental performance.

2. METHODS

2.1. Design and Participants

This study employed a structured literature-based review methodology to examine the applications of wearable sensor technologies and radio-frequency identification (RFID) systems in sport and sport psychology. The approach was designed to synthesize and organize existing scientific knowledge rather than to conduct experimental testing or collect primary data.

The review focused specifically on technologies used in sport performance and sport psychology contexts. Two groups of technologies were considered: 1) Wearable sensors. 2) RFID-based systems. The aim was to identify how these technologies are currently applied and how their functions relate to athletic performance, psychological processes, and health-related outcomes.

2.2. Analytical Framework

The analysis was organized into two main sections, corresponding to the two types of technologies examined.

- *Wearable sensors:* Wearable sensors were reviewed and discussed across three functional domains that emerged from the examined literature: physiological monitoring, stress detection, and biomechanical assessment. Within these domains, attention was given to how wearable systems are used to monitor bodily functions, detect indicators related to psychological stress, and assess movement and mechanical aspects of performance.
- *RFID-based systems:* RFID technologies were examined with respect to three primary areas of application: performance tracking, emotional state monitoring, and equipment interaction. The review considered how RFID systems enable tracking of athletes and sporting actions, how they may be used to infer or monitor emotional or psychological states, and how they facilitate interaction between athletes, equipment, and the sporting environment.

2.3. Method of Synthesis

The study relied on recent scientific literature to: identify technological trends, categorize sensor functions, and link technological applications to sport performance and sport psychology. The emphasis was on synthesizing findings rather than quantitatively evaluating them. The review considered how the identified technologies relate to athletic performance, mental resilience, and health optimization, as described across the consulted literature. No experimental procedures, interventions, or direct measurements were conducted as part of this study.

3. RESULTS

3.1. Wearable Sensor Applications in Sport and Sport Psychology

Physiological Monitoring with Wearable Sensors

Physiological wearable sensors continuously track athletes' bodily functions to assess training loads and recovery needs. Key physiological wearable sensors include:

- **Heart Rate (HR) and Heart Rate Variability (HRV) Sensors:** HR and HRV metrics are crucial indicators of an athlete's stress levels, recovery state, and training load. Wearable HR and HRV sensors (often in the form of chest straps or wristbands) provide real-time data, with low HRV typically indicating high stress levels and a greater need for recovery (Shaffer & Ginsberg, 2017). Such data assist in adjusting training intensity and optimizing recovery (Plews et al., 2013).
- **Respiration Rate (RR) and Oxygen Saturation (SpO2) Sensors:** Respiratory sensors monitor breathing rate and blood oxygen levels, which are essential for evaluating aerobic capacity and endurance, especially in endurance sports. These measurements provide insights into cardiovascular function and help adapt training based on respiratory needs (Scarpellini et al., 2024).
- **Electromyography (EMG) Sensors for Muscle Activity:** EMG sensors measure electrical activity in muscles, helping monitor muscle strength, coordination, and fatigue. This is particularly valuable during intensive training sessions, as EMG can detect imbalances or increased muscle tension that may predispose an athlete to injury (Li et al., 2024). EMG data also support safe load management by evaluating muscle fatigue levels.
- **Body Temperature (BT) and Galvanic Skin Response (GSR) Sensors:** Wearable GSR sensors measure sweat-induced changes in skin conductivity to detect physiological stress responses. Increased sweating and shifts in skin temperature during stressful situations are

captured by GSR sensors, providing crucial information for stress management (Raju et al., 2023).

Stress Detection with Wearable Sensors

Wearable sensors enable multifaceted stress detection, employing a range of methods to monitor physiological, non-physiological, and behavioural signs of stress. This provides sports professionals with a comprehensive toolkit for managing athletes' stress levels in both training and competitive environments:

Physiological Stress Detection Methods

- **Heart Rate (HR) and Heart Rate Variability (HRV):** HRV is widely recognized as a strong indicator of stress. In conditions of high stress or fatigue, HRV tends to decrease, signalling that an athlete may require additional recovery time. Wearable HRV sensors allow real-time monitoring, enabling immediate adjustments to prevent overtraining (Jerath et al., 2023).
- **Respiratory Rate and Oxygen Saturation:** A rising respiratory rate often indicates stress. Real-time respiration monitoring detects irregular breathing patterns associated with stress responses, such as shallow or rapid breathing, which can be managed through respiratory training and mindfulness techniques (Lange, 2021).
- **Galvanic Skin Response (GSR):** GSR sensors measure skin conductivity, which rises with increased sweating linked to stress. This wearable method detects acute stress responses, providing real-time feedback on psychological and physical stress levels during high-pressure situations like competitions (Satapathy et al., 2024).
- **Cortisol Detection (Saliva/Blood):** Some wearable sensors in development aim to measure cortisol, a primary stress hormone, providing biochemical validation of stress. These are particularly relevant for assessing chronic stress, although they are less commonly integrated into continuous wearable devices due to complexity in detection (Ding et al., 2024).
- **Non-Physiological Stress Detection Methods**
- **Facial Expression Analysis:** Wearable cameras and computer vision algorithms can analyse micro-expressions to detect stress. Subtle changes in expressions, such as tension around the eyes and mouth, indicate stress and can be analysed to understand the athlete’s emotional state without physical contact (Ben et al., 2021).

- **Voice Analysis:** Some wearables incorporate voice analysis to detect changes in pitch, tone, and speed, which tend to shift under stress. Voice patterns provide insights into stress levels by tracking increased pitch or changes in speech rhythm, particularly useful in monitoring stress before or after events (Biswas et al., 2024).
- **Behavioural Data (social media and digital activity):** Monitoring changes in digital behaviours—such as frequency of social media use—can provide indirect indicators of stress. Higher emotional engagement on digital platforms often correlates with increased stress levels, offering coaches a digital "footprint" of the athlete's stress (Gordon & Mendes, 2021).
- **Behavioural and Psychological Monitoring with Wearable Sensors**
- For athletes, behavioural monitoring is crucial for understanding how stress affects recovery, sleep, and overall mental well-being in athletes. Key behavioural indicators include:
- **Sleep Tracking Sensors:** Sleep quality directly impacts recovery and performance, with insufficient sleep linked to increased injury risk. Wearable sleep trackers monitor sleep cycles, deep sleep duration, and total sleep time, helping to identify poor sleep quality as a stress marker (Bardini et al., 2024).
- **Emotional and Mood Monitoring:** Wearable sensors that integrate HRV and EEG provide insights into athletes' emotional states by measuring stress responses and tracking how these change over time. Emotional state tracking aids in identifying times of heightened stress or fatigue, facilitating timely interventions by coaches or sports psychologists (Lin, 2024).
- **Biomechanical Monitoring with Wearable Sensors**
- Biomechanical wearable sensors analyse athletes' movement patterns, posture, and applied forces, enhancing movement efficiency and reducing injury risk:
- **Accelerometers and Gyroscopes for Movement Analysis:** These sensors track acceleration, rotation, and posture changes, allowing detailed analysis of an athlete's movements. Wearable devices equipped with accelerometers and gyroscopes can assess dynamics during running, jumping, or turning, helping detect abnormal motions that increase injury risk (Kovoor et al., 2024).
- **Pressure and Force Sensors for Ground Reaction Analysis:** Pressure sensors embedded in insoles or shoes measure force distribution during activities, helping identify gait or movement asymmetries. This data is instrumental in selecting appropriate footwear or adjusting running form, significantly reducing the risk of injuries (Civeriati et al., 2024).

Additionally, force platforms measure ground reaction forces, facilitating biomechanical analysis of athletic performance.

- **3D Motion Capture Systems with Wearable Sensors for Joint and Movement Analysis:** Integrated with wearable sensors, 3D motion capture systems provide detailed analyses of joint angles, forces, and velocities. This data is used to evaluate movement quality and refine technique, enhancing training outcomes (Moniruzzaman et al., 2023).

Finally, wearable sensor applications in sport and sport psychology, combined with comprehensive physiological and biomechanical data, provide invaluable insights into athletes' health. Coaches and sports psychologists can make informed, data-driven decisions for managing training loads, optimizing recovery, and enhancing mental resilience. By integrating stress detection with other health parameters, wearable technology enables a personalized and proactive approach to athletic training, supporting long-term well-being and performance optimization in modern sports science.

3.2. RFID Sensor Applications in Sport and Sport Psychology

As a cornerstone of the IoT, Radio Frequency Identification (RFID) sensors play a crucial role in enabling efficient tracking and management of both athletes and their equipment. RFID sensors offer real-time, wireless data transmission, making them ideal for environments where fast and reliable communication is essential. For example, RFID tags embedded in sportswear can continuously monitor vital statistics such as heart rate, temperature, and even muscle strain without disrupting the athlete's performance. This contactless technology allows data to be collected over extended periods, offering a comprehensive view of an athlete's condition. When integrated into the broader IoT ecosystem, RFID sensors ensure seamless connectivity between devices, cloud platforms, and analytics tools. As a result, coaches and medical staff can receive real-time alerts on potential risks, enabling timely interventions and personalized training programs. With their versatility and precision, RFID sensors are key to optimizing athletic performance and enhancing overall safety.

The integration of Radio Frequency Identification (RFID)-based sensors in wearable technology has the potential to revolutionize the way athletes and individuals monitor their health and performance, making it a crucial area of study in the field of physical science. RFID technology, known for its wireless data capturing capabilities, is increasingly being incorporated into wearable sensing devices, offering real-time monitoring of vital signs and facilitating the emergence of cost-effective, maintenance-free solutions for large-scale applications (Behera, 2021).

Radio-frequency identification (RFID) technology has been increasingly integrated into health monitoring systems, offering a variety of applications that enhance patient care and reduce medical costs (Nguyen, 2009). RFID sensors, both chip-based and chipless, are utilized for continuous or periodic health examination and monitoring, capable of wirelessly transmitting patient data to medical professionals for remote diagnosis and timely intervention (Nguyen, 2009; Subrahmannian & Behera, 2022; Behera, 2021). These sensors are employed in diverse settings, from individual health monitoring to simultaneous assessment in hospital environments, and are instrumental in managing chronic conditions, ensuring food quality, and monitoring structural health (Ahmadihaji et al., 2023; Behera, 2021). Interestingly, while RFID technology is lauded for its low-cost and battery-free operation, the transition from chip-based to chipless RFID sensors is highlighted as a means to overcome cost and implementation challenges (Ahmadihaji et al., 2023; Behera, 2021; Subrahmannian & Behera, 2022). Chipless RFID sensors, in particular, are gaining attention for their potential in cost-effective healthcare applications, supported by IoT technology to meet the growing demand for connected healthcare solutions (Behera, 2021; Subrahmannian & Behera, 2022). The integration of RFID with artificial intelligence and machine learning further enhances the sensitivity and selectivity of these sensors (Ahmadihaji et al., 2023). In summary, RFID-based sensors are proving to be a valuable asset in health monitoring, offering a range of applications from individual patient care to large-scale hospital management. The evolution towards chipless RFID sensors and the incorporation of IoT and machine learning technologies are key developments that promise to further optimize healthcare delivery and patient safety (Ahmadihaji et al., 2023; Behera, 2021; Subrahmannian & Behera, 2022). The continuous advancement in RFID sensor technology, along with its integration into healthcare systems, is expected to play a significant role in the future of medical monitoring and diagnostics (Behera, 2021; Subrahmannian & Behera, 2022; Nguyen, 2009).

RFID is a kind of technology that falls under the category of Wireless Sensor Networks (WSN). It allows for the immediate gathering and analysis of data by using radio frequency waves as a means of communication (Behera, 2021; Wang et al., 2022; Colella et al., 2023). RFID is widely used in all aspects of daily life and business because to its remarkable features, including fast data transfer, identification without physical touch, and the capacity to read data from different angles (Yu et al., 2023; Wang et al., 2022; Occhiuzzi et al., 2020; Colella et al., 2022). This technology is mostly used for item identification and tracking. An RFID tag is affixed to the things that need monitoring.

The objects may consist of inventory items and merchandise stored in warehouses. An RFID system consists of three primary components: an RFID reader, an RFID tag, and a host computer (Figure-1). Furthermore, the tags have the potential to be either active, passive, or semi-passive depend on their power supply. The RFID reader emits a constant stream of radio waves at a certain frequency, which provides enough energy to power the tag. Additionally, the reader serves as a carrier for transmitting data back to the reader and synchronizes its clock with the tag. RFID tags are activated and start the communication to the reader when the items are inside the reader's range. RFID systems have the ability to detect a wide range of physical parameters, including gas, temperature, humidity, pressure, and others, depending on the materials used and the applications they are utilized for.

RFID tags are mostly used at three distinct frequencies: low (125 or 134 kHz), high (13.56 MHz), and ultrahigh frequencies (860-960 MHz). The frequencies of operational RFID tags in the UHF band differ across countries, such as 865–868MHz in Europe, 917–922MHz in China, and 902–928MHz in North America. Microwave RFID tags operating in the 2.45–5.8 and 3.10–10.00GHz microwave bands are often classified alongside UHF tags (Gaspari & Quaranta, 2019). The low-frequency (LF) signals have a limited range and can only go a short distance. RFID tags operating in this low-frequency band have a maximum range of 10 cm. High-frequency (HF) RFID tags have a detection range of up to 1 meter, while ultrahigh frequency (UHF) RFID tags can detect things within a range of 10 to 15 meters. The RFID tags used for low and high frequency utilize the concept of inductive or near-field coupling (NFC), but the ultrahigh frequency RFID tag’s function based on the electromagnetic or far-field coupling. Tags, which possess distinctive information, capture data using an integrated circuit (IC) microchip and communicate wirelessly through an antenna. The wireless communication between tags and RFID readers relies on digital or backscattered modulation, which entails modifying the amplitude, phase, and frequency of radio waves (Lasantha et al., 2024). More precisely, when a tag is within range of an RFID reader, it receives the broadcast signal, alters it, and transmits it back as a modulated reflected signal via the antenna. The RFID reader digitizes the returning signal, decodes embedded information, and sends it to computer.

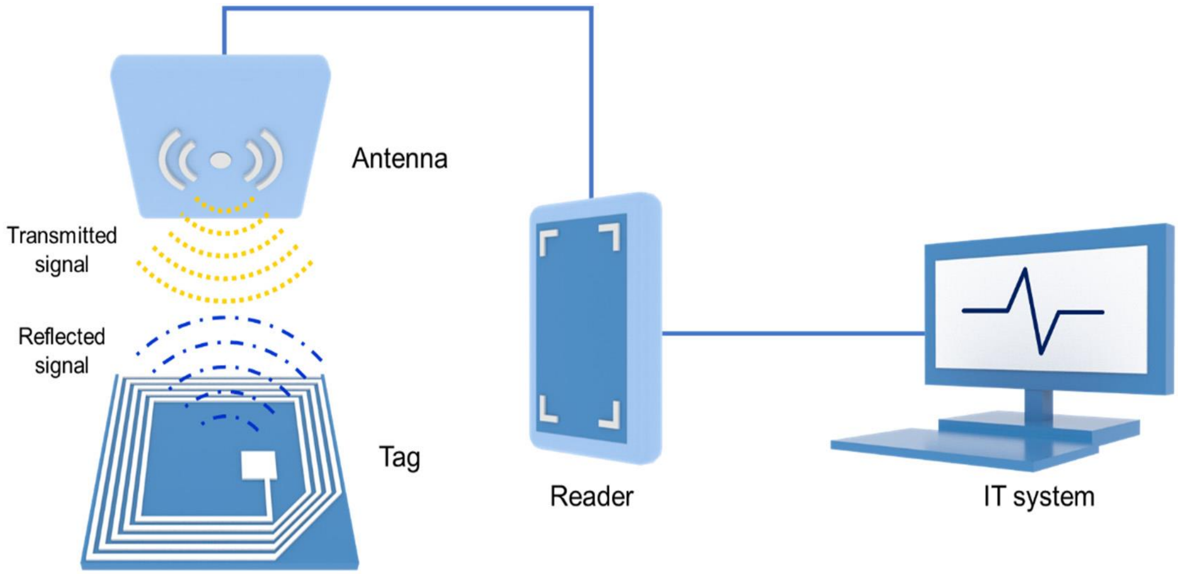

Figure 1. An RFID system consists of three primary components: an RFID reader, an RFID tag, and a host computer (Roh et al., 2024).

Chipped and chipless RFID sensors each present unique advantages and limitations, making them suitable for distinct applications. Chipped RFID sensors incorporate integrated circuits, offering advanced data processing capabilities. In contrast, chipless RFID sensors utilize resonator-based designs, providing cost-effective and adaptable solutions. Chipped RFID sensors, which include integrated circuits, offer robust data processing capabilities, making them ideal for applications requiring complex data handling and real-time analysis. However, they tend to be more expensive and less flexible. On the other hand, chipless RFID sensors rely on resonator-based designs that are more cost-effective and simpler to manufacture. These sensors are particularly advantageous in scenarios where cost is a critical factor, such as smart packaging and agriculture, due to their affordability and simplicity (Shen et al., 2023; Mulloni et al., 2024). Additionally, chipless RFID sensors can be fabricated on flexible substrates, allowing for miniaturized designs adaptable to various surfaces and environments, which is beneficial in applications like printed electronics (Mulloni et al., Nadeem et al., 2024). They also have the potential for a long lifespan and low power requirements, as they do not rely on power supplies or complex circuitry (Nadeem et al., 2024). However, the lack of integrated circuits in chipless RFID sensors limits their data processing and storage capabilities, reducing their effectiveness in applications that demand high precision or long-range detection (Yan et al., 2023; Lasantha et al., 2024). Additionally, they are more susceptible to environmental interference, which can affect their reliability in certain conditions (Shen et al., 2023). Thus, while chipless RFID sensors excel in cost-efficiency and flexibility, chipped RFID sensors are preferred for applications that require enhanced data processing, greater range, and reliability. The choice between these two technologies depends largely on the specific requirements and constraints of the intended application.

In athlete health, RFID sensors have emerged as a promising technology for tracking athletes' performance and behaviour. These sensors offer a non-invasive, cost-effective, and efficient way to monitor various aspects of athletic performance, ranging from motion sensing to physiological monitoring. Integrating RFID technology into sports can yield valuable insights into athletes' physical and psychological states, ultimately enhancing training and performance outcomes.

- **Motion Sensing and Performance Tracking:** RFID technology is highly effective for motion sensing in sports. For example, (Han & Hua, 2023) demonstrated the use of RFID backscatter for sport motion sensing, employing an ECOC-based SVM to classify different action poses with high accuracy. This approach leverages the received signal strength (RSS) of backscattered RFID signals, providing a reliable method for tracking and analyzing athletes' movements. Additionally, Colella et al. developed a UHF RFID sensor-tag system integrated with inertial measurement units (IMUs) to enhance biomechanical analysis, offering detailed insights into athletes' biomechanics by capturing human body movements to control musculoskeletal models (Colella et al., 2023).
- **Physiological Monitoring:** RFID sensors are also capable of monitoring physiological parameters, such as sweat pH and EMG. Riente et al. explored using RFID sensors with microfluidics to measure sweat pH which can indicate an athlete's hydration and metabolic state during physical activity, demonstrating the feasibility of real-time physiological monitoring (Riente et al., 2023). The ability to non-invasively monitor physiological parameters in real-time provides critical data for sport psychologists to assess stress levels, fatigue, and overall well-being, essential for optimizing performance and recovery strategies. RFID-enabled electromyographic (EMG) sensors can track muscle activity, offering data on muscle tension and relaxation. This information can be used to assess the physical manifestations of stress and anxiety, allowing for targeted mental training to reduce tension and improve focus (Miozzi et al., 2020).
- **Equipment and Environmental Interaction:** RFID technology extends beyond tracking athletes; it can also monitor sports equipment. Shah et al. describes a system where RFID tags are integrated into sports equipment to track motion and interactions, providing data on equipment usage and performance (Shah et al., 2017). This capability can be expanded to

analyze how athletes interact with their environment and equipment, offering insights into their behavior and decision-making processes during competitions or training sessions (Shah et al., 2017; Rennane et al., 2017). Sensors integrated into athletic equipment can detect contact and provide immediate feedback. This real-time data can be used to adjust training regimens and improve focus by reinforcing correct techniques and strategies (Yu et al., 2023).

- **Broader Implications and Future Directions:** The use of RFID sensors in sports is part of a broader trend toward integrating sensor technology into athletic performance measurement. Simbolon et al. highlight the growing interest in sensor technology within sports, noting its potential to revolutionize performance tracking and analysis (Simbolon et al., 2023). As RFID technology continues to evolve, its applications in sport psychology are likely to expand, offering new opportunities for personalized training and performance enhancement. While RFID sensors offer significant advantages in tracking athletic performance, challenges remain in data integration and interpretation. Developing comprehensive systems that combine RFID data with other sensor technologies, such as augmented reality and machine learning, could further enhance RFID's utility in sports. For instance, Cordeiro et al. propose an AR-based training system that uses performance data to improve decision-making, illustrating the potential for integrating RFID data into broader performance monitoring frameworks (Cordeiro et al., 2022). As these technologies advance, they are likely to play an increasingly important role in sport psychology, providing deeper insights into athletes' mental and physical states. On the other hand, the integration of RFID sensors in sport psychology settings offers significant benefits for monitoring athletes' mental states and emotions, though it also presents certain challenges. RFID technology, known for its contactless and convenient nature, can effectively track physiological signs such as respiration and heartbeat, which are indicative of emotional states. However, to fully leverage its potential in sport psychology, issues such as data accuracy, privacy concerns, and technological limitations must be addressed.
- **Benefits of RFID Sensors in Sport Psychology Contactless Monitoring:** RFID technology enables non-intrusive monitoring of physiological parameters like respiration and heartbeat, crucial for emotion recognition. This contactless approach is less invasive than traditional wearable sensors, making it more comfortable for athletes during training and competition (Xu et al., 2020).

- **Real-time Data Collection:** RFID sensors provide real-time data on athletes' physiological states, allowing coaches and psychologists to monitor and respond promptly to changes in mental states. This capability is vital for designing personalized training programs that consider both physical and psychological aspects (Ahmad et al., 2022).
- **Integration with IoT:** When used alongside IoT technology, RFID enhances the ability to monitor both psychological and physiological parameters. This integration allows for comprehensive data collection and analysis, improving the understanding of how mental states affect performance and vice versa (Ahmad et al., 2022).
- **Cost-effectiveness:** Compared to technologies like EEG, RFID sensors are relatively inexpensive, making them accessible for widespread use in sports settings. This affordability allows for the deployment of large-scale monitoring systems without significant financial burden (Wu et al., 2023).
- **Limitations of RFID Sensors in Sport Psychology Data Accuracy and Reliability:** Although RFID sensors can capture physiological data, the accuracy of emotion recognition based on these parameters can vary. The effectiveness of emotion recognition frameworks like Free-EQ depends on the quality of the data and the sophistication of the algorithms used (Xu et al., 2020).
- **Privacy Concerns:** The use of RFID technology raises privacy issues, as continuous monitoring of physiological data can lead to unauthorized access or misuse of sensitive information. Ensuring data security and privacy is essential to protect athletes' personal information (Zhu, 2023).
- **Technological Limitations:** RFID systems may encounter challenges such as interference from other electronic devices and limited range, which can affect the consistency and reliability of data collection. These limitations need to be addressed to ensure seamless operation in dynamic sports environments (Riente et al., 2023).
- **Limited Emotional Spectrum:** Current RFID-based systems may not capture the full spectrum of emotions as effectively as more advanced technologies like EEG. This limitation can hinder the comprehensive assessment of athletes' mental states, necessitating further research and development (Ahmad et al., 2022).

In summary, while RFID sensors offer promising benefits for monitoring athletic performance in sport psychology, their limitations underscore the need for ongoing research and development. Addressing issues such as data accuracy, privacy, and technological constraints will be crucial to maximizing the potential of RFID technology in monitoring and improving athletes' mental health and performance. As the technology evolves, RFID systems are expected to become more robust, providing deeper insights into the complex interplay between physical and mental states in sports settings.

4. DISCUSSION

The integration of RFID technology into sport psychology represents a promising yet underexplored frontier in sports science. While RFID is traditionally associated with tracking and equipment monitoring, its potential to enhance psychological preparedness and cognitive performance in athletes is gaining recognition. By merging RFID sensors with existing sport psychology tools, it becomes possible to gather real-time physiological and performance data, offering a more comprehensive understanding of the athlete's mental and physical states. This, in turn, supports the development of tailored interventions that promote focus, mental resilience, and optimal performance outcomes.

One significant avenue of innovation involves the combination of RFID with immersive technologies such as augmented reality (AR). When paired with RFID sensors, AR systems can simulate high-pressure competition scenarios, allowing athletes to train in cognitively demanding environments that mirror real-world conditions (Cieślński et al., 2016). This integration enhances engagement and supports the development of psychological resilience. Similarly, RFID-enabled sensors contribute to cognitive training by delivering continuous, real-time data on cognitive load, allowing for dynamic adjustments in training intensity (Kim et al., 2013). These capabilities not only improve mental sharpness but also allow coaches and psychologists to identify early signs of mental fatigue or overstimulation.

Beyond cognitive applications, RFID holds potential in more advanced, exploratory domains. For instance, signal-based mental state assessment involves analyzing variations in RF signal reflections and resonant frequencies to detect stress or relaxation states in athletes. Such an approach could deliver real-time insights into psychological readiness and emotional balance, thereby supporting targeted mental health interventions. In another novel application, the integration of RFID with micro-electro-mechanical systems (MEMS) may enable tracking of changes in skin microflora, providing non-invasive indicators of immune system status or potential skin infections—information that conventional sensors cannot readily capture.

RFID technology also opens new pathways in biomechanical and psychophysiological monitoring. By detecting micro-movements through RF signal distortions, RFID systems can assess subtle muscle tension, postural stability, or fatigue. This level of precision supports the fine-tuning of rehabilitation protocols and helps prevent overuse injuries. Moreover, RFID sensors may be linked to rhythmic feedback systems that use physiological indicators such as heart rate to generate tailored auditory stimuli—music or sound patterns that influence mood, motivation, or calmness, thus regulating emotional states during training or pre-competition routines.

The concept of dual feedback systems further illustrates RFID's utility in athlete self-regulation. Through real-time biometric monitoring—e.g., heart rate, skin temperature—and immediate visual or audio cues, athletes can make on-the-spot adjustments to maintain physiological equilibrium. Similarly, dynamic RFID tags with stress-sensitive coatings can provide visible feedback by changing color in response to physiological stress, helping coaches and athletes quickly evaluate stress levels and adjust training intensity accordingly.

From a tactical standpoint, RFID's ability to track positional data and movement patterns, when analyzed using machine learning algorithms, enables the assessment of decision-making, spatial awareness, and execution under pressure. This data can inform individualized mental training regimens, which may be further reinforced through RFID-based simulation scenarios. In parallel, integrating RFID with other biosensors such as accelerometers, hydration monitors, and EMG systems enhances predictive modelling capabilities. These hybrid systems can forecast injury risks, detect early signs of overtraining, and predict performance declines, facilitating proactive and personalized training adjustments.

However, while these developments are promising, broader considerations must also be addressed. The integration of RFID in sport psychology raises important questions about data accuracy, privacy, and dependency on technology. Although RFID systems are generally non-intrusive and cost-effective, the emotional insights they provide depend heavily on the quality of collected data and the robustness of interpretive algorithms. Moreover, continuous monitoring of sensitive physiological data demands strict adherence to data protection protocols to prevent misuse. As such, it is essential that technological innovation be balanced with traditional psychological methods and human intuition to maintain a holistic, ethical, and athlete-centered approach.

In conclusion, the evolving integration of RFID technology in sport psychology offers significant opportunities to improve mental training, emotional regulation, and injury prevention through data-driven personalization. By expanding beyond conventional tracking functions, RFID-enabled systems can play a central role in optimizing both physical performance and psychological well-being. Future research should continue exploring these novel applications while also addressing the ethical and practical challenges of implementing such technologies in dynamic, high-performance environments.

5. CONCLUSIONS

This study has reviewed and functionally categorized current and potential applications of wearable and RFID-based sensor technologies in sport and sport psychology. Drawing on a structured literature-based methodology, it examined how these technologies contribute to physiological monitoring, stress detection, biomechanical assessment, and mental performance enhancement. In particular, RFID sensors have demonstrated strong potential not only for tracking physical performance, but also for non-invasively monitoring emotional states, enabling real-time feedback, and supporting psychological preparedness. Emerging concepts such as microflora analysis, RF signal-based stress detection, rhythmic feedback systems, and integrated data fusion point toward the evolution of fully personalized, athlete-centered monitoring ecosystems. These findings highlight the transformative capacity of sensor technologies in modern sport science. Future work should focus on prototyping, real-world testing, and interdisciplinary collaboration to translate these innovations into practice and optimize both physical and psychological outcomes for athletes.

6. REFERENCES

1. Ahmad, W. N. W., Adib, M. A. H. M., Ahmad, Z., Zaihidee, F. M., & Txi, M. R. S. (2022). Integration of the Health Monitoring System with IoT Application in Sports Technology: A Review. *Jurnal Kejuruteraan*, *5*(2), 101-109.
2. Ahmadihaji, A., Izquierdo, R., & Shih, A. (2023). From chip-based to chipless rfid sensors: a review. *IEEE Sensors Journal*, *23*(11), 11356-11373.
3. Alzahrani, A., & Ullah, A. (2024). Advanced biomechanical analytics: Wearable technologies for precision health monitoring in sports performance. *Digital Health*, *10*, 1-18. https://doi.org/10.1177/20552076241256745
4. Bardini, S., Ginestretti, L., Lazzari, J., & Santambrogio, M. D. (2024, July). Towards a Greater Awareness of the Relevance of Sleep and Physical Activity for Personal Well-Being. In *2024 IEEE International Workshop on Sport, Technology and Research (STAR)* (pp. 109-114). IEEE. DOI: https://doi.org/10.1109/STAR62027.2024.10635937
5. Behera, S. K. (2021). Chipless RFID sensors for wearable applications: A review. *IEEE Sensors Journal*, *22*(2), 1105-1120. https://doi.org/10.1109/JSEN.2021.3126487
6. Ben, X., Ren, Y., Zhang, J., Wang, S. J., Kpalma, K., Meng, W., & Liu, Y. J. (2021). Video based facial micro-expression analysis: A survey of datasets, features and algorithms. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, *44*(9), 5826-5846 https://doi.org/10.1109/TPAMI.2021.3067464

7. Biswas, S., Roy, M., Mondal, A., & Karmakar, R. (2024, May). Voice-Based Automated Detection of Mental Health Considering Comparative Performances of Multiple Machine Learning Models. In *2024 5th International Conference for Emerging Technology (INCET)* (pp. 1-6). IEEE. https://doi.org/10.1109/INCET61516.2024.10592913
8. Cieśliński, W. B., Sobecki, J., Piepiora, P. A., Piepiora, Z. N., & Witkowski, K. (2016). Application of the augmented reality in prototyping the educational simulator in sport: The example of judo. *Journal of Physics: Conference Series*, *710*(1), 1-8. https://doi.org/10.1088/1742-6596/710/1/012016
9. Civeriati, V., Pugliese, B. L., Carraro, C., Corniani, G., Bauducco, F., Angelucci, A., *et al.* (2024). A sensorized insole to estimate ground reaction forces and center of pressure during gait. In *2024 IEEE International Workshop on Sport, Technology and Research (STAR)* (pp. 21–25). IEEE. https://doi.org/10.1109/STAR62027.2024.10636002
10. Colella, R., Mannini, L., Tumolo, M. R., Sabina, S., Molinaro, V., Ranavolo, A., *et al.* (2022). RFID-based sensing and reconstruction of human movements for safety monitoring of workers. In *2022 IEEE 12th International Conference on RFID Technology and Applications (RFID-TA)* (pp. 184–186). IEEE. https://doi.org/10.1109/RFID-TA54958.2022.9924040
11. Colella, R., Sabina, S., Mincarone, P., & Catarinucci, L. (2023). Semi-passive RFID electronic devices with on-chip sensor fusion capabilities for motion capture and biomechanical analysis. *IEEE Sensors Journal*, *23*(11), 11672-11681.
12. Cordeiro, M. C., Ó Catháin, C., & Rodrigues, T. B. (2022). The development of a machine learning/augmented reality immersive training system for performance monitoring in athletes. In *Proceedings of the 14th International Workshop on Immersive Mixed and Virtual Environment Systems* (pp. 19–22). https://doi.org/10.1145/3534086.3534332
13. Deshmukh, R. G., Pinjarkar, A., & Rana, A. K. (2022). IoT and wearable sensors for health monitoring. In *Advanced sensing in image processing and IoT* (pp. 137–152). CRC Press. https://doi.org/10.1201/9781003221333
14. Ding, Y., Tan, K., Sheng, L., Ren, H., Su, Z., Yang, H., Zhang, X., Li, J., & Hu, P. (2024). Integrated mental stress smartwatch based on sweat cortisol and HRV sensors. *Biosensors & Bioelectronics*, *265*, 1-16. https://doi.org/10.1016/j.bios.2024.116691
15. Fullagar, H. H., Skorski, S., Duffield, R., Hammes, D., Coutts, A. J., & Meyer, T. (2015). Sleep and athletic performance: the effects of sleep loss on exercise performance, and physiological and cognitive responses to exercise. *Sports Medicine*, *45*(2), 161-186. https://doi.org/10.1007/s40279-014-0260-0
16. Gaspari, F., & Quaranta, S. (2019). Nanostructured materials for RFID sensors. In *Nanomaterials design for sensing applications* (pp. 93–128). Elsevier. https://doi.org/10.1016/B978-0-12-814505-0.00003-5
17. Giles, S., Fletcher, D., Arnold, R., Ashfield, A., & Harrison, J. (2020). Measuring well-being in sport performers: where are we now and how do we progress?. *Sports Medicine*, *50*(7), 1255-1270. https://doi.org/10.1016/B978-0-12-814505-0.00003-5
18. Gordon, A. M., & Mendes, W. B. (2021). A large-scale study of stress, emotions, and blood pressure in daily life using a digital platform. *Proceedings of the National Academy of Sciences*, *118*(31), 1-7. https://doi.org/10.1073/pnas.2105573118
19. Han, L., & Hua, X. (2023). RFID Backscatter Based Sport Motion Sensing Using ECOC-Based SVM. *Sensors*, *23*(17), 1-15. https://doi.org/10.3390/s23177324
20. Huifeng, W., Kadry, S. N., & Raj, E. D. (2020). Continuous health monitoring of sportsperson using IoT devices based wearable technology. *Computer Communications*, *160*, 588-595. https://doi.org/10.1016/j.comcom.2020.04.025
21. Jerath, R., Syam, M., & Ahmed, S. (2023). The future of stress management: integration of smartwatches and HRV technology. *Sensors*, *23*(17), 1-14. https://doi.org/10.3390/s23177314

22. Kim, S., Mariotti, C., Alimenti, F., Mezzanotte, P., Georgiadis, A., Collado, A., ... & Tentzeris, M. M. (2013). No battery required: Perpetual RFID-enabled wireless sensors for cognitive intelligence applications. *IEEE Microwave Magazine*, *14*(5), 66-77. https://doi.org/10.1109/MMM.2013.2259398
23. Kovoor, M., Durairaj, M., Karyakarte, M. S., Hussain, M. Z., Ashraf, M., & Maguluri, L. P. (2024). Sensor-enhanced wearables and automated analytics for injury prevention in sports. *Measurement Sensors*, *32*(19), 1-24. https://doi.org/10.1016/j.measen.2024.101054
24. Lange, D. H. (2021). *U.S. Patent No. 10,952,638*. Washington, DC: U.S. Patent and Trademark Office.
25. Lasantha, L., Khan, S. I., Ray, B., & Karmakar, N. C. (2024). Enhancing quality factor of chipless RFID sensors by optimising the substrate properties and resonator geometry. In *2024 IEEE International Conference on RFID (RFID)* (pp. 125–130). IEEE. https://doi.org/10.1109/RFID62091.2024.10582558
26. Li, N., Zhou, R., Krishna, B., Pradhan, A., Lee, H., He, J., & Jiang, N. (2024). Non-invasive Techniques for Muscle Fatigue Monitoring: A Comprehensive Survey. *ACM Computing Surveys*, *56*(9), 1-40. https://doi.org/10.1145/3648679
27. Li, R. T., Kling, S. R., Salata, M. J., Cupp, S. A., Sheehan, J., & Voos, J. E. (2016). Wearable performance devices in sports medicine. *Sports Health*, *8*(1), 74-78. https://doi.org/10.1177/1941738115616917
28. Lin, J. (2024). Wearable Emotion Recognition Technology Based on Heart Rate Variability and EEG Rhythm. *Transactions on Computer Science and Intelligent Systems Research, 5*, 892-898. https://doi.org/10.62051/g4rwwf66
29. Miozzi, C., Errico, V., Marrocco, G., Gruppioni, E., & Saggio, G. (2020, June). RFID interface for compact pliable EMG wireless epidermal sensor. In *2020 IEEE International Workshop on Metrology for Industry 4.0 & IoT* (pp. 202-206). IEEE. https://doi.org/10.1109/MetroInd4.0IoT48571.2020.9138182
30. Moniruzzaman, M., Yin, Z., Hossain, M. S. B., Choi, H., & Guo, Z. (2023). Wearable motion capture: Reconstructing and predicting 3D human poses from wearable sensors. *IEEE Journal of Biomedical and Health Informatics*, *27*(11), 5345-5356. https://doi.org/10.1109/JBHI.2023.3311448
31. Mulloni, V., Marchi, G., Gaiardo, A., Valt, M., Donelli, M., & Lorenzelli, L. (2024). Applications of Chipless RFID Humidity Sensors to Smart Packaging Solutions. *Sensors*, *24*(9), 1-12. https://doi.org/10.3390/s24092879
32. Nadeem, M., Habib, A., & Umair, M. Y. (2024). Chipless RFID based multi-sensor tag for printed electronics. *Heliyon*, *10*(4), 1-17. https://doi.org/10.1016/j.heliyon.2024.e26494
33. Nguyen A. (2009). The potential implementation of radio-frequency identification technology for personal health examination and monitoring. *McGill Journal of Medicine*, *12*(2), 67-72.
34. Occhiuzzi, C., Parrella, S., & Marrocco, G. (2020, August). Flexible dual chip on-skin RFID sensor for body temperature monitoring. In *2020 IEEE International Conference on Flexible and Printable Sensors and Systems (FLEPS)* (pp. 1-4). IEEE. https://doi.org/10.1109/FLEPS49123.2020.9239531
35. Plews, D. J., Laursen, P. B., Stanley, J., Kilding, A. E., & Buchheit, M. (2013). Training adaptation and heart rate variability in elite endurance athletes: opening the door to effective monitoring. *Sports Medicine*, *43*, 773-781. https://doi.org/10.1007/s40279-013-0071-8
36. Qaim, W. B., Ometov, A., Molinaro, A., Lener, I., Campolo, C., Lohan, E. S., & Nurmi, J. (2020). Towards energy efficiency in the internet of wearable things: A systematic review. *IEEE Access*, *8*, 175412-175435. https://doi.org/10.1109/ACCESS.2020.3025270
37. Raju, A. R., Ramadevi, R., Babu, P. R., & Vetriselvi, D. (2023, August). Galvanic Skin Response based Stress Detection System using Machine Learning and IoT. In *2023 Second International*

Conference on Augmented Intelligence and Sustainable Systems (ICAISS) (pp. 709-714). IEEE. https://doi.org/10.1109/ICAISS58487.2023.10250663

38. Rennane, A., Abdelnour, A., Kaddour, D., Touhami, R., & Tedjini, S. (2017, August). Development of passive UHF RFID tag on flexible foil for sport balls pressure monitoring. In *2017 XXXIInd General Assembly and Scientific Symposium of the International Union of Radio Science (URSI GASS)* (pp. 1-2). IEEE. https://doi.org/10.23919/URSIGASS.2017.8105164
39. Riente, A., Bianco, G. M., Fiore, L., Arduini, F., Marrocco, G., & Occhiuzzi, C. (2023, March). An RFID sensor with microfluidic for monitoring the pH of sweat during sport activity. In *2023 17th European Conference on Antennas and Propagation (EuCAP)* (pp. 1-4). IEEE. https://doi.org/10.23919/EuCAP57121.2023.10133044
40. Roh, S., Nguyen, T. D., & Lee, J. S. (2024). Applications of Nanomaterials in RFID Wireless Sensor Components. *Applied Sciences*, *14*(3), 1-28. https://doi.org/10.3390/app14031216
41. Satapathy, C., Gokhale, H., Syed, A. Z., & Nersisson, R. (2024, March). Galvanic skin response-based stress level detection using supervised machine learning approach. In *AIP Conference Proceedings* (Vol. 2966, No. 1). AIP Publishing. https://doi.org/10.1063/5.0189783
42. Scarpellini, A., Aliverti, A., & Esmailbeigi, H. (2024, July). A Wireless Intra-Oral Device for Respiratory and Cardiovascular Monitoring in Sport. In *2024 IEEE International Workshop on Sport, Technology and Research (STAR)* (pp. 176-180). IEEE. https://doi.org/10.1109/STAR62027.2024.10635949
43. Seçkin, A. Ç., Ateş, B., & Seçkin, M. (2023). Review on Wearable Technology in sports: Concepts, Challenges and opportunities. *Applied Sciences*, *13*(18), 1-39. https://doi.org/10.3390/app131810399
44. Seshadri, D. R., Li, R. T., Voos, J. E., Rowbottom, J. R., Alfes, C. M., Zorman, C. A., & Drummond, C. K. (2019). Wearable sensors for monitoring the internal and external workload of the athlete. *NPJ Digital Medicine*, *2*, 1-12. https://doi.org/10.1038/s41746-019-0149-2
45. Shaffer, F., & Ginsberg, J. P. (2017). An overview of heart rate variability metrics and norms. *Frontiers in Public Health*, *5*, 1-17. https://doi.org/10.3389/fpubh.2017.00258
46. Shah, J. V., Lautner, D. A., & Hor-Lao, M. K. (2017). *U.S. Patent No. 9,740,899*. Washington, DC: U.S. Patent and Trademark Office. https://patents.google.com/patent/US9740899B1/en
47. Shen, X., Shi, G., Cheng, L., Gu, L., Rao, Y., & He, Y. (2023). Chipless RFID-inspired Sensing for Smart Agriculture: A Review. *Sensors and Actuators A: Physical*, *363*, 1-19. https://doi.org/10.1016/j.sna.2023.114725
48. Simbolon, M. E. M., Firdausi, D. K. A., Dwisaputra, I., Rusdiana, A., Pebriandani, C., & Prayoga, R. (2023). Utilization of Sensor technology as a Sport Technology Innovation in Athlete Performance Measurement: Research Trends. *IJEIS (Indonesian Journal of Electronics and Instrumentation Systems)*, *13*(2), 147-158. https://doi.org/10.22146/ijeis.89581
49. Song, Y., Min, J., Yu, Y., Wang, H., Yang, Y., Zhang, H., & Gao, W. (2020). Wireless battery-free wearable sweat sensor powered by human motion. *Science Advances*, *6*(40), 1-12. https://doi.org/10.1126/sciadv.aay9842
50. Subrahmannian, A., & Behera, S. K. (2022). Chipless RFID sensors for IoT-based healthcare applications: A review of state of the art. *IEEE Transactions on Instrumentation and Measurement*, *71*, 1-20. https://doi.org/10.1109/TIM.2022.3180422
51. Tariq, M. U. (2024). Advanced wearable medical devices and their role in transformative remote health monitoring. In *Transformative Approaches to Patient Literacy and Healthcare Innovation* (pp. 308-326). IGI Global. https://doi.org/10.4018/979-8-3693-3661-8.ch015
52. Wang, T., Dai, S., Liu, Y., & Ye, T. T. (2022). Battery-less sensing of body movements through differential backscattered RFID signals. *IEEE Sensors Journal*, *22*(9), 8490-8498. https://doi.org/10.1109/JSEN.2022.3161406

53. Waqar, A., Ahmad, I., Habibi, D., & Phung, Q. V. (2021). Analysis of GPS and UWB positioning system for athlete tracking. *Measurement: Sensors*, *14*(3), 1-16. https://doi.org/10.1016/j.measen.2020.100036
54. Wu, Y., Valdez, R., & Forlines, C. (2023, March). Cognitive and Emotional Monitoring with Inexpensive Wrist-Worn Consumer-Grade Wearables. In *2023 IEEE International Conference on Pervasive Computing and Communications Workshops and other Affiliated Events (PerCom Workshops)* (pp. 665-670). IEEE. https://doi.org/10.1109/PerComWorkshops56833.2023.10150338
55. Xu, Q., Liu, X., Luo, J., & Tang, Z. (2020). Emotion monitoring with RFID: An experimental study. *CCF Transactions on Pervasive Computing and Interaction*, *2*(4), 299-313. https://doi.org/10.1007/s42486-020-00043-1
56. Yan, D., Sun, X., Hu, S., & Zhang, K. (2023, November). Chipless RFID Humidity Sensor Based on Rectangular-Stub-Loaded SRR. In *2023 China Automation Congress (CAC)* (pp. 539-543). IEEE. https://doi.org/10.1109/CAC59555.2023.10450927
57. Yu, Y., Qi, Z., Yi, D., Tang, M. C., & Ziolkowski, R. W. (2023). Miniaturized and highly sensitive epidermal RFID sensor for reliable skin temperature monitoring at a distance. *IEEE Sensors Journal*, *23*(6), 5757-5765. https://doi.org/10.1109/JSEN.2023.3241155
58. Zhu, J. (2023). Real-time monitoring for sport and mental health prevention of college student based on wireless sensor network. *Preventive Medicine*, *173*, 1-17. https://doi.org/10.1016/j.ypmed.2023.107581

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

FUNDING

This research received no external funding.

COPYRIGHT