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Transformation of Internet of Things-Based Volleyball Training: Analysis of its Development and Prospects in Modern Sport Science

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The Internet of Things (IoT) is increasingly integrated into sports to provide accurate, real-time performance data. In volleyball, IoT technologies support technique analysis, athlete monitoring, and training load management through sensors, microcontrollers, and wearable devices. This study presents a narrative review of literature published between 2020 and 2025 to map the development o IoT in volleyball training. Findings indicate that IoT enhances technical evaluation and training control, yet its implementation in Indonesia remains limited. Further development of affordable devices and multi-sensor integration is needed to expand IoT adoption in future volleyball training practices.
Keywords: Internet of Things, Volleyball, Training, Sensors, Wearable Devices, Sports Science

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1. Introduction

The use of technology in sports is growing rapidly, along with the increasing demand for accurate, rapid, and evidence-based performance evaluation. This development aligns with the evidence-based practice paradigm in sports science, which emphasizes the importance of using objective data in training planning, implementation, and evaluation. According to McGuigan (2020), technology integration in sports plays a crucial role in improving the quality of athlete performance measurements and reducing reliance on subjective assessments. One rapidly developing technology in this context is the Internet of Things (IoT), a system that enables electronic devices, sensors, and microcontrollers to connect to each other via a network to automatically and continuously collect and transmit data.

IoT has become a relevant technology in sports due to its ability to provide real-time and continuous performance data. According to Peake et al. (2021), IoT and wearable technology enable coaches and sports researchers to monitor athletes' training loads, movement patterns, and physiological responses with a high degree of accuracy. This aligns with the core principles of sports science, which emphasize data-driven training and objective analysis to improve performance while minimizing the risk of injury. In the context of volleyball, the application of IoT is becoming increasingly important because this sport demands complex movement coordination and high technical precision.

In volleyball, basic techniques such as spiking, serving, passing, and blocking require high biomechanical accuracy, particularly in aspects of joint angles, movement speed, and body stability. Technique evaluations that rely solely on the coach's visual observation are often subjective and difficult to capture comprehensive movement details. According to Bartlett et al. (2020), the limitations of human visual observation lead to potential errors in assessing technique quality, particularly in high-speed movements like spiking and jump serves. In this regard, IoT offers a solution through the use of various sensors, such as Inertial Measurement

Units (IMUs), capacitive sensors, IoT-based radar, and wearable devices capable of generating objective, real-time biomechanical data. Research by Souza et al. (2021) showed that wearable devices can measure joint angles, arm acceleration, and body stability with a higher level of accuracy than manual observation, making the resulting data more reliable for technique evaluation and training planning.

Although global trends show rapid progress in the use of IoT for sports, its application in volleyball training in Indonesia remains relatively limited. Several national studies have developed training support devices, such as capacitive sensors on nets and microcontroller-based smart training kits (Mulyadi & Rubiono, 2021), but their implementation is not yet widespread in schools or sports clubs. According to Nugroho et al. (2022), limited infrastructure, development costs, and a lack of technological literacy are factors hindering the adoption of smart technology in sports development in Indonesia. This situation indicates a gap between the enormous potential of IoT technology and its practical application in the field.

Therefore, this research is needed to develop a comprehensive understanding of the development and utilization of IoT in volleyball training, particularly in supporting the evaluation of athlete technique and performance. By understanding the potential, limitations, and direction of IoT technology development, it is hoped that this research will provide a clear picture of IoT's contribution to improving the quality of volleyball training and serve as a foundation for the development of more adaptive sports technology in the future.

2. Research Method

This study employed a narrative literature review design designed to describe the development and utilization of the Internet of Things (IoT) in volleyball training. The entire review process was conducted descriptively and analytically, reviewing relevant research findings from various scientific sources. The articles studied consisted of international and national publications published between 2020 and 2025. Each article was treated as a data unit analyzed according to scientific eligibility criteria.

The literature search was conducted through the databases ScienceDirect, MDPI, IEEE Xplore, and Google Scholar. Search keywords included "IoT in volleyball training," "wearable sensors volleyball," and "microcontrollers in sports." The initial identification process yielded 30 articles. All articles were then screened through title screening, abstract screening, and full-text reading. The selection process yielded 15 articles that met the inclusion criteria: articles discussing the use of IoT, sensors, or wearable devices in the context of sports training.

A data extraction sheet was used to record information related to the article's identity, type of IoT technology, the original research objectives, measurement methods, key findings, and their relevance to volleyball training. All extracted data was analyzed using a thematic analysis approach. The analysis process involved open coding, grouping themes, comparing data, and developing a final synthesis. The results provide an overview of technology trends, the functions of IoT devices, their contribution to volleyball training, and directions for further research.

3. Result and Discussion

A review of 15 articles published between 2020 and 2025 shows that the use of the Internet of Things (IoT) in volleyball training focuses on five technology categories: capacitive sensors, wearable IMUs, smart training kits, biometric sensors, and microcontroller-based devices. The distribution of articles in each category is shown in Table 1, while a visualization of the trends for each category is presented in Figure 1. Wearable IMUs are the most dominant category, with five articles. This dominance can be scientifically explained because IMUs are capable of recording acceleration, rotation, and body orientation in three dimensions, making them highly relevant for analyzing complex volleyball techniques. The increasing use

of IMUs is also influenced by increasingly affordable sensors and the need for objective biomechanical data in sports science.

Capacitive sensors appear in three articles and function in detecting net touches during blocking practice. Scientifically, this technology works by utilizing changes in capacitance when the hand touches the sensor surface, producing a more accurate digital signal than manual observation. This trend is growing due to coaches' need for more objective and easily monitored technique evaluation. Meanwhile, smart training kits and biometric sensors were used in five articles to monitor physiological variables such as heart rate, exercise duration, body temperature, and HRV. These variables are important in analyzing an athlete's internal load and assessing fatigue levels, allowing coaches to more accurately adjust training intensity.

Microcontroller-based devices were found in two articles, most of which originated from research in Indonesia. These devices were used to create simple analysis tools such as ball speed meters and serve evaluation systems. Although fewer in number, their presence demonstrates the pursuit of more affordable and adaptable technological innovations to local facilities. Overall, the technology trends in Table 1 and Figure 1 support the hypothesis that IoT has the potential to improve the quality of volleyball training through objective biomechanical and physiological measurements. However, most of the research is still at the prototype stage and has not been widely implemented in schools or clubs, supporting the second hypothesis that IoT adoption in Indonesia is still limited. Thus, these findings indicate that IoT has moved in a direction that can strengthen engineering analysis and performance monitoring, but still requires ecosystem support and broader field testing for optimal implementation.

Table 1. Review: 15 articles

No	Author & Year	Key Findings	Sensor Type / Technology
1	(Sousa et al., 2023)	Wearables are used to monitor the biomechanical and physiological performance of volleyball athletes.	IMU, Wearable HR
2	(Català et al., 2025)	The variability of volleyball players' spike movements can be analyzed with a 3D IMU.	IMU
3	(Schleitzer et al., 2022)	Development of an IMU for jump detection and jump height estimation in beach volleyball.	IMU
4	(Villarejo-García et al., 2023)	Validity and reliability of an IMU in measuring volleyball player technique and jumps.	IMU
5	(Salim et al., 2024)	Wearables and ML improve the accuracy of volleyball training analysis.	IMU, Pressure mat, ML
6	(Salim et al., 2024)	Wearable biometrics predict athlete performance based on physiological data.	IMU, EMG, HR
7	(Xu et al., n.d.)	Automatic detection of jumps and jump heights using IMU and AI.	IMU + ML
8	Shang et al. (2023)	Classification of volleyball jumps (blocks, smashes, serves) using an IMU.	IMU
9	(Imu et al., n.d.)	Jump loads in beach volleyball can be accurately measured with an IMU.	IMU
10	(Zhu et al., 2025)	IMUs are used for biomechanics in multi-sports,	IMU

No	Author & Year	Key Findings	Sensor Type / Technology
		including volleyball.	
11	Villarejo-García et al. (2023)	A systematic review of the validity and reliability of IMUs in volleyball, valid for counting jumps.	IMU
12	(Macdonald et al., 2017)	Validation of IMUs for counting total jumps and estimating jump height.	IMU
13	(Xu et al., n.d.)	Development of an AI-assisted system to automatically detect and classify jump types using a waist-worn IMU.	IMU, Machine Learning (MS-TCN)
14	(Liu et al., 2022)	Development of a self-powered sensor to monitor spike movements and physiological data.	Sensor Piezoelektrik (PVDF), Wearable Sensor
15	(Wang et al., 2018)	Assessment of volleyball spiker skill levels using a single wrist-worn micro-IMU.	IMU Mikro

The integration of IoT into volleyball training offers significant opportunities to improve the quality of technique development and training load control. Wearable devices capable of providing real-time biomechanical data enable coaches to analyze technical errors more accurately than observational methods. For example, analyzing shoulder angles during spikes or body stability during passes becomes easier to assess using IMU data. Furthermore, IoT strengthens the application of sports science principles, particularly in training load monitoring. Biometric sensors can directly identify athletes' intensity and physiological responses, allowing coaches to adjust training programs based on their fitness and fatigue levels.

Several obstacles exist in the implementation of IoT in Indonesia. Low technological literacy among coaches, a lack of supporting sports laboratory facilities, and the absence of national standards for IoT use are factors that hinder the adoption of this technology. Most research still focuses on prototype development, requiring more extensive field testing to ensure the reliability of devices in real-world training situations.

Future directions for IoT development include multi-sensor integration to generate more comprehensive data, the development of cloud platforms as long-term training databases, and collaboration between educational institutions, sports clubs, and the government to expand technology adoption. The development of low-cost local IoT devices is also an important step towards implementing the technology in schools and clubs.

4. Conclusion

This study concludes that the use of the Internet of Things (IoT) significantly contributes to improving the quality of volleyball training. Based on an analysis of 15 articles, IoT has been shown to provide accurate and measurable biomechanical and physiological data, thus supporting technique evaluation and training load management more objectively than conventional methods. The predominant use of wearable IMUs, coupled with the use of capacitive and biometric sensors, indicates that the primary need in volleyball training lies in real-time monitoring of athlete movement and condition. Therefore, the hypothesis that IoT has the potential to improve the effectiveness of volleyball training is accepted. Furthermore, this study also confirms that the level of IoT implementation in training practices, especially in Indonesia, is still limited. This limitation arises because most research is at the prototype development stage and has not been fully integrated into sports coaching systems. This situation indicates a gap between the scientific potential of IoT and its practical implementation in the field. In line with these findings, further research should be

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directed at testing devices in real-world training environments, developing multi-sensor-based training systems, and providing more adaptive and affordable IoT devices for schools and sports clubs. These efforts are expected to strengthen the sports digitalization ecosystem and support the sustainable implementation of IoT in volleyball development.

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