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Integration of the Health Monitoring System with IoT Application in Sports Technology: A Review

(Integrasi Sistem Pemantauan Kesihatan dengan Aplikasi IoT dalam Teknologi Sukan: Satu Kajian)

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ABSTRACT

Nowadays, monitoring health systems in robust technology has been extensively applied in the sports field. Even though massive utilization of wearable device technologies aims to quantify athlete performance, inconsistent performance still exists between training sessions and competition. The rigorous discussion about the latest research in monitoring technological systems will help trainers obtain accurate data about athlete performance. This paper focuses on the athlete monitoring system in terms of psychological and physiological parameters and applications in individual sports based on Internet of Things (IoT) Technology. The study incorporates three factors: the parameters that affect athlete performance, multiple device sensors in sports health monitoring, and IoT technology's application for athletes. Based on analysis and observation, efficient sports health monitoring can effectively enhance athlete performance in physiological and psychological conditions. An IoT system encompasses four main aspects: sensing, networking, data processing and application layer. These aspects provide real-time information on the athlete's body condition during training and games. Therefore, this monitoring system greatly assists coaches in designing practical training and activities for athletes. It is highlighted that wearable health monitoring systems by IoT technology will be further built based on athlete requirements.

Keywords: Athlete performance; biosensor; internet of things; monitoring system; wearable sensor

ABSTRAK

Perkembangan sistem pemantauan kesihatan dalam Teknologi yang mapan telah digunakan secara meluas dalam bidang sukan. Walaupun penggunaan teknologi peranti boleh pakai ini bertujuan untuk mengukur prestasi atlet namun masih ada prestasi atlet yang tidak konsisten wujud antara sesi latihan dan pertandingan. Perbincangan yang teliti tentang penyelidikan tentang penggunaan alat memantau sistem teknologi dibuat untuk membantu jurulatih mendapatkan data yang tepat tentang prestasi atlet. Kertas kerja ini memberi tumpuan kepada sistem pemantauan atlet dari segi parameter psikologi dan fisiologi serta aplikasi dalam sukan individu berdasarkan Teknologi Internet of Things (IoT). Kajian ini menggabungkan tiga faktor: parameter yang mempengaruhi prestasi atlet, penderia berbilang peranti dalam pemantauan kesihatan sukan dan aplikasi teknologi IoT terhadap atlet. Berdasarkan analisis dan pemerhatian, kami memperoleh bahawa pemantauan kesihatan sukan yang cekap boleh meningkatkan prestasi atlet dalam keadaan fisiologi dan psikologi dengan berkesan. Sistem IoT merangkumi empat aspek utama, iaitu penderiaan, rangkaian, pemprosesan data dan lapisan aplikasi. Aspek-aspek ini boleh memberikan maklumat yang terperinci dan tepat tentang keadaan badan atlet secara masa nyata semasa latihan dan permainan. Oleh itu, sistem pemantauan ini banyak membantu jurulatih dalam mereka bentuk latihan dan aktiviti amali untuk atlet. Hasil kajian ini menyatakan bahawa terdapat keperluan dalam membangunkan sistem pemantauan kesihatan boleh pakai yang mempunyai integrasi dengan teknologi IoT terhadap prestasi atlet.

Kata Kunci: Prestasi atlet; penderia bio; internet pelbagai benda; sistem pemantauan; peranti boleh pakai

INTRODUCTION

The advancement in individual sports achievements has emerged with the development of technologies. A particular necessity in individual sports depends on self-paced sports like archery, rifle shooting, dart, golf, ice skating, running, and diving (Kolayis et al. 2014; Norlander et al. 1999). In today's athlete society, an increasing number of athletes suffering from an inconsistent performance between their training sessions and real game lead be a significant issue in the sports field (Karahan 2020). Some have become a part of athletes' and sports trainers' everyday lives as aiding tools to monitor athletes' conditions. Information and communication technology are also extensively advancements with the explosive growth of monitoring systems in assistive sports devices. Intelligent and personalized assessment of athlete condition through wireless sensor network composed of multi-source sensors, extensive data analysis and Internet of Things (IoT) Technology is at the heart of research in today's sports advancement. In an endeavour to improve athletes' performance in line with sustainable Technology, real-world applications from IoT systems are highly relevant to producing wearable health devices for athletes' benefit and coaches' referrals (Wan Ahmad 2022).

Various monitoring gadgets have been studied and manufactured to improve athlete performance on both psychological and physiological levels (Fry 2019). Various existing health monitoring systems have been discovered, including real-time monitoring of the athlete's health condition (Naranjo-Hernández et al. 2017). Besides that, the health monitoring system can record and compare the previous athlete performance data before, during and after the training session or competition (Taffoni et al. 2018). Significantly, it can be seen from various perspectives, either in physiological and psychological aspects in real-time during training or competition. Zhao and Li (2020), a researcher from China, reported that there are still relatively few studies about wearable health monitoring devices with integration between IoT sensing systems used in sports backgrounds. The existing Technology with IoT devices is more geared toward health monitoring that specifically involves patients and focuses on the medical field (Sec & Shanmugam, 2016). Therefore, this paper wants to review current research on implementing athlete monitoring systems based on IoT for individual sports performance. The purposes concentrate on three critical areas: 1. Study parameters that affect athlete performance; 2. Study on multiple device sensors in sports health monitoring; 3. Application of IoT's system toward athlete progression. Although such applications remain a long way from widespread sports applications as several key technical and fundamental scientific issues are yet to be overcome, notable scientific advancements and applications have been achieved in these areas. This paper aims to summarize the characteristics and applications of monitoring health systems used in sport among sports trainers, coaches, and athletes, present the recent innovation and discuss existing issues with health monitoring systems related to sport application.

PARAMETER MEASUREMENTS IN ATHLETE PERFORMANCE

Sports performance during training and actual games is an essential indicator of an athlete's achievement, whether in the beginner, intermediate or elite categories. Each type of sport has its criteria for getting a win. An individual sport involving high accuracy or concentration like archery, rifle shooting, and dart requires psychological and physiological aspects. Mental strength, known as psychology, is required to ensure that the arrow's precision on the target butt is always on target (Rizal et al. 2019). In contrast, physiology like body movement, sweating skin, and muscle strength are essential in high-accuracy games to maintain a consistent score (Pelana & Winata 2018). Multi physiological parameters required to complete the human health analysis include the combination of heart rate, pulse rate, and blood pressure in real-time reading (Saçakli 2019). Generally, physiological reaction engages with the whole parts of the athletes' physical body. While psychological, it is the reaction that engages with athletes' mental manifestations, such as anxiety, stress, and depression. Both aspects have several parameters that must be clearly emphasized in athlete performance during training and competition. Hence, an assistive monitoring technology device is necessary to collect and store the athlete's data. The obtained parameter reading from the athlete's condition was recorded for further analysis, and the sports trainer was able to arrange compatible training to enhance the athlete's performance.

PSYCHOLOGICAL AND PHYSIOLOGICAL PARAMETER

Emotion and mental manifestation are essential components of psychology in an individual sport. Previous research described athletes who engage in individual sports experience higher anxiety than team sports (Soltani et al. 2016). Individual athletes are more engaged in their skills and abilities without depending on other athletes. A study from Bali (2015) revealed that athlete psychological preparation is 90% significant in sports games to help athletes better deal with the challenge of competition and training. General mental preparation for games in terms of arousal, self-confidence, and focus level should be psychological preparation. Athletes must work on psychological skills to perform well (Ismail, 2019). Psychology in an individual sport such as shooting, dart and archery depends on athlete abilities. Anxiety, motivation, stress, self-confidence, general activation, attention, and team cohesion are all psychological factors that influence athletes' performance and well-being (Liao et al. 2020).

HEALTH MONITORING SYSTEM

The application of health monitoring plays a vital role in advancing sports technology and performance. The monitoring system is essential to sports trainers in optimizing athlete performance and improving their condition throughout their training session or during the actual competition (Asthana et al. 2017). The primary

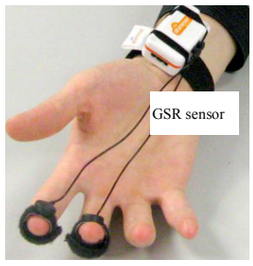
purposes are to monitor the athlete's health condition and help to indicate the precaution of athlete health in the early stage throughout their training or during games. Typically, this health monitoring system consists of two categories that act as a preventive and responsive system. A responsive system can detect health conditions early and provide various health options based on the normal situation. Mosenia et al. (2017) described the responsive health monitoring system as capable of detecting users' health conditions early before reaching the worst stage and providing continuous monitoring.

The most popular preventive health monitoring system types are fitness trackers to measure heart rate, blood pressure, and calories burned (Rao, 2019). This monitoring system can encourage healthy habits and reduce the risk of significant illness by automatically identifying and notifying athletes about unhealthy practices. Utilizing monitoring system technologies in athletes as assistive devices has contributed to incorporating additional devices that improve physical resistance and players' health. Furthermore, Guembe et al. (2021) study revealed that the monitoring system consists of multiple sensors that detect a possible mistake during any movement. The device will alert the player. Thus, this monitoring system could detect possible faults while performing movements, and the device would alert the player throughout the game session. With this, the improvement in the athlete's performance becomes better and more consistent. However, there are limitations in providing direct information about an athlete's condition and requiring accurate readings of athlete data for coach action and supervision from the appropriate sensor selection

WEARABLE BIO-SENSING DEVICE

Sensor technologies enable the development of real-time information systems based on digital data integration. This section presents a wearable bio-sensing modality used in health monitoring systems in sports applications. It can be described as sensing behaviour emerging from physiological and psychological parameter alterations among body athlete's conditions. Thus, wearable sensors have extensively provided actual sensing capability in daily user activities. The advantage of modern wearable sensors is that they are integrated into the IoT's system and can be monitored in any location, not restricted by time and space. Moreover, wearable sensors can directly obtain data from the athlete's body and transform information into an analytically valuable signal (Garcia-Ceja et al. 2018). Feedback from the sensor's device would be beneficial for real-time monitoring of any reaction and response from the athlete's body and other markers to obtain and explain the athletes' physiological responses during the training or game sessions.

(a) IMU-Sensor (b) Pebble watch sensor



(c) Galvanic skin reaction sensor

FIGURE 1. Types of the wearable sensor for the athlete (Ahmad et al. 2014)

Figure 1 indicates a few examples of wearable bio-sensing devices commonly found in sports applications. A study in netball sport locates the wearable IMU accelerometer and gyroscope in a pocket worn underneath the athlete's dress, as shown in Figure 1 (a). Then, in tennis, a wearable pebble watch sensor is attached to the hand athlete's upper limb to monitor the racquet motion in Figure 1 (b). While in archery, the GSR sensor locates at the archer's fingers to monitor the skin reaction during the gripping and release of the string for the shooting process, as shown in Figure 1 (c).

Table 1 summarizes the bio-signal sensor commonly used in the health monitoring system by the athlete, sport-person, and coach during any sports activities. These sensors are essential in obtaining actual readings from the athlete's parameter condition, both physiologically and psychologically. The common characteristics of these technological sensors should be sensitive, responsive, adaptive, transparent, ubiquitous and unobtrusive (Vigneshvar et al. 2016).

TABLE 1. The summary of the bio-signal sensor in the health monitoring system

Ref.	Sensors	Application	Description of parameter
(Guembe et al. 2021)	Accelerometer	Monitor body movements	Acceleration forces in the body activity
(Zhong et al. 2020)	Arm cuff-based monitor	Monitor Blood pressure	Force exerted by circulating blood
(Iliadis et al. 2021)	CO_2 gas sensors	Monitor respiration (gaseous carbon dioxide)	Measure the percentage of CO_2 in the body
(Kuan et al. 2016)	Galvanic skin response (GSR)	Monitor skin conductivity	The electrical conductance of the skin activity
(Iliadis et al. 2021)	Electrocardiography sensors (ECG)	Monitor cardiac activity and Monitor heart rate variability	Electrical activity of the heart (cardiac cycle)
(Park et al. 2015)	Electroencephalography sensors (EEG)	Monitor brain activity	Electrical spontaneous brain activity
(Taborri et al. 2020)	Electromyography sensors (EMG)	Monitor muscle activity	Electrical activity of skeletal muscle
(Claudia C et al. 2017)	Electrooculography sensors (EOG)	Monitor eye movements	Providing information on eye movement amplitude
(Speer et al. 2020)	Finger monitor	Monitor heart rate variability	Quantify heart rate variability data
(Fu & Liu, 2015)	Pulse oximeters	Measure the oxygen level of the blood	Oxygen saturation
(Lang, 2017)	Photoplethysmography sensors (PPG)	Monitor the rate of blood flow	Volumetric changes in blood perfusion during cardiac cycles
(Scataglini et al. 2020)	Skin patch	Monitor skin temperature	Measure the body's ability (generate or get rid) of heat
(Thomas et al. 2016)	Strip-base glucose meters	Monitor blood glucose concentration	Measure the amount of glucose in the blood
(Brzostowski & Szwach, 2018)	Wrist-worn	Monitor the movement stroke	Measure the physical body motion

THE INTEGRATION OF IOT TECHNOLOGY IN HEALTH MONITORING APPLICATION

Applications based on IoT devices are getting more attention because of their capabilities to cover many aspects under one system. IoT technologies are intentionally developed to enhance athlete performance through monitoring, evaluating, and analysing sports demand. Integrating IoT technology is vastly better than traditional or manual tracking and monitoring the athlete's performance. The IoT technology can connect functions between sensors, microcontrollers, cloud systems, technological devices, and digital equipment for the targeted users. The general architecture of an IoT-enabled health monitoring system for sports performance is illustrated in Figure 2. It has four layers, namely, the sensing, networking, data processing and application layers. IoT technology applications are extensively implemented in healthcare, transportation, business, marketing, entertainment, education, and construction.

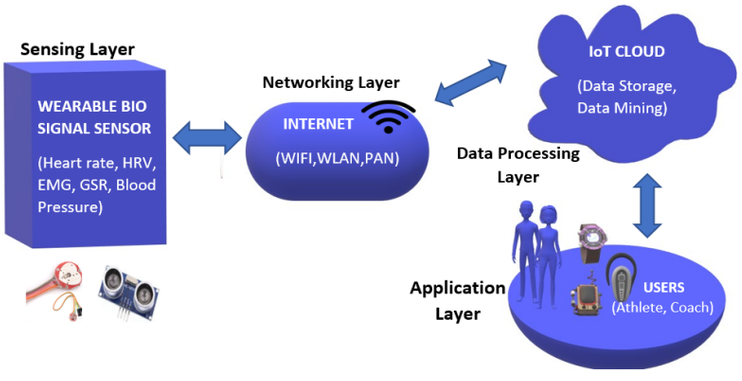


FIGURE 2. The basic architecture diagram of the Internet of Things system

1. The basic IoT system architecture can be divided into several layers. The three layers (Rizal et al. 2019), four layers (Wan et al. 2018) and five layers (Sethi & Sarangi, 2017). This review focused on individual sports health monitoring systems that followed four layers of the basic architecture of the IoT's system. Hence, we outline the function of the four layers.
2. The sensing layer is the physical sensor layer involving various sports devices and athletes' bodies. It senses the physical parameters or identifies other input signals obtained from the sensors from the attached part of the athlete's body will then be passed next through the sensor-based network layer.
3. The networking layer is enabled to connect sensors to other network devices and servers using long-distance communication via the cellular network and short-distance wireless communication technology. Its features efficiently classify and secure data transmitting to corresponding data process units for real-time collection of vast amounts of data generated from the sensing layer.
4. The data processing layer is responsible for storing and retrieving valuable data, analyses, and processes data mining in the recent advancement of cloud computing servers.

The application layer is the purpose of developing the Internet of Things. This layer provides a human-computer interaction interface between human feedback information and the application for user demand in the actual production of the device.

The IoT technologies have a great potential to influence the overall health monitoring in sports applications as each device and object can be explicitly recognized within the connection of modern internet infrastructure and provide vast benefits for athlete achievement. These benefits typically consist of advanced systems, monitoring screens, and devices involving multiple sensors' applications. The foremost use of IoT-based monitoring systems in sport application is to monitor the condition of athletes effectively and help coaches get an accurate picture of the condition of athletes more effectively than manual observation (Segura-Garcia et al. 2018). Obtaining actual data from athlete conditions assists the coach in preparing the appropriate training schedule without burdening the athlete physically and mentally (Huifeng et al. 2020). Kos et al. (2019) explained that the interaction between coach and athlete conditions signifies a unique application space for utilizing IoT technology.

The involvement of IoT Technology in sports can improve the performance of athletes in a consistent and controlled manner. Systematic monitoring and data storage can help coaches design and organize training fitness programs accurately based on the current ability and fitness of the athletes to be more excellent (Shah et al. 2019). The trainers can precisely regulate the difficulty level of training activity according to the athlete's capability. That is because the level of ability in every person is different. The collected data from the sensors must be stored and processed intelligently to derive helpful inferences. The communication between IoT devices is mainly wireless. In wearable health monitoring system technology, a wireless component must be used for system interfacing. It acts for real-time or sporadic updating to a remote processing node, downloading the collected, stored data, or transmitting data from a sensor node to the on-body or remote processing unit (Rizal et al. 2019). Health monitoring Internet of Things in sports is a vast system involving various sensors and a massive number of data analyses and processing. Hence, the system enables a broad range of interactions worldwide and leads to ingenious technologies within this high network. Table 2 shows the standard athlete health monitoring sensor integrated with IoT technological system.

TABLE 2. Identification of selected muscle and electrode placement position

Ref.	Sensor Involve	IoT's App and storage system
(Iliadis et al. 2021)	ECG and pulse oximeter	Mobile Wireless technology, Android apps, Bluetooth
(Snyder et al. 2021)	Accelerometer and gyroscope	Mobile application smartphone with Bluetooth
(Scataglini et al. 2020)	Running Kinematic (IMUs) Body-worn accelerometer	Mobile application with Wireless sensor system
(Smith & Bedford 2020)	Accelerometer and gyroscope	Video software and window laptop
(Speer et al. 2020)	Polar H10 heart rate (HR) And finger monitor	Mobile application with Bluetooth 4.0 signals and wireless system
(Ahmadi et al. 2015)	Inertial sensor	Wireless Inertial Measurement Units (WIMUs) and Discrete Wavelet Transform (DWT)
(Viqueira et al. 2012)	Galvanic skin conductance sensor	Wireless communication system
(Brzostowski & Szwach 2018)	Wrist-worn motion sensor	Fusion algorithm and mobile device system
(Ha et al. 2018)	ECG, PPG and optoelectronic	Signal transmission, wireless systems

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(Maheswari et al. 2021)	Temperature, respiratory and heart rate sensor	WiFi Chip with Arduino microcontroller (connect a variety of sensors)
(Brueck et al. 2018)	Calorimetric sweat rate sensor	WiFi and Cloud
(Sun et al. 2012)	Shimmer ECG, GSR and accelerometer sensor	Data transmitted to PC via Bluetooth and Wireless sensor system
(Rao 2019)	Pulse Oximeter, ECG, and temperature sensor	Web server via WiFi
(Pasha & Shah 2018)	Accelerometer, gyro, and proximity sensor	Web server, XML, Bluetooth and wireless

* ECG-Electrocardiogram, IMUs- Inertial Sensors System EMG- Electromyogram, GSR-Galvanic Skin Reaction, PPG-Photoplethysmography,

DISCUSSION

In determining victory, every sport has its criteria. An athlete needs multiple preparations to be an expert in the sport he is involved in. Experienced athletes find that physiological and psychological preparation is essential in ensuring that their performance is consistent, whether during training or actual competition. For example, the sport of archery requires a high focus to ensure that each archer is on a set target. Both Psychological (anxiety and concentration, body temperature) and physiological parameters (heart rate, muscle activation, skin conductance) need to be given attention by athletes (Snyder et al. 2021). If these two main parameters are not achieved at optimal levels, the athlete will face inconsistent and debilitative performance and vice versa. Due to that, individual sports are seen as more challenging than group sports (Ismail, 2019). Most coaches are concerned about these basic parameters in determining their athlete's performance. The critical parameters such as heart rate level, muscle activation, skin conductivity, body movements, oxygen levels and blood pressure have been listed in Figure 3.

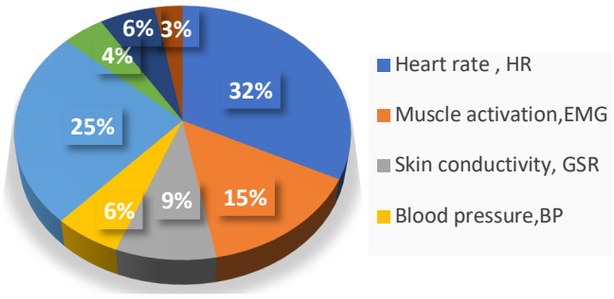

FIGURE 3. Percentage of Individual Sport Monitoring Sensor-IoT Based System

The assistance of sensor devices in advancing sports technology can help athletes and coaches accurately obtain data from the parameter. Ogan et al. (2015) stated that excellent monitoring of the critical parameter reading would assist their athletes in maintaining and consistently performing in every training session. Thus, IoT Technology and the health monitoring system can collect all the essential parameter readings from the bio-signal sensor. This review shows that the sensors can retrieve and analyse digital data (Shah et al. 2019). By comparing and studying the IoT device in sports health monitoring systems, we can better understand that the configuration of the Internet of things for health monitoring systems is different for each purpose. The researchers have focused on implementing and designing IoT sports health monitoring to enhance the current services for athlete performance and helping the coach in analyzing the athlete's condition. However, some open research challenges and issues still need to be considered. In some conditions, the athlete and coach require long-term and continuous monitoring. The types of sports requiring a high concentration level include rifle shooting, archery, golf, dart, and even athletics (running, long jump, disc jump, and high jump). That kind of sport is under the individual sports category that highly depends on the monitoring sport application—seeing that the individual sport entirely relies on the athlete's fitness. Consequently, monitoring individual athletes is essential to ensuring that the coach can monitor the athlete's condition throughout the training or games session.

By comparing and studying the IoT device in sports health monitoring systems, we can better understand that the configuration of the Internet of things for health monitoring systems is different for each purpose. Typically, the existing health monitoring devices are equipped with a small form factor to provide limited battery-powered, which imposes constraints for long-term monitoring from the coach and

athlete to obtain factual information during training or competition (Shah et al. 2019). Integrating the device with IoT technology allows the power supply to be transmitted via wireless and Bluetooth from a plug-in charger in the stage of the network layer (Qiu et al. 2021). Hence, the limitation can be overcome when the battery is easily accessible for wireless charging (Kos et al. 2019). In other studies, most of the sport's health monitoring devices have limited built-in memory and computing capacity. Hence, integrating with the Internet of Things (IoT), the memory will be transmitted to another processing server, where cloud computing is commonly adopted. The sensor data from the monitoring device can be transmitted to the cloud server. The users can access the data with any Internet-enabled device anytime from anywhere (Wan et al. 2018).

CONCLUSION

Internet of Things has become a real-life changer in the recent past through its applicability in sports technology. A need for real-time monitoring system for athlete activity recognition with wearable IoT sensors is essential for current assistive paradigms in sports technological advancement. This paper briefly reviews the current health monitoring system that integrates IoT technologies. Secondly, this paper explicates the critical parameters and applicable sensors between physiological and psychological for individual athletes to enhance their performance. Thirdly, the essential characteristics required to enable the real-time monitoring of the athlete users and allow the obtained information to be accessed from the cloud system directly.

To conclude, the outcomes of this research presented beneficial information regarding health monitoring systems for the individual athlete, coach, sports trainer, and policymakers operational in the field of sport and the IoT-based. Based on this review, the researchers recommended that future research upgrade and facilitate the accessibility in terms of readings of various parameters from one device and applied during actual training sessions and competitions. For recommendations, developing a wearable monitoring system may improve the wearable characteristics of the device in terms of accuracy data reading, long-lasting battery, creating an alert system for monitoring critical information, and focusing on the ergonomic design system for athlete comfort.

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