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AN IOT-BASED SMART TRAINING KIT FOR FUTSAL ATHLETE FITNESS MONITORING: EFFECTIVENESS AND PERCEPTION

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Abstract
This study aimed to evaluate the effectiveness and users perceptions of STARK (Smart Training Kit), an Internet of Things (IoT)-based device for monitoring the physical fitness of futsal athletes. The research adopted a Qualitative research design with descriptive apporach. The study was conducted at a futsal training center in Indonesia, involving ten athletes aged 17–25 years and one coach, selected through purposive sampling. Data collection tools included structured observation sheets, semi-structured interviews, and device-generated physiological data (heart rate and estimated VO_2 Max). Instruments were validated by sport science experts. Data were analyzed through descriptive qualitative techniques involving data reduction, thematic coding, and triangulation to ensure trustworthiness. The findings demonstrated that STARK effectively recorded real-time biometric data, showing an average heart rate increase of 86.42% post-training and an average estimated VO_2 Max of 43.76 ml/kg/min, indicating good aerobic fitness. Athletes and coaches reported high satisfaction with the device's usability, accuracy, and training relevance. STARK also contributed to optimizing training load management and injury prevention. Despite limitations such as a small sample size and focus on limited physiological parameters, STARK offers a promising, user-friendly, and affordable solution for enhancing training quality in futsal. This study provides a foundation for future research on the broader application of IoT technology in sports science and practice.

Keywords: futsal athletes, Internet of Things, monitoring, physical fitness, smart training kit

Introduction

Physical fitness is one of the fundamental elements in maintaining health and enhancing the quality of human life (Pranata et. al., 2022). Optimal physical condition not only supports individuals in performing daily activities efficiently but also reduces the risk of various health issues such as heart disease, hypertension, and obesity (Rahayu, 2024). Fitness encompasses multiple physiological aspects of the body, including muscular strength, cardiorespiratory endurance, flexibility, balance, and a healthy and proportional body composition (Alfarisal et al., 2023). With good physical fitness, individuals are able to maintain productivity, emotional stability, and high resilience in facing life's pressures. Therefore, efforts to improve and maintain physical fitness should be a priority both on a personal and social level. Fitness is not only required for daily activities such as working, studying, or socializing, but is also a crucial requirement in sports activities both recreational and professional. In the realm of sports, physical fitness serves as the main foundation for executing technical movements, applying strategies, and competing fairly under various match conditions (Hung et al., 2023).

Sports serve as an activity to train the body, not only physically, but also spiritually, mentally, and socially (Yasutomi et al., 2019). Engaging in sports activities helps individuals develop discipline, teamwork, and better stress management skills (Baharuddin et al., 2024). Sports provide numerous health benefits, as regular physical activity enhances the efficiency of the body's metabolic system. A well-functioning metabolism facilitates the effective distribution of oxygen and absorption of nutrients, ensuring that body cells receive sufficient energy to function optimally. Beyond physical benefits, sports also contribute significantly to improved sleep quality, hormonal regulation, and mood stability. Moreover, sports can serve as a medium for self-actualization and achievement, while also playing an important role as a social and economic platform becoming a livelihood for professional athletes, coaches, and those involved in the sports industry. In the context of competitive sports, physical fitness functions as a key indicator of the body's readiness to face training loads and competitions. This includes various components of fitness such as cardiovascular endurance to sustain prolonged activity, muscular strength for explosive movements, flexibility to prevent injuries, balance for maintaining body stability, and good motor coordination that enables athletes to move efficiently and effectively. The systematic and measurable improvement of physical fitness is a primary focus in athletic training programs, as it directly influences athletic performance, the body's ability to adapt to both physical and psychological pressures, and reduces the risk of injuries during training and matches. One sport that requires physical fitness as a major determinant of athlete performance is futsal, known for its high-intensity gameplay and the demand for stable physical capacity within short time intervals.

Futsal is a team sport that demands high levels of speed, agility, and physical endurance (Faozi & Rahmawati, 2019). Unlike traditional outdoor football, futsal is played on a smaller court with shorter match durations, yet with a much faster game tempo. This requires futsal players to perform high-intensity movements in a short period of time, execute sudden changes in direction, and maintain focus and strategic sharpness under pressure. During training, coaches often face difficulties in directly and accurately monitoring the physical development of athletes. The lack of monitoring tools, combined with the high dynamics of movement in futsal, makes it challenging to evaluate physical performance effectively. To date, the physical condition of futsal athletes is still monitored manually-through visual observation, subjective assessment, and simple record-keeping after training sessions. These conventional methods have limitations in terms of efficiency, data consistency, and assessment accuracy, which may lead to errors in designing targeted training programs. This situation highlights the growing need for a technology-based monitoring system capable of providing relevant real-time data.

Along with the advancement of science and technology, approaches in sports training have also undergone significant transformation. Training methods that were once based primarily on intuition and experience are now shifting toward data-driven and evidence-based approaches. This modern approach emphasizes the importance of accurate data in the planning, implementation, and evaluation of training programs. With the rise of digital technologies, various training tools have emerged, such as wearable sensors, performance monitoring applications, and biomechanical analysis systems capable of detecting detailed body movements. The use of digital devices and wearable technology has become one of the most popular and effective methods for monitoring athletes' fitness and performance in real-time. These technologies not only provide objective physiological data, but also assist coaches in designing training programs that align with each athlete's capacity and individual needs. Among the many sports that require strict physical monitoring, futsal stands out as a prominent example. As a high-intensity indoor team sport with a fast-paced rhythm, futsal demands players to possess excellent cardiorespiratory endurance, rapid reaction time, muscular strength, and a high level of movement coordination. The fast game tempo, dynamic movements, and competitive pressure make physical monitoring a crucial aspect of every training session. Futsal matches, which consist of two short halves and involve rapid player substitutions, require efficient, data-based fitness management to enable coaches to make informed decisions regarding team composition, training intensity, and player recovery

Unfortunately, in Indonesia, most futsal training at the school, community, and semi-professional levels still relies on conventional approaches that depend on visual observation and the coach's subjective perception in evaluating athletes' physical performance (Fetru & Ramadhan, 2022). Although some coaches have recognized the importance of fitness monitoring, limitations in resources, lack of access to technology, and low digital literacy remain major obstacles to implementing training technologies. The absence of accurate and affordable tools to monitor physical fitness is one of the main challenges in improving training quality and safeguarding athletes' health. In fact, physiological data such as heart rate, acceleration levels, fatigue estimates, and muscle movement are crucial in ensuring that athletes train within a safe and effective zone. Without accurate and real-time data, coaches risk assigning training loads that are misaligned with the athlete's physical capacity, potentially leading to performance decline or even injury (Irwansyah et al., 2025). To address these challenges, the integration of Internet of Things (IoT) technology into the sports domain has emerged as a promising and innovative solution.

The Internet of Things (IoT) refers to a network of interconnected physical devices capable of exchanging data through internet connectivity, whether via Wi-Fi, Bluetooth, or other wireless communication systems (Nahdi & Dhika, 2021). In the context of sports, IoT enables the automatic and real-time collection of physiological and biomechanical data, providing information that can serve as a basis for strategic decision-making by coaches, medical teams, and the athletes themselves. IoT applications in sports may include heart rate sensors embedded in training garments, motion trackers that record body speed and acceleration, posture monitors for technique evaluation, and training systems that adapt based on the athlete's physical condition(Fakhruzzaman, 2018). With the support of this technology, coaches can objectively monitor training loads, detect early signs of fatigue, and design appropriate recovery strategies. The main advantage of implementing IoT lies in its ability to deliver responsive personalized training, enhance recovery efficiency after training or competition, and prevent injuries through measurable and well-documented objective data.

Driven by the need for an effective, affordable, and practical fitness monitoring tool suitable for futsal training environments, STARK (Smart Training Kit) was developed. STARK stands for Smart Training Kit, a wearable device based on Internet of Things (IoT) technology specifically designed to monitor athletes' physical fitness in real time (Pujirianto, 2024). This device can be used under various training conditions without interfering with the athlete's movements and is equipped with wireless connectivity that allows data to be transmitted directly to the coach's device. STARK is connected to an Android-based application that displays physiological data in real time and stores it in a cloud database for further daily or periodic evaluations. STARK not only provides objective insights into the athletes' physical condition to both coaches and athletes, but also serves as an educational medium that encourages coaches to adopt data-driven coaching in sports environments that have not yet optimally embraced digital technology. Thanks to its ease of use, STARK can act as a bridge between conventional and modern approaches in the sports training landscape in Indonesia.

Based on this background, this study aims to comprehensively evaluate its effectiveness in monitoring the physical fitness of futsal athletes, and explore user experiences regarding the device's performance, comfort, and benefits in everyday training contexts. Specifically, this study is guided by the following research questions: (1) How effective is the STARK device in providing accurate and real-time monitoring of athletes' physiological data? (2) What are the perceptions of athletes and coaches regarding the usability and practicality of STARK in regular futsal training sessions? This research is expected to contribute significantly to strengthening technology-based training practices in the field of sports particularly futsal and to broaden the discourse on the implementation of the Internet of Things within the domain of sport science and sport technology in Indonesia.

Literature Review

The following literature review presents key concepts and previous research relevant to this study, including physical fitness, the use of Internet of Things (IoT) in sports, and the use of smart training devices such as STARK. These topics are crucial to understanding the theoretical foundation and technological context of the research, as they highlight how digital innovation can enhance monitoring, evaluation, and overall training effectiveness for athletes, particularly in high-intensity sports like futsal.

Physical fitness

Physical fitness is a fundamental aspect of maintaining and improving human quality of life, particularly in the realm of sports, which demands optimal physical readiness. According to (Sujoko & Saputra, 2021), physical fitness refers to an individual's ability to carry out daily activities without excessive fatigue and still retain enough energy to enjoy leisure time and respond to emergency situations. In professional sports, physical fitness encompasses various components such as cardiovascular endurance, muscular strength, speed, flexibility, coordination, and balance. Futsal athletes, for example, are required to possess high endurance, quick movements, the ability to adapt to fluctuating physical demands, as well as strong concentration and mental resilience.

Internet of things (IoT) in sports

The Internet of Things (IoT) is a technology that enables physical devices to connect and exchange data over the internet. According to (Faozi & Rahmawati, 2019), IoT in sports refers to the application of technology that links physical devices such as sensors, wearable devices, and monitoring systems to the internet in order to collect and analyze data in real time. Through IoT, athlete performance can be accurately monitored using various sensors that measure heart rate, speed, position, and other physiological parameters, allowing coaches to optimize training programs and reduce the risk of injury. Furthermore, IoT enhances spectator experience through interactive applications that provide real-time match data and statistics. In the context of sport science, IoT facilitates systematic measurement and evaluation of athletic performance for example, through agility tests integrated with sensors and microcontroller-based devices enabling more effective monitoring and analysis of training outcomes. Overall, IoT has become a key pillar in the transformation of modern sports by enhancing athletic performance, safety, and spectator engagement through integrated smart technologies

Smart training kit (STARK)

The Smart Training Kit (STARK) is a concept of an intelligent training device that combines fitness monitoring capabilities through sensors with IoT-based communication systems (Pujirianto, 2024). STARK is designed to support physical training processes by not only monitoring athletic performance, but also storing and automatically analyzing collected data, which can later be accessed by coaches or athletes through a digital dashboard. STARK integrates the principles of wearable devices, cloud-based data processing, and technology-enhanced learning approaches. When applied in futsal training, STARK functions both as a physical condition evaluation tool and as a learning medium that allows athletes to understand their bodily responses to training loads in real time. Which state that IoT-based devices in sports training can enhance motivation, active participation, and athletes' understanding of their training processes. The STARK system, based on the Internet of Things (IoT), operates through three main system blocks: input, processing, and output. The input block features a strain gauge, an electronic component used to measure pressure or strain. The analog signal from the input is then processed in the processing block, which uses an Arduino Uno microcontroller as the control device. This block executes the decision-making process based on the input data. A NodeMCU Lua V3 wireless module transmits the data to a cloud database. The online data is stored on a cloud server using Firebase.com, enabling real-time access via web platforms or Android-based smartphones/tablets. These devices act as monitoring displays for athlete activity. The data from Firebase.com is sent to the smartphone/tablet and presented through a user-friendly interface, allowing for convenient remote monitoring and control of the device's function.

Methodology

Research design and approach of the study

This study employed a Qualitative design which is widely used to explore and understand complex phenomena, contexts, and/or eexperiences through in-depth analysis (Creswell, 2018). Qualitative design was chosen for this specific study because of the advatages including flexibility, no large study sample required and oppotunity to have an in-depth understanding of the respondents' perception (Oranga et. al, 2023). This study tried to find out the effectiveness and explored the perception of users, athletes and coach, on the use of IoT-based Smart Training Kit (STARK) in monitoring their phisyiological data during training session. The research procedures began with preliminary research and data collection, which involved observations of futsal training sessions and interviews with coaches to identify user needs and technical requirements.

Following the observation and interview, the Smart Training Kit (STARK) was subjected to testing with ten futsal athletes aged 17–25 years. During these sessions, physiological data (heart rate and estimated VO_2 Max) were collected, and athletes' feedback regarding usability and performance was recorded through interviews and direct observation (Riandini et al., 2018). Data analysis was conducted using a descriptive qualitative approach (Kurniawan et al., 2024), focusing on the effectiveness of the device in monitoring physical fitness, the accuracy of recorded data, and user perceptions regarding its integration into regular training routines.

Research site and participant

This research was conducted at a futsal training center, chosen as a strategic location due to its well-equipped sports facilities and regular use by student-level and semi-professional futsal athletes. The participants in this study consisted of active futsal athletes aged between 17 and 25 years who regularly engaged in training sessions at least three times per week. In addition, the coach responsible for training the athletes at the facility was also involved as a respondent, providing insights based on their observations and experiences in using the device. Participants were selected using purposive sampling, based on the criteria that they had direct experience with physical training, were willing to participate in the device trial, and were able to provide relevant information regarding the effectiveness and potential development of the STARK device.

Data collection and analysis

Data collection in this study involved observation sheets, semi-structured interviews, and device-generated physiological data, carried out directly by the researcher. Data collection began from the early stages of the research through observations of futsal training sessions to better understand the physical demands of the sport and identify key physiological indicators. An observation sheet was formulated based on physical fitness indicators adapted from Wilmore and Costill (2004), including heart rate dynamics and endurance responses. The observation instrument was reviewed and validated by two sport science experts to ensure content validity and relevance to futsal training.

Semi-structured interviews were also conducted with futsal coaches and selected athletes to capture their perceptions of STARK's functionality, usability, and contribution to training. The interview protocol was developed based on the Technology Acceptance Model (Davis, 1989), ensuring alignment with research objectives. The instrument underwent expert review to strengthen its validity. Interview data provided qualitative insights that complemented the objective data generated by the device. In parallel, physiological data including heart rate measurements and estimated VO_2 Max were automatically recorded by the STARK device during training sessions. These quantitative data served as a critical source for evaluating the device's accuracy and contribution to performance monitoring (Fakhruzzaman, 2018).

Data analysis was conducted using a descriptive qualitative approach (Creswell, 2018). The process began with organizing and reducing raw data from observations, interviews, and device readings. The physiological data were analyzed descriptively to evaluate consistency and accuracy. Finally, data from multiple sources were triangulated to strengthen the credibility and trustworthiness of the findings. This systematic analysis provided a comprehensive understanding of how STARK performed in supporting real-time monitoring of futsal athletes' physical fitness.

Results

The researcher conducted preliminary observations of futsal training sessions and semi-structured interviews with the team coach to identify key physical fitness indicators that would be most beneficial to monitor during training. From this data, heart rate and VO_2 Max were identified as two essential indicators as they provide reliable measures of cardiovascular fitness and aerobic capacity in futsal athletes. From this preliminary phase, two testing phases were conducted to find the effectiveness of the STARK device in providing accurate and real-time monitoring of athletes' physiological data. The result of those two testing phases are as followed:

Testing phase 1 (Heart Rate Monitoring)

Following the preliminary observations and semi-structured interviews, field testing was conducted to assess the STARK device's ability to monitor heart rate accurately during actual futsal training sessions. Heart rate data were collected from ten athletes before and after training sessions. This phase aimed to validate the functionality of the heart rate sensors and their ability to provide consistent and reliable readings under dynamic training conditions. The results of the heart rate measurements are presented in the table below:

Table 1. *Heart rate data before and after training*

Athlete	Heart Rate Before Training (bpm)	Heart Rate After Training (bpm)	Increase (%)
A1	76	141	85.5
A2	74	137	85.1
A3	79	147	86.0
A4	75	140	86.6
A5	78	143	83.3
A6	77	146	89.6
A7	74	138	86.4
A8	76	139	82.8
A9	80	150	87.5
A10	75	144	92.0

Formula for Heart Rate Increase:

$$\text{Increase (\%)} = \frac{Heart\ Rate\ After - Heart\ Rate\ Before}{Heart\ Rate\ Before} x\ 100\%$$

Testing phase 2 (VO_2 Max Estimation)

In addition to heart rate monitoring, the STARK device was also tested for its capability to estimate VO_2 Max, a key measure of aerobic fitness. This was accomplished through a 12-minute Cooper Test, where the distance covered by each athlete was recorded using the STARK device, and the corresponding VO_2 Max values were calculated. This phase demonstrated the device's ability to capture performance data relevant to endurance capacity. The results of this phase are shown below:

Table 2. *Estimated VO2 max of athletes*

Athlete	Distance Covered (m)	VO2 Max (ml/kg/min)
A1	2300	40.13
A2	2400	42.33
A3	2500	44.55
A4	2250	39.01
A5	2600	46.78
A6	2550	45.67
A7	2450	43.45
A8	2350	41.24
A9	2500	44.55
A10	2650	47.89
	Average	43.76

VO_2 Max Formula:

$$VO_2 \text{ Max} = \frac{Distance\ covered\ (m) - 504.9}{44.73} x\ 100\%$$

The two testing phases showed that the STARK device is able to capture the physiological data of the athletes, heart rate and VO_2 Max, very effectively. After testing phase, the users' perceptions and feedback were evaluated, focusing on both athletes' experiences and the coach's feedback on using the device during training. This evaluation was crucial to understand the usability and practicality of STARK in regular futsal training sessions. The results were elaborated as follows:

Athletes' perceptions of the STARK device

Perception testing was conducted using a Likert scale (1–5) to assess several aspects of the device's use by futsal athletes. A total of ten athletes participated in this assessment after using the STARK device during their training sessions. The aspects evaluated included ease of use, perceived usefulness, and safety while using the device. The results showed that athletes generally reported very positive experiences, with an overall average score of 4.6 out of 5. The details of this evaluation are presented below:

Table 3. *Athletes' perceptions of the STARK device*

Statements	Average Scores
STARK is easy to use	4.8
STARK helps me understand my physical condition	4.6
The visualization of training data is highly informative	4.7
The device motivates me to train more regularly	4.5
I feel safe training with STARK	4.6
Average	**4.6**

The highest rating was given to the "ease of use" aspect (4.8), indicating that the athletes found the device highly user-friendly and simple to operate during training. Other aspects, such as helping athletes better understand their physical condition (4.6), informative visualization of training data (4.7), and motivation to train more regularly (4.5), also received strong positive feedback. Importantly, athletes also felt safe when using the device, with an average score of 4.6, suggesting that the STARK device was well-accepted in terms of comfort and usability during dynamic futsal activities. These findings indicate that the STARK device was well-received by the athlete participants, providing not only practical utility in monitoring physical condition but also enhancing their engagement and motivation during training.

Coach's feedback of the STARK device

In addition to the athlete feedback, the futsal coach also provided an evaluation of the STARK device, focusing on its practical application in real-world training sessions. The coach assessed several key aspects, including data accuracy, practicality of use, relevance to training programs, and the potential for further development. The details of the coach's feedback are summarized in the table below:

Table 4. *Coach's evaluation of the STARK device*

Aspects	Coach's Feedback
Data Accuracy	Heart rate and distance data are fairly accurate, with a deviation of less than 5%.
Practicality of Use	The device is lightweight, easy to use, and does not interfere with movement.
Relevance to Training Program	Suitable for medium- to high-intensity training needs
Development Potential	Can be further developed for long-term athlete performance monitoring

The coach reported that the device delivered accurate heart rate and distance data, with a deviation of less than 5%, which is acceptable for training purposes. Furthermore, the device was considered lightweight, easy to use, and non-intrusive, allowing athletes to maintain natural movement during high-intensity sessions. The coach also noted that the device is highly relevant for monitoring athletes in medium- to high-intensity training programs and saw potential for further development of STARK into a long-term athlete performance monitoring system. This feedback suggests that STARK has practical value and usability in actual coaching environments, providing coaches with an objective tool to enhance training quality and athlete performance monitoring.

Discussion

The STARK (Smart Training Kit) device is designed as a physical training aid based on Internet of Things (IoT) technology, enabling coaches and athletes to monitor physiological conditions in real-time and with high accuracy. The main function of STARK is to detect key biometric parameters during training, such as heart rate and VO_2 Max, which are essential indicators in evaluating fitness levels and the effectiveness of training programs (Riandini et al., 2018).

Firstly, the increase in heart rate during training is a normal physiological response to physical activity, where the body attempts to enhance blood flow and oxygen delivery to working muscles. This aligns with Wilmore & Costill's (2004) theory of exercise physiology, which explains that as physical activity intensifies, the cardiovascular system adapts by increasing heart rate to meet the metabolic demands of muscle cells (Salome et al., 2010). Observational findings showed that the device successfully recorded an average heart rate increase of 86.42% in ten athletes after undergoing an intensive training session. This figure confirms that STARK operates with high precision in capturing cardiovascular workload dynamics, which form the basis for assessing training intensity and effectiveness.

Next, VO_2 Max is a physiological parameter that reflects the body's maximum capacity to consume oxygen during intense physical activity (Boihaqi et al., 2021). In the context of futsal training, which requires a balance of both aerobic and anaerobic abilities, VO_2 Max serves as a vital indicator of an athlete's fitness level. The VO_2 Max test in this study was conducted using the Cooper Test method (12-minute run), and the values were calculated using the following formula:

$$VO_2 \text{ Max} = \frac{Distance\ covered\ (m) - 504{,}9}{44{,}73} x\ 100\%$$

As a result, an average VO_2 Max of 43.76 ml/kg/min was obtained, which falls into the "good" category for the 17–25 age group according to the classification by the American College of Sports Medicine (ACSM, 2018)(Nasrullah et al., 2019). The VO_2 Max measurement using STARK proved to be efficient, as it not only recorded the distance covered but also simultaneously monitored heart rate during the activity—allowing for a more comprehensive interpretation of athlete performance. This finding aligns with the perspective of (Rubiono et al., 2019) who argued that technology in sports training enables objective and rapid estimation of physiological capacity, especially when used consistently throughout various training cycles. According to (Watulingas, 2014), an effective training program should consider VO_2 Max as a fundamental parameter to prevent overtraining-related injuries while promoting progressive performance improvement. This result prove that an effective training program could be achieved since the STARK device supports the implementation of the principle of individualized training, enabling coaches to adjust training loads based on each athlete's aerobic capacity.

These findings are further supported by the concept of load monitoring in sports training science, wherein the use of wearable devices or digital monitoring systems provides the quantitative data necessary to adjust training loads more precisely (Kusuma et al., 2023). With STARK, coaches can instantly identify whether a training session falls within a safe and effective zone or poses a risk of overtraining—an essential component in planning training periodization. According to (Kurniawan et al., 2024), digital technologies that deliver objective, real-time data strengthen the feedback loop between coach and athlete. Therefore, STARK is not merely a data-logging tool, but serves as an effective decision-making system based on evidence, aligning with the evidence-based coaching approach.

This study also tried to find out the perceptions of users -athletes and coach- in using the STARK device in training. The questionnaire results from athletes indicated a very high level of acceptance of the STARK device, with an average perception score of 4.64 out of 5. This score encompasses various aspects such as ease of use, user interface design, and the device's ability to assist athletes in understanding their physical condition. The highest scores were recorded for the aspects of "ease of use" (4.8) and "data visualization" (4.7), suggesting that STARK is perceived as user-friendly and capable of presenting data in an intuitive and easily comprehensible manner.

According to the Technology Acceptance Model (TAM) by Davis (1989), two main variables influence the acceptance of technology: perceived usefulness and perceived ease of use (Davis, 1989). The findings of this study demonstrate that STARK fulfills both of these components. The respondents' strong agreement with the statements related to the utility of the device and how simple it is to use suggests that the STARK device has met both of TAM's main variables. The ease in which the users can operate the device combined with the highly informative visualization appears to reduce the potential of resistance in adopting this device for monitoring training session. Therefore, the potential for regular implementation of the device in training sessions is considerably high, especially because athletes feel empowered by having access to real-time information about their own bodies without any complication.

Furthermore, the findings of Hapzi Ali et al. (2022) who extended the development of TAM indicated that external factors such as interface design, system support, and compatibility with user needs also significantly influence technology adoption. STARK; high ratings in user interface and visual presentation suggest that the device not only function effectively to capture both heart rate and VO_2 Max but also tailored to the athletes' expectations of such devices.

Not to mention, feedback from coaches provided essential validation regarding the effectiveness and relevance of STARK within the context of high-intensity training. Coaches assessed that the device did not hinder athletes' movement, delivered reliable data with less than 5% deviation, and produced reports that were immediately useful for evaluating daily training outcomes. Furthermore, the immediate availability of information regarding the athlete's physiological data was regarded as highly beneficial for performance evaluation on a daily basis. This validation from the coach aligns with the principles of the Evidence-Based Training approach proposed by Daniyati (2013), where concrete data is utilized to design targeted and efficient training programs. With this device, coaches are no longer dependent solely on observational judgment or subjective assessment, instead they are supported by real-time digital feedback accurately informing them on tactical and strategic decisions during training session.

In addition, STARK is considered to have fulfilled the principles of practicality and usability within the Technological Pedagogical Content Knowledge (TPACK) framework in the context of sport science. According to this framework, effective technology integrations within the sport training context must not rely on the sophistication of the technology rather on the technology's ability to complement pedagogical strategies and content delivery. STARK's compatibility with the dynamic and the high-performance training environments that are often unpredictable shows that the device meets these criteria. This suggests that the STARK device is not merely a tool for monitoring but a pedagogical asset for enhancing the learning and development process for sport related settings with its intuitive interface, seamless functionality and contextual relevance.

Conclusion and Recommendations/Implications

The use of STARK as a physical fitness monitoring device has proven effective in enhancing the quality of futsal athlete training. By utilizing IoT technology, STARK provides accurate and real-time data on athletes' physiological conditions, such as heart rate and estimated VO_2 Max. This data is crucial for helping coaches design more precise training programs tailored to each athlete's individual needs. The findings indicate that STARK not only improves monitoring efficiency but also assists in identifying fatigue, managing recovery, and preventing injuries. Moreover, feedback from both athletes and coaches suggests that the device is highly user-friendly and capable of delivering informative data visualizations. With high scores in ease of use and perceived usefulness, STARK can serve as an educational tool that encourages coaches to adopt a more data-driven approach to training. Therefore, STARK holds great potential as an innovative solution for advancing sports training practices in Indonesia and promoting broader adoption of technology in the field of sports. This study is expected to contribute significantly to improving training practices and athletic performance, while also paving the way for future research on the integration of IoT technology in the domain of sports science.

To expand on these findings, future research should explore the development of an enhanced version of STARK with broader monitoring capabilities, such as muscle fatigue indicators, hydration levels, and stress markers. Additionally, testing with a larger and more diverse athlete population—including female athletes, professional teams, and different sports disciplines would strengthen the generalizability of results. Longitudinal studies are also recommended to assess the long-term effects of using STARK on athletic performance, injury prevention, and training adaptation. Finally, further research could investigate the integration of STARK with broader sports performance platforms or coaching management systems to provide a more comprehensive digital ecosystem for sports training.

Implications for practitioners, the findings suggest that STARK can serve as a practical and affordable entry point for coaches seeking to implement data-driven training in futsal. The device may encourage a shift from subjective to objective assessment in sports coaching, particularly in community-based and semi-professional settings. For future researchers, this study provides a framework for developing more comprehensive IoT-based sports monitoring tools, emphasizing the importance of multi-parameter tracking and user-centered design. Scaling the product for broader sports applications such as basketball or badminton also represents an important direction for further investigation. For policymakers and sports administrators, this study underscores the need to support the integration of emerging technologies into athlete development programs, particularly in grassroots and school-level sports. By facilitating access to affordable and practical tools like STARK, training quality and athlete safety can be significantly improved.

Limitations of the Study

This study also has some methodological limitations. The participant group consisted of only ten futsal athletes and one coach from a single training center. While purposive sampling was appropriate for this particular study, a broader participant base would increase the generalizability of findings. Furthermore, the research was conducted over a relatively short time span, which limited the ability to evaluate the long-term impact of using STARK in regular training cycles. The focus was also limited to a small set of fitness parameters; thus, additional variables and longer-term evaluation would be valuable for future research.

Disclosure Statement

The author declares that there is no potential conflict of interest in this study. All data and information presented in this research are the original work of the author and do not involve any third parties with financial or non-financial interests. This study was conducted with a high level of academic integrity and in full compliance with all applicable research ethics guidelines.

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