Development of IoT-based pulse rate detection bracelet for volleyball endurance training

Desarrollo de una pulsera de detección de frecuencia cardíaca basada en IoT para el entrenamiento de resistencia en voleibol

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How to cite in APA

Muharram, N. A., Pratama, B. A., & Indarto, P. (2025). Development of IoT-based pulse rate detection bracelet for volleyball endurance training. *Retos, 65*, 931–940. https://doi.org/10.47197/retos.v65.109938

Abstract

Introduction: The use of equipment in volleyball training, especially IoT-enabled heart rate monitoring bracelets for endurance workouts, is still limited and not fully developed, despite the significant impact this technology has on improving training outcomes.
Objective: This research aims to develop an IoT-based pulse rate detection bracelet designed specifically for endurance training in volleyball.
Methodology: The research utilized a R&D approach, implementing small-scale experiments at various universities, such as Universitas Nusantara PGRI Kediri. The participants included experts in materials and media, as well as volleyball coaches and players. A combined method strategy was employed, collecting information via interviews and surveys. The qualitative analysis was carried out according to the five phases of the ADDIE model: Analysis, Design, Development, Implementation, and Evaluation. Quantitative analysis was conducted through expert assessments, represented as percentages, while the validity and reliability of the tools were evaluated using SPSS software.
Results: The research results show the following: (1) An IoT-enabled pulse monitoring bracelet for volleyball endurance training was developed utilizing the ADDIE model, incorporating elements like an Arduino microcontroller, a BPM sensor, a battery, and an LED indicator. The bracelet features a blue body paired with a black elastic band. The viability of the bracelet was assessed by material specialists (82%), media specialists (80%), and trainers (79.78%). (3) The bracelet exhibited robust validity, attaining a coefficient of 0.954, and exceptional reliability, achieving a score of 0.945.
Conclusions: the IoT-based pulse rate detection bracelet for volleyball endurance training is proven to be suitable for use.

Keywords

Endurance; detection bracelet; self triage bracelet, volleyball.

Resumen

Introducción: La utilización de dispositivos tecnológicos en el entrenamiento de voleibol, especialmente pulseras IoT para el seguimiento de la frecuencia cardíaca en sesiones de resistencia, sigue siendo escasa, a pesar de su capacidad para optimizar el rendimiento.
Objetivo: Este estudio tiene como finalidad crear una pulsera para monitorear la frecuencia cardíaca, basada en IoT, enfocada en entrenamientos de resistencia en voleibol.
Metodología: Se utilizó un método de I+D, llevando a cabo experimentos a pequeña escala en instituciones académicas como la Universitas Nusantara PGRI Kediri. Los participantes abarcaron especialistas en materiales, medios, entrenadores y atletas. Se empleó un enfoque combinado, reuniendo información a través de entrevistas y cuestionarios. El estudio cualitativo se llevó a cabo siguiendo las etapas del modelo ADDIE (Análisis, Diseño, Desarrollo, Implementación y Evaluación). El análisis cuantitativo abarcó evaluaciones de especialistas y la validez y confiabilidad fueron evaluadas con SPSS.
Resultados: (1) Se creó una pulsera IoT para el seguimiento de pulso durante entrenamientos de resistencia, incluyendo un microcontrolador Arduino, sensor BPM, batería y LED. Su diseño presenta un cuerpo azul y una cinta elástica negra. La factibilidad fue analizada por especialistas en materiales (82%), métodos (80%) y entrenadores (79.78%). La pulsera exhibió una elevada validez (0.954) y consistencia (0.945).
Conclusiones: La pulsera IoT creada es apropiada para ser utilizada en entrenamientos de resistencia en voleibol.

Palabras clave

Resistencia; pulsera de detección; pulsera de auto-triaje, voleibol

Introduction

Playing volleyball requires not only technical ability but also physical conditioning (Puspodari & Nur Ahmad Muharram, 2020). Physical condition is one of the prerequisites that is very necessary in every effort to improve an athlete's performance, it can even be said to be the basic starting point for starting a sports performance (Muharram et al., 2023). Physical condition is an absolute requirement in improving an athlete's performance, it can even be said to be a basic need that cannot be postponed or negotiable (Junaidi & Muharram, 2021) states physical conditions, including endurance, strength, speed, power, flexibility, agility, coordination and balance. Components of physical condition in volleyball according to (Machado et al., 2018) that the physical conditions required in playing volleyball are aerobic endurance and anaerobic endurance, agility, explosive power, speed, flexibility and strength (Zhang, 2020). The components of physical condition consist of strength, endurance, muscular power, speed, flexibility, agility, coordination, balance, accuracy and reaction. The main target of physical exercise is to improve the quality of energy fitness and muscle fitness (Ye, 2020).

Energy fitness includes increasing low-intensity, moderate-intensity, high-intensity aerobic abilities and both alactic and lactic-inducing aerobics (De Waelle et al., 2021). Meanwhile, muscle fitness is the general state and functionality of your muscles, which are essential for supporting movement, balance, and physical abilities (Pratiwi et al., 2018; Witard et al., 2022). Energy fitness and muscle fitness are key factors in enhancing athletic performance. While these aspects are crucial for an athlete's success, the availability of advanced technology specifically designed to monitor and improve athlete performance remains limited (Wijaya et al., 2024). Technological innovations in this area are still emerging (Putra et al., 2024), providing opportunities to further support and optimize athletic training and performance tracking. Early research indicates that volleyball, along with other sports, can see improvements in endurance training by incorporating technology. One technological advancement is the use of IoT-based pulse detection bracelets to monitor athletes' heart rates during training. This new technology allows for immediate monitoring of an athlete's cardiovascular abilities, providing useful information for improving endurance workouts (Huiqiang, 2021). The design and implementation of the pulse predictor tool are crucial for training (Kay et al., 2015). Through the use of IoT devices, coaches and trainers can use data to enhance athletes' fitness and performance.

The Internet of Things (IoT) and related technologies, including wireless sensor networks (WSN), are advancing quickly, with their new innovations and applications significantly impacting our daily lives (Farrokhi et al., 2021). IoT-based technology allows users to interact with virtual objects in real time (Duan, 2021). There are three characteristics of IoT-based technology including: (1) relationships between virtual objects in the real world (2) users can interact in real time (3) display objects in 3D form. This application can also be developed by utilizing innovative technology such as mobile devices and computers (Astuti et al., 2022). The Internet of Things (IoT) in health and fitness enables the collection, transmission, and analysis of data anytime and anywhere, allowing for real-time access to individuals' daily exercise and health information. This technology provides accurate health assessments and exercise guidance, effectively serving as a personal health advisor that is always accessible (Huiqiang, 2021).

The study introduces an innovative wearable device equipped with inductive sensors embedded in the fabric, designed to continuously monitor heart activity. This device offers athletes real-time feedback on both their heart rate and respiratory patterns, enabling more precise tracking of physiological responses during physical exertion. This real-time data can help optimize athletic performance and endurance training by allowing for immediate adjustments based on cardiovascular metrics (Brezulianu et al., 2019). In recent years, increasingly advanced technological developments can be implemented using mobile devices that have advantages such as graphics processing, portability, user friendliness, and personnel operation (Hidayah et al., 2024; Nurkadri et al., 2024). The biological pulse sensor and its wearable application in physical education (Zhong, 2021). Creating a pulse detection bracelet based on IoT for volleyball endurance training that aligns with University Key Performance Indicators (IKU) will greatly impact research and technological innovation. This project aids in implementing research discoveries in the fields of education and sports growth. Multiple university IKUs related to this project involve boosting research and innovation focusing on societal needs, enhancing education quality, improving student learning experiences, and incorporating technology into different aspects of life (Fani & Sukoco, 2019).

Based on this information, the researchers intend to create a pulse detection bracelet to help volleyball players with their endurance training. It is anticipated that the creation of an IoT-enabled device will improve training effectiveness by enabling coaches to monitor the endurance progress of individual players more easily. This technology will offer live data, making it easier to track athletes' heart performance and giving useful information for improving training plans. The expectation is that the pulse detection bracelet based on IoT will prove to be a useful instrument in enhancing volleyball endurance training (Muharram & Putra, 2019). The novelty and specifications of the development of this Internet of Things (IoT) based tool are: The product developed in this research is an Internet of Things (IoT) based pulse rate detection bracelet for endurance training in volleyball. Based on this background, this research aims to develop an IoT-based pulse rate detection bracelet designed specifically for endurance training in volleyball.

Method

Research Design

This study adopts a Research and Development (R&D) strategy, a technique utilized to design targeted products and evaluate their efficacy. The ADDIE model is widely used in research and development for designing learning products among the various development models in use. The ADDIE model is composed of Analysis, Design, Development, Implementation, and Evaluation phases, offering a systematic approach for creating educational tools and technologies (Cahyadi, 2019). This research uses quantitative and qualitative approaches.

The methods section in a research is an important basis for understanding the steps taken in the research process. One of the key elements that must be present in the methods section is a research flow diagram. This flow diagram aims to provide a visual overview of what has been carried out in the research as well as the work plan that will be carried out during the proposed time. In research and development procedures, there are several stages that must be carried out in a research based on theories from several experts (Widyastuti & Susiana, 2019).

The outcomes of this research and development effort are outlined in the following product specifications: a) The bracelet is 2 cm wide, b) It contains components like an Arduino, BPM sensor, battery, charger module, and other supporting elements, c) IoT technology is utilized for smartphone connectivity via Wi-Fi, Google or Chrome apps are employed to capture and show data from the BPM sensor in the bracelet, and e) The updated app can exhibit pulse rate data (BPM) from 24 or more devices. The method to solve these problems includes several steps: Needs Assessment, Creation of the pulse detection bracelet, Software Development, Testing and Assessment, Validation and Reliability testing, and finally, Optimization and Enhancement. This method seeks to create a dependable and efficient IoT-enabled wristband for detecting pulses, which will improve volleyball endurance training and make a significant contribution to enhancing athlete performance and overall sports progress (Claver Rabaz et al., 2017).

Participants and data collection

The sampling technique in this study used purposive sampling. The participants in this study were volleyball coaches and players from Nusantara PGRI Kediri University, Kahuripan Kediri University, Sebelas Maret University, and Surabaya State University, amounting to 24 players and 4 coaches. The validation by experts included three professionals: a media specialist, a materials expert, and a trainer. The media expert has skills in media-related areas, while the material expert has knowledge in sports technology and volleyball training. The coach has extensive experience in volleyball. The stages in this research are expert testing, then product validity and reliability testing. Tests were done on the 24 players to confirm the precision and dependability of the findings.

Table 1. Assessment Grid for Material Experts

No	Aspect	Indicator	Amount
1	Material Quality	Clarity of study instructions	1
		Provisions for selecting the materials provided	1
		Determination of language selection in explaining material	1
		Material quality	1
2	Fill	The truth of the content/concept	1
		Depth of material	1
		Clarity of material	1
		Material sufficiency	1
		Systematic logical presentation	1
		Accuracy in selecting images and material	1
		Number of Items	10

Table 2. Assessment Grid for Media Experts

No	Aspect	Indicator	Amount
1	Display Aspects	Accuracy of button placement	1
		Button consistency	1
		Clarity of light color	1
		Tampilan warna sensor	1
		Clarity of signal from sensor light	1
		Image clarity	1
		Slide design display	1
		Clarity of font size	1
		Accurate selection of fonts	1
		Accuracy of technology background design	1
		Similarity in the choice of text and background colors	1
		Composition of each slide	1
		Image size accuracy	1
		Button size	1
		Button clarity	1
2	Programming Aspects	Slide presentation aesthetics	1
		Ease of interaction in detecting recorded data	1
		Clarity of instructions for use	1
		Clarity of instructions for use	1
		Has attraction	1
		Number of Items	20

Statistical analysis

According to Hazlina Hashim & Jones (2007) validity is a way to determine the accuracy of an instrument in terms of its measuring purpose. Statistical analysis of percentage test to calculate the results of 3 experts (media, materials, and trainers) and field trials, Validity test using Product Moment correlation and the reliability used the Cronbach Alpha with the help of SPSS 22.0 for Microsoft Windows (Summerley, 2020).

Results

The researchers have qualitatively presented the early findings of the study, focusing on the process of developing the product. The results show that the creation of a pulse detection bracelet for volleyball endurance training based on the Internet of Things (IoT) was successfully completed. The ADDIE model guides the development process through five stages: Analysis, Design, Development, Implementation, and Evaluation. The bracelet is made up of an Arduino microcontroller to collect and analyze data, a BPM sensor (max30100 pulse oximeter heart-rate sensor module), a BL-4c battery, and an LED indicator light. The outer part and band of the bracelet are constructed from stretchy material, with four screws situated at the base. The blue color scheme makes a bold statement when worn, and the bracelet strap is black in color.

In the analysis phase, a requirement for a device that can track heart rate in real-time while engaged in volleyball endurance training was recognized. This examination required collecting data on the importance of heart rate tracking for measuring exercise intensity and assessing athletes' fitness levels. A study was performed to explore the shortcomings of current training techniques that do not include

direct heart rate monitoring devices. Moreover, the traits of users, including coaches and volleyball players, were investigated to confirm the device would satisfy their unique requirements.

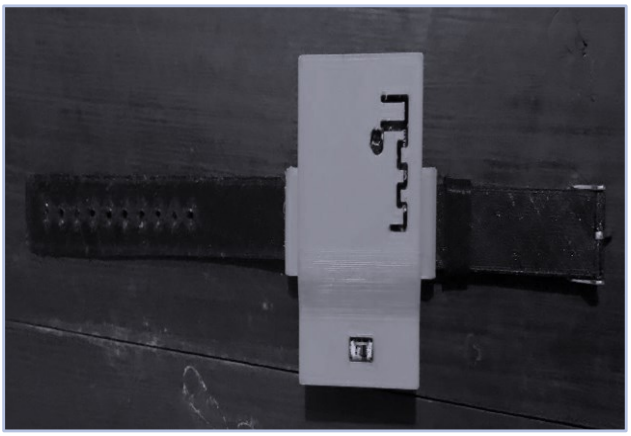
During the design stage, the features and specifications of the heart rate monitoring watch were created, considering the needs for volleyball endurance training. This involved creating the user interface (e.g., heart rate monitor, alerts for achieving certain heart rate zones) and establishing technical requirements, like incorporating Internet of Things (IoT) technology for immediate data transfer. The design additionally focused on the ways heart rate information would be tracked, analyzed, and displayed on alternative devices (such as mobile applications), as well as how it could offer users suggestions for exercise and fitness levels.

During the development stage, the hardware and software elements of the heart rate monitoring watch were produced. This included creating an accurate heart rate monitor, a comfortable and long-lasting watch band, and a mobile app integrated with IoT technology. The prototype watch was evaluated to guarantee precise heart rate tracking and efficient feedback delivery. Moreover, the device underwent testing in actual training scenarios to verify its resilience during intense volleyball practice.

The assessment stage involved collecting input from coaches and athletes following their use of the heart rate monitor during training. Information regarding the watch's efficiency in improving volleyball endurance training was examined. If any problems were found, like the need for better sensor precision or a more intuitive interface, modifications were implemented. Continuous assessments guaranteed that the device remained effective in providing useful insights and contributed to enhanced endurance performance for volleyball players.

Utilizing the ADDIE approach, the creation of this heart rate monitor was methodical and tailored to the precise requirements of volleyball endurance training, guaranteeing its effectiveness and user satisfaction. The products produced in this development are shown in Figure 1.

Figure 1. IoT Based Heart Rate Detection Bracelet



The pulse-detecting bracelet designed for volleyball endurance training using IoT technology has been created and is considered appropriate for usage. The following findings will show numerical information based on expert assessments and evaluations regarding the product's validity and reliability.

Table 3. Expert Tests

No	Indicator	Standar Deviasi	Confidence Intervals	Percentage	Information
1	Media	4.75	59.10, 62.90	80.00%	Quite Feasible
2	Material	2.75	31.92, 34.08	82.00%	Quite Feasible
3	Trainers	3.25	65.68, 68.32	79.78%	Worthy

Table 3 shows that the IoT-based pulse detection bracelet for volleyball endurance training that was developed is suitable with a material expert assessment of 82.00% in the quite feasible category, a media

expert assessment of 80.00% in the quite feasible category, and a trainer assessment of 79.78% in the category worthy. The results of the expert test are presented in more detail in the figure below:

Figure 2. Expert Tests (Media, Material, and Trainers)

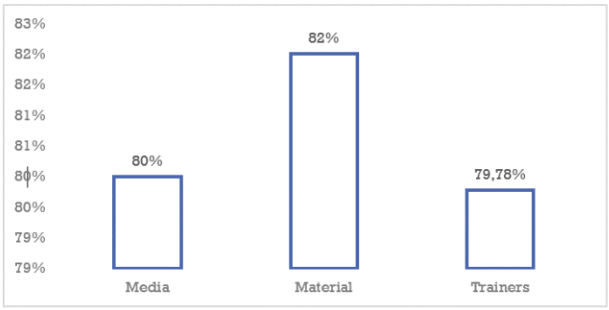


Table 4. Validity and Reliability tests

Product	Product Moment	Cronbach Alpha
Internet of Things (IoT) based pulse detection bracelet (self-triage bracelet)	0.954	0.945
Information	Valid	Reliable

The evaluation shows that the volleyball endurance training pulse detection bracelet using Internet of Things (IoT) technology has a validity coefficient of 0.954 and a reliability score of 0.945. An accuracy level of 0.954 in the validity coefficient indicates the IoT heart rate monitor's effectiveness in measuring athletes' heart rates accurately during workout sessions. The validity coefficient being near 1 suggests the device's measurements closely match the intended conditions for assessment. A reliability score of 0.945 indicates that the device is consistent, yielding dependable and consistent outcomes in similar situations. This level of dependability ensures that the device is reliable for obtaining consistent measurements each time it is utilized. The pulse detection device's high validity and reliability scores together confirm its accuracy and dependability, making it an excellent tool for monitoring volleyball athletes' endurance training.

The mix of qualitative and quantitative findings demonstrates that the pulse rate detection bracelet based on IoT is viable and effective for volleyball endurance training.

Discussion

Based on the research results, the development of IoT-based pulse rate detection bracelet for volleyball endurance training is feasible to use. The product manufacturing process is in accordance, the expert test was deemed feasible, the field trial was found to be feasible, and the validity and reliability tests confirmed the product as valid and reliable.

The results obtained in the study are in line with previous research that the use of Virtual Reality Technology as a Factor to Improve University Sports (Turdaliyev et al., 2024). The Internet of Things (IoT) is a worldwide network that links physical objects and devices using data capture and communication technologies. This structure combines current networks and the web, allowing for the creation of self-sufficient systems and apps. The foundation for independent and cooperative services is created by IoT through object identification, sensor capabilities, and network connectivity. Important aspects of IoT include strong independence, effective data collection, communication of events, connection to networks, and compatibility, enabling smooth communication between various devices and systems (Pratama et al., 2020). The Internet of Things (IoT) is a setup where objects and people have specific identities, enabling them to share information through a network without relying on direct human-to-human or human-to-computer interaction. This technology is a major development in enhancing everyday life by utilizing intelligent sensors and devices that communicate through the internet. IoT involves

a variety of connected devices such as electronics, sensors, software, and connectivity tools that collaborate to improve service delivery and generate more value for users (Muharram et al., 2023).

IoT is a technology that allows objects around you to be connected to the internet network. This technology was discovered by Kevin Ashton in 1999. Until now, IoT technology has been developed and applied (Eraslan, L., Castelein, B., Spanhove, V., Orhan, C., Duzgun, I., & Cools, 2021). One common use of the Internet of Things (IoT) that everyone knows about is the Global Positioning System (GPS) service. GPS operates by enabling internet-connected devices to be accessed and monitored at any location and time. The idea of IoT involves allowing specific objects to independently transmit data across a network, without the need for human interaction with other humans or devices. This technology improves connectivity and data sharing among different systems, forming a more cohesive and effective network of devices (Widyastuti & Susiana, 2019). The Internet of Things (IoT) is transforming various aspects of our daily lives. Among its diverse applications, health and wellness have emerged as a prominent area, with IoT providing innovative services, including smart fitness solutions (Farrokhi et al., 2021).

Pulse Rate Predictor for training is really needed in coaching (Kay et al., 2015). The device created in this research demonstrates a significant advancement in live heart rate tracking, providing beneficial perks for athletes, especially in athletics. Athletes can keep track of their heart rate and monitor their physical condition while training with this tool, which is important for assessing exercise intensity and overall fitness levels. This ability to monitor in real-time helps athletes improve their training sessions and effectively handle their health (Widiastuti et al., 2024). This tool enables athletes and coaches to fine-tune training intensity for better performance and decreased chances of fatigue or injury. Therefore, this enhanced monitoring can enhance training efficiency, promote improved attainment of fitness goals, and guarantee athletes are physically prepared (Tomoliyus et al., 2024). The study explains that data mining technology is utilized in the field of human motion state recognition, incorporating interdisciplinary knowledge and approaches to effectively address the issue of classifying unknown label data with a limited training set (Huiqiang, 2021). The development of technology in the world of coaching is very important (Smiley et al., 2023). Advances in technology now enable endurance athletes, sports teams, and clinicians to monitor lifting functions, workloads, and biomarkers, helping to optimize performance and minimize the risk of injury (Zhong, 2021). Therefore, the use of IoT-based is very supportive in the development of this tool so that it can be used appropriately in training.

Conclusions

The main goal of this research is to create a pulse detection bracelet using IoT technology to assist in volleyball endurance training. The results indicate that creating this IoT pulse detection device for volleyball endurance training is possible for implementation. The researchers believe that this pulse detection bracelet will improve training quality for coaches and players by tracking endurance development and allowing coaches to monitor progress more effectively. The scope of this research is limited to analyzing the development process, testing by experts (including media, material, and trainer assessments), and evaluating the validity and reliability of the product. The results of this study suggest that more training tools should be developed in the future. There is a need for future studies to examine how the IoT pulse rate detection bracelet can enhance the stamina of volleyball players.

Acknowledgements

This research was funded through grant research activities from the Directorate of Research, Technology and Community Service (DRTPM) for Fiscal Year 2024. We would like to express our thanks to the Student Activity Unit (UKM) of Universitas Nusantara PGRI Kediri, the Student Activity Unit (UKM) of Sebelas Maret University, The Surabaya State University Student Activity Unit (UKM) and the Kahuripan Kediri University Student Activity Unit (UKM) have facilitated the sampling.

Funding

This research was funded through grant research activities from the Directorate of Research, Technology and Community Service (DRTPM) for Fiscal Year 2024.

Conflicts of interest

The authors affirm that there are no conflicts of interest, whether financial or otherwise, that might have impacted the research process, data analysis, or the conclusions drawn in this article.

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