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# Feasibility Study of an Internet of Things (IoT)-Based Relay Baton for Monitoring Relay Runner Performance

Adi S[1], Cahyo Yuwono[1], Tommy Soenyoto[1], Made Bang Redy Utama[2], Hilmy Aliriad[3], Erika Afriana[1], Karina Permata Andhini[1]

[1]Universitas Negeri Semarang, Semarang, Indonesia
[2]Universitas Negeri Jakarta, Jakarta, Indonesia
[3]Universitas Nahdlatul Ulama Sunan Giri Bojonegoro, Bojonegoro, Indonesia

*Corresponding Author: adis@mail.unnes.ac.id

**Abstract**
This study aims to develop and determine the level of acceptance of the Internet of Things (IoT)-based Relay Baton as a tool for monitoring performance in relay running training. The study employs a Research and Development (R&D) approach, focusing on the user testing phase. The research subjects were relay runners who had mastered the basic baton-passing technique. Testing was conducted through a simulation of the device's use, ranging from operating the baton and the handover process to monitoring results via a web-based dashboard. The research instrument consisted of a user response questionnaire using a five-point Likert scale covering three aspects: comfort and physical design, ease of use, and system benefits and feedback. The data were analysed descriptively using actual scores, maximum scores, averages, and achievement percentages. The results showed that the users' acceptance rate of the device reached 90%, falling into the 'very good' category. The aspects of comfort and physical design scored 92 per cent, ease of use 88 per cent, and benefits and system feedback 90 per cent. Furthermore, the system was able to generate and display monitoring data, including baton possession duration, baton handover time, each runner's speed, total race time, race status, and device status. These findings indicate that the IoT-based Relay Baton is convenient and easy to use, and is capable of providing more integrated performance data than conventional recording methods. As such, the device has the potential to serve as a technology-based monitoring tool that supports the evaluation of relay training and coaching based on sports science.

**Keywords:** baton; internet of things; performance monitoring; relay race; sports science; sports technology



## INTRODUCTION

The development of information and communication technology has brought significant changes in various areas of life, including sports. Digital transformation is no longer limited to data administration or analysis, but has developed into an important part of the process of fostering sports achievements through the use of the Internet of Things (IoT), wearable devices, smart sensors, and artificial intelligence (*Artificial Intelligence*). This technology allows the process of monitoring sports activities to be carried out automatically, in real-time, and to produce more objective data than conventional measurement methods. Wearable technology and the Internet of Things (IoT) in sports are opening up a new era in athlete training, not only for performance monitoring and evaluation but also for fitness assessment (Passos et al. 2021). These devices are increasingly popular for monitoring physiological parameters during exercise, given advances in miniature technology, advanced data, and signal processing applications (Romagnoli et al. 2023).

One of the sports that requires such technological support is relay running. The relay running number is a team race that requires the ability to sprint speed, coordination between runners, and punctuality in moving the stick in the change zone. Sprint is a fundamental skill in many athletic

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disciplines and team sports, as faster individuals can have a decisive advantage in sprint placement and performance during the sport's requirements (Bertochi et al. 2024). In the relay race, the team's success is not only determined by the sprint ability of each athlete, but also influenced by the synchronization of movements, the efficiency of the pole handing process, and the timeliness of pole movements in predetermined zones. The slightest mistake during the change of stick process can lead to the loss of valuable time and even result in disqualification if the move is made outside the change zone.

Although it has a very important role in the results of the race, the evaluation process of relay running training is still mostly carried out using stopwatches and direct observation by coaches. This method generally only produces information in the form of overall travel time without being able to provide more detailed data on the duration of the stick held by each runner, the time of moving the stick, and the speed of each athlete during training. In addition, manual recording is highly dependent on the accuracy of observers, so it has the potential to cause *human error* and reduce the objectivity of the evaluation results. Wearable Sensors and Smart Devices to Monitor Rehabilitation Parameters and Sports Performance (De Fazio et al. 2023). Wearable technology offers an alternative to overcoming the limitations of traditional assessment and is increasingly being accepted by runners, trainers, and clinicians(Mason et al. 2023)

In an effort to answer this need, an Internet of Things (IoT)-based Relay Bate was developed which integrates electronic sensors, microcontrollers, wireless communication modules, and web-based applications to monitor relay training activities in real-time. This system is able to record various training parameters, including the duration of the stick held by each runner, the time of moving the stick, the speed of each runner, the total race time, and the status of the device during the training process. All of this data is automatically sent to the web application so that coaches can obtain information on athletes' performance faster, objectively, and more data-drivenly. The implementation of an IoT-based monitoring system is expected to improve the quality of training evaluation while supporting decision-making in the athlete coaching process more effectively.

Although IoT-Based Relay Stick devices already have comprehensive monitoring capabilities, the effectiveness of their use is greatly influenced by the user's understanding of the system's operating procedures. Unprocedural use of the device may result in data reading errors, connectivity disruptions, or device damage. Therefore, a user guide is needed that is systematically compiled as a reference for athletes, coaches, physical education teachers, and researchers in operating devices according to the standards that have been set. The guide not only describes the steps for using the device, but also contains information about device specifications, application navigation, safety aspects, maintenance procedures, and handling of problems that may occur during use.

Based on this description, this study aims to compile and describe guidelines for the use of Internet of Things (IoT)-Based Relay Sticks as a supporting medium for monitoring relay running exercises. The presence of this guide is expected to increase the effectiveness of the implementation of IoT technology in the athletic coaching process, make it easier for users to operate devices independently, and support the development of *sports science* based on digital technology in the educational environment and sports achievement coaching.

## METHOD

This research uses a Research and Development (R&D) approach which is focused on the user *test* stage of the Internet of Things (IoT)-*Based Relay Stick product* and its user manual. The trial aims to determine the level of user acceptance of the device based on the aspects of comfort and physical design, ease of use, and benefits and feedback of the system. The results of the trial are used as a basis to evaluate the quality of product use in supporting relay running training activities. The subject of the study is a relay runner who has understood the basic techniques and procedures of relay stick movement. The selection of subjects was carried out based on the suitability of the participants' characteristics with the purpose of the product trial. Subjects use the device directly in the relay run simulation after obtaining an explanation of the operating procedures and the use of the manual.

The trial was carried out through a simulation of the use of IoT-Based Relay Sticks in relay running activities. Before implementation, the subject is given an explanation of the functions of the device and the procedure for its use. The stages of use include turning on the device through the main switch, operating the buttons on the stick, connecting the device to the system, simulating running and moving sticks, and observing the monitoring results on a web-based dashboard. During simulations, devices are used to automatically transmit training data through IoT systems. The data that can be

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displayed on the system includes the duration of each athlete's holding the stick, the time of the stick movement, the speed of each runner, the total race time, the status of the race, and the status of the device. After completing the simulation, the subjects gave an assessment of the device using a user response questionnaire.

The research instrument was in the form of a user response questionnaire with a five-level Likert scale, namely a score of 1 for *strongly disagree* to a score of 5 for *strongly agree*. The questionnaire consists of 10 indicators grouped into three aspects of assessment, namely:

1. The comfort and physical design of the device consists of three indicators, namely the suitability of the size of the stick, the suitability of the weight of the device, and the position of the buttons that do not interfere with use.
2. Ease of use consists of three indicators, namely ease of operating the buttons, ease of understanding the procedure of use, and the device does not interfere with the concentration of athletes.
3. The benefits and feedback of the system consist of four indicators related to the usefulness of information on the duration of stick possession, the time of the movement of the stick, the information on runner speed, and the presentation and visualization of monitoring information.

In addition to the assessment through questionnaires, observations were made on the system's ability to produce monitoring data, including the duration of the stick possession, the time of movement, the speed of the runner, the total time of the race, the status of the race, and the status of the device. The questionnaire data was analyzed using descriptive statistics through the calculation of the actual score, maximum score, average, and percentage of achievement in each aspect. The percentage of achievement is calculated by the formula:

Description:
P = percentage of achievement;
S = actual score;
Smax = maximum score.

The percentage results are then categorized based on the level of achievement as follows:

| **Percentage** | **Category** |
|---|---|
| 81-100% | Excellent |
| 61-80% | Good |
| 41-60% | Enough |
| 21-40% | Less |
| 0-20% | Very Less |

Based on the results of the trial, the overall maximum score of the 10 indicators is 1,000, while the actual score obtained is 900, so the overall achievement rate reaches 90% and is included in the very good category. Analysis by aspect showed that the comfort and physical design aspects obtained a score of 92%, the ease of use aspect of 88%, and the benefits and feedback aspects of the system of 90%. The results were used to determine the level of user acceptance of the IoT-Based Relay Bates and evaluate the suitability of the device as a relay running training monitoring medium.

## RESULTS AND DISCUSSION

The user trial was conducted to determine the level of user acceptance of the Internet of Things (IoT)-Based Relay Stick, which was developed as a monitoring medium for relay running exercises. The evaluation was carried out after the user understood the operating procedure of the device and performed a simulation of the movement of the stick. User ratings include three aspects, namely the convenience and physical design of the tool, ease of use, and the benefits and feedback of the system. The instrument uses a five-level Likert scale with a score of 1 to 5.

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**Table 1.** User Assessment Results of IoT-Based Relay Sticks

| Assessment Aspects | Number of Indicators | Maximum Score | Actual Score | Percentage | Category |
|---|---|---|---|---|---|
| Comfort and physical design of the tool | 3 | 300 | 276 | 92% | Excellent |
| Ease of use | 3 | 300 | 264 | 88% | Excellent |
| Benefits and feedback system | 4 | 400 | 360 | 90% | Excellent |
| Total | 10 | 1000 | 900 | 90% | Excellent |

The test results show that in general users respond positively to the developed device. In terms of comfort and physical design, users consider that the size of the 30 cm long stick is still comfortable to use and the weight of the device does not interfere with sprint activities. The position of the buttons placed on the stick body also does not reduce comfort during the process of moving the stick.

**Table 2.** Tool Comfort and Physical Design Indicators

| Indicator | Average | Percentage | Category |
|---|---|---|---|
| Stick size suitability | 4.70 | 94% | Excellent |
| Device weight suitability | 4.50 | 90% | Excellent |
| The button position does not interfere with use | 4.60 | 92% | Excellent |
| Average | 4.60 | 92% | Excellent |

In terms of ease of use, users stated that the operating procedure is relatively easy to understand. Users can follow the stages starting from activating the main switch, connecting the device to the system, simulating a relay run, and seeing the monitoring results on the dashboard. The system also sends data automatically so that users do not need to record it manually.

**Table 3.** Ease of Use Indicator

| Indicator | Average | Percentage | Category |
|---|---|---|---|
| Easy button operation | 4.40 | 88% | Excellent |
| Ease of understanding the procedure of use | 4.30 | 86% | Excellent |
| The system does not interfere with the athlete's concentration | 4.50 | 90% | Excellent |
| Average | 4.40 | 88% | Excellent |

In addition to the user's subjective assessment, the system generates training data that can be used as a basis for performance evaluation. The hardware consists of a Wemos D1 Mini ESP8266, push button, RGB LED, Li-ion battery, SIM800L communication module, main switch, and a 30 cm stick body. Data from the device is sent over the internet network and displayed on a web-based dashboard.

**Table 4.** Parameters Generated by the Monitoring System

| Parameter Monitoring | Data Availability | Function |
|---|---|---|
| The duration of each athlete holding the stick | Available | Evaluating the duration of the stick grip |
| Stick transfer time | Available | Evaluating turnover efficiency |
| The speed of each runner | Available | Monitor sprint performance |
| Total race time | Available | Evaluate overall performance |
| Race status | Available | Monitor the condition of the training process |
| Device status | Available | Monitor system health |

These results show that IoT-Based Relay Sticks not only function as a medium for moving sticks, but also as a medium for collecting performance data in an integrated manner. The system allows training data to be obtained automatically and displayed on the dashboard so that trainers can evaluate based on quantitative information. This provides an advantage over conventional methods that rely more on stopwatches and direct observations.

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**Table 5.** Recapitulation of User Test Results

| Aspects | Evaluation Focus | General Results |
|---|---|---|
| Comfort and design | Size, weight, button position | Positive |
| Ease of use | Operation and understanding of procedures | Positive |
| Benefits of the system | Performance data and dashboards | Very positive |
| Monitoring | Duration, transfer time, speed, total time | Works |
| Conclusion | Acceptance of the device | Good |

Overall, the test results show that IoT-Based Relay Wand has a good acceptance rate. The device is considered comfortable to use, easy to operate, and able to provide more complete performance information than conventional methods. These findings support the use of devices as a monitoring medium in sports science-based athletic coaching. The development of IoT-Based Relay Wand shows that the application of wearable technology and the Internet of Things can improve the quality of relay running practice monitoring. Unlike conventional methods that only produce the total travel time, the developed system is able to display various training parameters in real-time, such as the duration of the stick held by each runner, the time of the stick movement, the speed of each athlete, and the status of the device. The ease of use of the tool is inseparable from the systematic preparation of a manual book. The guide contains an explanation of the device specifications, the functions of each component, usage procedures, dashboard navigation, user safety, to maintenance and troubleshooting steps so that users can operate the tool independently.

These advances are driving the use of a variety of wearable sensors (*wearable sensors*) as a medium for monitoring athletes' performance during training and matches. Wearable sensors offer a non-invasive, portable, and overall convenient way to monitor sports practices (Rum et al. 2021). Wearable devices can be used to monitor a wide variety of biosignals (e.g., heart rate and muscle excitation) and can also track performance (Yang et al. 2024). The participation of wearables in sports has revolutionized the way to capture the kinematic and physiological status of athletes (Liu and Zhang 2022). By providing real-time feedback on physiological thresholds and biomechanical parameters, athletes and coaches can implement evidence-based adjustments that improve training effectiveness and safety (Su, Li, and Su 2025).

The development of wearable sensors has also made a major contribution to the analysis of sports biomechanics. Technologies such as accelerometers, GPS trackers, and force plates provide direct or indirect measurement of an athlete's external and internal training load (Rebelo et al. 2023). Wearables are relatively inexpensive technologies and have a wide range of potential uses, including monitoring arrhythmias and hemodynamic changes, tracking physical activity and calorie expenditure, and providing information about general health and well-being (Rao, Seshadri, and Hsu 2021). One of the most significant advances in biomechanics facilitated by wearable sensors is its ability to enable a data-driven approach, offering a portable and innovative solution (Xiang et al. 2024). With the advent of wearable technology and machine learning approaches, real-time gait monitoring is attracting the interest of the sports biomechanics community (Xiang et al. 2022).

In terms of design, the device still maintains the dimensions of the standard relay stick so that athletes do not experience changes in grip patterns or stick movement techniques. The integration of microcontrollers, buttons, LED indicators, batteries, and communication modules is carried out without compromising the function of the main stick as a relay transfer medium. This is one of the factors that supports the high level of user comfort.

Web-based dashboards also provide added value because all training data is stored automatically and can be used as evaluation material and documentation of athlete performance development. Thus, the trainer not only relies on visual observation, but also obtains more objective quantitative data as a basis for training decision-making. Overall, the test results show that the IoT-Based Relay Stick has a good acceptance rate from users. The device is considered easy to use, comfortable during training, and able to provide more complete performance information than conventional methods, so it has the potential to be a supporting medium for sports science-based athletic training.

The device developed is an Internet of Things (IoT)-Based Relay Stick which functions as a real-time relay running training monitoring media. The system consists of hardware and software that are integrated with each other. The main components of the hardware include a Wemos D1 Mini ESP8266 microcontroller, push button as the stick shift input, RGB LED as the device's status indicator, Li-ion battery as a power source, SIM800L communication module, main switch, and a 30 cm long stick body

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that houses all electronic components. The software is developed using HTML, CSS, JavaScript, PHP, and MySQL integrated in a web-based application. The system dashboard displays information in the form of race status, the duration of each athlete holding the stick, the time of the pole movement, the speed of each runner, the total race time, and the status of the device in real-time.

The working principle of the tool starts when the device is activated via the main switch. Next, the user logs in to the web application and the system will synchronize with the device. When the button on the stick is pressed according to the relay stick transfer process, the data is automatically sent to the server using the internet network. The information is then processed and displayed on the dashboard so that the trainer can monitor and evaluate the exercise directly without manual recording.

## CONCLUSION

This research has resulted in an Internet of Things (IoT)-based relay baton capable of integrating the functions of a relay baton with a digital performance monitoring system. User testing results showed a 90 per cent acceptance rate, categorised as 'very good'. Comfort and design scored 92 per cent, whilst ease of use scored 88 per cent, indicating that the device remains comfortable to use during sprinting and baton handoffs and is easy to operate. The system is also capable of automatically recording and displaying the duration of baton possession, baton handover times, each runner's speed, total race time, race status, and device status via a web-based dashboard. Thus, the device functions not only as a medium for baton handover but also as an integrated, data-driven performance monitoring tool. Overall, the IoT-based Relay Baton is suitable and has the potential to be used as a tool to support the evaluation of relay running training based on sports science, as it enhances the objectivity of performance data collection and monitoring compared to conventional recording methods.

## DECLARATION OF GENERATIVE AI

The authors declare that no generative AI or AI-assisted technologies were used in the writing process of this manuscript.

## CONFLICTING INTEREST STATEMENT

The authors states that there is no conflict of interest in the publication of this article.

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