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# Innovating Badminton Agility Training Through an Integrated Reaction Light and Sensor System: A Systematic Review

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## Abstract

**General Background** Sensor and Internet of Things technologies support data-driven training methodologies in modern sports science. **Specific Background** Badminton demands rapid footwork agility, visual-motor coordination, and fast reaction times to respond dynamically to game stimuli. **Knowledge Gap** Although various technological tools exist, their application remains fragmented across isolated devices without fully unified platforms. **Aims** This study analyzes the utility of sensor technologies and reaction light systems in improving athletes' agility and reaction time through a systematic literature review. **Results** Utilizing the PRISMA methodology across articles published from 2020 to 2026, 15 studies met the inclusion criteria, revealing that wearable sensors, inertial measurement units, reaction lights, and Internet of Things applications significantly improve visual-motor coordination, footwork, and real-timeperformance tracking. **Novelty** The systematic evaluation highlights the necessity of shifting from isolated device applications toward unified, data-driven intelligent training systems for racket sports. **Implications** Integrating these smart technologies provides coaches with objective, real-time diagnostic metrics to optimize athletic performance and program individual development.

## Highlights

- Wearable sensors and inertial measurement units provide objective data for analyzing footwork speed and movement patterns.
- Reaction light systems and visual stimuli significantly improve reactive agility and decision-making capabilities.
- Internet of Things integration facilitates real-time performance monitoring and data-driven training evaluations.

## Keywords

Agility Training; Reaction Time; Sensor Technology; Badminton; Smart Training Systems

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## INTRODUCTION

Advances in sports technology over the past few years have driven a shift in athletes' training methods toward data-driven and digital sensor-based approaches. The introduction of standalone sensors can be used to monitor athletes' movements and identify deficiencies in their training processes [1]. Wearable sensors and AI can collect data from players across skill levels, providing a basis for system development [2]. Real-time image processing of badminton trajectories based on IoT (Internet of Things) machine vision adopts binocular stereo vision technology, fast-moving object recognition, and trajectory prediction [3]. The use of wearable sensors, the Internet of Things (IoT), artificial intelligence (AI), and interactive visual stimuli is beginning to be applied in training processes to enhance the effectiveness of real-time monitoring of athlete performance.

Badminton is a sport that demands speed in movement as well as reaction speed [4]. Footwork agility is the primary foundation of technical performance in badminton [5]. Reaction time significantly influences an athlete's ability to make decisions and respond to game stimuli (Huda et al., 2025). These technological advancements are highly relevant because badminton demands reaction speed, visual-motor coordination, agility, and the ability to change direction rapidly.

Traditional endurance training methods in badminton typically involve on-court drills, shuttle runs, and general cardiovascular exercises [6]. The types of exercises provided to athletes lack variety, and there has been no development of new exercise formats [7]. Reactive agility tests have proven to be more effective and reliable than conventional testing methods for measuring agility [8]. These exercises tend to be monotonous, lack adaptability to game situations, and do not provide random stimuli that mimic actual game conditions. Additionally, athlete performance evaluation is still conducted subjectively based on the coach's visual observations without the support of an objective measurement system.

Stimulus processing, motor response initiation, and reaction time are crucial in badminton, particularly when receiving serves, returning smashes, and making interceptions [9]. Stimulus speed conditions are used to validate results at both slow and fast visual movement speeds [10]. Improving reaction speed is closely related to the game because the visual stimulus during play is the shuttlecock, which players must respond to [11]. This situation results in athletes being under-trained in handling rapid and unexpected stimulus changes during matches. Coaches also face difficulties in accurately monitoring athletes' reaction time, movement speed, and footwork patterns because real-time data is not available during training sessions.

Previous research indicates that the use of sensor technology and reaction light systems can significantly enhance athletic performance. Training with reaction lights improves the footwork agility of athletes aged 10–15 years [12]. Inertial sensors can objectively analyze athletes' movement patterns [13]. Wearable sensors can provide accurate data on activity and movement control during training [14]. However, most previous studies have focused on the use of these technologies separately and have not integrated sensor systems, visual stimuli, and mobile applications into a single connected training platform.

This study aims to examine the effectiveness of using an integrated sensor system in improving badminton athletes' agility and to identify the influence of visual stimulus technology on athletes' reaction time. Additionally, this study identifies trends in sensor-based intelligent training systems and research gaps in the development of technology-integrated badminton agility training.

## METHOD

This study employed a quantitative descriptive SLR to identify, assess, and synthesize research on sensor technology for badminton agility training. A systematic literature review synthesizes previous research to strengthen knowledge on a particular topic [15]. The review involved searching and selecting literature based on keywords and publication years, followed by analysis and synthesis of relevant information [16]. Selection focused on article titles, abstracts, and keywords as key representations of the content [17]. This study employed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) method. Literature selection included national and international articles published from 2020 to 2026, obtained from Scopus, PubMed, Google Scholar, and ScienceDirect. The review focused on agility, reaction time, wearable sensors, and smart training. Articles were screened using the PRISMA approach based on titles, abstracts, and full texts. Since the study did not involve human subjects, ethical approval and informed consent were not required.

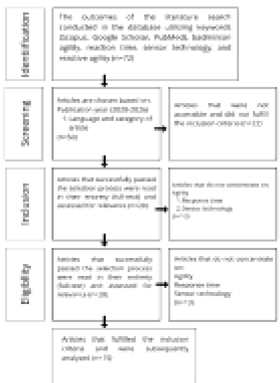


**Figure 1.** *Article Selection Process Using the PRISMA Method*

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Data were analyzed using qualitative descriptive analysis through the processes of article identification, classification of research themes, analysis of research results, synthesis of key findings, and identification of research gaps regarding the use of sensor technology in agility training for badminton athletes.

The study analyzed literature using inclusion-exclusion criteria, focusing on sensors for real-time monitoring of reaction, coordination, and footwork.

## RESULTS AND DISCUSSION

| Year | Number of Articles | Percentage |
|---|---|---|
| 2020 | 2 | 13% |
| 2021 | 2 | 13% |
| 2022 | 3 | 20% |
| 2023 | 3 | 20% |
| 2024 | 3 | 20% |
| 2025 | 1 | 7% |
| 2026 | 1 | 7% |
| Total | 15 | 100% |

**Table 1.** *Trend In The Number of Publications Per Year*

Sensor technology publications in sports increased from 2022 to 2024, reflecting growing interest in smart sports.

| No | Author(s) | Technology/Method | Main Findings |
|---|---|---|---|
| 1. | [18] | Inertial sensors | Sensors objectively analyze footwork speed and movement patterns. |
| 2. | [19] | Footwork training | Footwork evaluation still lacks objective data support. |
| 3. | [20] | Reaction time analysis | Reaction time influences performance and decision-making. |
| 4. | [12] | Reaction light training | Reaction-light training improves footwork agility significantly. |
| 5. | [21] | IoT-based monitoring | IoT enables real-time and data-driven training evaluation. |
| 6. | [2] | Wearable sensors and artificial intelligence (AI) | Wearable sensors integrated with AI objectively monitor athlete movement and performance in real-time. |
| 7. | [22] | Random visual stimulus | Random stimuli improve adaptive response ability. |
| 8. | [23] | Smart racket sensors | Accelerometers identify movement techniques automatically. |
| 9. | [24] | Information technology | Sensors provide biomechanical performance analysis. |
| 10. | [25] | IMU and wearable systems | Wearables analyze movement and playing style in real time. |
| 11. | [26] | LED reaction systems | Sensor-based LED systems reliably measure reaction time. |
| 12. | [27] | FitLight and IMU | Sensor integration improves training effectiveness. |
| 13. | [28] | Game-based training | Game-based training is more effective than conventional methods. |
| 14. | [29] | Autonomous sensors | Sensors help monitor athlete deficiencies during training. |
| 15. | [30] | Wearable sensors and AI | AI-based sensors provide objective athlete performance metrics. |

**Table 2**. *Trend In The Number of Publications Per Year*

Research findings indicate that sensor-based technology can enhance training effectiveness through objective performance measurement, real-time monitoring, improved reaction time, enhanced visual-motor coordination, and data-driven footwork analysis.

Zhang et al. (2023) explain that inertial sensors can record athletes' movement patterns in detail, thereby facilitating the evaluation of footwork technique. Rizki et al. (2024) found that reaction light training improves athletes' change-of-direction speed compared to conventional training. Wang et al. (2023) also explain that wearable sensors can provide real-time biomechanical data, allowing coaches to evaluate training more objectively.

Horvath et al. (2022) showed that light-based visual stimuli improve reactive agility and decision-making, while Han and Wang (2024) demonstrated that biomechanical sensors enhance movement analysis accuracy. Overall, integrating sensors and digital monitoring supports improvements in agility and reaction time in badminton athletes. Agility involves responding quickly to the shuttlecock, anticipating its direction, and executing precise footwork [31], which contributes to competitive performance [32]. Elite athletes possess better anticipatory reaction abilities than novice athletes [33]. Player movement on the field is influenced by coordination between the nervous system, visual perception, and motor skills.

The use of wearable sensors and IMUs offers advantages in objectively measuring the biomechanics of movement. The use of sensors in sports allows for a more detailed analysis of an athlete's movements, enabling coaches to evaluate the quality of the movements performed by the athlete [34]. The integration of 5G IoT and accelerometer sensors enables real-time motion monitoring through high-speed data acquisition [35][36]. This technology helps coaches analyze athletes' footwork, directional changes, reaction time, and movement balance during training.

Visual stimuli based on reaction lights have also been shown to improve athletes' visual-motor coordination and reaction time. This system provides random stimuli that mimic real-game situations, making athletes more adaptable to changes in the direction of play. Technology-based training devices are increasingly being used to enhance the quality of athletes'

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training, one of which is a training device based on light stimuli or reaction lights [37]. Reaction lights clearly fall under the category of perceptual-motor training that simultaneously stimulates the visual, cognitive, and neuromuscular systems [38]. Training programs focused on integrating visual stimuli with motor responses can improve athletes' movement coordination, agility, and technique in team sports [39]. Found a significant improvement in agility footwork after athletes participated in reaction light-based training [12].

The development of the Internet of Things (IoT) in sports also supports the implementation of smart training systems. Training with LED discs (FitLight, ReactionX, BlazePod) places multiple light sources in the training space; athletes must respond to randomly lit lights with specific movements [40]. One innovative method for improving agility is the FitLight Trainer by FITLIGHT Sport Corp [41]. The FitLightTM, BlazePod, and XLiGHT sports training systems were evaluated in terms of usability, features, performance, and diagnostic potential [42]. Exercises using visual stimuli such as the BlazePod can improve athletes' ability to respond to randomly occurring external stimuli [23].

The implementation of wireless sensor networks in badminton training can monitor various athlete data indicators in real-time and make scientific and rational decisions regarding badminton training based on the analysis of these data indicators [43]. By combining advanced sensing, machine learning, and explainable AI, this system sets a new benchmark for smart sports monitoring, with broad applications in sports training [44]. Therefore, reaction time measurements are frequently used in sports research to evaluate the effectiveness of specific training methods [45]. The integration of sensors with mobile applications allows training data to be automatically stored and analyzed directly by coaches. This approach supports the concept of data-driven training, which is gaining traction in modern sports science.

In coaching practice, wireless sensor networks not only function as data-recording tools but also support the design, monitoring, and evaluation of training. Real-time data such as movement speed, reaction time, changes of direction, footwork patterns, and movement balance can help identify athletes' performance characteristics. This information can serve as a basis for coaches to adjust training, for example, by focusing on acceleration and changes of direction when footwork speed is low or using reaction-light training when responses to visual stimuli remain slow. Thus, training can be tailored to the needs of individual athletes.

Wireless sensor networks provide objective data on reaction time, footwork, errors, and response consistency to monitor athletes' progress and adjust training programs. This technology supports a shift toward data-driven coaching, while coaches remain responsible for interpreting results and determining appropriate interventions.

However, most previous studies have taken a fragmented approach, focusing on a single specific technology. Few studies have integrated wearable sensors, visual stimuli, mobile applications, and automated evaluation into a single integrated training system. Therefore, the development of an integrated smart agility training system presents a highly relevant research opportunity for enhancing the effectiveness of modern badminton training.

## CONCLUSION

Based on the systematic review, integrated sensor systems have been shown to improve badminton athletes' agility and reaction time. Wearable sensors, IMUs, reaction lights, and IoT-based visual stimuli enable objective, accurate, and real-time performance measurement.

Integration with mobile applications and digital monitoring also facilitates data-driven evaluation and helps optimize training programs. This study found that most previous studies still utilized technology only partially; therefore, the development of an integrated training system that combines sensors, visual stimuli, and automated evaluation within a single platform is necessary.

Analysis of 15 articles indicates that sensors, IMUs, IoT, mobile applications, and AI support real-time data-driven badminton training by improving reaction, footwork, coordination, and performance evaluation, making training more objective, adaptive, and effective.

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