Smart badminton coaching: development machine learning-based training system for basic badminton technique

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Abstract. Badminton is one of the most popular sports in Indonesia, yet the training of its fundamental techniques has traditionally relied on conventional and subjective methods. To address this limitation, we developed the Shuttle Smart Training Model, a machine learning-based system that integrates an AI-powered shuttle launcher (Shuttle Smart Machine) and a validated measurement tool (Shuttle Smart Test). The system was designed to improve the forehand and backhand clear techniques among athletes aged 15–17 years. Data collection involved expert validation, small and large group trials, and effectiveness testing with experimental and control groups. Results showed that the experimental group significantly improved their performance (post-test mean = 75.21; N-Gain = 56%) compared to the control group (post-test mean = 57.84; N-Gain = 20%). Statistical analysis ($t = 13.087$, $p < 0.001$) confirmed the model's effectiveness. This research demonstrates the novelty of integrating structured drill-based training, AI-assisted devices, and objective testing instruments into a comprehensive badminton training system. The findings highlight the potential of technology-assisted sports coaching to enhance skill acquisition and provide a scalable solution for grassroots development.

1. Introduction

Badminton has long been a sport of national pride in Indonesia. Despite its popularity, the training of fundamental techniques—particularly the forehand clear and backhand clear—remains largely dependent on conventional methods. Such approaches are often limited by subjectivity and lack of objective measurement, which can hinder effective skill development. In response to these challenges, this study introduces the Shuttle Smart Training Model, a training innovation supported by an AI-based shuttle launcher (Shuttle Smart Machine) and an evaluation tool (Shuttle Smart Test). The aim is to enhance the effectiveness, objectivity, and consistency of technical training for youth athletes, particularly in the 15–17 age group. This study addresses the research gap

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by combining structured drill methods with machine learning and sport technology, offering a novel framework for youth badminton training.

Using data from Scopus, Crossref, PubMed, and Web of Science, bibliometric mapping was conducted with Publish or Perish and VOSviewer. Results showed increasing research attention (2023–2024) on the application of machines, robotics, and AI in sports performance and training load. However, integration of these elements within badminton remains limited. This gap provides the basis for the novelty of this study: combining AI-powered devices with structured training models for fundamental badminton skills.

Previous studies highlight the growing use of robotics and AI in training, talent identification, and performance analysis [1-4]. AI-driven training devices have proven effective but often face challenges of cost and practicality [5, 6]. Additionally, most existing systems lack adaptability in training load adjustment, a critical factor for injury prevention. Therefore, the novelty of this study includes:

- Developing a structured drill-based training model for youth athletes (15–17 years).
- Designing a cost-effective AI-based shuttle launcher (Shuttle Smart Machine).
- Creating a standardized testing instrument (Shuttle Smart Test).
- Producing practical outputs: training manuals, international seminar presentations, intellectual property rights (IPR), and Scopus-indexed publications.

2. Research Method

This study adopted a Research and Development (R&D) approach using the Borg & Gall model (1983) [7], which consists of ten systematic steps: (1) research and information collecting, (2) planning, (3) developing preliminary product, (4) preliminary field testing, (5) main product revision, (6) main field testing, (7) operational product revision, (8) operational field testing, (9) final product revision, and (10) dissemination and implementation. The research was conducted between 2023 and 2025 in several badminton clubs in Karawang, Indonesia, including PB Bhinneka, PB Victory, PB Karawang Badminton Academy, PB Putra Mandiri, PB Purnama, and PB Karyamakmur.

Participants included athletes aged 15–17 years: 20 players for small group trials, 80 players for large group trials, 20 players for instrument testing, and 50 players for effectiveness testing. The Shuttle Smart Training Model consisted of three components: (1) Shuttle Smart Training Model (drill-based program), (2) Shuttle Smart Machine (AI-powered shuttle launcher), and (3) Shuttle Smart Test (validated performance measurement tool). Data analysis involved descriptive statistics, normality and homogeneity testing, N-Gain analysis, and independent t-tests using SPSS 23.

The research was conducted from 2023–2025 in six badminton clubs across Karawang, including PB Bhinneka, PB Victory, PB Karawang Badminton Academy, PB Putra Mandiri, PB Purnama, and PB Karyamakmur. This study followed the Borg & Gall

(1983) R&D model, consisting of ten steps: need analysis, planning, product development, small-scale trials, revisions, large-scale trials, operational revisions, effectiveness testing, final revisions, and dissemination [7].

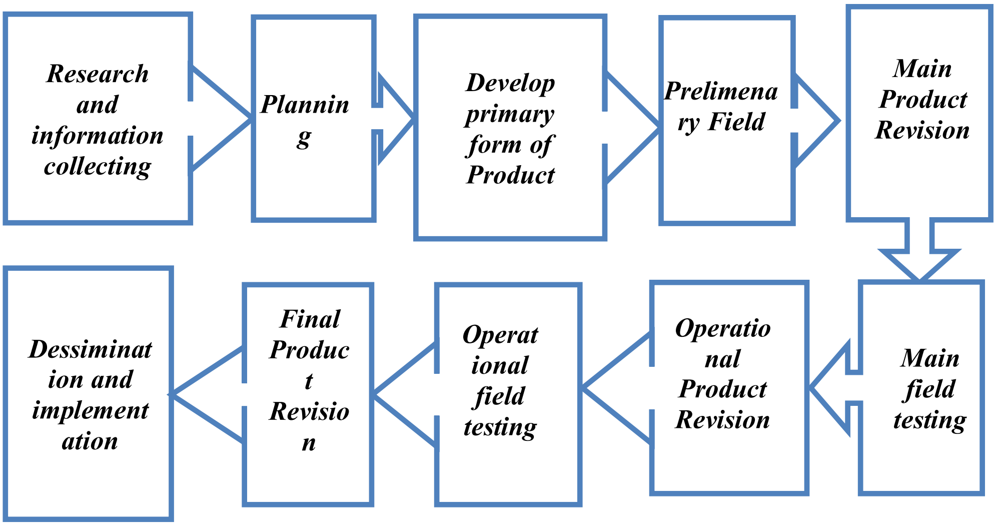

Figure 1. Borg & Gall Development Model
Source: Borg & Gall (1983)

The subject of this experiment:
- Small group trial: 20 athletes (PB Bhinneka).
- Large group trial: 80 athletes (five clubs).
- Instrument testing: 20 athletes (PB Victory).
- Effectiveness test: 50 athletes (PB Karawang Badminton Academy), divided equally into experimental and control groups.

The effectiveness test applied a pretest-posttest control group design. The experimental group trained with the Shuttle Smart Training Model, while the control group followed conventional methods. Both groups were assessed using the Shuttle Smart Test, validated by experts (reliability = 0.912, very good). Data were analyzed using normality and homogeneity tests, N-Gain analysis, and independent sample t-tests with SPSS 23.

3. Results and Discussion

The expert validation confirmed that the Shuttle Smart Training Model, along with its supporting tools, was feasible for use in badminton training. The small and large group trials demonstrated that athletes and coaches accepted the practicality of the model. The effectiveness test showed significant improvements: the experimental group achieved a post-test mean score of 75.21 with an N-Gain of 56% (moderately effective), while the control group only reached a post-test mean of 57.84 with an N-Gain of 20% (not effective). Statistical testing ($t = 13.087$, $p < 0.001$) confirmed the superiority of the model compared to conventional training. These results indicate that integrating AI-assisted devices into structured drill-based training can enhance technical skill acquisition, provide objective assessment, and optimize training load management.

4. Conclusion

This research successfully developed and validated the Shuttle Smart Training Model, supported by the Shuttle Smart Machine and Shuttle Smart Test, to improve fundamental badminton techniques among youth athletes. The findings demonstrated the model's effectiveness in enhancing forehand and backhand clear performance compared to conventional methods. The novelty lies in combining structured drills, AI-powered tools, and validated testing instruments into a comprehensive training system. Future research is recommended to expand the model to other fundamental skills, enhance machine adaptability, and broaden implementation across different age categories and training settings.

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