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Development and validation of an android-based data-driven badminton performance analysis application for beginner athletes

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Abstract

Background: Conventional badminton performance analysis primarily relies on manual observation and recording, making the process time-consuming, subjective, and unable to provide immediate feedback for evidence-based coaching. These limitations reduce the efficiency of training evaluation, particularly for beginner athletes.
Aims: This study aimed to develop and validate an Android-based data-driven badminton performance analysis application featuring real-time tagging and performance visualization to improve the efficiency and objectivity of coaching practices.
Method: A Research and Development (R&D) approach employing the ADDIE model was adopted. The application was validated by three experts in badminton, educational technology, and sports coaching, followed by field testing involving 30 beginner badminton athletes. User acceptance was evaluated using the Technology Acceptance Model (TAM), while effectiveness was determined by comparing application-based and conventional performance analysis methods.
Results: The application achieved excellent validity with an expert agreement score of 1.00 and a reliability coefficient of 1.000. Field testing revealed a significant improvement in performance analysis compared with conventional methods ($t = 51.95 > 2.00$), indicating greater efficiency, objectivity, and accuracy in processing performance data.
Conclusion: The developed application is highly valid, practical, and effective, providing an accessible digital solution that supports objective, data-driven badminton performance analysis for beginner athletes.

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INTRODUCTION

The rapid advancement of digital technology has fundamentally transformed the landscape of sports science by enabling the systematic collection, processing, and interpretation of performance data to support evidence-based decision-making in athlete development. Contemporary sports performance analysis increasingly relies on computational approaches that convert large volumes of observational data into meaningful information for evaluating technical, tactical, physical, and psychological performance (Cossich et al., 2023; Davis et al., 2024; Jia et al., 2025; Lutz et al., 2019). The emergence of sports analytics has further strengthened the integration of data-driven methodologies into coaching practices by facilitating objective performance assessment and continuous athlete monitoring. These developments have shifted coaching paradigms from

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experience-based judgment toward analytical decision-making supported by quantitative performance indicators. Mobile computing technologies have accelerated this transformation by providing portable platforms capable of recording, organizing, and visualizing performance information in real time (Dubuc et al., 2021; Q. Liu et al., 2021; Suo et al., 2023). As a result, coaches are increasingly able to obtain immediate feedback that supports timely instructional adjustments and individualized training strategies. Such technological innovations have also improved the accessibility of digital performance analysis by reducing dependence on sophisticated laboratory equipment and desktop-based analytical systems. Within racket sports, particularly badminton, the ability to capture performance data during training and competition has become increasingly important because match outcomes are strongly influenced by technical execution, tactical decision-making, movement efficiency, and consistency under dynamic playing conditions (Edmizal et al., 2024; Sheng et al., 2025). Consequently, integrating digital technologies into badminton performance analysis has become an essential component of modern coaching systems that emphasize accuracy, efficiency, and evidence-based evaluation. These developments demonstrate that data-driven performance analysis has evolved into a strategic instrument for improving coaching quality and optimizing athlete performance across different levels of competition.

Despite substantial progress in sports analytics, the implementation of digital performance analysis in badminton coaching remains uneven, particularly in beginner development programs and community-based training environments. Many coaches continue to evaluate athlete performance through handwritten notes, direct observation, and subjective recall because accessible digital analytical tools are still limited. These conventional approaches often require considerable time, are susceptible to observer bias, and provide only fragmented information regarding athletes' technical and tactical performance (Afonso et al., 2025; Ashford et al., 2021; Biró et al., 2023; Lutz et al., 2019). Furthermore, manually recorded data are difficult to organize into structured datasets that support longitudinal monitoring and comprehensive performance evaluation. The absence of dedicated badminton performance analysis applications also limits coaches' ability to quantify essential performance indicators, including stroke frequency, shot accuracy, movement patterns, and rally characteristics during training sessions (Ghosh et al., 2022; T. Lin et al., 2024; Pang & Jiang, 2026). Without systematic quantitative analysis, coaching decisions frequently rely on subjective interpretation rather than objective evidence derived from measurable performance metrics. Although several commercial sports analysis platforms offer advanced analytical capabilities, their high implementation costs, licensing requirements, and technical complexity restrict their adoption among local badminton clubs and beginner coaching programs (Chen & Zheng, 2025; Seong et al., 2024; Zhou et al., 2025). This technological disparity creates unequal opportunities for athletes to benefit from evidence-based coaching supported by digital performance analytics. Consequently, beginner athletes often receive less comprehensive performance evaluation than athletes trained within technologically advanced environments. Addressing these limitations requires the development of affordable, practical, and user-friendly digital systems capable of supporting objective badminton performance analysis without imposing substantial financial or technical barriers.

The widespread availability of Android-based mobile devices provides a promising technological foundation for developing accessible performance analysis systems that support data-driven badminton coaching. Android offers an open, flexible, and cost-effective computing platform that enables real-time performance recording, automated data processing, interactive visualization, and database management through portable mobile applications (Dahunsi et al., 2021; Huynh et al., 2023; Palekar et al., 2025; Thai et al., 2024). Integrating these capabilities into badminton coaching allows technical performance indicators to be recorded directly during training and competition

while minimizing the limitations associated with manual observation (Chen & Zheng, 2025; Ghosh et al., 2022; Jia et al., 2025). Automated visualization of performance metrics further assists coaches in identifying strengths, weaknesses, and performance trends more efficiently than conventional recording methods. The availability of objective digital performance reports also supports individualized training program design by enabling evidence-based evaluation of athletes' developmental progress. Moreover, systematic digital data storage facilitates continuous performance monitoring and simplifies longitudinal comparisons across multiple training sessions. Such integration of mobile technology and sports analytics contributes to more transparent, consistent, and reliable coaching practices that emphasize objective performance measurement rather than subjective judgment (Cossich et al., 2023; Lutz et al., 2019; Mănescu, 2025; Souaifi et al., 2025). From a broader perspective, affordable mobile-based analytical systems can reduce technological inequalities by extending access to computational performance analysis beyond elite sports organizations. This approach not only strengthens the application of data-driven methodologies within badminton coaching but also supports the broader digital transformation of sports education and athlete development. Therefore, developing an Android-based data-driven badminton performance analysis application represents a scientifically relevant effort to improve the accessibility, objectivity, and effectiveness of performance evaluation for beginner badminton athletes.

Although recent studies have substantially advanced sports performance analysis through the integration of big data analytics, artificial intelligence, wearable sensing technologies, predictive modeling, and sports analytics to support performance optimization and evidence-based decision-making, their primary emphasis remains on elite athlete evaluation, computational modeling, tactical analysis, and sophisticated analytical frameworks rather than practical coaching applications (Chmait & Westerbeek, 2021; Ghosh et al., 2023; Mănescu, 2025). Similarly, recent badminton studies have predominantly investigated tactical patterns, match dynamics, biomechanical datasets, scoring behavior, and performance indicators using advanced analytical methods, network science, wearable sensors, and predictive analytics, providing valuable theoretical insights into badminton performance but offering limited support for practical performance monitoring in everyday coaching environments (Edmizal et al., 2024; Gómez et al., 2021; Hammes & Link, 2024; Seong et al., 2024). Furthermore, although mobile technologies have been increasingly adopted in sports and physical activity, most existing applications focus on physical activity promotion, athlete monitoring, or general sports participation rather than providing an integrated mobile system for badminton-specific performance analysis with real-time recording and automated visualization (Perez-Aranda et al., 2021; Pradal-Cano et al., 2020). Consequently, there remains a significant research gap in developing an affordable, data-driven, Android-based badminton performance analysis application that combines real-time tagging, automated performance visualization, and systematic user validation to support objective coaching and evidence-based decision-making for beginner athletes. This study addresses this gap by developing and validating an Android-based data-driven badminton performance analysis application using the ADDIE development model and the Technology Acceptance Model (TAM), thereby providing an accessible digital coaching solution specifically designed for beginner badminton athletes.

Considering the continuing reliance on conventional performance evaluation methods and the limited availability of affordable digital solutions for beginner badminton coaching, this study aimed to develop and validate an Android-based data-driven badminton performance analysis application to support objective and efficient coaching practices. The application was designed to facilitate real-time recording of technical performance indicators through an intuitive mobile interface that can be easily operated by coaches and athletes. It also integrates automated

performance visualization to transform raw observational data into meaningful analytical information that supports evidence-based decision-making. The development process followed a systematic research and development framework to ensure that the resulting application met appropriate standards of functionality, usability, and educational relevance. Product quality was examined through expert validation involving specialists in badminton, educational technology, and sports coaching. The practicality of the application was subsequently evaluated through user acceptance testing involving beginner badminton athletes using the Technology Acceptance Model. In addition, the effectiveness of the application was assessed by comparing its performance analysis capability with conventional manual recording methods. Through this comprehensive evaluation process, the study sought to determine whether the developed application could improve the efficiency, objectivity, and accessibility of badminton performance analysis. The findings are expected to contribute to the advancement of technology-assisted sports coaching by providing an affordable digital solution that supports data-driven coaching practices in beginner badminton development.

LITERATURE REVIEW

Developing educational and technological products requires a systematic framework that ensures the resulting innovation addresses users' needs while maintaining scientific rigor throughout the development process. Researchers widely adopt research and development approaches because these approaches enable them to design, refine, validate, and evaluate products through iterative procedures before broader implementation (Duarte et al., 2025; McKenney & Reeves, 2021; Moore et al., 2024). Among various development frameworks, the ADDIE model provides a structured process that guides developers from identifying problems to evaluating the effectiveness of the final product. The model organizes development activities into the sequential phases of analysis, design, development, implementation, and evaluation, allowing each phase to inform improvements in the subsequent stage. Developers frequently select this framework because its systematic yet flexible structure accommodates continuous revisions according to empirical findings obtained during product development. The analysis phase identifies user characteristics, contextual problems, and functional requirements that become the foundation for determining appropriate design specifications. The design and development phases subsequently transform these specifications into functional prototypes while integrating technological, pedagogical, and usability considerations into a coherent product architecture (J. Lin et al., 2024; Mata et al., 2026; Nazlidou et al., 2024; Sadri, 2025; Xu et al., 2024). Developers then implement the prototype within authentic user environments to examine its practicality and identify potential improvements before wider deployment. The final evaluation phase examines whether the developed product achieves acceptable levels of validity, practicality, and effectiveness while providing meaningful solutions to previously identified problems. Consequently, the ADDIE model offers a comprehensive methodological foundation for developing digital applications that integrate technological innovation with empirical validation to produce reliable and user-oriented products.

Building upon this systematic development framework, software applications have become increasingly important instruments for transforming raw information into meaningful knowledge that supports efficient decision-making across numerous professional fields. Developers design software applications to process user inputs, manage digital data, execute computational procedures, and generate outputs that address specific operational objectives. Modern application development therefore emphasizes not only functional performance but also reliability, usability, maintainability, and compatibility with users' working environments (Arshad et al., 2025; Ntoa, 2025). These quality

attributes determine whether an application can effectively support users in completing tasks accurately, efficiently, and consistently under real operational conditions. Developers also prioritize intuitive interface design because users are more likely to adopt systems that present information clearly and simplify operational procedures. Effective interface design minimizes cognitive load, reduces operational errors, and improves user satisfaction by enabling users to understand application workflows without extensive technical training. Furthermore, integrating structured database management allows applications to organize, retrieve, and process historical information efficiently, thereby supporting long-term monitoring and analytical decision-making (Anthony Jnr et al., 2020; Ionescu & Diaconita, 2023; Theodorakopoulos et al., 2024). As digital technologies continue to evolve, software applications increasingly incorporate interactive visualization features that transform complex datasets into understandable graphical representations for end users (Shakeel et al., 2022; Shen et al., 2023). These capabilities make digital applications particularly valuable in environments that require rapid interpretation of quantitative information, including sports performance evaluation and coaching activities. Therefore, developing a high-quality sports performance analysis application requires integrating systematic software engineering principles with user-centered design to ensure that the resulting system functions effectively while remaining practical and accessible for its intended users.

As software applications continue to evolve, researchers and coaches increasingly integrate digital technologies into sports performance analysis to improve the objectivity and efficiency of athlete evaluation. Sports performance analysis systematically collects, records, processes, and interprets performance data to produce meaningful information that supports coaching decisions (Davis et al., 2024; Goes et al., 2021; Mateus et al., 2024; van den Berg et al., 2020). Rather than depending exclusively on subjective observation, coaches increasingly utilize quantitative performance indicators to evaluate technical execution, tactical behavior, movement efficiency, and competitive consistency. This analytical approach enables coaches to identify performance strengths and weaknesses more accurately while monitoring athletes' developmental progress across multiple training sessions. In badminton, performance analysis plays a particularly important role because the sport requires players to execute rapid technical movements, tactical adaptations, and precise decision-making within continuously changing game situations (Chen & Zheng, 2025; Edmizal et al., 2024; Feng & Liu, 2025). Coaches therefore evaluate various technical indicators, including stroke accuracy, service quality, smash effectiveness, drop shot execution, net play, footwork efficiency, rally characteristics, and error frequency to understand overall athlete performance. These measurable indicators provide valuable evidence for designing individualized training programs that address specific technical deficiencies while reinforcing existing strengths. Furthermore, systematic performance analysis supports continuous athlete monitoring by producing objective datasets that allow coaches to evaluate improvement trends over time rather than relying solely on isolated observations (Cossich et al., 2023; Lutz et al., 2019; Madrigal-Cerezo et al., 2026; Mănescu, 2025). The growing adoption of sports analytics has further strengthened this process by integrating computational techniques that transform raw performance data into actionable coaching information through statistical analysis and visual interpretation. Consequently, sports performance analysis has become an essential scientific component of contemporary badminton coaching because it enables evidence-based decision-making supported by objective and measurable performance data.

The increasing availability of digital performance data has simultaneously accelerated the development of data-driven coaching approaches that emphasize analytical decision-making throughout the athlete development process. Data-driven coaching encourages coaches to formulate training strategies based on systematically collected performance evidence rather than depending

primarily on personal experience or intuitive judgment (Decabooter et al., 2024; Madrigal-Cerezo et al., 2026; Todorovich, 2026). This approach combines sports science, data analytics, and computational technologies to generate comprehensive performance profiles that support more accurate coaching interventions. Advances in database technology, statistical computing, and interactive visualization have enabled coaches to process increasingly complex datasets while presenting analytical results in forms that are easier to interpret during practical coaching activities (Cossich et al., 2023; Jin & Zhan, 2024; T. Lin et al., 2024; Mănescu, 2025; Salim et al., 2024). Interactive dashboards, graphical summaries, and automated statistical reports allow coaches to recognize performance trends rapidly and adjust training programs according to athletes' current developmental needs. The integration of objective performance metrics also improves evaluation consistency by reducing observer bias and increasing the reliability of coaching decisions across different evaluators and training sessions. Furthermore, longitudinal performance databases facilitate continuous monitoring of athlete progression and provide evidence for evaluating the effectiveness of specific training interventions over extended periods. These analytical capabilities contribute to more transparent, accountable, and evidence-based coaching systems that support sustainable athlete development. As sports organizations increasingly adopt digital transformation strategies, data-driven coaching has emerged as an important foundation for improving coaching quality, competitive performance, and organizational decision-making within modern sports environments. Therefore, integrating sports analytics into a mobile performance analysis application represents a logical advancement that combines computational technology with practical coaching needs to support objective badminton performance evaluation for beginner athletes.

The preceding literature demonstrates that advances in software engineering, mobile computing, sports analytics, and data-driven coaching have substantially expanded opportunities for improving athlete performance evaluation through digital technologies. Nevertheless, existing technological developments have primarily concentrated on elite sports environments, sophisticated analytical platforms, and computational systems that often require substantial financial resources and advanced technical expertise (Ghosh et al., 2023; Sadri, 2025; Zhao et al., 2025). Consequently, beginner badminton coaches and community-based training programs continue to experience limited access to affordable digital tools capable of supporting objective and systematic performance analysis. Existing studies have also tended to examine application development, performance analysis, sports analytics, mobile technologies, and technology acceptance as separate research domains rather than integrating them into a unified coaching support system. This separation reduces the practical value of current technologies because coaches frequently require a single platform that combines real-time data collection, structured database management, automated performance visualization, and user-friendly operation within everyday training environments. Integrating these capabilities into an Android-based application would enable coaches to collect technical performance data efficiently while simultaneously transforming raw observations into meaningful analytical information that supports evidence-based coaching decisions (Loumakou et al., 2026; Purwanto et al., 2026; Roussou et al., 2023). Such integration would also strengthen the implementation of data-driven coaching by providing objective performance metrics that facilitate continuous athlete monitoring and individualized training program development. Furthermore, validating the developed application through expert assessment, user acceptance evaluation, and effectiveness testing would ensure that the resulting technology satisfies scientific standards while remaining practical for real-world coaching applications. Therefore, developing an Android-based data-driven badminton performance analysis application represents an important contribution to the intersection of sports science, mobile computing, educational technology, and computational performance analytics by addressing both technological and practical challenges encountered in

beginner athlete development. Based on this conceptual foundation, the present study develops and validates an Android-based data-driven badminton performance analysis application designed to provide an accessible, objective, and efficient digital solution for supporting performance evaluation and evidence-based coaching among beginner badminton athletes.

METHOD

Research Design

This study employed a Research and Development (R&D) design to develop and validate an Android-based data-driven badminton performance analysis application for beginner athletes. The research adopted the ADDIE (Analysis, Design, Development, Implementation, and Evaluation) development model because it provides a systematic, iterative, and user-centered framework for developing technology-based applications. The model facilitated continuous refinement by integrating needs assessment, software development, expert validation, field implementation, and product evaluation into a structured development cycle. During the analysis stage, the researchers identified limitations associated with conventional badminton performance analysis through literature review, field observations, and interviews with coaches and athletes. The findings obtained during this stage established the functional requirements and analytical specifications of the application. The design stage translated these requirements into system architecture, database structures, user interface layouts, navigation systems, and performance analysis workflows. Subsequently, the development stage transformed the design specifications into a functional Android application by integrating performance recording modules, database management, graphical visualization, and interactive user interfaces. The implementation stage involved limited field trials under authentic badminton training conditions to evaluate the application's operational performance and usability. Finally, the evaluation stage assessed the application's validity, practicality, user acceptance, and initial effectiveness before producing the final product. The overall research procedure based on the ADDIE development model is illustrated in **Figure 1**.

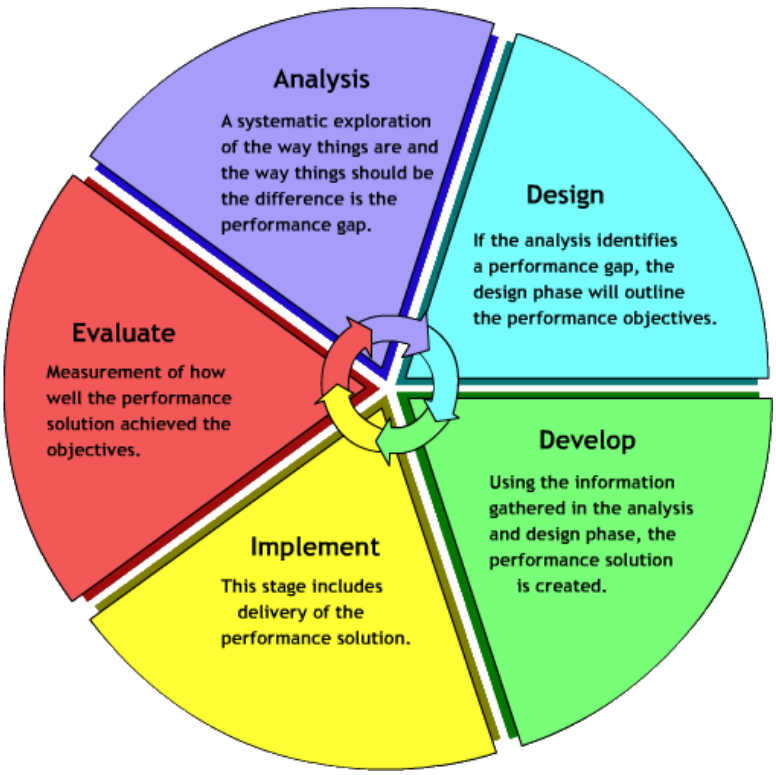

Figure 1. Research Procedure Based on the ADDIE Development Model

Participants

The study involved two groups of participants representing both product evaluators and prospective end users. The first group consisted of three experts who participated in the product validation stage, including one badminton expert with professional coaching experience, one educational technology expert specializing in instructional media development, and one sports coaching expert with more than five years of coaching experience. These experts evaluated the application in terms of content accuracy, software functionality, interface design, analytical features, usability, and overall feasibility. Their recommendations were subsequently used to revise and improve the application before field implementation. The second group consisted of 30 beginner badminton athletes aged between 13 and 14 years recruited from local badminton clubs in Padang City and surrounding areas. These athletes represented the intended users of the developed application because they regularly participated in structured beginner-level badminton training. Participants were selected using purposive sampling to ensure that they met the predetermined inclusion criteria and represented the characteristics of the target users. Coaches supervising these athletes also participated during the implementation stage by operating the application and providing practical feedback regarding its functionality during coaching activities. The combination of expert validators, coaches, and athletes enabled comprehensive evaluation from scientific, technological, and practical perspectives.

Instruments and Data Collection

The researchers employed multiple research instruments to evaluate different aspects of the developed application throughout the development process. Expert validation questionnaires were used to assess content quality, interface design, software functionality, analytical features, usability, and overall product feasibility. The validation instrument employed a five-point Likert scale ranging from one (very invalid) to five (very valid). Product practicality and user acceptance were measured using a structured questionnaire based on the Technology Acceptance Model (TAM). The questionnaire also employed a five-point Likert scale and evaluated perceived usefulness, perceived ease of use, operational convenience, interface clarity, and users' overall acceptance of the application. To evaluate the application's initial effectiveness, the researchers compared Android-based performance analysis with conventional manual recording methods. The effectiveness assessment focused on two principal indicators, namely data processing efficiency and the objectivity of performance analysis. In addition, structured observations documented user interactions, application stability, operational challenges, and implementation fidelity during badminton training sessions. Semi-structured interviews with coaches complemented the quantitative findings by identifying practical strengths and limitations encountered during application use. Simultaneously, the application automatically stored performance records in an integrated database, enabling subsequent statistical analysis and performance visualization. The integration of questionnaires, observations, interviews, and application-generated data provided comprehensive evidence regarding the application's validity, practicality, usability, and initial effectiveness.

Data Analysis

The researchers analyzed quantitative and qualitative data according to the objectives of each evaluation stage. Expert validation data were analyzed descriptively by calculating the percentage of agreement among validators to determine the overall level of product validity. The validation results were subsequently interpreted using predetermined feasibility criteria to determine whether revisions were required before implementation. Practicality data obtained from the Technology Acceptance Model questionnaire were analyzed descriptively by calculating the mean score and percentage of each assessment indicator. The resulting scores were interpreted

according to established practicality categories to determine users' acceptance of the application. Initial effectiveness was evaluated by comparing the time required to complete badminton performance analysis using the Android application and conventional manual recording methods. The comparison also examined the objectivity and consistency of analytical results generated by both approaches. Qualitative data obtained from observations and interviews were analyzed thematically to identify users' experiences, operational strengths, and areas requiring further improvement. Finally, the researchers integrated all quantitative and qualitative findings to produce a comprehensive evaluation of the application's overall performance and determine the final revisions before product completion.

Research Procedure

The research procedure followed the five sequential phases of the ADDIE development model over a six-month development period. During the analysis phase, the researchers conducted literature reviews, field observations, and interviews with badminton coaches and athletes to identify existing problems associated with conventional performance analysis and determine user requirements. Based on these findings, the design phase focused on developing the application architecture, including system workflows, database structures, navigation systems, user interfaces, coding templates, and performance visualization components. During the development phase, the researchers programmed the Android application by integrating performance recording modules, database management systems, statistical visualization, and interactive reporting features into a functional software platform. The completed prototype subsequently underwent expert validation, after which the researchers revised the application according to the recommendations provided by the validators. The implementation phase involved limited field trials with beginner badminton athletes and coaches who received brief training before using the application during regular badminton practice sessions. Throughout implementation, the researchers collected expert validation data, user practicality responses, observational records, interview data, and application-generated performance records. The evaluation phase consisted of continuous formative evaluation during every development stage, followed by summative evaluation examining product validity, practicality, user acceptance, and initial effectiveness. The researchers analyzed the evaluation results to identify strengths and remaining limitations before conducting the final product revision. Ultimately, this systematic development procedure produced an Android-based data-driven badminton performance analysis application that satisfied scientific, technological, and practical requirements for supporting objective, efficient, and evidence-based badminton coaching among beginner athletes.

RESULTS AND DISCUSSION

Results

Product Validation

The Android-based data-driven badminton performance analysis application underwent expert validation before field implementation to determine its content validity, technical feasibility, and suitability for practical use in badminton coaching. Three experts representing complementary areas of expertise participated in the validation process, including a badminton specialist, an educational technology specialist, and a sports coaching specialist. Each expert independently evaluated the application based on predefined assessment criteria covering content accuracy, software functionality, interface design, analytical features, and overall usability. The validation results demonstrated excellent agreement among all validators, indicating that the developed

application satisfied the expected quality standards. All experts assigned identical validation scores, resulting in an agreement coefficient of 1.00, which corresponds to the Highly Valid category. Furthermore, reliability analysis produced a coefficient of 1.000, indicating perfect consistency among expert evaluations. Overall, the experts concluded that the application was suitable for field implementation with only minor revisions related to improvements in the user interface layout. These revisions primarily concerned visual presentation and did not affect the application's analytical functions or operational performance. Therefore, the application fulfilled the required validity and reliability criteria before proceeding to the implementation stage.

Table 1. Expert Validation Results of the Android-Based Badminton Performance Analysis Application

Validator	Area of Expertise	Validation Score	Category
Expert 1	Badminton Material	1.00	Highly Valid
Expert 2	Media and Educational Technology	1.00	Highly Valid
Expert 3	Sports Coaching	1.00	Highly Valid
Average	—	**1.00**	**Highly Valid**
Reliability Coefficient	—	**1.000**	**Very High Reliabilit**

The expert validation findings indicate that the developed application satisfies the required standards for content quality, software functionality, interface design, and analytical capability. Consequently, the application was considered feasible for implementation in beginner badminton coaching environments.

Field Implementation and Initial Effectiveness

Following expert validation, the revised application was implemented during field testing involving 30 beginner badminton athletes. The implementation stage aimed to evaluate the application's initial effectiveness by comparing Android-based performance analysis with conventional manual performance recording methods. During field implementation, coaches utilized the application to record badminton performance data while simultaneously conducting conventional manual observations for comparison purposes. The comparison focused on the efficiency of data processing and the objectivity of the resulting performance analysis. Statistical analysis revealed a substantial difference between the two performance analysis approaches. The experimental group that utilized the Android-based application achieved a calculated t-value of 51.95, which greatly exceeded the critical t-table value of 2.00. These findings indicate a statistically significant difference between the experimental and control groups. The results demonstrate that the Android-based application produced superior performance analysis outcomes compared with conventional manual recording. The application also enabled coaches to complete performance recording and data processing more efficiently while generating more objective analytical information for evaluating athlete performance. Collectively, these findings provide empirical evidence that the developed application effectively supports data-driven badminton performance analysis during beginner-level coaching activities.

Table 2. Comparison of Performance Analysis Results Between the Experimental and Control Groups

Variable	Experimental Group (Android Application)	Control Group (Manual Recording)
Performance Analysis Method	Android-Based Application	Conventional Recording
Calculated *t*-value	**51.95**	—
Critical *t*-value	**2.00**	—
Statistical Decision	**tcalculated > ttable**	—

Interpretation	Significant Difference	—

The comparison demonstrates that the Android-based badminton performance analysis application significantly improved the efficiency and objectivity of performance analysis compared with conventional recording methods. These findings support the feasibility of implementing the developed application as a practical digital tool for evidence-based badminton coaching among beginner athletes.

Discussion

The findings of this study demonstrate that the Android-based data-driven badminton performance analysis application achieved an excellent level of validity before being implemented in real coaching environments. The unanimous validation score of 1.00 obtained from the badminton expert, educational technology expert, and sports coaching expert indicates that the developed application successfully fulfilled the expected standards in terms of content accuracy, software functionality, interface quality, and practical feasibility. Such unanimous agreement among experts is relatively uncommon in educational technology development and reflects the consistency of the application's design with the intended objectives of badminton performance analysis. The perfect reliability coefficient (1.000) further indicates that the assessment instrument generated highly consistent evaluations across different expert perspectives. This consistency suggests that the application's design integrates technical, pedagogical, and sport-specific components into a coherent analytical system capable of supporting evidence-based coaching practices (Dergaa et al., 2026; Park & Ha, 2026; Smith et al., 2023; Todorovich, 2026). The validation results also imply that the development process successfully translated user needs identified during the analysis stage into software features that met expert expectations. From a software development perspective, the iterative nature of the ADDIE model likely contributed to this outcome by allowing continuous refinement throughout successive development stages. Similar findings have been reported in previous studies on educational and sports technology applications, where systematic development frameworks have consistently produced highly valid digital products before implementation (Chugh et al., 2023; Martín-Rodríguez & Madrigal-Cerezo, 2025; Mohammadi et al., 2023; Müller & Wagner, 2026; Susilawati et al., 2025). Previous research has likewise emphasized that expert validation is an essential quality assurance mechanism because it minimizes technical deficiencies before field testing and increases the likelihood of successful implementation in authentic learning or coaching environments. Therefore, the excellent validation outcomes obtained in this study provide strong empirical evidence that the developed application possesses adequate scientific and technical quality to support beginner badminton coaching.

The implementation results further revealed that the Android-based application produced significantly better outcomes than conventional performance recording methods, as demonstrated by the calculated *t*-value of 51.95, which substantially exceeded the critical *t*-table value of 2.00. This finding indicates that integrating digital technology into badminton performance analysis can substantially improve the quality of coaching support compared with traditional manual observation methods. Conventional recording generally depends on handwritten notes and subjective observations, making it difficult for coaches to document large amounts of performance information accurately during fast-paced badminton matches. In contrast, the developed application enables systematic recording, organized data management, and immediate retrieval of athlete performance information, thereby reducing the possibility of recording errors and increasing analytical efficiency. The superiority of the Android-based system observed in this study is consistent with the broader transition toward data-driven decision-making in sport, where digital technologies increasingly assist coaches in evaluating athlete performance objectively. Sports analytics has become an

important component of contemporary coaching because quantitative performance information enables coaches to identify strengths, weaknesses, and tactical patterns more accurately than subjective observation alone. The present findings therefore reinforce previous studies reporting that mobile applications and digital performance analysis systems contribute positively to coaching effectiveness by providing timely, accurate, and structured information for decision making (Cosa & Torelli, 2024; Cossich et al., 2023; Nascimento et al., 2023; Rivera et al., 2021). Furthermore, Android-based platforms offer practical advantages because of their portability, accessibility, and relatively low implementation costs, allowing digital coaching technologies to be adopted in various training environments. These characteristics are particularly important for beginner athlete development, where coaches frequently require efficient monitoring tools without relying on expensive commercial performance analysis systems. Consequently, the significant difference observed between the experimental and control groups suggests that the developed application represents a practical technological innovation capable of improving the effectiveness of beginner badminton coaching.

Another important finding concerns the successful integration of sports science, educational technology, and mobile computing within a single analytical platform designed specifically for badminton performance evaluation. Rather than functioning merely as a digital recording tool, the application was designed to facilitate systematic data collection and objective performance analysis that can support evidence-based coaching decisions. This integration reflects the growing recognition that digital technologies should not simply replace conventional documentation but should also transform raw performance data into meaningful information that assists coaches during training evaluation. The positive outcomes obtained in this study indicate that the application successfully fulfilled this broader analytical function while maintaining operational simplicity suitable for beginner coaching environments. The findings also support current perspectives emphasizing that digital transformation in sport should focus on improving coaching quality through objective performance measurement rather than solely introducing new technological devices (Glebova et al., 2025; Luczak et al., 2020; Lutz et al., 2019; Qi et al., 2024). Similar conclusions have been reported in previous investigations showing that sports analytics applications improve coaching quality when technological innovation is aligned with practical coaching requirements and user-centered system design (Dindorf et al., 2025; Yang & Wang, 2025). Moreover, integrating performance recording with structured analytical outputs enables coaches to monitor athlete development more consistently across successive training sessions, thereby supporting long-term athlete development strategies. The present study therefore contributes to the growing body of literature demonstrating that mobile technologies can strengthen evidence-based coaching by increasing the availability, accuracy, and usability of performance information during routine practice. Although this study focused specifically on beginner badminton athletes, the development framework adopted here has the potential to be adapted for other sports requiring objective performance monitoring through mobile-based analytical systems. Accordingly, the developed application represents not only a technological product but also an example of how interdisciplinary collaboration between sports science and information technology can contribute to the modernization of coaching practice.

The effectiveness demonstrated by the developed application also highlights the importance of integrating mobile technology into the coaching process to improve both analytical efficiency and decision-making quality. The significant difference identified between the experimental and control groups indicates that digitalization can reduce the limitations commonly associated with conventional performance evaluation methods, particularly those related to recording accuracy, information management, and analytical consistency. Traditional coaching practices frequently rely

on manual observation and handwritten notes, which are vulnerable to human error and often fail to capture detailed performance indicators during high-intensity training sessions. By contrast, Android-based applications enable coaches to document performance data systematically while simultaneously organizing the collected information into structured records that are readily available for subsequent analysis. This capability supports more objective coaching decisions because athlete evaluation is based on measurable performance indicators rather than solely on subjective impressions. Previous investigations have similarly reported that digital sports applications contribute to greater coaching precision by facilitating continuous monitoring and longitudinal evaluation of athlete development (Liang et al., 2025; S. Liu et al., 2024; Madrigal-Cerezo et al., 2026; Sédiri et al., 2026). Furthermore, mobile technologies provide coaches with immediate access to historical performance data, allowing them to compare athlete progress across multiple training sessions and identify developmental trends more effectively. Such continuous monitoring is particularly valuable for beginner athletes because their technical skills typically improve progressively and require regular evaluation to ensure that coaching interventions remain appropriate. The present findings therefore support the growing body of evidence suggesting that sports analytics applications can improve coaching quality by transforming large volumes of performance data into meaningful information that assists instructional planning and performance evaluation (Cossich et al., 2023; Lutz et al., 2019; Mănescu, 2025; Souaifi et al., 2025). Consequently, the Android-based badminton performance analysis application developed in this study represents a practical technological solution capable of strengthening evidence-based coaching through more efficient, objective, and systematic performance assessment.

Beyond its practical contribution, this study also provides theoretical implications regarding the integration of sports science and digital technology within contemporary coaching practice. The successful development and validation of the application demonstrate that interdisciplinary collaboration between sports coaching, educational technology, and software engineering can produce innovative tools capable of addressing practical challenges encountered during athlete development. The findings reinforce the view that technological innovation should be designed not merely to digitize existing coaching procedures but to enhance the quality of performance analysis through systematic data management and objective evaluation (Cosa & Torelli, 2024; Cossich et al., 2023; Dias et al., 2021). This perspective is consistent with recent developments in sports analytics, which emphasize that coaching effectiveness increasingly depends on the ability to transform performance data into actionable knowledge for improving athlete performance. The present study contributes to this growing field by providing empirical evidence that a mobile-based analytical application can satisfy expert quality standards while simultaneously demonstrating superior effectiveness compared with conventional recording approaches. Unlike many digital coaching tools that primarily emphasize performance documentation, the developed application integrates data collection, performance recording, and analytical support within a single operational platform, thereby increasing its practical usefulness during routine coaching activities. The combination of high expert validity, excellent reliability, and significant implementation outcomes further indicates that the application possesses both scientific credibility and practical applicability for beginner badminton coaching. Although this research focused specifically on badminton, the systematic development framework employed in this study offers opportunities for adaptation to other sports requiring objective performance monitoring and data-driven coaching support. Future technological developments may further expand the application's analytical capabilities by incorporating automated performance tracking, artificial intelligence, or real-time statistical visualization to support more comprehensive coaching decisions. Overall, the findings of this study strengthen the growing consensus that mobile-based sports analytics applications constitute an important

component of modern coaching systems by promoting objective evaluation, efficient information management, and evidence-based athlete development.

Implications

The findings of this study have important theoretical and practical implications for the advancement of sports coaching and digital sports analytics. From a theoretical perspective, the study extends the growing body of knowledge on technology-enhanced coaching by demonstrating that the integration of mobile computing, sports science, and data-driven performance analysis can produce a valid and effective analytical tool for athlete evaluation. The successful development of the Android-based badminton performance analysis application also reinforces the applicability of the ADDIE development model for designing digital innovations that integrate technical functionality with practical coaching requirements. Furthermore, the study provides empirical support for the increasing role of evidence-based coaching, where coaching decisions are informed by objective performance data rather than relying solely on subjective observations and personal experience. From a practical perspective, the application offers badminton coaches a systematic and efficient instrument for recording, organizing, and analyzing athlete performance during training sessions, thereby reducing the limitations associated with conventional manual documentation. The high validity and reliability obtained during expert evaluation indicate that the application possesses sufficient scientific quality to support routine implementation within beginner badminton coaching programs. The significant improvement observed during field implementation further suggests that the application can enhance the efficiency and objectivity of performance evaluation, enabling coaches to identify athletes' strengths and weaknesses more accurately and provide more targeted technical feedback. In addition, the portability and accessibility of the Android platform make the application suitable for adoption in various coaching environments without requiring sophisticated or expensive technological infrastructure. The integration of structured performance records within a digital database also creates opportunities for longitudinal athlete monitoring, allowing coaches to evaluate developmental progress across successive training periods and formulate more informed coaching strategies. Beyond badminton, the systematic development framework presented in this study may serve as a reference for researchers and software developers seeking to design similar mobile-based performance analysis systems in other sports requiring objective athlete evaluation. The study therefore contributes to the ongoing digital transformation of sports coaching by illustrating how interdisciplinary collaboration between sports science, educational technology, and software engineering can generate practical innovations that improve coaching quality and support data-driven decision-making. Ultimately, the developed application represents not only a technological product but also a scalable model for integrating digital analytics into athlete development programs, thereby promoting more efficient, objective, and evidence-based coaching practices across diverse sporting contexts.

Limitations and Suggestions for Future Research

This study has several limitations that should be considered when interpreting its findings. First, the implementation involved only 30 beginner badminton athletes, limiting the generalizability of the results to broader populations and different levels of athletic performance. Second, the application was evaluated only for its initial validity and effectiveness during limited field implementation, without examining its long-term impact on athlete development and coaching outcomes. Third, the current application still relies on manual data input by coaches and has not integrated advanced technologies such as artificial intelligence or automated motion tracking. Future research is therefore recommended to involve larger and more diverse participant groups across different competitive levels and training environments. Longitudinal studies are also needed to

evaluate the sustained effectiveness of the application in supporting athlete performance development over time. In addition, integrating artificial intelligence, computer vision, or wearable sensor technologies may further enhance the accuracy and efficiency of performance analysis. Future studies should also investigate user acceptance, usability, and implementation readiness to support broader adoption in coaching practice. Expanding the application to other racket sports may further demonstrate its adaptability and practical value across different sporting contexts. Overall, addressing these limitations will contribute to the development of more intelligent and comprehensive mobile-based sports analytics systems.

CONCLUSION

This study successfully developed and validated an Android-based data-driven badminton performance analysis application for beginner athletes using the ADDIE development model. The expert validation results demonstrated that the application achieved the Highly Valid category with perfect agreement among validators and excellent reliability, indicating that the developed product meets the required standards for content quality, functionality, and practical implementation. These findings confirm that the systematic development process effectively produced a scientifically sound and operationally feasible digital coaching tool. The field implementation further demonstrated that the application performed significantly better than conventional manual performance recording methods. The significant difference observed between the experimental and control groups indicates that the application provides a more effective approach for supporting badminton performance analysis. The integration of mobile technology into coaching activities enables more systematic, objective, and efficient performance recording and data management during training sessions. Consequently, the application has the potential to support coaches in making more informed decisions based on structured performance data rather than subjective observation alone. The study also highlights the value of combining sports science, educational technology, and mobile computing in developing practical solutions for evidence-based coaching. These findings contribute to the growing body of research on digital transformation in sports coaching by demonstrating the effectiveness of mobile-based performance analytics in beginner athlete development. From a practical perspective, the application provides an accessible and efficient alternative to conventional performance analysis methods without requiring sophisticated technological infrastructure. The systematic development framework adopted in this study may also serve as a reference for future research involving mobile-based performance analysis systems in other sports. Overall, the developed application represents a valid, reliable, and effective technological innovation that supports objective, data-driven, and evidence-based badminton coaching for beginner athletes.

AUTHOR CONTRIBUTIONS STATEMENT

Rizky Ardian Sardi contributed to the conceptualization of the study, research design, application development, data collection, data curation, formal analysis, interpretation of the findings, visualization, and preparation of the original manuscript draft. Ardo Okilanda contributed to the research methodology, supervision of the product development process, validation of the sports coaching aspects, interpretation of the results, and critical revision of the manuscript. Nurul Ihsan contributed to the validation of badminton performance analysis content, methodological refinement, data interpretation, and manuscript review and editing. Muhammad Arnando contributed to software evaluation, product validation, supervision of the implementation process, critical review of the manuscript, and verification of the final research outcomes. All authors reviewed, approved, and agreed to the final version of the manuscript prior to submission.

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