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Technology Utilization in Tennis Coaching Clinics to Improve Beginners' Basic Tennis Skills

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ABSTRACT

The rapid advancement of sports science and digital technology has transformed contemporary tennis coaching, particularly in the development of fundamental technical skills for beginner athletes. This study aims to analyze the utilization of technology in tennis coaching clinics to enhance basic tennis skills, with a specific focus on serve and forehand techniques. A qualitative literature review method was employed by systematically examining peer-reviewed scientific articles, academic books, and authoritative scholarly sources published between 2015 and 2025. The reviewed literature encompasses studies in tennis biomechanics, motor learning, video-based feedback, wearable sensors, and artificial intelligence–assisted motion analysis. The findings indicate that technology-based tools, such as video analysis and AI-driven motion tracking systems, provide objective, accurate, and visually interpretable feedback that significantly accelerates the acquisition and correction of fundamental tennis techniques. These technologies enable detailed identification of movement errors across key stroke phases, improve posture and intersegmental coordination, and support the development of efficient and safe movement patterns among beginner athletes. Empirical evidence also suggests that technology-assisted feedback reduces the persistence of repetitive technical errors and enhances athletes' cognitive understanding of biomechanical principles underlying effective stroke execution. In addition to technical benefits, the use of technology has been shown to positively influence motivation and learning engagement by allowing athletes to visually track their progress and performance improvements. Nevertheless, the implementation of technology in tennis coaching clinics faces practical challenges, including limited infrastructure, high equipment costs, and varying levels of technological competence among coaches. Therefore, this study recommends a hybrid coaching model that integrates traditional training methods with context-appropriate technological support as the most feasible and sustainable approach for tennis development, particularly within the Indonesian coaching environment.

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INTRODUCTION

The rapid development of sports science over the past decade has driven a significant transformation in the approach to modern tennis coaching. Coaching practices that previously relied heavily on conventional teaching and technique repetition are now shifting toward evidence-based coaching, utilizing technology for more objective, measurable, and precise movement analysis. However, in the context of coaching beginner athletes, particularly in basic coaching clinics, the application of this technology still faces various conceptual and practical challenges.

Serving and groundstrokes are complex fundamental skills, involving multi-body segment coordination, momentum transfer, and highly precise control of force and timing. Biomechanical studies show that even small errors in joint angles, muscle activation sequences, or timing can significantly impact ball speed, accuracy, and the risk of injury, particularly to the shoulder and elbow joints. Unfortunately, in many coaching clinics, technique evaluation is still conducted visually and subjectively, relying on the coach's experience, which is susceptible to perceptual bias and inconsistencies in assessment.

In developing countries, including Indonesia, this problem is exacerbated by the dominance of traditional methods, limited access to sports science equipment, and minimal integration of technology into early childhood development programs. As a result, novice athletes are at risk of internalizing inefficient movement patterns from an early age, which not only hinders long-term performance development but also increases the potential for injury due to the accumulation of suboptimal mechanical loads. Therefore, there is an urgent need to formulate a coaching approach that bridges the gap between the scientific demands of modern tennis technique and the realities of on-court coaching practice.

Recent literature consistently demonstrates that technology-based biomechanical analysis makes a significant contribution to performance improvement and injury prevention in tennis. Experimental research and field studies report that biomechanical variables such as momentum, force impulse, power, joint angles, and segmental sequences are strongly correlated with stroke speed and consistency, particularly in serves and forehands. The use of video analysis and motion tracking allows for objective identification of these variables, surpassing the capabilities of visual observation alone.

Long-term field studies in elite athletes have shown that biomechanics-based training can improve technical efficiency, reduce non-functional movement variability, and improve the consistency of competitive performance. Furthermore, recent systematic reviews and scoping reviews confirm that kinematic, kinetic, and electromyographic analysis provide a strong scientific basis for determining efficient and safe technique, particularly in high-mechanical variations of serves and groundstrokes.

Furthermore, the development of digital technologies—such as wearable sensors, AI-based monitoring systems, and motion analysis software—has expanded the scope of tennis performance evaluation. These technologies not only improve the accuracy of

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technique assessment but also enable monitoring of training load, early detection of injury risk, and the design of individualized training programs. Recent literature reviews position technology as a key element in the modern tennis training ecosystem, capable of holistically integrating biomechanics, physiology, and training management.

However, comparative studies between qualitative assessments by elite coaches and biomechanical analysis indicate that, despite the value of coach experience, the reliability of subjective assessments remains lower in detecting subtle technical details. These findings strengthen the argument that technology is not a substitute for coaches, but rather a strategic supporting tool to increase the objectivity and consistency of technique evaluation.

Despite growing empirical evidence regarding the benefits of technology in tennis technique analysis, most research still focuses on elite or sub-elite athletes, in laboratory settings or sophisticated facilities. Studies specifically exploring the implementation of technology in coaching clinics for novice athletes are still relatively limited, both in terms of intervention design and the context in which it is applied on the field.

Furthermore, there is a gap between scientific recommendations and the realities of coaching practice, particularly in developing countries. Many studies emphasize the importance of motion capture, wearable sensors, or AI-based analysis, but they do not sufficiently explain how these technologies can be realistically adapted to foundational coaching programs that face limitations in resources, costs, and the technical competence of coaches.

Furthermore, research integrating hybrid approaches—combining traditional methods with technological support—has rarely been systematically explored, particularly in the context of improving fundamental technique skills and motor learning in novice athletes. Yet, the motor learning literature emphasizes that the early phase of skill acquisition is a critical period, where accurate and timely feedback is crucial for the long-term quality of movement patterns.

Thus, there is a clear research gap regarding how technology, specifically video analysis and AI-based motion tracking, can be effectively and contextually integrated into tennis coaching clinics for beginner athletes, and how this approach contributes to the continuous improvement of fundamental technique.

Based on these research issues and gaps, this study aims to explore and analyze the role of technology—specifically video analysis and AI-based motion tracking—in tennis coaching clinics as a strategy for improving the fundamental technique skills of beginner athletes. Specifically, this study focuses on how technology integration can improve the accuracy of technique evaluation, accelerate the motor learning process, and minimize the risk of movement errors that could potentially lead to injury.

The novelty of this study lies in the proposed applicative and contextual approach, namely the development of a hybrid-based coaching clinic model that combines traditional coaching methods with the support of affordable and adaptive motion analysis technology. Unlike previous studies, which tend to focus on elite athletes and

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laboratory settings, this study places the primary focus on beginner athletes and the context of fundamental coaching, taking into account the realities of facilities and coaching needs in Indonesia.

Thus, this research is expected to provide theoretical contributions to the development of a sports science-based tennis coaching model, as well as practical contributions for coaches and coaching institutions in designing more effective, objective, and sustainable coaching clinics. This approach is also expected to serve as a strategic foundation for accelerating the adoption of coaching technology at the grassroots level, to support the improvement of tennis athletes' quality from the early stages of development.

METHODS

This study employed a qualitative research design using a library research (literature-based analysis) approach. The selection of this method was based on the study's objective to critically examine and synthesize scientific evidence regarding the utilization of technology in tennis coaching clinics, particularly in improving beginners' basic tennis skills. A qualitative library research design is considered appropriate for mapping conceptual frameworks, identifying empirical trends, and evaluating theoretical developments in sport science and coaching studies, especially when the focus is on emerging practices and interdisciplinary integration.

The data sources consist of peer-reviewed national and international journals, scholarly books, conference proceedings, and authoritative academic documents related to tennis coaching clinics, biomechanics, motor learning, and sport technology. Only publications released between 2015 and 2025 were included to ensure the relevance and currency of the findings in line with recent developments in sport science, digital technology, and evidence-based coaching practices. This time frame reflects the period in which video analysis, wearable sensors, motion tracking systems, and artificial intelligence began to be widely applied in tennis performance analysis and coaching contexts.

Literature identification was conducted through systematic database searches using Google Scholar and major sport science journal platforms. The search strategy employed a combination of keywords and Boolean operators, including “tennis coaching clinic,” “tennis biomechanics,” “video analysis in tennis,” “motion tracking,” “wearable technology,” “AI in sports coaching,” and “technology-assisted skill acquisition.” This keyword strategy was designed to capture studies addressing both conceptual models and empirical evidence related to technology-supported tennis coaching, particularly at the beginner and developmental levels.

The selection process followed clear inclusion and exclusion criteria. Included studies were required to: (1) focus on tennis or closely related racket sports; (2) discuss the application of technology in coaching, performance analysis, or skill development; (3) provide conceptual, experimental, or review-based evidence; and (4) be published in reputable journals or academic sources. Studies were excluded if they lacked

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methodological clarity, were not relevant to coaching or skill acquisition, or focused solely on elite performance without implications for beginner development.

Data analysis was conducted using a descriptive-analytical synthesis approach. The selected literature was regularly grouped and compared based on thematic categories, such as types of technology used (e.g., video analysis, motion tracking, wearable sensors), targeted technical skills (e.g., serve, forehand, groundstroke), coaching contexts (elite vs. beginner), and reported outcomes (performance improvement, injury prevention, learning efficiency). Through this process, recurring patterns, strengths, limitations, and implementation challenges were identified and critically interpreted.

To enhance analytical rigor, findings from empirical studies were contrasted with theoretical and review-based literature, allowing for triangulation of perspectives. This approach facilitated a comprehensive understanding of how technology contributes to technical skill acquisition, feedback accuracy, and learning efficiency in tennis coaching clinics. As this study relied exclusively on secondary data, the resulting recommendations are interpretative and contextual, requiring adaptation to real-world coaching environments, particularly in regions with varying levels of technological access and infrastructure.

RESULTS AND DISCUSSION

Result

The Effectiveness of Video Analysis in Tennis Coaching Clinics for Beginners

Video analysis technology has been proven effective in helping coaches and athletes, especially beginners, to visually identify technical errors, which is difficult to do during fast-paced training or on a crowded court. The study Biomechanical Analysis of Tennis Spin Serve Technique Using Kinovea shows that the use of motion analysis software (Kinovea) allows for the objective identification of aspects of serve technique, such as body rotation and dynamic balance, two important factors in producing accurate and powerful serves (Aprilo, I., Asmawi, M., & Tangkudung, 2025).

With slow-motion videos from various angles of the backswing, toss, uncoiling, strike zone, and follow-through, coaches and athletes can review movements in detail, compare them with ideal models, and identify errors in posture or timing. This provides much clearer feedback on movement than verbal instructions or direct observation on the field (which is often too fast or obscured by blind spots).

For beginners, whose body awareness and coordination control are still developing, this kind of visualization helps accelerate movement adaptation. For example, a beginner can see that their hip rotation is less than optimal during the backswing, then correct it in the next training session—something that would likely be missed in traditional training.

Practical implications: Video analysis can be a relatively inexpensive, easily accessible (camera/mobile phone + simple software), and very useful basic correction tool in clubs or colleges with limited resources, making it suitable for the Indonesian context.

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The Benefits of Biomechanics & Motion Tracking (Including AI/ML) for Serving & Forehand Techniques

More than just visualization, biomechanical analysis and motion tracking (including the use of optoelectronic systems or sensors) enable quantitative measurement of critical variables: joint angles, racket speed, acceleration, load distribution, and whole-body coordination synchronization. The Kinematics of the Tennis Serve Using an Optoelectronic System study found a very high correlation between joint parameters (such as shoulder rotation, knee flexion, hip extension) and racket speed, which ultimately affects the speed of the serve (Jacquier-Bret, J., 2024).

Similarly, the study Biomechanical analyses of different serve and groundstroke techniques in tennis: A systematic scoping review, which summarizes various kinematic, kinetic, and electromyographic studies on various types of serves and groundstrokes, shows that variations in technique (serve type, stance, groundstroke direction) result in significant differences in biomechanical parameters and performance (Lambrich, J., & Muehlbauer, 2023).

For beginners, this kind of data is invaluable: rather than simply feeling that they are doing it "right," they can get quantitative feedback such as "your hip rotation is too small," "the angle of your shoulder when contacting the ball is not optimal," or "your arm speed is too low." This makes technical corrections much more precise and targeted.

Furthermore, a recent study, Enhancing Tennis Serve Performance Through AI-driven Video Analysis, shows that with an eight-week intervention using video + AI/ML analysis, the participants' serve performance (speed and accuracy) improved significantly compared to the control group (Huang, C. Y., 2025).

Practical implications: For tennis clubs or institutions with access to technology (cameras, software, sensors), the implementation of video analysis + motion tracking can accelerate the process of mastering ideal basic techniques for beginner athletes as well as long-term performance development.

Comparison of Results: Traditional Training vs Technology Specifically for Beginners

According to the scoping review literature by (Lambrich, J., & Muehlbauer, 2023), there are variations in results depending on the method: some studies show significant performance improvements with technology, but these results are not always consistent across all conditions (age, athlete level, stroke type, stance, etc.).

However, in the context of beginners where basic techniques are not yet strong, the potential benefits of technology are greater. For example:

1. With video analysis, beginners can accelerate their adaptation of basic techniques such as grip, swing path, and follow-through.
2. With motion tracking, coaches can obtain objective data on each athlete's progress, facilitating personalized training.
3. The risk of movement errors or bad habits (which are difficult to correct if left unchecked) can be detected early, preventing bad habits from becoming ingrained.

Thus, the combination of traditional methods and technology (hybrid) emerges as the ideal approach: basic techniques are built through drilling and routine training, while technology is used as a tool for evaluation and correction.

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Challenges & Obstacles to Implementing Technology in Coaching Clinics in the Indonesian Context

Despite its great potential, literature and practice show that there are several real obstacles to implementing technology:

1. Not all clubs or universities have sophisticated equipment (high-speed cameras, motion capture systems, inertial sensors).
2. Coaches may not yet have the competence to operate analysis software or read biomechanical data.
3. Infrastructure such as indoor space, lighting conditions, field surfaces, and access to electricity/internet can limit the use of technology.
4. Cost: 3D motion capture systems or advanced sensors can be expensive compared to the budgets of small clubs.

These factors make it difficult to implement the technology widely, especially in suburban clubs or areas with limited facilities. Therefore, gradual adaptation, starting with simple video analysis, or implementing a hybrid model is more realistic.

Hybrid Coaching Clinic Model: Practical Recommendations for Beginners & Intermediate Clubs

Based on the above findings, the most realistic and effective model to implement is:

1. Drills & basic techniques (traditional) form the foundation of grip, footwork, and swing path.
2. Video analysis is conducted weekly to evaluate technique, posture, and visual errors.
3. Motion tracking (optional/if available) to evaluate biomechanical aspects, movement efficiency, and long-term progress.

This model allows clubs/campuses with limited resources to still benefit from technology without relying on expensive equipment.

It is also important for coaches to receive minimal training on interpreting analysis results so that the feedback given to athletes is relevant and on target.

Discussion

The findings of this study reinforce the growing consensus in sport science literature that technology-assisted coaching, particularly through video analysis, plays a crucial role in accelerating technical skill acquisition among beginner tennis players. Video-based feedback allows movements to be captured from multiple angles—such as backswing, ball toss, impact phase, and follow-through—enabling coaches and athletes to identify subtle errors in posture, timing, and coordination that are often missed during real-time observation. Previous studies confirm that slow-motion replay and frame-by-frame analysis significantly enhance error detection and motor awareness, leading to faster and more precise technical corrections compared to verbal feedback alone (Reid & Quinn, 2019; López & Martín, 2022; Croser et al., 2020).

From a motor learning perspective, augmented visual feedback supports the formation of more accurate internal movement representations, which is particularly

critical during the cognitive and associative phases of skill acquisition typical of beginner athletes. Research in racket sports demonstrates that early exposure to visual feedback reduces the likelihood of stabilizing inefficient movement patterns, thereby improving long-term technical consistency (Williams & Hodges, 2017; Müller et al., 2018). In this context, the present findings align with studies showing that video analysis not only improves immediate technical outcomes but also facilitates deeper understanding of movement mechanics among novice players.

Beyond video analysis, the integration of wearable sensors and AI-based motion tracking systems offers a more comprehensive biomechanical evaluation of tennis techniques. These technologies provide quantitative data on joint angles, racket velocity, acceleration profiles, load distribution, and segmental coordination, which collectively describe the efficiency and safety of movement execution. Empirical evidence suggests that such objective biomechanical feedback enables more targeted and individualized technique correction, particularly for beginners who lack proprioceptive awareness and conceptual knowledge of tennis biomechanics (Lambrich & Muehlbauer, 2023; Whiteside et al., 2019; Sgro et al., 2021). By translating complex biomechanical variables into interpretable feedback, technology helps bridge the gap between abstract technical instruction and practical motor execution.

The combined use of video feedback and biomechanical analysis tools appears to yield synergistic benefits. Experimental and quasi-experimental studies consistently report that athletes exposed to multimodal feedback—visual, numerical, and kinematic—demonstrate superior improvements in stroke accuracy, movement stability, and consistency compared to those trained using traditional methods alone (López & Martín, 2022; Bastien et al., 2020; Kovalchik & Reid, 2017). These findings support the notion that technology-enhanced feedback accelerates the learning curve of fundamental strokes such as serves and forehands by providing immediate, precise, and actionable information.

Importantly, the discussion should not be limited to technical outcomes alone. Several studies highlight the psychological and motivational impact of technology use in beginner coaching contexts. Visualizing progress through video comparisons and quantitative performance indicators fosters a sense of achievement and self-efficacy, which are key determinants of sustained participation and training adherence (Carvalho & Santos, 2014; Hays et al., 2021). For novice athletes, who are particularly vulnerable to boredom and dropout due to repetitive drills, technology-supported training introduces variability, novelty, and clear performance benchmarks, thereby enhancing engagement and intrinsic motivation (Ryan & Deci, 2017; Reid et al., 2016).

Despite these advantages, the present analysis also confirms that technological implementation in tennis coaching clinics is constrained by practical limitations. Cost remains a major barrier, as advanced cameras, wearable sensors, and motion analysis software are often inaccessible to small clubs and grassroots programs. Additionally, limited technological literacy among coaches and insufficient institutional support further widens the gap between scientific recommendations and on-court practice

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(Carvalho & Santos, 2014; Bailey et al., 2019). These challenges highlight the risk of technological disparity, where only well-funded programs can fully benefit from sport science innovations.

In response to these constraints, recent literature increasingly advocates for a hybrid coaching model, in which traditional drills are complemented by accessible technologies such as smartphone-based video analysis and simplified motion-tracking applications (Bittencourt et al., 2018; Torres-Ronda & Schelling, 2017). Such an approach preserves the pedagogical value of conventional coaching while enhancing objectivity and feedback quality. For developing tennis environments, including Indonesia, this hybrid model represents a pragmatic and scalable solution that aligns scientific rigor with contextual feasibility.

Overall, the discussion underscores that technology utilization in tennis coaching clinics should not be viewed as a replacement for coaching expertise, but rather as a strategic tool to enhance instructional accuracy, learning efficiency, and athlete motivation. When appropriately integrated, technology-supported coaching has the potential to improve the quality of beginner tennis training, reduce early-stage technical errors, and establish a solid foundation for long-term athlete development.

CONCLUSION

This study confirms, both conceptually and empirically, that the integration of technology in tennis coaching clinics plays a substantial role in enhancing the basic technical skills of novice athletes. The utilization of AI-based video analysis and motion tracking systems enables the provision of objective, accurate, and easily interpretable feedback, which significantly accelerates the motor learning process. Through detailed visualization and biomechanical quantification, beginner athletes are able to improve posture, movement coordination, and stroke consistency while reducing the likelihood of developing inefficient or potentially harmful technical patterns.

Compared with conventional coaching methods that rely predominantly on subjective visual observation, technology-assisted analysis allows for more precise identification of technical errors across critical stroke phases, including preparation, impact, and follow-through in both serve and forehand techniques. This precision facilitates more focused and individualized corrective interventions, leading to more efficient skill acquisition and improved training outcomes at the early stages of athlete development.

Nevertheless, this study also acknowledges practical challenges associated with technology implementation, particularly in the form of limited infrastructure, high equipment costs, and varying levels of technological literacy among coaches. In response to these constraints, the adoption of a hybrid coaching model—combining traditional instructional methods with context-appropriate technological tools—emerges as the most feasible and sustainable strategy for tennis coaching clinics in Indonesia.

Overall, technology should be viewed not merely as a supplementary tool, but as an essential component of modern tennis coaching. When applied adaptively, technology-supported coaching contributes to the development of more efficient, safe, and competitive technical foundations for beginner tennis athletes.

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