Exploration of the role of technology in tennis assessment: a literature review

Exploración del papel de la tecnología en la evaluación del tenis: una revisión de la literatura

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Abstract

Introduction: Technological advancements have significantly influenced the field of sports, particularly in performance assessment within tennis. However, the impact of technology integration on assessment effectiveness, as well as the challenges associated with its implementation, remain underexplored.
Objective: This study aims to examine the role and impact of technology in tennis assessment, including athlete performance evaluation, training load monitoring, and injury risk prevention and management, through a systematic review of recent literature.
Methodology: A systematic review was conducted using the PRISMA framework. Scientific articles indexed in Scopus, Web of Science, PubMed, Google Scholar, and ScienceDirect were screened to identify studies on the integration of various technologies in tennis assessment. Articles published between 2014 and 2024 that focused on technology, performance assessment, and tennis-related injuries were included based on predefined inclusion criteria. Results: Findings from 20 relevant articles indicate that the application of wearable sensors, video analysis, artificial intelligence, data mining, and digital monitoring systems enhances the accuracy, efficiency, and objectivity of performance assessment and injury detection. These technologies also support personalization, training load monitoring, and the optimization of athlete rehabilitation programs. Nonetheless, concerns remain regarding data privacy, high costs, limited validation, and uneven technology adoption across different levels of play. Conclusions: The integration of emerging technologies serves as a catalyst for innovation and evidence-based progress in tennis assessment. Multidisciplinary collaboration between sports science, engineering, and data analytics is recommended to sustainably support performance optimization, injury prevention, and informed decision-making for athletes and coaches in modern tennis.

Keywords

Sports technology; sports evaluation; sports assessment; performance analysis.

Resumen

Introducción: Los avances tecnológicos han influido significativamente en el ámbito deportivo, en particular en la evaluación del rendimiento en tenis. Sin embargo, el impacto de la integración de la tecnología en la eficacia de la evaluación, así como los retos asociados a su implementación, siguen sin explorarse.
Objetivo: Este estudio busca examinar el papel y el impacto de la tecnología en la evaluación del tenis, incluyendo la evaluación del rendimiento de los atletas, la monitorización de la carga de entrenamiento y la prevención y gestión del riesgo de lesiones, mediante una revisión sistemática de la literatura reciente. Metodología: Se realizó una revisión sistemática utilizando el marco PRISMA. Se revisaron artículos científicos indexados en Scopus, Web of Science, PubMed, Google Scholar y ScienceDirect para identificar estudios sobre la integración de diversas tecnologías en la evaluación del tenis. Se incluyeron artículos publicados entre 2014 y 2024 centrados en tecnología, evaluación del rendimiento y lesiones relacionadas con el tenis, según criterios de inclusión predefinidos.
Resultados: Los hallazgos de 20 artículos relevantes indican que la aplicación de sensores portátiles, análisis de vídeo, inteligencia artificial, minería de datos y sistemas de monitorización digital mejora la precisión, la eficiencia y la objetividad de la evaluación del rendimiento y la detección de lesiones. Estas tecnologías también facilitan la personalización, la monitorización de la carga de entrenamiento y la optimización de los programas de rehabilitación de los atletas. Sin embargo, persisten las preocupaciones sobre la privacidad de los datos, los altos costos, la validación limitada y la adopción desigual de la tecnología en los diferentes niveles de juego.
Conclusiones: La integración de tecnologías emergentes actúa como catalizador de la innovación y el progreso basado en la evidencia en la evaluación del tenis. Se recomienda la colaboración multidisciplinaria entre las ciencias del deporte, la ingeniería y el análisis de datos para apoyar de forma sostenible la optimización del rendimiento, la prevención de lesiones y la toma de decisiones informada para atletas y entrenadores del tenis moderno.

Palabras clave

Tecnología deportiva; evaluación deportiva; valoración deportiva; análisis del rendimiento.

Introduction

The use of technological aids for sports is very necessary, given its significant impact on various aspects of athletic activities. Technology enhances efficiency, accuracy, and overall experience in both training and matches (Abdioğlu et al., 2024; Ambarwati et al., 2024). Among the most notable developments are wearable devices that monitor athletes' health and fitness, as well as advanced analytical systems that provide real-time performance data (De Fazio et al., 2023; Guppy et al., 2023). These innovations enable coaches and athletes to maximize their potential. In addition, technology contributes to audience engagement through digital charts and instant match analysis (Arrum et al., 2024).

The function of technology application has an impact on training, game strategy, and performance evaluation. A prominent example is the Hawk-Eye system, which supports referees in determining the validity of shots, thereby enhancing fairness and objectivity in matches (Takahashi, 2023; Fitzpatrick et al., 2024). Other technologies, such as video analysis, tracking devices, and biomechanical sensors, provide valuable insights into player techniques and strategies, helping both coaches and players to optimize performance (Prieto-Lage et al., 2023; Ye et al., 2024).

Integrating technology into tennis assessment generates multiple benefits, including greater accuracy in evaluating player performance (Chen, 2022). Objective, data-driven analysis enables coaches to more effectively identify strengths and weaknesses (Pan et al., 2022; Zhang, 2023). This reduces reliance on subjective manual evaluation while streamlining training design. Moreover, technology helps prevent injuries by offering detailed biomechanical analysis of player movements, thereby identifying and correcting potentially harmful techniques (Qi et al., 2024; Kovoor et al., 2024; Kurniawan et al., 2024).

A central research problem in this field is understanding the extent to which technology integration improves the effectiveness of tennis assessment, as well as the challenges faced in its implementation. This study seeks to explore and elaborate on the role of technology in tennis assessment through a systematic literature review. The findings are expected to provide recommendations for the development and application of more effective technologies in the future, ultimately enhancing the quality and objectivity of tennis assessment (Frevel et al., 2022).

Method

Research Design

This study adopts a systematic review design aimed at synthesizing existing research on the role of technology in tennis assessment. This method was selected to provide a comprehensive and structured overview of the latest technological advancements in this field (Pollock & Berge, 2018). The review follows the PRISMA guidelines (Preferred Reporting Items for Systematic Reviews and Meta-Analyses), ensuring transparency, replicability, and scientific rigor at every stage (Rethlefsen et al., 2021).

Literature Search Resources and Strategies

Relevant studies were identified through searches of leading academic databases, including Scopus, Web of Science, PubMed, Google Scholar, and ScienceDirect. The search was conducted in June - July 2025. The literature search was conducted using the main keywords, so complete search series used is as follows:

("technology assessment" OR "sports technology" OR "wearable devices" OR "sensor technology" OR "artificial intelligence" OR "machine learning" OR "data mining" OR "video analysis" OR "motion capture" OR "IoT" OR "digital assessment") AND ("tennis" OR "tennis player" OR "tennis court") AND ("assessment" OR "evaluation" OR "monitoring" OR "performance analysis" OR "injury prevention" OR "biomechanics").

A combination of keywords and Boolean operators was strategically used to obtain relevant results. In addition to database searches, relevant articles were also collected in stages.

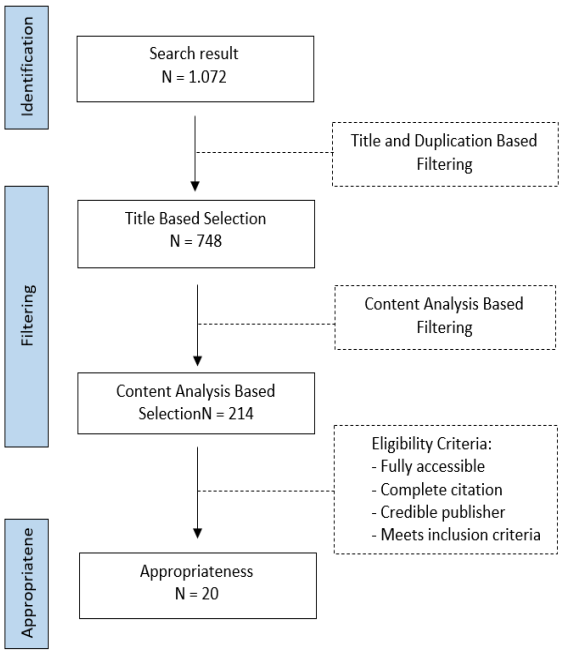
Inclusion and Exclusion Criteria

The inclusion criteria in this study comprised original research articles or review articles that discuss the role of technology in tennis assessment, whether in singles, doubles, or other relevant forms of tennis. The articles had to be written in English, published between 2014 and 2024 (at the time of this study), and available in full-text format. The exclusion criteria included editorials, letters to the editor, short reports, proceedings, abstracts without full-text, as well as studies that did not specifically address technology in the context of tennis assessment or duplicate publications.

Study Selection Process

Article selection was conducted in three stage which are title and abstract screening, full-text review, and resolution of disagreements between two independent researchers, with a third researcher involved when necessary. The selection process is illustrated using the PRISMA flowchart (Figure 1).

Figure 1. Number of visibility and gender fitness in PE Textbooks from Grade 1.



Data Extraction

Data extraction was conducted using a standardized form, capturing article identity (title, author, year of publication), study objectives, research design, type of technology examined, aspects of assessment evaluated, research population, main findings, recommendations, and limitations. Extraction was performed independently by two researchers to ensure objectivity.

Study Quality Assessment

The methodological quality of the included studies was evaluated using established instruments such as Joanna Briggs Institute Critical Appraisal Tool for systematic reviews and qualitative studies, CASP Checklist for review articles, and Cochrane Risk of Bias Tool for experimental studies. Only studies rated medium to high quality were synthesized.

Data Analysis and Synthesis

Data analysis was conducted narratively, using a thematic synthesis approach. Findings were organized into themes such as roles of technology, challenges of implementation, and opportunities for innovation in tennis assessment. Where homogeneous quantitative data were available, meta-analysis was considered. However, emphasis was placed on producing a descriptive, in-depth narrative synthesis.

Validity and Reliability

To ensure validity and reliability, all processes of selection and extraction were independently conducted with double screening. The entire procedure was documented to ensure transparency, repeatability, and auditability. Methodological decisions and discussions were systematically recorded to reinforce the study's integrity.

Research Ethics

As this study relies exclusively on secondary data from published articles, no additional ethical approval was required. All sources were cited according to scientific standards (e.g., APA style), and research integrity was prioritized throughout the review process.

Results

After applying the inclusion and exclusion criteria, a total of 20 scientific articles were included in the final analysis. The initial search identified 1,072 articles across major databases. Following the removal of duplicates, 748 articles remained. Screening based on exclusion criteria further reduced the pool to 214 articles. Applying inclusion criteria resulted in a final selection of 20 articles.

Data from the 20 included articles were extracted using a standardized form as described in the research methods section. The extracted data were then analyzed thematically to identify recurring patterns and themes related to the role of technology in tennis assessment. This thematic analysis process involved several steps: (1) Coding relevant data from each article, including the type of technology used, the assessment aspects evaluated, and key findings; (2) Grouping codes with similar meaning or function into broader categories; and (3) Developing conceptual themes that represented the primary focus of the reviewed literature. This systematic approach ensured that the identified themes were derived directly from the primary data, thus providing full transparency to the synthesis process.

These selected studies were analyzed according to their objectives, research design, technologies used, participant samples, aspects of assessment evaluated, data collection methods, main findings, recommendations, and limitations.

Table 1. Results of Relevant Article Selection

No	Title (Author, Year)	Purpose of the research	Study Design	Technology Used	Sample	Aspects assessed	Data Collection Method	Key Results	Implications/ Recommendations	Limitations
1	Real-Life Application of a Wearable Device towards Injury Prevention in Tennis: A Single-Case Study (Kramberger et al., 2022)	Testing the use of Armbeep wearables in real applications for weight monitoring and recovery of tennis players' workouts	Case Study	Wearable sensors (Armbeep), cloud analytics	1 tennis player, training & competition	Exercise time, workload, recovery, physiological indicators & movement	Sensors on wrist, data sent via cloud	Objective monitoring assists with workload adjustment & injury prevention.	Wearable effective for load monitoring & supporting return to play	Single study, results cannot be generalized
2	Ultrasound-guided procedures in common tendinopathies at the elbow: From image to needle (Mezian et al., 2021)	Examines the use and advantages of high-resolution ultrasound for the diagnosis and treatment of guided elbow tendinopathy, including tennis elbow	Clinical review/narrative	Ultrasound (USG), real-time imaging	Illustration of various cases of elbow tendinopathy patients	Diagnosis of elbow lesions (tennis/golfer's elbow)	Cadaver & patient ultrasound, images, case narratives	Ultrasound is effective for diagnosis of ambiguous cases & injury intervention	Ultrasound is recommended for the diagnosis/procedure of guided tennis elbow	Narrative studies, need greater population validation
3	Assessment of knee resistance by applying computational methods (Adamović et al., 2020)	Develop non-invasive biomechanical computational methods to assess a tennis player's knee resistance at serve	Development studies, simulation of biomechanical models	Finite Element Method, biomechanical modeling, force/kinematic tracking	Individual model, tennis movement simulation	Knee resistance, deformation, risk of service injuries	Kinematic tracking, force measurement, computational models	Can predict the vulnerability of knee injuries, more accurate diagnosis	Practical diagnosis & prevention of tennis knee injuries	Model-based studies, have not been tested on many real samples

4	Construction of an intelligent campus tennis players' body data monitoring and injury warning system based on data fusion (Yan Li, 2021)	Developing a physical monitoring system for campus tennis athletes & early warning of injuries based on fusion data	System development, application case studies	Data fusion, biomechanical diagnosis, force-time recording, computerization	Campus tennis athletes, monitoring during practice & competition	Biomechanical data, physical status & risk of injury	Force-time curve measurement, computer data processing	Efficient system monitors physical status & provides early warning of injuries	Recommended for athlete injury monitoring & management	Long-term system validation is still needed
5	The expert eye? An inter-rater comparison of elite tennis serve kinematics and performance (Wood et al., 2023)	Could you assess the reliability of coaches/biomechanics in assessing tennis service techniques through 2D videos?	Inter-rater reliability study	2D video analysis, Likert scale, Krippendorffs alpha	2 raters, 300 tennis athletes, different ages & genders	13 service mechanical variables (power, speed, rhythm)	2 angle video, 1-7 Likert assessment, score analysis	Reliability is quite high in most aspects, video is effective	Video analysis is quite reliable for elite technical assessments	Results depend on rater experience & video quality
6	Hand-arm vibration assessment and changes in the thermal map of the skin in tennis athletes during the service (Amaro et al., 2019)	Hand-arm vibration evaluation & skin thermography during tennis service for early detection of injury risk	Biomechanical experiments	HAV sensor, infrared thermography	Tennis athlete, grip variation, wear/no anti-vibrator	HAV value, skin temperature, tennis elbow risk	HAV sensor & infrared thermal camera	Anti-vibrator effectively reduces vibration; thermography of injury risk detection	Recommended use ofanti-vibrator & thermography for injury detection	Laboratory studies, conditions limited to servicing
7	Early Warning System of Tennis Sports Injury Risk Based on Mobile Computing (Yupeng Li et al., 2021)	Developing a tennis injury early warning system based on mobile computing and neural network	System development, effects studies	Mobile computing, RBF neural network	48 tennis athletes of all ages, in China	Injury history & risk, training monitoring	Surveys, interviews, system usage, injury statistics	Injuries were significantly reduced: from >30% to 5% after the system	The system is feasible for the monitoring of tennis injuries	Study in 1 country, need international validation
8	Analysis Technology of Tennis Sports Match Based on Data Mining and Image Feature Retrieval (Huang & Deng, 2020)	Developing machine learning & image analysis models to analyze tennis match techniques from videos	Model development, controlled experiment	Machine learning, image recognition, data mining	Tennis match video data	Technique, motion characteristics, statistics	Video/image analysis, ML, data mining	Effective and accurate models for match analysis	Can be adopted for data-driven training & strategies	Video & noise quality is an obstacle
9	Data Analysis of Sport Specific Variables for Performance Consistency Evaluation in Critical Moments of College Tennis Matches (Vancurik & Dale, 2022)	Performance assessment model at critical moments using wearables (speed, HR) in university tennis matches	Field experiment, data analysis	Wearable sensors (movement & HR)	15 varsity tennis players, 60 sessions	Swing speed, HR, consistency under pressure	Wearable sensors, recording, statistical analysis	Models are able to identify performance patterns at crucial moments	Can be for strategy or reflection for coaches & athletes	Small sample, only students
10	Constructing a Gaming Model for Professional Tennis Players Using the C5.0 Algorithm (Chang & Qiu, 2022)	Create an expert analytical system of professional tennis techniques & tactics with the C5.0 algorithm	Model development, notational analysis	C5.0 decision tree, notational analysis, court mapping	Federer & Nadal match data, 10 matches	Punch technique/score specification/ habits	Video & scoring skills, AI analysis	The expert system compiles play patterns, predictions of each player's superior techniques	It could be a technique imitation training and learning tool	Data is only 2 players, need more extensive validation
11	Analysis and Improvement of Tennis Motion Recognition Algorithm Based on Human Body Sensor Network (Pan et al., 2022)	Develop identification of tennis service errors using body sensor network	Model development, experimental simulation	Human body sensor network, image recognition	Test simulation (not explained by real participants)	Service error, technical error detection	Sensor network, image/motion analysis	Engineering fault detection accuracy is much better than the old method	Sensor network is recommended for technique evaluation	Limited samples/simulations, need application in real practice
12	Optimization of a Wireless Sensor-Based Tennis Motion Pattern Recognition System (Ruan &	Evaluation & improvement of tennis motion recognition system using wireless sensor &	Algorithm development, simulation	Wireless sensors, video action recognition, IoT	Simulation of anchor nodes, applications on video/mov	Movement patterns, recognition errors, the effectiveness of the tracking	Wireless sensor, video analysis, modeling	The new algorithm reduces errors, the efficiency of determining	Potential for data research & coaching, monitoring efficiency	Has not been tested extensively in real athletes

	Zhang, 2022)	action recognition		ement	system		the location of the upward movement		
13	Match analysis and probability of winning a point in elite men's singles tennis (Prieto-Lage et al., 2023)	Pattern analysis & probability OF points winning IN elite men 'S tennis using notational analysis	Observational-notational study	Notational analysis, statistical integration	4669 rally from 2021 Grand Slam final, 3 surfaces	Service effectiveness, rally, surface type	Observation & recording OF variable statistics	Revealing the key winning pattern, the short rally is very dominant	Assist with coach strategy & decisions at elite level	Elite only, do not test to junior/amateur
14	A real-time tennis level evaluation and strokes classification system based on the Internet of Things (Wu et al., 2022)	Real-time tennis punch classification & level scoring with IMU wrist & ML	Experiment, model evaluation	IMU wrist sensor, ML (SVM, KNN, NB), cloud	36 participants, ITN & field tests	Ability level, f1-score classification serve/forehand/backhand/volley	IMU wearable, cloud, ML, ANOVA statistics	Accuracy > 0.90 for serve&fore/backhand, <0.90 for volley	Effective, can feedback on athletes' skills in the field	Volley hit accuracy is not optimal
15	Algorithms for tennis racket analysis based on motion data (Skublewska-Paszkowska et al.,2016)	Motion analysis of fore/backhand tennis racket using motion capture data & measurement algorithm	Algorithm development, experimentation	Optical motion capture (Vicon), biomechanical modeling	1 professional trainer, 10 x each condition	Head speed/grip & racket orientation	Motion capture marker-based; 3D trajectory recording	The racket motion data visualization algorithm is very precise & detailed	Used for precision engineering training	Single experiment, limited scale
16	Optimization Analysis of Tennis Players' Physical Fitness Index Based on Data Mining and Mobile Computing (S. Zhang & Mao, 2021)	Monitoring & optimizing physical fitness index and training load with big data & ML	Analytical-computational studies	MobilePerfMiner (XGBoost, data mining), mobile counters	Tennis athletes in the training process	Physical index, load, kinematic parameters	Physiological & technical data via mobile, XGBoost	Models improve exercise efficiency and fitness >17%	Coach/athlete suggested framework	Only physical-technical parameters, not long-term studies
17	Application ofstate-of-the-art computer technology to strength training in tennis instruction (Pei et al., 2023)	Evaluate the effectiveness of strength & posture training with computer data feedback	Reviews, experimental & comparative studies	Computerized data feedback, real-time/edge/cloud computing	Tennis athletes in the strength training program	Posture, technique accuracy, physiological indicators	Computer data capture, comparative analysis	Yield/technique accuracy increased by 20%, data validity increased	Real-time computer feedback is relevant for technical improvement	Participants & study details are not explained
18	Analysis of GPS and UWB positioning system for athlete tracking (Waqar et al., 2021)	Comparing GPS & UWB accuracy for tennis athlete performance tracking + AI	Hardware experiments, comparisons	GPS, UWB wearable, AI-model	Attachment of the device to tennis athletes	Distance, speed, acceleration, performance tracking	GPS/UWB sensor data, AI-accuracy evaluation	UWB is more accurate, AI suppresses UWB's main shortcomings	Recommended for clubs/coaches monitoring athlete performance	Limitations: fees & complicated setup
19	Vibration-Damping technology in tennis racquets: Effects on vibration transfer to the arm, muscle fatigue and tennis performance (Yeh et al., 2019)	Effect of racket vibration dampening technology on vibration transfer, fatigue, tennis performance	Crossover experiment	VDT racket, tri-ax accelerometer, EMG	19 young tennis players/competition	Vibration, arm muscle EMG, hit accuracy	Accelerometer on racket/hand, EMG	VDT reduces vibration by 40%, fatigue drops, accuracy rises	It is recommended to prevent fatigue & hit accuracy	Limited number & age of participants
20	Artificial Intelligence Technology to Record the Number of Times the Ball Passes the Net in Tennis Matches (Liu et al., 2022)	The use of AI vision to measure net ball crossing in tennis matches	AI development, comparative testing	AI (CenterNet, DBSCAN), drone video	Tennis match video, drone footage	Number of ball crosses, recording accuracy	AI target detection, clustering accuracy	DBSCAN recall is higher, the statistical accuracy of ball crossing is very high	Can automate the recording of match statistics	Focus only on counting, not technical skills

1. Based on Table 1, one study found that up to two to three technologies were used simultaneously. However, the researchers managed to identify five main themes based on similar functions and purposes of technology:

2. Wearable Sensor & IMU (Inertial Measurement Unit): Aims to monitor physical condition, technique, training load (player load), swing speed, heart rate, and other physiological or movement indicators.
3. Video Analysis, Motion Capture, & Image Recognition: Intended for engineering, motion, or kinematic analysis using 2D/3D video, motion capture, image processing, and digital image.
4. Artificial Intelligence (AI), Machine Learning (ML), & Data Mining: Aims for technical or tactical pattern recognition, outcome prediction, analysis automation, classification and clustering.
5. Advanced Biomechanical or Physiological Monitoring: Includes Force Plates, EMG (Electromyography), Thermography, and Ultrasonography (USG) for biomechanical monitoring, force timing, vibration, and injury prevention and diagnosis.
6. Decision Support System & Notational Analysis: Aims to process and automate match statistics, analyze game patterns, win probabilities, and record statistics.

Discussion

The role of technology in the performance and health assessment of tennis athletes has entered the digital revolution era, marking a fundamental change in how data is collected, analyzed, and used as a basis for decision making. The integration of technology, from wearable electronics and multi-source sensors to cloud computing and artificial intelligence (AI), has strengthened the foundations of sports engineering, opening up opportunities for biomechanical, kinematic, and physiological assessment with an unprecedented level of detail in tennis and other sports (Edriss et al., 2024).

Wearable technology has become a milestone in modern tennis assessment. Several studies highlight the crucial role of IMUs, heart-rate monitors, and cloud-enabled devices in real-time monitoring of workload, swing speed, heart rate, and player load (Kramberger et al., 2022; Vancurik & Dale, 2022; Rebelo et al., 2023; Seçkin et al., 2023). Wearable devices not only provide coaches and athletes with objective data that has long been difficult to obtain through conventional observation, but also enable the personalization of training programs, early detection of overtraining, and precise adjustment of workloads over time. Furthermore, wearable data play a crucial role in injury prevention, as highlighted by Rebelo et al. (2023), through metrics such as workload ratio and acute–chronic workload, which have been shown to be relevant in predicting injury risk.

Video analysis and image-based technologies also represent essential innovations. Studies demonstrate that 2D video and 3D motion capture effectively identify key kinematic parameters in tennis strokes such as serve, forehand, and backhand (Skublewska-Paszkowska et al., 2016; Wood et al., 2023). Visualization techniques, slow-motion playback, and marker-based analysis enhance technical evaluations while minimizing subjectivity. Integrating machine learning (ML) into video analysis further automates error detection and stroke classification, enabling real-time technical feedback (Huang & Deng, 2020; Ruan & Zhang, 2022; Mei, 2023). Wu et al. (2022) combined IMU data with ML models for automated skill-level assessment and stroke recognition, illustrating the potential of hybrid systems in performance evaluation.

Artificial intelligence and big data analytics have become increasingly important in automating assessments and deepening tactical insights. Decision tree algorithms (Chang & Qiu, 2022) can replicate coach decision-making patterns, while advanced notational analysis (Prieto-Lage et al., 2023) integrates statistical models and AI to predict winning probabilities in elite matches. Other algorithms, such as clustering and computer vision (Liu et al., 2022), enable automatic ball-tracking and event classification, significantly reducing manual workload for coaches. Emerging technologies, including augmented reality, virtual reality, and automated visualization tools are expanding cross-sport applications of performance analysis (Cossich et al., 2023; Subramaniam et al., 2023).

In line with the digitalization of the sports industry, as highlighted by Zhang and Zhao (2023), the emergence of the Internet of Things (IoT) and cloud-computing systems facilitates the seamless collection, integration, and analysis of data between coaches, athletes, wearable devices, and the broader sports

infrastructure ecosystem. Li (2021) demonstrated a data fusion and mobile computing–based monitoring system for injury warning, while Wu et al. (2022) introduced an integrated system combining IMU, cloud, and machine learning (ML) to classify and assess playing levels and stroke techniques in real time, thereby enabling instant on-court feedback for athletes.

Specifically, in the area of injury prevention and management, technology plays a central role through two main pathways: monitoring physical load and detecting abnormal biomechanical/physiological biomarkers. Amaro et al. (2019) and Yeh et al. (2019) utilized vibration sensors (HAV), infrared thermography, surface electromyography, and racket-based vibration damping to monitor vibration transfer and potential injuries such as tennis elbow. Reducing vibration and optimizing equipment were shown to lower the risk of injuries and muscle fatigue. Similarly, Adamović et al. (2020) and Yupeng Li et al. (2021) introduced biomechanical modeling approaches, including finite element methods, force–time curves, and dynamic chain modeling, to detect and predict potential knee injuries or other biomechanical risks during competition and intensive training.

As noted by Rebelo et al. (2023), force plates and biomechanical wearables have become essential tools for detecting fatigue, supporting recovery programs, and enriching rehabilitation and injury-prevention data in high-risk sports such as tennis, soccer, and volleyball. By integrating workload, fatigue, and injury-risk analyses through technology, athlete training and rehabilitation programs have shifted from relying primarily on coach intuition to being grounded in scientific evidence.

The transformation of sports assessment is inseparable from the need for multidisciplinary collaboration. Fury et al. (2022) emphasized the importance of integrating sports medicine, sports analytics, and sport science to ensure that granular data from wearables, tracking systems, and big data platforms can effectively translate into training design, return-to-play monitoring, and long-term athlete health management. The challenges of algorithm validation, data interpretation, and translating research findings into actionable protocols underscore the need for stronger interdisciplinary synergy.

Despite the demonstrated benefits of objectivity, precision, and granularity, several challenges remain, including data privacy, acquisition and maintenance costs, user comfort, data security, and improving device accuracy and personalization (Seçkin et al., 2023). Furthermore, some systems still require validation in larger populations, practical testing across different competition levels, and continuous algorithm updates to suit the characteristics of specific sports and user cultures.

The future of tennis assessment, and sports assessment more broadly, will be strongly shaped by advancing cutting-edge technologies, from increasingly miniaturized wearables and AI-driven sensor fusion to immersive VR/AR-based training. All of these are supported by IoT ecosystems that enable digital coaching, remote rehabilitation, personalized recovery, and comprehensive data-science–driven performance evaluation. Accordingly, technology is no longer merely an auxiliary tool but has become, and will continue to be, the cornerstone of modern athletes' and teams' strategic decision-making, spanning injury prevention, performance enhancement, and long-term career management.

Findings from this systematic review demonstrate that integrating technologies such as wearable sensors, video analysis, artificial intelligence, and digital monitoring systems provides high levels of objectivity and efficiency in performance assessment and injury management in tennis. These findings serve as a foundation for developing data-driven training practices and policy innovations in sport science, particularly in supporting coaches' decision-making while enhancing athlete safety and performance. Nevertheless, this study has several limitations, including the predominance of laboratory-based research with small samples, heterogeneity in technological applications, and the lack of long-term validation in real-world or large-population contexts. Therefore, further research is needed to evaluate these technologies' effectiveness, usability, and long-term impact in actual tennis training and competition settings.

Conclusions

This systematic review concludes that emerging technologies, including wearable sensors, video analysis, artificial intelligence, data mining, and digital monitoring systems, transform tennis performance assessment and injury management. Devices and techniques such as IMUs, EMG, thermography,

and ML-based algorithms enable objective, real-time evaluation of technical execution, workload, recovery, and injury risk. These advances enhance the accuracy, efficiency, and personalization of training and rehabilitation while empowering coaches and athletes with evidence-based decision-making. At the same time, integrating big data, cloud computing, and IoT platforms strengthens monitoring capabilities and opens new opportunities for rapid, data-driven feedback. Nevertheless, this study highlights several limitations, including the dominance of laboratory-based studies, small sample sizes, heterogeneity in technologies, and the limited validation of tools in real-world competitive settings. Future research should focus on validating these technologies in diverse, real-world tennis contexts, while addressing challenges related to data security, cost-effectiveness, user comfort, and long-term effectiveness. Multidisciplinary collaboration between sports science, engineering, and data analytics will be crucial in ensuring that technological innovations in tennis assessment continue to support performance optimization, injury prevention, and sustainable athlete development.

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Conflict of Interest

The author of this study states that he has no conflict with other authors.

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