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Review Article

Technological Innovation in Pencak Silat Training as a Component of Indonesian Cultural Heritage: A Systematic Literature Review

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Abstract

Background. Examining technology integration in Pencak Silat training is considered as an essential aspect, focusing on its potential to enhance physical, technical, and mental performance while preserving its cultural and philosophical values.

Objectives. The study aimed to evaluate the effectiveness of augmented reality (AR), virtual reality (VR), and sensor-based systems in improving skill acquisition, performance monitoring, and training customization. It also addresses challenges in technology implementation and examines its adaptability to practitioners of varying skill levels.

Materials and methods. A systematic literature review (SLR) was conducted in accordance with the PRISMA guidelines. Scopus served as the primary database, focusing on studies published within the past decade. Inclusion criteria prioritized studies addressing technological innovations in Pencak Silat training, while irrelevant or low-quality studies were excluded. Data were extracted using a standardized form and analyzed thematically to identify trends, challenges, and gaps.

Results. The findings highlight significant AR, VR, and sensor technological advancements, demonstrating their effectiveness in enhancing physical and technical performance. However, barriers such as high costs, limited accessibility, and the need for tailored solutions continue to persist. Technology showed varying effectiveness based on athlete competence, with professionals benefiting more from advanced features, while tailored tools proved effective for amateurs.

Conclusions. Technology has revolutionized Pencak Silat training, but its integration requires addressing accessibility and adaptation challenges. Future innovations should combine traditional practices with modern advancements to preserve cultural values.

Keywords: Pencak Silat, augmented reality, virtual reality, sensor technology, training innovation, systematic literature review.

Introduction

Pencak Silat is a martial art deeply rooted in Indonesia and Southeast Asia's cultural and philosophical traditions. Its rich history and unique techniques have solidified its status as a significant component of Indonesia's cultural identity. Over the years, Pencak Silat has evolved from a traditional practice into a globally recognized sport. This transformation is supported by national and international initiatives, such as its integration into school extracurricular programs in Indonesia, which have significantly increased youth participation (Burhanuddin et al., 2023; Hariono et al., 2024; Sudiana et al., 2023). The Indonesian government has played a pivotal role in promoting Pencak Silat by hosting national and international competitions, further strengthening its position as a competitive sport (Kusuma & Novita, 2023).

Globally, Pencak Silat's inclusion in prestigious events like the Asian Games has elevated its status as a sport of international repute (Irianto & Lumintuarso, 2020; Subekti

et al., 2020). Beyond competition, Pencak Silat's training philosophy combines physical conditioning, mental discipline, and spiritual development. This holistic approach has drawn global attention, fostering cross-cultural collaborations and exchanges (Imtihansyah et al., 2024; Nugroho et al., 2024). Training in Pencak Silat traditionally involves repetitive practice of foundational movements and techniques guided by experienced mentors. This method develops muscle memory and coordination and instills cultural values and discipline (Ihsan, 2021; Karo-Karo, 2023). These elements reflect Pencak Silat's dual role as a physical practice and a medium for cultural preservation making it a vital and dynamic tradition in Indonesia and beyond.

Technological advancements have significantly influenced sports training in the past decade, including traditional martial arts like Pencak Silat. These innovations have modernized training methodologies, making them more interactive and practical. Digital tools and multimedia applications, such as video-based tutorials and simulation software, are increasingly integrated into Pencak Silat training to enhance skill acquisition and performance. Technologies like augmented reality (AR) and virtual reality (VR) provide immersive training environments, enabling athletes to visualize and practice techniques more effectively (Mulyana, 2024; Sampoerna et al., 2021a). Wearable devices and sensor-based tools have also emerged as pivotal innovations, offering real-time feedback on performance metrics such as speed, power, and movement accuracy (Ihsan et al., 2024; Maghribi, 2024). These technologies enable athletes and coaches to analyze data and refine techniques more precisely. This shift towards technology-supported training demonstrates the potential of digital innovations to revolutionize the practice of Pencak Silat while preserving its traditional essence.

Despite the transformative potential of technology in Pencak Silat training, several critical gaps remain unaddressed. One prominent issue is the limited research on the long-term impact of technology on skill retention, mental development, and the philosophical core of Pencak Silat. Current studies primarily focus on improving physical performance metrics, such as speed and strength, leaving the integration of mental and spiritual dimensions underexplored (Ihsan et al., 2022; Lanos et al., 2023a; Lubis et al., 2021, 2024). Another gap lies in the accessibility and adaptability of technological tools. Many innovations are not tailored to the unique requirements of Pencak Silat training, which involves complex, dynamic movements. This lack of customization can hinder their effectiveness, particularly for advanced practitioners (Widiastuti et al., 2022). Additionally, logistical barriers, such as the high cost of equipment and limited access to underdeveloped regions, restrict the widespread adoption of these technologies. Addressing these gaps is essential for ensuring inclusive and comprehensive advancements in Pencak Silat training.

The main strength of this study lies in the systematic approach used to summarize and evaluate the current literature on technology integration in Pencak Silat training over the past ten years. Based on the initial analysis, most of the existing studies still focus on the application of technology to improve physical and technical performance, such as kick speed, movement coordination, and explosive power (Ihsan et al., 2022; Mardius et al., 2024: Wijaya et al., 2024). However, there are still significant research gaps, especially regarding the long-term impact of technology on skill retention, mental development, and the core philosophy of this martial art. Furthermore, this study also identified emerging challenges, including limited access to technology in areas with inadequate infrastructure and the lack of technology adaptation to the unique needs of Pencak Silat training (Widiastuti et al., 2022).

Furthermore, this study offers new value in evaluating the effectiveness of technology based on the athlete's competency level, namely amateurs compared to professionals. Previous studies often generalize the impact of technology without considering the variation in athlete abilities, creating a gap in understanding how technology can be adapted to the specific needs of each competency level (Anifah & Zuhrie, 2021, 2023; Lubis et al., 2022a; Subekti et al., 2021). This study also addresses the issue of technology accessibility, which is often a significant barrier in populations with low technological literacy or low socioeconomic status. This perspective is essential to ensure that technology adoption is not limited to professional athletes or areas with good infrastructure but is accessible to practitioners from various backgrounds.

This systematic literature review (SLR) examines the role of technological innovation in transforming Pencak Silat training, focusing on its potential to enhance physical, technical, and mental performance while preserving the cultural and philosophical roots of the art. The study aims to synthesize current research to identify the benefits, challenges, and opportunities associated with integrating technologies such as augmented reality (AR), virtual reality (VR), and wearables into training methodologies. The scope includes an analysis of the effectiveness of these technologies in enhancing skill acquisition, providing real-time feedback, and tailoring training for practitioners at varying levels of competence, from amateurs to professionals. The review also addresses the accessibility, affordability, and adaptability of technological tools to changing training needs. The review aims to provide actionable insights for practitioners, coaches, and policymakers by bridging traditional training practices with contemporary advancements, ensuring Pencak Silat's inclusive and sustainable evolution in modern technology.

Materials and Methods

This study employs a systematic literature review (SLR) to explore the technological innovations that have been developed, evaluate their advantages and disadvantages, and contextualize their application in Pencak Silat training. The review adopts a structured approach to ensure comprehensive coverage of the most relevant and high-quality research. This study aims to address the following questions to clarify the role of technology in the development of Pencak Silat martial arts:

- How does technology use impact the physical and technical performance of Pencak Silat athletes?
- What are the challenges in implementing modern technology in Pencak Silat training?
- Are there differences in the effectiveness of technology based on the level of competence (amateur vs professional)?

- What are the prospects for developing new technologies to enhance Pencak Silat training?

Database Selection

This systematic literature review utilizes Scopus as the sole database to identify relevant studies. Scopus is widely recognized for its extensive coverage and rigorous indexing of peer-reviewed literature across various disciplines, making it an ideal platform for conducting a comprehensive review in line with guidelines such as PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) (Ferrara et al., 2023; Pandini, 2022; Ponce et al., 2022). Scopus provides access to a vast collection of high-quality articles, ensuring that the literature included in this review is both relevant and credible. The platform's robust search functionality enables researchers to efficiently identify studies aligned with the research objectives, minimizing the risk of publication bias and enhancing the systematic nature of the review process (Ertem & Aypay, 2023; Miseliūnaitė et al., 2022). In addition to its comprehensive literature coverage, Scopus offers tools for citation analysis and bibliometric studies. These tools are utilized to assess research trends and evaluate the impact of key studies in this field. Such analytical capabilities are critical for synthesizing existing knowledge and identifying gaps in the literature regarding technological innovations in Pencak Silat training (Corrales, 2023; Silva et al., 2021; Zgliczyńska & Kosińska-Kaczyńska, 2021).

Search Strategy

The literature search in this study was exclusively focused on the Scopus database, widely recognized as a trusted source for high-quality scientific literature. The search process was conducted using relevant keywords to identify studies that focus on technology in martial arts training, particularly Pencak Silat. For the Scopus search, the focus was on titles, abstracts, and keywords, using the following terms: ((“Pencak Silat training” AND “technology”) AND (“Augmented reality” AND “martial arts training”) AND (“Motion analysis” AND “Pencak Silat”) AND (Technological innovations in combat sports)). This approach ensures the inclusion of studies directly aligned with the research objectives, capturing the intersection of technological advancements and martial arts training methodologies.

Inclusion and Exclusion Criteria

Table 1 outlines the inclusion and exclusion criteria utilized in this study to guarantee the review's relevance and quality.

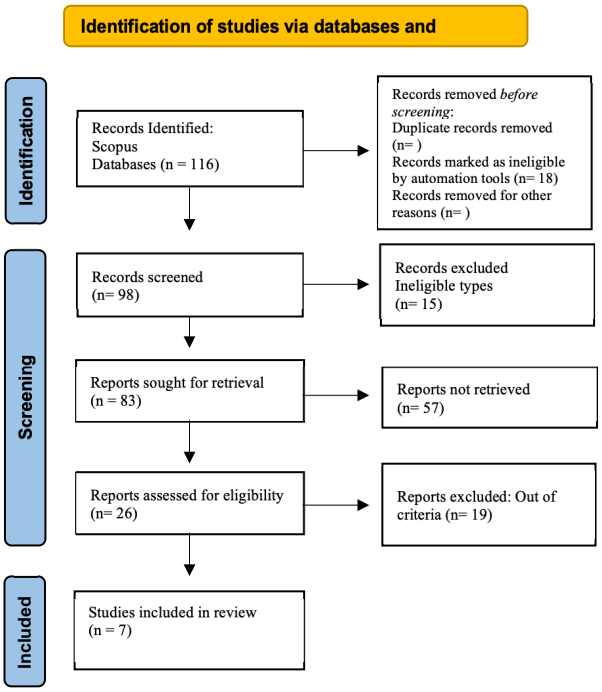

Fig. 1. PRISMA Flow

Study Selection Process

The study selection process followed the PRISMA framework to ensure a systematic and transparent approach. Initially, a comprehensive search was conducted in the Scopus database using pre-defined keywords. Duplicate and ineligible records were removed, and the remaining studies underwent a two-stage screening process. First, titles and abstracts were reviewed to exclude irrelevant or low-quality studies. Next, full-text articles were assessed for eligibility based on the inclusion criteria, focusing on relevance and recent technological advances in martial arts training. This ensured a robust data set for analysis.

Data Extraction and Synthesis

The data extraction process employed a structured approach to ensure comprehensive and consistent information collection from the selected studies. A standardized data extraction form was used to capture key details, including study objectives, methodologies, types of technologies examined, sample characteristics, and key findings. This process was conducted independently by two reviewers to minimize bias and ensure reliability, with discrepancies resolved through discussion or consultation with a third reviewer.

Table 1. Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
• Studies should directly address technological aspects of Pencak Silat training, such as the effectiveness of training tools or technological methods. • Studies published in the last five to ten years were prioritized to reflect recent technological advances. • Empirical studies such as experimental, intervention, or developmental research that are relevant to the research topic.	• Studies that do not directly address technology in the context of Pencak Silat or other martial arts. • Opinion articles, editorials, or systematic reviews • Studies that do not provide sufficient data or methodology to be evaluated. • Only the most comprehensive publications were selected for studies that duplicated findings from other articles.

Thematic analysis was applied to synthesize the extracted data, allowing for the identification of recurring themes, trends, and challenges in the integration of technology into Pencak Silat training. Key themes included the effectiveness of augmented reality (AR) and virtual reality (VR) in skill acquisition, the utility of wearable devices in performance monitoring, and the accessibility challenges faced by practitioners. The synthesis process highlighted gaps in the literature, such as the limited focus on mental and philosophical training, providing a foundation for future research directions.

Limitations

This systematic literature review has several limitations that must be acknowledged. First, the review focuses exclusively on studies published in English, which may exclude valuable research in other languages. Second, using a single database, Scopus, while ensuring high-quality sources, may have overlooked relevant studies indexed elsewhere. Third, the review considered publications from the last decade, potentially omitting earlier baseline studies. Furthermore, the variability in methodology and results across the selected studies poses challenges in synthesis and generalization. Finally, there is limited research on the use of technology in pencak silat training and the long-term impacts of technology use, highlighting areas that require further investigation.

Result and Discussion

Technology integration into Pencak Silat training has brought about transformative changes, increasing the effectiveness and precision of training methodologies. This review highlights the growing use of technology to enhance skill acquisition, performance monitoring, and tactical understanding. These innovations demonstrate a shift towards data-driven and interactive training approaches, benefiting practitioners at all skill levels.

Table 2. Technological Innovation in Pencak Silat Training

Author(s) (Year)	Study Title	Technologies Used	Impact on Performance	Implementation Challenges	Effectiveness Differences	Prospective Technologies
Omar Syarif et al. (2020)	Kinect-Based Application System Design for Pencak Silat Movement using SVMs	Kinect motion sensing and SVM	Improved movement detection accuracy (>90%)	Requires specific hardware and expertise for setup	Effective for all skill levels, especially beginners	AI-integrated motion sensing for advanced feedback
Muktiani et al. (2022)	Augmented Reality Mobile App-Based Multimedia Learning of Pencak Silat	Augmented Reality mobile app	Significant improvement in students' skills ($p < 0.05$)	AR adoption limited by device compatibility	More effective for younger learners in structured settings	AR with real-time feedback and gamification features
Usra et al. (2024)	Augmented Reality Training on Combat Sport	Augmented Reality training platform	Enhanced physical fitness (HDT, MST, $p < 0.05$) and technical performance	Training depends on user engagement and AR familiarity	More effective for experienced athletes (physical fitness gains)	Integration with AI for personalized training plans
Hasibuan et al. (2024)	Interactive Learning Media for Martial Arts Using Smart Apps Creator	Smart Apps Creator for mobile learning	Significant score improvement (pre-test: 7.6; post-test: 8.73, $p = 0.001$)	Limited to Android devices, requiring user proficiency	Universally effective across skill levels	Expansion to cross-platform compatibility (iOS, Web)
Rohayati et al. (2022)	Development of 3D VR Technology for Learning Pencak Silat Curriculum	3D Virtual Reality (VR)	Supported technical and cognitive skill development	High cost of VR setups and teacher training	More suitable for visual learners and language-focused instruction	Advanced VR simulations with haptic feedback
Sampoerna et al. (2021)	Virtual Reality Game for Introducing Pencak Silat	Virtual Reality rhythm game	High user satisfaction (78.61%) and immersion (77%)	Limited game content for diverse skill levels	Engages younger users more effectively	Integration with AI to enhance adaptive learning
Ihsan et al. (2024)	Sensor-Based Scoring System for the Fighting Category in Pencak Silat	Sensor-based scoring system	Increased scoring objectivity and reliability (ICC > 0.05)	Sensor calibration and durability in real competitions	Minimized scoring bias across athletes of different skill levels	Wearable sensors with real-time analytics

The technologies used include Augmented Reality (AR), Virtual Reality (VR), hardware-based sensor systems, mobile-based learning applications, and Kinect-based systems. These technologies support Pencak Silat movement learning, performance analysis, and objective assessments. These technologies generally show positive impacts such as increased movement detection accuracy (>90%), significant technical skills, physical fitness, and user satisfaction improvements. For example, AR improves technical skills and physical fitness, while VR provides an immersive experience that increases user interest. Research shows great potential for further development, such as the integration of AI, real-time feedback, and haptic technology for more realistic simulations. Wearable sensors have also been identified as a potential solution for improving analysis and training.

Research Question 1: Summary of Findings

Technology integration into Pencak Silat training has demonstrated transformative impacts on physical and technical performance. Technologies such as augmented reality (AR), sensor-based systems, and digital learning platforms have revolutionized training methodologies by providing real-time feedback, enhancing skill acquisition, and optimizing physical conditioning. For example, AR training has significantly improved physical fitness and technical skills, particularly among younger athletes, by offering an immersive and interactive learning environment (Usra et al., 2024). Similarly, digital platforms have proven effective in integrating theoretical and practical aspects of the sport, creating a comprehensive and engaging learning experience for athletes (Mulyana, 2024).

Sensor technologies have also emerged as critical tools in performance measurement, offering precise feedback on athletes' movements to refine techniques and assess performance more accurately. These systems are especially valuable when combined with traditional methods, as they help athletes achieve higher levels of physical and technical excellence (Ihsan et al., 2024; Maghribi, 2024). For instance, sensor-based scoring systems provide objective evaluations, address traditional judging methods' biases, and enhance competition fairness (Ihsan et al., 2024).

In addition to enhancing technical skills, technology has also contributed to optimizing physical conditioning. High-intensity interval training (HIIT), supported by technology-assisted programs, has significantly improved athletes' endurance and technical performance (Syarif et al., 2020; Usra et al., 2024; Zarya et al., 2023). Biomechanical tools such as Kinovea software have further enabled coaches to analyze athletes' movements effectively, resulting in improved techniques and performance (Irawan et al., 2021; Lubis et al., 2022; Sinulingga et al., 2023; Syaifullah et al., 2023).

Combining traditional training methods with innovative technologies offers a comprehensive approach to developing Pencak Silat athletes. While conventional methods instill cultural values and foundational skills, technology provides precision, objectivity, and efficiency in training. This dual approach ensures that athletes not only excel in physical and technical aspects but also maintain Pencak Silat's cultural and philosophical essence. Thus, the strategic application of technology represents a vital step toward advancing this martial art's performance and training methodologies.

Research Question 2: Challenges in Implementing Modern Technology in Pencak Silat Training

Implementing modern technology in Pencak Silat training has several challenges that impact its widespread adoption and effectiveness. A significant obstacle is the resistance to change among coaches and athletes, many of whom prefer traditional training methods. This resistance often stems from a lack of familiarity with technological tools and skepticism regarding their benefits. The effectiveness of innovations such as augmented reality (AR) and digital learning platforms depends on the willingness of practitioners to embrace these methods, which requires targeted efforts to demonstrate their value and practicality (Muktiani et al., 2022; Mulyana, 2024).

Another significant challenge is the lack of infrastructure and resources, particularly in rural areas where Pencak Silat is deeply rooted. Inadequate access to reliable internet, modern devices, and training facilities limits the feasibility of implementing digital tools, further widening the gap between urban and rural practitioners (Yudaparmita et al., 2023). High financial costs associated with acquiring and maintaining advanced technologies such as sensor-based systems and VR setups also pose a barrier for many training centers, making affordability a critical issue for sustained implementation (Sampoerna et al., 2021).

The complexity of Pencak Silat's movements adds another layer of difficulty, requiring specialized technologies capable of accurately analyzing dynamic and intricate techniques. Developing and maintaining such systems can be resource-intensive and time-consuming, particularly for smaller organizations (Ihsan et al., 2024). Moreover, insufficient training for athletes and coaches to effectively utilize these technologies reduces their impact, emphasizing the need for tailored training programs to ensure proper usage and maximize benefits (Widiastuti et al., 2022).

Addressing these challenges requires a multifaceted approach. Increasing accessibility to technological resources, funding support for rural areas, and offering comprehensive training for practitioners are critical steps. Additionally, fostering awareness and understanding of the benefits of technology in improving physical and technical performance can help overcome resistance. By addressing these barriers, the integration of modern technology can achieve its full potential in advancing Pencak Silat training while preserving its cultural and traditional essence.

Research Question 3: Differences in the Effectiveness of Technology Based on the Level of Competence

The effectiveness of technology in Pencak Silat training demonstrates distinct variations between amateur and professional athletes due to differences in skill level, motivation, and access to resources. With their advanced physical and technical skills, professional athletes are often better positioned to maximize the benefits of augmented reality (AR) and sensor-based tools. For instance, AR has been shown to enhance technical performance and physical fitness, particularly for athletes with a well-developed

foundation of skills, as they can adapt more quickly to the advanced functionalities these tools offer (Usra et al., 2024). Additionally, professionals typically exhibit greater motivation and discipline, facilitating the seamless integration of new training methods into their routines (Nurhidayah, 2024).

In contrast, amateur athletes may face challenges in utilizing these technologies effectively. A lack of foundational skills and limited familiarity with the complexities of Pencak Silat training can hinder the adoption of advanced tools, reducing their potential impact (Ihsan et al., 2022). For example, sensor-based systems that require precise execution of movements might be more effective for professionals who can provide consistent inputs, whereas amateurs might struggle to meet these requirements. Similarly, the accessibility of technological resources is often limited for amateur athletes, particularly in settings where training facilities lack adequate funding or infrastructure (Mulyana, 2024).

Research also highlights differences in the psychological adaptability of athletes at varying levels. Professionals tend to exhibit higher engagement and commitment to training innovations, making them more receptive to technology-driven enhancements (Festiawan et al., 2024; Hasibuan et al., 2024). Conversely, amateur athletes may require additional motivation and simplified interfaces to effectively use these tools, underscoring the need for tailored solutions that address their specific learning and developmental needs (Anifah & Zuhrie, 2024; Burhanuddin et al., 2023; Halomoan et al., 2023). While technology holds promise for enhancing performance across all levels, its implementation must be adjusted to match the athlete's competence. Professionals can leverage advanced features for optimization, while amateurs benefit more from tools focused on foundational skill-building and accessibility. By addressing these differences, technological innovations can create equitable opportunities for improvement, fostering growth and excellence across all levels of Pencak Silat training.

Research Question 4: Prospects for Developing New Technologies to Enhance Pencak Silat Training

The future of Pencak Silat training is poised for significant advancements by integrating cutting-edge technologies, which promise to revolutionize traditional methodologies. Key innovations such as augmented reality (AR), virtual reality (VR), sensor-based systems, and artificial intelligence (AI) are paving the way for more effective, personalized, and engaging training experiences. AR and VR technologies are at the forefront of these advancements. AR applications enable athletes to visualize and practice complex movements in an immersive and controlled environment, enhancing technical skill acquisition (Muktiani et al., 2022; Usra et al., 2024). Similarly, VR provides an opportunity to simulate combat scenarios, allowing practitioners to refine their tactics and cognitive responses in lifelike yet safe conditions (Rohayati et al., 2022). These tools are especially valuable for younger athletes, combining interactive learning with technical development and making training more accessible and engaging (Mulyana, 2024).

Sensor-based systems are another promising area, offering precise measurement of performance metrics such as kick speed, power, and movement accuracy (Damrah, 2023; Ihsan et al., 2024). These systems provide real-time feedback, allowing athletes to adjust their techniques dynamically during training sessions. Coaches can leverage the data collected by these sensors to design personalized training regimens tailored to each athlete's specific strengths and weaknesses (Maghribi, 2024). Artificial intelligence (AI) and machine learning further enhance the potential for personalized training. These technologies can analyze athletes' movement patterns and identify areas for improvement with greater precision than traditional methods. For example, AI-driven tools can predict injury risks based on biomechanical data, enabling preventive measures and safer training environments (Atqia & Suryani, 2023). IoT-enabled devices, such as pressure-sensitive mats, provide instant feedback on posture and execution, ensuring that athletes maintain proper form during practice (Ambarwati et al., 2024; Anifah & Zuhrie, 2024; Atqia & Suryani, 2023).

As these technologies continue to evolve, their integration into Pencak Silat training holds immense potential to bridge the gap between traditional practices and modern innovations. By combining cultural and philosophical values with technological advancements, future training methodologies can provide a holistic and inclusive approach, benefiting amateur and professional athletes. Ultimately, these developments are set to redefine the landscape of Pencak Silat, making it more effective, engaging, and accessible for practitioners worldwide.

The integration of technology in Pencak Silat training influences not only the physical and technical aspects of the sport but also its cultural and philosophical values. By embedding traditional teachings into digital tools, such as augmented reality (AR) and multimedia platforms, technology enhances the transmission of discipline, respect, and spiritual development central to Pencak Silat. These innovations create immersive learning environments that connect practitioners to the martial arts's core values while making these teachings accessible to a broader audience (Muktiani et al., 2022; Usra et al., 2024).

Maintaining cultural and philosophical values, which include lessons on discipline, respect, and spiritual development in technology-based training

AR and virtual reality (VR) provide engaging experiences where students can explore Pencak Silat's historical and cultural elements, helping them understand its philosophical underpinnings. For example, VR-based scenarios simulate real-life combat or training environments, enabling athletes to practice and embody values such as respect for opponents and self-discipline (Hadiana et al., 2022; Sampoerna et al., 2021). These tools improve physical training outcomes but also immerse practitioners in the cultural heritage of Pencak Silat, fostering a holistic appreciation of the art form.

Incorporating technology into structured training programs can instill ethical principles and life skills among young athletes. Studies suggest that technology-enhanced training, such as interactive multimedia platforms, supports the positive development of character traits such as responsibility and teamwork (Hadiana et al., 2022; Mulyana, 2024). Digital learning materials that highlight Pencak Silat's historical narratives and spiritual teachings encourage

deeper engagement with the philosophy of the art, ensuring that students gain a comprehensive understanding beyond physical performance.

Furthermore, using digital coaching platforms promotes a culture of continuous self-improvement. These platforms provide real-time feedback and facilitate detailed performance evaluations, encouraging athletes to refine their skills while respecting the traditions and techniques of Pencak Silat (Hasibuan et al., 2024; Ihsan, 2021; Sinulingga et al., 2023). Such advancements make it easier to balance innovation with preserving traditional values, ensuring that technology is a bridge rather than disrupting the martial arts legacy.

Community engagement is another critical aspect reinforced by technology in Pencak Silat training. Digital tools enable practitioners to connect with peers and mentors globally, fostering a sense of unity and shared cultural appreciation (Fahmi et al., 2024; Lanos et al., 2023). This strengthens interpersonal bonds among practitioners and ensures the continuity of collective values, such as mutual respect and support. While technology is primarily used to enhance physical and technical training, its influence on cultural and philosophical dimensions is equally significant. Through immersive tools, structured programs, and global connectivity, technology ensures that Pencak Silat remains a holistic practice, blending modern innovation with preserving its timeless values. This integration reaffirms Pencak Silat's role as not only a martial art but also a vehicle for cultural heritage and moral education.

Conclusions

Technology integration in Pencak Silat training has proven transformative, enhancing physical and technical performance while promoting engagement and learning efficiency. Tools such as augmented reality (AR), virtual reality (VR), and sensor-based systems have modernized traditional practices, enabling precise performance monitoring and immersive learning experiences. Despite these advancements, challenges such as accessibility, cost, and technology adaptation to meet diverse training needs persist. Addressing these issues is essential to ensure that the benefits of technology are equitably distributed among practitioners at all skill levels. Several steps should be taken to ensure the successful integration of technology in Pencak Silat training. First, efforts must be made to expand access to technology by providing funding and resources to rural and underprivileged areas, ensuring equitable opportunities for practitioners across all regions. Training tools should be tailored to the unique requirements of Pencak Silat, focusing on accommodating complex movements and preserving the cultural values inherent in martial arts. Additionally, structured training programs should be implemented for both coaches and athletes to maximize the effective use of technological tools in improving performance. Furthermore, there is a need to promote research, mainly longitudinal studies, to assess the long-term impacts of technology on skill retention, mental development, and the preservation of philosophical principles in Pencak Silat. Finally, fostering interdisciplinary collaboration between biomechanics, education, and cultural studies can help create holistic and innovative training methodologies that seamlessly integrate traditional and modern practices.

Conflict of Interest

All authors declare no conflict of interest.

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Інноваційні технології у тренуванні з Пенчак Сілату як складової культурної спадщини Індонезії: Систематичний огляд літератури

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 10 с., 2 табл., 1 рис., 52 джерела.

Історія питання. Вивчення питання щодо інтеграції технологій у тренуваннях з Пенчак Сілату розглядається як важливий аспект, що акцентує увагу на потенціалі впровадження технологій з метою підвищення фізичної, технічної та розумової працездатності, водночас зберігаючи культурні та філософські цінності.

Мета дослідження. Дослідження мало на меті оцінити ефективність застосування доповненої реальності (ДР), віртуальної реальності (ВР) та сенсорних систем для покращення набуття навичок, моніторингу результативності та кастомізації тренувань. У дослідженні також розглядаються проблеми впровадження технологій і вивчається їх адаптованість до потреб практикуючих фахівців з різним рівнем кваліфікації.

Матеріали та методи. Систематичний огляд літератури (СОЛ) проведено відповідно до рекомендацій PRISMA. В якості основної бази даних використовувалась наукометрична база даних Scopus, з акцентом на дослідженнях, опублікованих протягом останнього десятиліття. Критерії включення визначали пріоритетність досліджень, присвячених інноваційним технологіям у тренуваннях з Пенчак Сілату, тоді як нерелевантні або низькоякісні дослідження були виключені. Збір даних здійснювався за допомогою стандартизованої форми та тематичного аналізу з метою визначення тенденцій, проблематики та наявних прогалин.

Результати. Отримані дані свідчать про значні технологічні досягнення в галузі доповненої і віртуальної реальності та сенсорних технологій, демонструючи їхню ефективність у підвищенні фізичної та технічної результативності. Однак продовжують існувати такі перешкоди, як висока вартість, обмежена доступність і потреба в індивідуальних рішеннях. Технології показали різну ефективність залежно від компетенції спортсмена: професіонали отримують більше переваг від розширених функціональних можливостей, тоді як для аматорів ефективними виявилися спеціалізовані інструменти.

Висновки. Технології революціонізували тренування з Пенчак Сілату, але їхня інтеграція вимагає розв'язання проблем, пов'язаних із доступністю та адаптацією. Подальші інновації мають поєднувати традиційні практики із сучасними досягненнями задля збереження культурних цінностей.

Ключові слова: Пенчак Сілат, доповнена реальність, віртуальна реальність, сенсорна технологія, інновації у тренуванні, систематичний огляд літератури.

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