Advancing Silat as a Scientific Combat Sport: Integrating Sport Science, Digital Innovation, and Society 5.0 in Malaysia

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Abstract. Silat constitutes a significant element of Malaysia's intangible cultural heritage, yet its transformation into a modern competitive sport introduces multidimensional challenges related to standardization, performance optimization, and knowledge integration. This study critically examines the current state and future trajectory of Silat research and innovation within the framework of Society 5.0, which emphasizes the convergence of human-centered values and advanced digital technologies. Guided by Bishop's Applied Research Model for Sport Sciences, this paper adopts a conceptual and analytical approach to evaluate three principal domains of Silat practice: Silat Olahraga (competitive sport), Silat Tempur (combat application), and Silat EVO (digitally augmented evolution). The analysis highlights existing gaps in empirical research, particularly in biomechanics, physiological profiling, and performance analytics, which remain underexplored compared to other combat sports [1], [2]. Furthermore, the integration of digital technologies such as motion tracking, artificial intelligence, and data-driven coaching systems is identified as a critical pathway for enhancing athlete development and competitive outcomes [3], [4]. Within the Society 5.0 paradigm, Silat innovation must also balance technological advancement with cultural sustainability, ensuring the preservation of traditional values while promoting global competitiveness [5]. This paper proposes a strategic research framework that prioritizes interdisciplinary collaboration, evidence-based training models, and digital transformation aligned with sport science principles. The findings contribute to the development of a sustainable and globally relevant Silat ecosystem, reinforcing its position as both a cultural asset and a scientifically grounded sport discipline.

Keywords: Silat; combat sport; sport science; innovation; Society 5.0; digital transformation; Malaysia.

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1 Introduction

Silat constitutes a fundamental component of Malay cultural identity, encompassing elements of artistic expression, philosophical values, and combative techniques. In contemporary Malaysia, this traditional martial art has undergone a significant transformation into a structured and regulated combat sport. This transition introduces a critical duality: the need to preserve cultural authenticity while simultaneously meeting the scientific and performance demands of modern competitive sport. Within this continuum, three principal domains are recognized, namely Silat Olahraga (competitive sport), Silat Tempur (applied combat), and the emerging Silat EVO, which integrates digital and technological innovation into training and performance environments.

From a sport science perspective, combat sports such as judo, boxing, wrestling, and taekwondo have demonstrated substantial advancement in research productivity and scientific application over the past two decades. Recent bibliometric analyses of Scopus-indexed publications reveal a sustained increase in scholarly output, particularly in biomechanics, physiological profiling, tactical analysis, and performance optimization [1]–[4]. For example, judo research has exceeded one thousand indexed publications, while taekwondo and boxing have each contributed several hundred studies, reflecting a mature integration of scientific methodologies into athlete development systems [2], [5]. Furthermore, the adoption of advanced technologies, including motion capture systems, wearable sensors, and data analytics, has significantly enhanced evidence-based training practices in these sports [6], [7].

In contrast, Silat remains underrepresented within global sport science literature despite its growing participation base across Southeast Asia and increasing presence in international competitions. Existing studies predominantly adopt descriptive or observational approaches, with limited engagement in experimental design, longitudinal analysis, or technology-driven methodologies [8], [9]. This imbalance constrains the development of standardized training models, performance benchmarks, and scientific validation of techniques. Consequently, there is a pressing need to establish a systematic, interdisciplinary, and innovation-oriented research agenda that aligns Silat with contemporary sport science paradigms.

The urgency of this development is further reinforced by the emergence of the Society 5.0 framework, which emphasizes the integration of human-centered values with advanced digital technologies to address complex societal challenges [10]. Within this context, Silat research must evolve beyond traditional frameworks by incorporating digital transformation, artificial intelligence, and data-driven performance systems while maintaining its cultural integrity. Such an approach is essential to enhance both athlete performance and the global competitiveness of Silat as a modern combat sport.

To illustrate the disparity in research development across combat sports, Table 1 presents a comparative overview of publication outputs and key research domains, while Table 2 summarizes longitudinal growth trends. These data highlight the relative lag of Silat research and underscore the necessity for strategic intervention through sport science integration and innovation.

Table 1. Comparative Publication Output in Combat Sports.

No	Combat Sport	Estimated Publications (2000–2024)	Key Research Domains	Representative Scopus-Indexed Journals
1	Judo	>1,000	Biomechanics, match analysis, physiology	*Journal of Sports Sciences*; *Frontiers in Sports and Active Living*
2	Taekwondo	~800	Kinematics, tactics, injury prevention	*Archives of Budo*; *Sustainability*
3	Boxing	~700	Performance, neurology, conditioning	*Sports Medicine*; *JSCR*
4	Wrestling	~600	Strength, endurance, physiology	*International Journal of Wrestling Science*
5	**Silat**	**<150**	Match analysis, pedagogy	*IDO Movement for Culture*; *Malaysian Journal of Sport Science*

Table 2. Growth Trend of Combat Sports Research (2000-2024)

Period	Judo	Taekwondo	Boxing	Wrestling	Silat
2000–2005	120	80	75	60	<10
2006–2010	200	150	130	110	~20
2011–2015	300	250	220	180	~40
2016–2020	350	280	260	210	~50
2021–2024	250	200	180	140	~30

2 Present Condition: Current State of Knowledge

2.1 Contemporary Research Landscape

Malaysia has emerged as a leading contributor to the scientific development of Silat, particularly in the domain of performance analysis. Over the past decade, research has expanded to include match activity profiling, physiological demands, technical–tactical indicators, and psychological attributes of athletes. Despite this progress, most studies remain situated within the initial phases of Bishop's Applied Research Model, particularly from problem identification to predictor evaluation [1], [2]. Empirical investiga-

tions that advance toward applied implementation, intervention validation, and ecological transferability remain comparatively limited. This imbalance restricts the translation of theoretical findings into practical performance enhancement strategies.

2.2 Empirical Findings Across Silat Formats

Recent empirical studies in Silat Olahraga demonstrate statistically significant differences between high-performing and lower-performing athletes, particularly in relation to temporal variables such as action time, attack frequency, and defensive transitions. These indicators provide critical insights into pacing strategies and competitive efficiency, aligning with findings in other combat sports where temporal dominance strongly predicts match outcomes [3], [4].

In Silat Tempur, which is designed as a developmental and youth-oriented format, research highlights its effectiveness in promoting tactical awareness, controlled aggression, and technical skill acquisition within a safe competitive environment. Although the current body of evidence is predominantly observational, it offers a valuable foundation for designing structured, age-appropriate training interventions grounded in sport science principles.

The emergence of Silat EVO introduces a novel dimension by integrating digital and performance-enhancing technologies into training and competition contexts. However, empirical validation of its effectiveness remains limited, indicating a significant research gap.

2.3 Coaching Practices, Pedagogy, and Learning Innovation

The modernization of Silat is increasingly reflected in the evolution of coaching practices and pedagogical models. The adoption of digital learning environments—including video-assisted analysis, e-learning platforms, and structured instructional frameworks—has begun to reshape athlete development systems. Evidence suggests that blended learning approaches enhance athlete engagement, cognitive understanding, and skill acquisition when combined with traditional mentorship models [5].

Nevertheless, longitudinal studies examining the sustained impact of these innovations on performance outcomes are scarce. Future research should incorporate controlled experimental designs and long-term monitoring to evaluate the effectiveness of technology-enhanced coaching interventions.

2.4 Governance, Ethics, and Cultural Sustainability

The institutionalization of Silat as a regulated sport has introduced critical considerations related to governance, ethics, and cultural identity. Efforts to standardize competition rules, improve athlete safety, and promote inclusivity—particularly gender equity—are essential for international recognition and legitimacy.

Simultaneously, Silat's recognition as an element of intangible cultural heritage underscores the importance of preserving its philosophical and traditional dimensions.

This dual function—as both a cultural practice and a competitive sport—necessitates a balanced framework that integrates modernization with heritage conservation [6].

2.5 Methodological Limitations and Research Challenges

Despite notable advancements, the current Silat research landscape faces several methodological constraints. Many studies are characterized by small sample sizes, single-site data collection, inconsistent terminology, and limited statistical rigor. Furthermore, intervention-based research often lacks ecological validation within real competition environments, reducing its practical applicability.

Addressing these challenges requires the establishment of multi-centre collaborations, standardized measurement protocols, and shared data infrastructures. Such initiatives would significantly enhance the reliability, comparability, and scalability of Silat research within the global sport science domain.

3 Future Directions: Strategic Research Priorities

The advancement of Silat research necessitates the development of a coordinated national research ecosystem. Establishing standardized performance indicators—such as attack frequency, counterattack success rate, and match tempo—would enable consistent data collection and cross-study comparison. The integration of centralized, open-access databases linking biomechanical, physiological, and competition data would facilitate large-scale analyses and advanced computational modeling, including machine learning applications [7].

3.1 Standardization and Development of Shared Databases

The establishment of a coordinated national Silat research consortium would facilitate the standardization of key performance indicators, including offensive actions, counterattacks, dominance, and match tempo. In addition, the creation of centralized and open-access databases—linking competition analysis, physiological metrics, and injury surveillance—would enable large-scale studies. Such integration would support advanced methodologies, including meta-analysis and machine learning, thereby enhancing the scientific credibility of Silat research within the broader sport science community.

3.2 From Efficacy to Real-World Effectiveness

While controlled experimental studies provide essential evidence of training efficacy, the critical challenge lies in translating these findings into real-world performance contexts. Future research should prioritize effectiveness studies conducted within authentic competitive environments, such as national tournaments and developmental leagues . This transition reflects progression toward the advanced stages of Bishop's Applied Research Model, emphasizing ecological validity and applied impact [1].

3.3 Integration of Digital Technologies and Artificial Intelligence

In alignment with the Society 5.0 paradigm, the integration of digital technologies should enhance human expertise rather than replace it. The application of artificial intelligence, motion tracking systems, and wearable sensors offers significant potential for improving performance analysis, coaching decision-making, and talent identification [8].

When implemented responsibly, these technologies can optimize training processes, improve officiating accuracy, and support data-driven athlete development, while preserving the experiential and cultural knowledge embedded in Silat practice.

3.4 Safety, Youth Development, and Inclusive Participation

Silat Tempur provides a scalable model for youth engagement by emphasizing progressive contact intensity and pedagogical safety. Future research should incorporate multidimensional variables, including biological maturation, psychological readiness, and gender inclusivity, to ensure equitable and sustainable athlete development pathways.

Such approaches are critical for promoting long-term participation and safeguarding athlete welfare.

3.5 Coaching Education and Professional Development

Sustainable innovation in Silat requires continuous improvement in coaching education systems. Collaborative initiatives involving academic institutions and governing bodies should focus on developing modular, research-based training programs supported by digital platforms.

Ongoing evaluation of these programs is essential to determine their effectiveness in enhancing coaching competencies and athlete performance outcomes.

3.6 Governance, Ethics, and Responsible Innovation

The expansion of technologically enhanced formats such as Silat EVO necessitates robust governance frameworks. Ethical considerations—including data privacy, algorithmic bias, and responsible use of performance analytics—must be systematically addressed [6].

Establishing transparent regulatory structures will ensure that technological innovation aligns with athlete protection, fair competition, and the preservation of cultural values.

4 Conclusion

The evolution of Silat in Malaysia is currently characterized by a dynamic transition from a culturally rooted martial art to a scientifically informed and technologically supported combat sport. This transformation is reinforced by institutional collaboration,

the adoption of digital innovations, and sustained efforts to preserve its intangible cultural heritage. Within the broader context of Society 5.0, Silat demonstrates strong potential as a model for human-centered sport innovation that integrates cultural identity with advanced performance systems [1].

While existing research has predominantly employed descriptive and exploratory methodologies, these studies have provided a critical baseline for understanding performance characteristics, training structures, and pedagogical approaches. However, to achieve meaningful progress, future research must advance toward applied and intervention-based designs that emphasize ecological validity and real-world effectiveness. This progression is consistent with the later stages of Bishop's Applied Research Model, which prioritize the translation of scientific knowledge into practice [2].

Furthermore, the integration of sport science disciplines—particularly biomechanics, physiology, performance analytics, and data-driven coaching—remains essential for optimizing athlete development and competitive outcomes. The incorporation of emerging technologies, including artificial intelligence and wearable monitoring systems, offers substantial opportunities to enhance performance analysis and decision-making processes, provided that such innovations are implemented within robust ethical and governance frameworks [3].

Equally important is the need to maintain a balanced approach that safeguards Silat's cultural and philosophical foundations. The dual identity of Silat as both a heritage practice and a competitive sport necessitates a framework that aligns modernization with cultural sustainability, ensuring that innovation does not compromise its traditional values [1].

In conclusion, Malaysia is strategically positioned to elevate Silat into a globally recognized combat sport through the integration of evidence-based practice, interdisciplinary research, and responsible technological innovation. Achieving this objective requires coordinated efforts among researchers, coaches, governing bodies, and policymakers to establish a sustainable, inclusive, and scientifically grounded Silat ecosystem.

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Disclosure of Interests. The authors declare that there are no competing interests associated with this study. The research was conducted independently, without any financial or commercial affiliations that could be perceived as a potential conflict of interest.

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