



Deep Learning Applications in Physical Education: A Systematic Review of Educational and Sport Science Perspectives

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Abstract. The rapid advancement of artificial intelligence (AI), particularly deep learning algorithms, has created significant opportunities for innovation in physical education and sport science. Deep learning enables high-precision analysis of human movement, biomechanical patterns, image recognition, and video-based performance assessment, thereby supporting data-driven instruction, motor skill evaluation, and adaptive learning environments. This study systematically reviews the implementation of deep learning technologies in physical education research and practice. The review employed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework to identify, screen, and analyze relevant studies published between 2015 and 2025. Data were collected from Scopus, Web of Science, and Google Scholar databases using keywords related to deep learning, physical education, motor learning, and sport analytics. The findings reveal that deep learning has been extensively applied in motion recognition, posture correction, skill classification, injury prevention analysis, and personalized feedback systems. Several studies also reported improvements in learning efficiency, student engagement, and accuracy of motor performance assessment through computer vision and wearable sensor integration [1], [2]. Nevertheless, the existing literature remains heavily concentrated on elite sports performance and higher education settings, while empirical applications in elementary and secondary school physical education are comparatively limited. In addition, challenges related to technological infrastructure, teacher digital competence, data privacy, and implementation costs continue to hinder broader adoption in school contexts [3], [4]. This review concludes that deep learning possesses substantial potential to transform physical education into a more adaptive, evidence-based, and technology-enhanced discipline. However, future studies should prioritize school-based interventions, longitudinal validation, and pedagogical integration models suitable for diverse educational environments. The novelty of this review lies in its emphasis on the educational implications of deep learning beyond competitive sport analytics, particularly within the context of inclusive and student-centered physical education.

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1 Introduction

Physical education plays a strategic role in the educational system by promoting students' physical fitness, motor competence, cognitive development, emotional regulation, and social interaction. Beyond improving physical performance, physical education also contributes to the formation of lifelong healthy behaviors, teamwork, discipline, and sportsmanship values [1], [2]. In contemporary educational practice, the effectiveness of physical education learning is strongly influenced by instructional strategies, assessment quality, technological integration, and teachers' pedagogical competence in evaluating student movement performance [3], [4]. Consequently, innovation in instructional and assessment approaches has become increasingly important in response to the demands of digital-era education.

One of the persistent challenges in physical education is the subjective nature of motor skill assessment. In many school settings, teachers continue to rely primarily on direct visual observation to evaluate students' movement quality and physical performance. Although observational assessment is practical, it is frequently constrained by limited instructional time, large class sizes, and variations in student motor abilities [5], [6]. These limitations reduce assessment consistency and hinder the provision of individualized feedback. As a result, students may not receive accurate corrective input necessary for optimal motor learning and skill acquisition. Previous studies have indicated that objective and technology-supported assessment systems can significantly improve reliability and instructional effectiveness in movement education [7], [8].

The rapid advancement of artificial intelligence (AI) has introduced new possibilities for improving educational practices, including physical education and sport science. Among AI technologies, deep learning has demonstrated substantial capability in processing large-scale and complex datasets, including images, videos, and wearable sensor signals [9], [10]. Deep learning models, particularly convolutional neural networks (CNNs), recurrent neural networks (RNNs), and long short-term memory (LSTM) architectures, have achieved high levels of accuracy in pattern recognition, posture estimation, motion tracking, and activity classification [11], [12]. These developments have accelerated the integration of AI into human movement analysis and sports performance evaluation.

In the context of physical education, deep learning technologies offer opportunities to transform conventional teaching and assessment approaches into more objective, adaptive, and data-driven systems. By utilizing computer vision and sensor-based analysis, deep learning systems can automatically identify movement errors, evaluate biomechanical performance, and provide immediate feedback during learning activities [13], [14]. Such capabilities are particularly relevant for motor skill acquisition, where timely and precise feedback is essential for improving movement quality and learning outcomes. Furthermore, AI-assisted learning environments may enhance student engagement and motivation through interactive and personalized instructional experiences [15].

Recent studies have shown a significant increase in the application of deep learning within sport science and physical activity research. Existing literature predominantly focuses on elite athlete monitoring, tactical analysis, injury prevention, rehabilitation, and professional sports performance optimization [16], [17]. However, empirical studies investigating deep learning implementation in school-based physical education remain relatively limited, particularly at elementary and secondary education levels. This imbalance indicates an important research gap because school physical education differs substantially from elite sport environments in terms of pedagogical objectives, learner diversity, curriculum orientation, and technological accessibility [18].

Despite its promising potential, the implementation of deep learning in educational contexts also presents several challenges. Limited technological infrastructure, insufficient teacher digital literacy, high implementation costs, and ethical concerns related to data security and student privacy remain major barriers to adoption [19], [20]. In addition, the lack of standardized implementation frameworks and pedagogical integration models has hindered the widespread utilization of AI-based systems in physical education settings. Without comprehensive evaluation and contextual adaptation, the application of deep learning technologies may not effectively address educational needs or improve learning quality.

Given these conditions, a systematic review is necessary to synthesize current evidence regarding the implementation of deep learning in physical education. Systematic reviews provide a structured approach for identifying research trends, evaluating methodological developments, classifying application domains, and identifying unresolved gaps in the literature [21]. Through this approach, researchers and practitioners can better understand the effectiveness, opportunities, and limitations of deep learning technologies in educational and sport science contexts.

Therefore, this study aims to systematically review the implementation of deep learning in physical education research published between 2015 and 2025. Specifically, this review examines: (1) the major application areas of deep learning in physical education; (2) the dominant deep learning models and technologies employed; and (3) the opportunities, limitations, and future challenges associated with AI integration in school-based physical education. The findings of this study are expected to contribute to the development of evidence-based, technology-enhanced, and sustainable physical education practices aligned with current advancements in sport science and educational technology.

2 Method

2.1 Research Design

This study employed a systematic review design to comprehensively identify, evaluate, and synthesize previous research related to the implementation of deep learning in physical education and sport science. A systematic review approach was selected because it enables the integration of findings from multiple studies in a transparent, structured, and reproducible manner, thereby facilitating the identification of research trends, methodological developments, technological applications, and

existing research gaps [1]. In addition, systematic reviews are considered highly relevant for rapidly developing interdisciplinary fields such as artificial intelligence in education and human movement analysis.

The review procedure followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines to ensure methodological rigor, transparency, and consistency throughout the review process [2]. The PRISMA framework was utilized to guide article identification, screening, eligibility assessment, and inclusion stages. This methodological framework also supports replicability and minimizes potential selection bias during literature analysis.

The scope of this review focused on studies investigating the application of deep learning technologies in physical education, motor learning, movement analysis, sport pedagogy, and technology-assisted assessment systems. Particular attention was given to research discussing computer vision, wearable sensor integration, posture estimation, movement classification, and AI-supported learning environments within educational and sport science contexts.

2.2 Data Sources and Literature Search Strategy

A systematic literature search was conducted using three major scientific databases: Scopus, Web of Science, and Google Scholar. These databases were selected because of their extensive international coverage and strong relevance to educational technology, artificial intelligence, sport science, and physical education research [3]. The search process was conducted during the final stage of the study and included publications published between 2015 and 2025 to capture the most recent developments in deep learning implementation.

The search strategy combined keywords and Boolean operators to improve search precision and relevance. The primary search terms included: “deep learning” AND “physical education”; “artificial intelligence” AND “movement learning”; “deep learning” AND “human motion analysis”; “computer vision” AND “physical education”; and “AI-based assessment” AND “sport education.” Searches were applied to titles, abstracts, and author keywords to ensure that retrieved articles were directly related to the objectives of the review.

To improve methodological quality, the inclusion criteria were defined as follows: (1) articles published in peer-reviewed journals or conference proceedings; (2) studies discussing the application of deep learning or AI technologies in physical education, sport science, or movement learning; (3) publications written in English; and (4) studies published between 2015 and 2025. Meanwhile, articles were excluded if they: (1) focused exclusively on medical diagnosis without educational relevance; (2) lacked empirical or methodological explanation; (3) consisted only of editorials, opinion papers, or non-scientific reports; or (4) were duplicate publications across databases..

2.3 Article Selection Process (PRISMA)

The article selection procedure followed the four stages recommended in the PRISMA 2020 framework: identification, screening, eligibility assessment, and

inclusion [2]. During the identification stage, all relevant publications retrieved from the selected databases were collected and exported into a reference management system. Duplicate records were subsequently removed to improve data accuracy.

In the screening stage, article titles and abstracts were reviewed to eliminate studies that did not align with the research objectives. The eligibility stage involved full-text evaluation to determine whether each study satisfied the predetermined inclusion criteria. Finally, eligible studies were included in the final synthesis and analyzed according to research focus, methodological approach, deep learning model type, application domain, and educational context.

To enhance analytical consistency, the selected studies were categorized into several thematic areas, including motion analysis, motor skill assessment, posture recognition, adaptive learning systems, and AI-assisted instructional media. This thematic classification facilitated a clearer interpretation of current trends and emerging directions in deep learning applications for physical education.

2.4 Data Extraction and Analysis

Data extraction was conducted systematically using a structured review matrix. The extracted information included author names, publication year, country of study, research objectives, sample characteristics, deep learning techniques employed, data acquisition methods, and principal findings. Additional information regarding educational level, technological tools, and reported implementation challenges was also documented to support comparative analysis.

The collected data were analyzed using a qualitative descriptive synthesis approach. This approach enabled the interpretation of patterns, methodological tendencies, and technological developments across studies without conducting a statistical meta-analysis. The qualitative synthesis was considered appropriate because the reviewed studies demonstrated substantial heterogeneity in research design, data collection procedures, and application contexts [4].

2.5 Research Ethics

This study utilized secondary data derived exclusively from published scientific literature and therefore did not involve direct interaction with human participants. Consequently, formal ethical approval was not required. Nevertheless, all reviewed sources were cited and referenced in accordance with international academic and publication ethics standards to maintain research integrity and avoid plagiarism or misinterpretation of previous findings.

3 Result and Discussion

The results of this study were obtained through a systematic review of articles addressing the implementation of deep learning in physical education, movement learning, physical activity, and sports. The findings are presented in detail based on the

number of included articles, publication trends, application contexts, types of deep learning models, implementation formats, and key research outcomes.

The findings of this study were derived from a systematic review of publications examining the implementation of deep learning in physical education, movement learning, physical activity, and sport science contexts. The analysis focused on publication trends, application domains, dominant deep learning models, implementation formats, and the principal contributions of the reviewed studies. The reviewed literature demonstrates that deep learning technologies have increasingly influenced educational and sport science research, particularly in the areas of human motion analysis, automated assessment, and adaptive learning systems.

Based on the literature search conducted through Scopus, Web of Science, and Google Scholar databases, 312 articles were initially identified. Following title and abstract screening, 189 articles were excluded because they did not align with the objectives of the study. Full-text evaluation was subsequently conducted for 123 articles, resulting in the exclusion of 76 studies that failed to satisfy the inclusion criteria. Consequently, 47 articles were considered eligible and included in the final synthesis. The selection process demonstrates that although research related to artificial intelligence and human movement has expanded considerably, relatively few studies specifically investigate deep learning implementation in school-based physical education contexts.

The PRISMA-based literature selection procedure is illustrated in Figure 1.

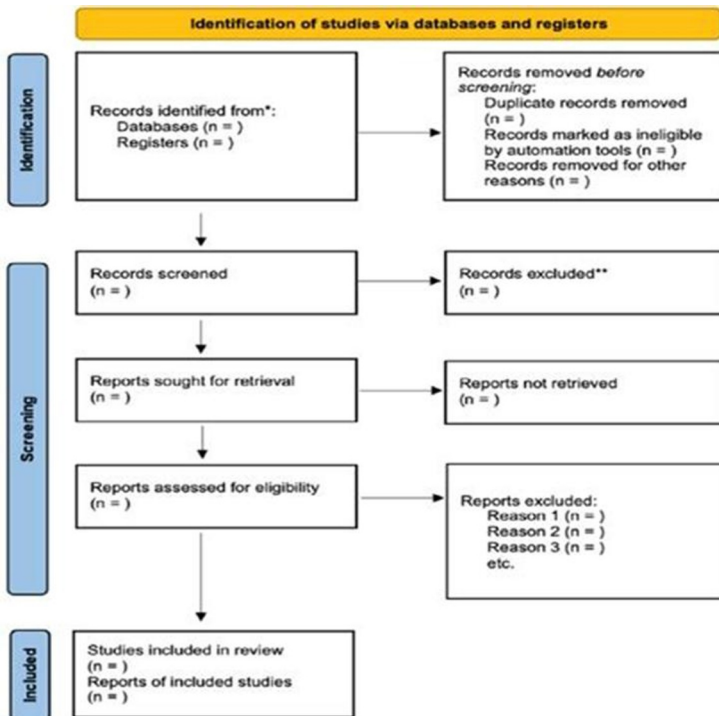


Fig. 1. PRISMA 2020 Literature Selection Flow Diagram.

3.1 Scientific Publication Trends

The analysis of publication years revealed a substantial increase in research productivity after 2018, with the highest number of publications occurring between 2021 and 2024. This trend reflects growing academic interest in the integration of deep learning technologies within physical education and sport science research. The increasing availability of computer vision systems, wearable devices, and machine learning frameworks has accelerated interdisciplinary studies combining artificial intelligence and human movement analysis [1], [2].

Table 1. Distribution of Publication Years

Publication Period	Number of Articles	Percentage
2015–2017	6	12,8%
2018–2020	14	29,8%
2021–2024	27	57,4%
Total	47	100%

The substantial increase in publications during the 2021–2024 period indicates that deep learning in physical education remains an emerging and rapidly evolving research area. This trend is also associated with the broader adoption of AI-based technologies in educational environments following the acceleration of digital transformation during the post-pandemic period [3].

3.2 Context of Deep Learning Implementation

The reviewed studies demonstrate that deep learning applications are predominantly concentrated in elite sports and higher education settings, whereas research conducted in elementary and secondary school physical education remains comparatively limited. Competitive sport environments often possess stronger technological infrastructure, larger research funding opportunities, and access to performance data, thereby facilitating the implementation of advanced AI technologies [4].

Table 2. Context of Deep Learning Application

Research Context	Number of Articles	Percentage
Competitive Sports	21	44,7%
Higher Education	15	31,9%
School Physical Education	11	23,4%
Total	47	100%

These findings indicate a clear research gap regarding the implementation of deep learning in school-based physical education. The relatively low number of studies

conducted in primary and secondary schools suggests that educational applications of AI technologies have not yet been fully adapted to the pedagogical and infrastructural realities of school environments.

3.3 Data Types and Deep Learning Models

The findings reveal that video-based movement data represent the dominant source of information utilized in deep learning applications. Video and image data are particularly suitable for computer vision approaches because they enable the identification of body posture, movement sequences, and biomechanical patterns [5]. Convolutional Neural Networks (CNNs) emerged as the most frequently employed architecture due to their effectiveness in spatial feature extraction and visual pattern recognition.

Table 3. Data Types and Deep Learning Models

Data Type	Dominant Model	Number of Articles
Motion Video	CNN	19
Image Data	CNN & Pose Estimation	12
Sensor/Wearable Data	LSTM / RNN	10
Combined Data	CNN + LSTM	6

The integration of CNN and Long Short-Term Memory (LSTM) models was commonly observed in studies requiring both spatial and temporal movement analysis. While CNN models effectively identify visual movement characteristics, LSTM architectures improve the analysis of sequential and temporal motion patterns, particularly in repetitive physical activities and continuous movement assessment [6].

3.4 Forms of Deep Learning Implementation

The thematic analysis identified five dominant forms of deep learning implementation within physical education and sport science research. Motion analysis emerged as the most frequently investigated application, particularly for evaluating running techniques, jumping mechanics, posture correction, and movement efficiency.

Table 4. Forms of Deep Learning Implementation

Implementation Form	Number of Articles	Application Examples
Motion Analysis	18	Running and jumping techniques
Automated Assessment	9	Basic motor skill scoring
Instructional Media	8	AI-assisted learning videos
Personalized Training	7	Adaptive exercise recommendations
Fitness Monitoring	5	Student physical activity tracking

The dominance of motion analysis applications reflects the central role of biomechanical evaluation in physical education and sport science. AI-assisted movement analysis systems have demonstrated the capacity to provide objective feedback with higher consistency than traditional observational assessment methods [7].

3.5 Main Research Findings

The synthesis of reviewed studies indicates several important findings regarding the educational potential of deep learning technologies. First, deep learning significantly improves the objectivity and consistency of motor skill assessment compared with conventional teacher observation methods. Second, AI-based systems demonstrate strong capability in detecting movement errors and generating immediate visual feedback, which supports more effective motor learning processes [8].

Third, several studies reported that AI-assisted instructional systems increased student engagement, motivation, and learning participation. Interactive visualization and adaptive feedback mechanisms allowed students to receive individualized learning experiences that aligned with their motor competence levels. Finally, despite these advantages, implementation within school physical education remains constrained by technological, pedagogical, and infrastructural challenges.

3.6 Synthesis of Research Results

The overall synthesis demonstrates that deep learning possesses substantial potential to support the transformation of physical education into a more evidence-based, adaptive, and technology-enhanced discipline. The reviewed studies consistently highlight the capacity of AI technologies to improve movement assessment accuracy, personalize learning experiences, and facilitate data-driven instructional decision-making. However, effective implementation requires contextual adaptation to student characteristics, curriculum objectives, technological readiness, and teacher competencies.

The findings also suggest that deep learning should not merely function as a technological innovation but should be integrated pedagogically to support holistic student development, including motor, cognitive, and affective domains. Therefore, the successful integration of AI technologies depends on balancing technological sophistication with educational practicality and accessibility.

3.7 Discussion

The results of this systematic review indicate that the implementation of deep learning in physical education has expanded considerably over the last decade, particularly in motion analysis and motor skill evaluation. The predominance of studies conducted in competitive sports and higher education environments suggests that AI-based technologies are initially adopted in settings characterized by stronger infrastructure and higher levels of technological readiness [9]. This finding confirms that school-based physical education remains in the early stages of AI integration.

One of the most significant findings is the dominant use of CNN and pose estimation models in movement analysis. This trend is understandable because physical education learning largely involves visual and biomechanical movement data. CNN architectures have demonstrated strong effectiveness in recognizing spatial movement characteristics, including posture alignment, joint positioning, and movement sequencing [10]. In physical education contexts, these capabilities are highly relevant for supporting objective evaluation of students' movement techniques and reducing subjectivity in teacher assessment.

The findings further indicate that automated assessment systems possess considerable potential for improving evaluation consistency. Several studies reported that AI-based assessment systems achieved scoring accuracy levels comparable to expert evaluators [11]. This development is particularly important in school physical education, where teachers frequently encounter limited instructional time and high student-to-teacher ratios. Nevertheless, the findings emphasize that deep learning systems should function as supportive pedagogical tools rather than replacements for teachers. Human interaction, instructional feedback, and motivational support remain essential components of effective physical education learning.

Another important observation concerns the growing use of deep learning for personalized training and adaptive learning environments. AI-supported instructional systems can provide individualized feedback based on students' movement performance and learning progression. Such approaches align with contemporary educational paradigms emphasizing differentiated instruction and learner-centered pedagogy [12]. Interactive visualization, real-time correction, and adaptive exercise recommendations may enhance student engagement and improve motor skill acquisition.

Despite these opportunities, several implementation barriers remain significant. Limited technological infrastructure, including inadequate hardware availability, unstable internet connectivity, and restricted access to motion sensors, continues to constrain implementation in many school environments [13]. Teacher digital literacy also represents a major challenge because effective AI integration requires both technological understanding and pedagogical adaptation. Furthermore, ethical concerns

related to student privacy and movement data protection must be addressed carefully, particularly when video-based systems are utilized in educational settings.

From a pedagogical perspective, deep learning technologies should be positioned as educational support systems that strengthen learning quality rather than purely technological innovations. The integration of AI into physical education should remain aligned with curricular objectives, student developmental characteristics, and the promotion of lifelong physical activity participation. Consequently, future deep learning systems should prioritize usability, affordability, pedagogical relevance, and accessibility for teachers and students.

The findings of this review also reveal a substantial research gap in elementary and secondary school physical education contexts. Future studies should therefore focus on developing low-cost, context-sensitive, and user-friendly AI models suitable for school implementation. Experimental and research-and-development studies are also needed to evaluate the effectiveness of deep learning technologies in authentic educational environments.

Overall, the present review confirms that deep learning represents a promising strategic innovation in physical education and sport science. When implemented appropriately, AI technologies can facilitate the development of more objective, adaptive, and data-driven learning environments while preserving the teacher's central role as educator, facilitator, and mentor in motor learning processes.

4 Conclusion

This systematic review demonstrates that deep learning has substantial potential to transform physical education into a more objective, adaptive, and technology-enhanced learning environment. The findings indicate that deep learning technologies are primarily utilized in motion analysis, motor skill evaluation, posture recognition, and automated assessment systems, with Convolutional Neural Networks (CNNs) and video-based pose estimation models emerging as the most dominant approaches. These technologies have shown considerable effectiveness in improving the accuracy and consistency of movement assessment while supporting real-time feedback and personalized learning experiences [1], [2].

The review further reveals that current deep learning applications are predominantly concentrated in competitive sports and higher education contexts, whereas implementation in elementary and secondary school physical education remains comparatively limited. This imbalance suggests that the integration of artificial intelligence into school-based physical education is still at an early stage of development and requires stronger pedagogical adaptation, infrastructure readiness, and institutional support. In addition, several barriers continue to hinder broader implementation, including limited technological facilities, insufficient teacher digital competence, high implementation costs, and concerns regarding ethical issues and student data privacy [3].

From a sport science and educational perspective, deep learning should not merely be regarded as a technological innovation, but as a pedagogical support system capable of enhancing movement learning, assessment quality, and student engagement. The integration of AI technologies into physical education must therefore remain aligned with curriculum objectives, student developmental characteristics, and inclusive learning principles. Effective implementation requires collaboration among educators, sport scientists, and technology developers to ensure that AI-based systems are practical, accessible, and educationally meaningful.

This review contributes to the growing discourse on artificial intelligence in education by emphasizing the need for contextual and school-oriented deep learning applications within physical education. Future research should prioritize the development of low-cost, user-friendly, and pedagogically relevant AI models that can be implemented effectively in diverse educational settings. Furthermore, experimental, and longitudinal studies are necessary to evaluate the long-term effectiveness of deep learning technologies in improving motor learning outcomes, physical activity participation, and educational quality in school physical education programs.

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