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SYSTEMATIC REVIEW

Machine Learning in Physical Education, Sports, and Recreation: Opportunities, Challenges, and Ethical Considerations – A Systematic Review

Aprendizaje Automático en Educación Física, Deportes y Recreación: Oportunidades, Desafíos y Consideraciones Éticas – Una Revisión Sistemática

Stephen Ayoade Fadare[1], Jay-R L. Beterbo[2], Frederick Ybanez[3], Jack Ryan Abdulrajak Isahac[4], Maria Cecilia Fadare[5], Edris Aloy Barahimin[6], Sittie Aina T. Pandapatan[1]

[1]Mindanao State University-Main, Mamitua Saber Institute of Research and Creation, Marawi City, Philippines.
[2]De La Salle Santiago Zobel School, PE Faculty. Muntinlupa City, Philippines.
[3]Bukidnon State University, Baungon Satellite Campus. Bukidnon, Philippines.
[4]Sulu State College, College of Arts and Sciences, Jolo. Sulu, Philippines.
[5]Saint Louis College, School Nurse/SPED Teacher. City of San Fernando, La Union, Philippines.
[6]Mindanao State University- Sulu Campus, Jolo Sulu, Philippines.

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Corresponding author: Stephen Ayoade Fadare

ABSTRACT

Introduction: machine learning, a subfield of artificial intelligence, is rapidly transforming the landscape of sports science. It enables more informed decision-making across various sectors, including healthcare, agriculture, and, notably, sports. This study aims to investigate how machine learning can improve athletic performance, injury prevention, and coaching efficacy.
Method: this systematic review utilized a comprehensive search strategy across 510 articles to identify studies focused on machine learning (ML) in the fields of physical education, sports, and recreation. A total of 36 studies met the inclusion criteria and were thoroughly reviewed for their relevance to the outcomes within the search scope. The search commenced in January 2025 and continued through July 2025. It covered several databases, including PubMed, Scopus, Web of Science, ScienceDirect, and the Cochrane Library. The focus was on publications from 2015 to 2025, using keywords such as "artificial intelligence," "athletic performance," "coaching efficacy," "injury prevention," and "machine learning."
Results: the results demonstrate that machine learning significantly enhances athletic performance, injury prevention, and coaching effectiveness. It facilitates tailored training and data-driven decision-making, which lead to improved skill development and rehabilitation outcomes. In the realm of physical education, machine learning supports personalized instruction that increases student engagement. However, challenges remain, including issues with data integrity, high computing costs, and a shortage of expertise. Ethical concerns—particularly related to privacy, bias, and transparency—require immediate attention. While machine learning has the potential to transform both sports and education, it must be implemented appropriately to ensure fairness, accuracy, and accessibility for all users.
Conclusions: the outcome indicates that machine learning enhances physical education and athletics by improving performance analysis, reducing injury risk, and enabling coaches to personalize training. Although there are challenges such as data quality and ethical concerns, the effective use of machine learning can significantly support athlete development. The combination of machine learning with coaching and educational methods fosters inclusive, data-driven strategies that improve skill acquisition, ensure safety, and promote the long-term well-being of athletes.

Keywords: Machine Learning; Physical Education; Sports; Recreation; Opportunities; Challenges; Ethical Considerations.

RESUMEN

Introducción: el aprendizaje automático (ML), una subdisciplina de la inteligencia artificial, está transformando rápidamente el campo de la ciencia del deporte. La creación de modelos predictivos a partir de datos permite una toma de decisiones más informada en diversos sectores, incluyendo la salud, la agricultura y, especialmente, el deporte.
Método: esta revisión sistemática utilizó una estrategia de búsqueda rigurosa para identificar estudios sobre el uso del aprendizaje automático (ML) en la educación física, el deporte y la recreación. La búsqueda se realizó en enero de 2025 en bases de datos como PubMed, Scopus, Web of Science, ScienceDirect y Cochrane Library, centrada en publicaciones entre 2014 y 2025. Se utilizaron palabras clave como "inteligencia artificial", "aprendizaje automático", "lesión deportiva" y "predicción de riesgos". De los 510 estudios identificados, 36 cumplieron los criterios de inclusión y fueron revisados completamente.
Resultados: el análisis reveló que el aprendizaje automático mejora significativamente el rendimiento deportivo, la prevención de lesiones y la eficacia del entrenamiento. Permite entrenamientos personalizados y decisiones basadas en datos, favoreciendo el desarrollo de habilidades y la rehabilitación. Algoritmos como random forests y redes neuronales convolucionales ayudan a predecir lesiones y optimizar estrategias. En la educación física, ML permite una enseñanza personalizada que mejora la participación estudiantil. Sin embargo, persisten desafíos como la calidad de los datos, los altos costos computacionales y la falta de experiencia. Las cuestiones éticas—como la privacidad, el sesgo y la transparencia—requieren atención urgente. ML tiene un potencial transformador tanto en el deporte como en la educación, pero debe implementarse correctamente para garantizar equidad, precisión y accesibilidad para todos los usuarios.
Conclusiones: el aprendizaje automático mejora la educación física y el deporte al perfeccionar el análisis del rendimiento, reducir el riesgo de lesiones y facilitar entrenamientos personalizados. A pesar de los desafíos, su aplicación adecuada puede potenciar el desarrollo atlético. Su integración con metodologías educativas y de entrenamiento promueve estrategias inclusivas e informadas por datos que mejoran la adquisición de habilidades, la seguridad y el bienestar a largo plazo de los atletas.

Palabras clave: Aprendizaje Automático; Educación Física; Deporte; Recreación; Oportunidades; Desafíos; Consideraciones Éticas.

INTRODUCTION

Machine learning (ML), a branch of artificial intelligence (AI), has changed a lot since its early theoretical beginnings in the 1950s, when pioneers like Alan Turing and Arthur Samuel laid the groundwork for computers that could learn on their own.[1] Computer science and business primarily used ML in the late 20th century. It wasn't used much in sports or school since computers weren't powerful enough and there wasn't enough data. But the early 2000s saw a tremendous change. New technologies like big data analytics, cloud computing, and sensors made it possible to gather and analyze immense amounts of performance-related data.[2] This change made it possible for the first uses of ML in sports sciences, like predicting injuries, analyzing matches, and finding talented players. ML has revolutionized both sports and physical education.[3] Wearables with AI, computer vision, and real-time analytics are becoming more common. These technologies make it easier to keep track of biomechanics, measure workload, and improve technique.[4] Sports organizations are increasingly utilizing ML models to prevent player injuries, make tactical decisions, and customize training.[5] Physical education programs are now using ML-driven feedback systems to construct learning environments that work for individuals with different skills.[6] This approach makes sure that ML is used in sports and schools in a way that is fair and open to everyone. ML has demonstrated its usefulness in sports by examining performance from various perspectives, such as physiological, psychological, and environmental.[7] For example, ML algorithms can improve the technical execution of skill-based sports like tennis and basketball, figure out how likely an athlete is to get hurt by looking at their training loads, and come up with the best ways to help each athlete recover based on their needs.

In the field of education, machine learning improves physical education by letting teachers keep track of students' development, determine areas where they need to work on their motor abilities, and supply them individualized help.[8] This method helps students learn new skills and stay motivated, and it also encourages inclusion by allowing students of all physical abilities to participate. The importance and urgency of this study reside in its capacity to demonstrate how ML-driven methodologies can revolutionize both athletic

performance and physical education. ML presents us useful information that can improve health, performance, and accessibility by analyzing complicated datasets that people can't handle. Its integration immediately helps with global development goals, like the United Nations Sustainable Development Goals (SDGs), especially SDG 3 (Good Health and Well-being), SDG 4 (Quality Education), SDG 9 (Industry, Innovation, and Infrastructure), and SDG 10 (Reduced Inequalities). These linkages show how ML can help society as a whole by improving health, fairness, and new ideas. In this context, investigating ML in sports is both academically significant and practically imperative. As schools, coaches, and other organizations go through digital transformation, it's important to know how to use machine learning to improve sports performance, avoid injuries, and make teaching more effective.

METHOD

This systematic review employed a thorough search strategy across 510 articles to identify studies centered on machine learning (ML) within the domains of physical education, sports, and recreation. We meticulously examined 36 studies that fulfilled the inclusion criteria for their relevance to the specified outcomes. The search began in January 2025 and continued until July 2025, encompassing several databases, including PubMed, Scopus, Web of Science, ScienceDirect, and the Cochrane Library. The focus was on publications from 2015 to 2025, written in English, and selected using keywords such as "artificial intelligence," "athletic performance," "coaching efficacy," "injury prevention," and "machine learning." The selected literature reviews the current state, opportunities, and challenges associated with machine learning in physical education, sports, and recreation. Researchers developed a model that incorporates opportunities, challenges, and ethical considerations relevant to these fields. This analysis resulted in practical recommendations for integrating machine learning into school curricula and programs. To address ethical considerations, the reference page includes citations of the literature that met the established criteria.

The inclusion and exclusion criteria for screening and selecting papers

Inclusion Criteria

- Focus on studies and articles that demonstrate the application of machine learning (ML) techniques in physical education, sports, and recreation.
- Research must include a quantitative or qualitative assessment of the impact of ML on relevant outcomes, such as performance, injury risk, or engagement.
- The study must be published in a peer-reviewed journal (Scopus, Web of Science, PubMed) covering the years 2015–2025.
- The study must be written in English.

Exclusion Criteria

- Studies that do not directly apply machine learning techniques in physical education, sports, or recreation will be excluded.
- Any studies that do not concentrate on machine learning applications are also excluded.
- Studies lacking sufficient data to assess the impact of machine learning are deemed unacceptable.
- Research types that are not original or peer-reviewed, including editorials, conference abstracts, brief messages, or videos, will not be considered.
- Articles that lack empirical data or rely solely on unsupported opinions are unacceptable.
- We reject studies that employ outdated methods or are not aligned with the study's focus.

RESULTS

The results of this research provide valuable insights into the challenges, opportunities, and ethical considerations surrounding the use of machine learning in physical education, sports, and recreation within curriculum and education programs. Through a systematic literature review, comparative analysis, and evaluation of existing models, we identified the following key findings.

Literature Overview

Applying established inclusion criteria, we selected 36 peer-reviewed articles that explored the challenges, opportunities, and ethical considerations associated with machine learning. These articles revealed several important points:

- Publication Trends: Research on interdisciplinary approaches involving artificial intelligence, sports, and physical health education has consistently increased, especially over the past five years.
- Geographical Focus: There is a significant gap in research from developing countries, with the majority of studies conducted in Europe yielded 26,4 %.

Table 1. Distribution of Articles review

Key Metrics	Statistics
Total Articles screened	510
Articles Selected for Analysis	36

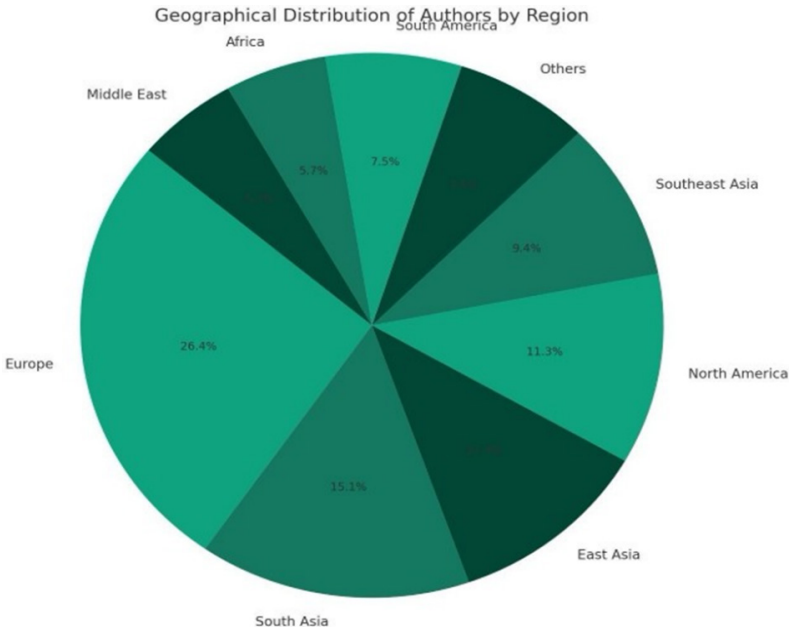

Figure 1. Geographical Distribution of Cited Authors by Region

DISCUSSION

The Current State

Various ML techniques, including deep learning and neural networks, are utilized in sports to analyze complex datasets and identify patterns that can inform training and injury prevention strategies.[9] The effectiveness of ML varies based on the specific sport, the quality of the data, and the application context, which emphasizes the value of customizing ML solutions to the unique characteristics of each scenario.[9]

Current research emphasizes refining ML models and addressing ethical concerns, demonstrating a commitment to ensuring the responsible and ethical use of ML.[10] A significant trend in sports science is the shift from reactive to proactive injury management, with ML playing a vital role in identifying athletes at risk of injury and implementing targeted prevention strategies.[11] AI technologies improve athlete safety, optimize performance, and minimize human error, demonstrating machine learning's potential to transform sports training and healthcare entirely.[9]

The application of ML in physical education, sports, and recreation is still nascent, but the potential advantages are substantial. As ML technology continues to advance, it is expected to play a more prominent role in improving athlete outcomes and promoting physical activity among diverse populations. Machine learning algorithms empower physical education teachers to collect and analyze data on student performance and behavior, enabling them to develop personalized learning experiences that address the unique needs of each student.[8] This tailored approach can lead to increased engagement, enhanced skill development, and a deeper appreciation for physical activity.

This research emphasizes the educational and developmental aspects of machine learning in sports, highlighting its potential to serve elite athletes and transform student-athletes and physical education programs. ML fosters inclusivity by tailoring feedback to individual learning needs, allowing students of varying skill levels and abilities to participate meaningfully. The study underscores the significance of contextual adaptation, emphasizing the need to design ML applications in sports around distinct socio-cultural, institutional, and resource conditions. The integration of ML in sports and education is linked to broader societal imperatives like digital transformation, health promotion, and equity, offering practical insights for coaches, educators, and policymakers.

This section explains the researcher-made model called Fadsteps' conceptual model, as illustrated in figure 2, and highlights its relationship with the topic under review. The accompanying figure demonstrates the relevance of the literature review to this study. The central image, shown in blue, represents the primary focus of the discussion regarding machine learning in physical education, sports, and recreation. The light

blue section emphasizes the opportunities machine learning presents in SPEAR, while the red section outlines the challenges associated with it. Additionally, the brown section addresses the ethical considerations linked to machine learning in this context. All these elements connect to the main topic of machine learning in physical education, sports, and recreation. Meanwhile, the background features a color scheme that symbolizes machine waves.

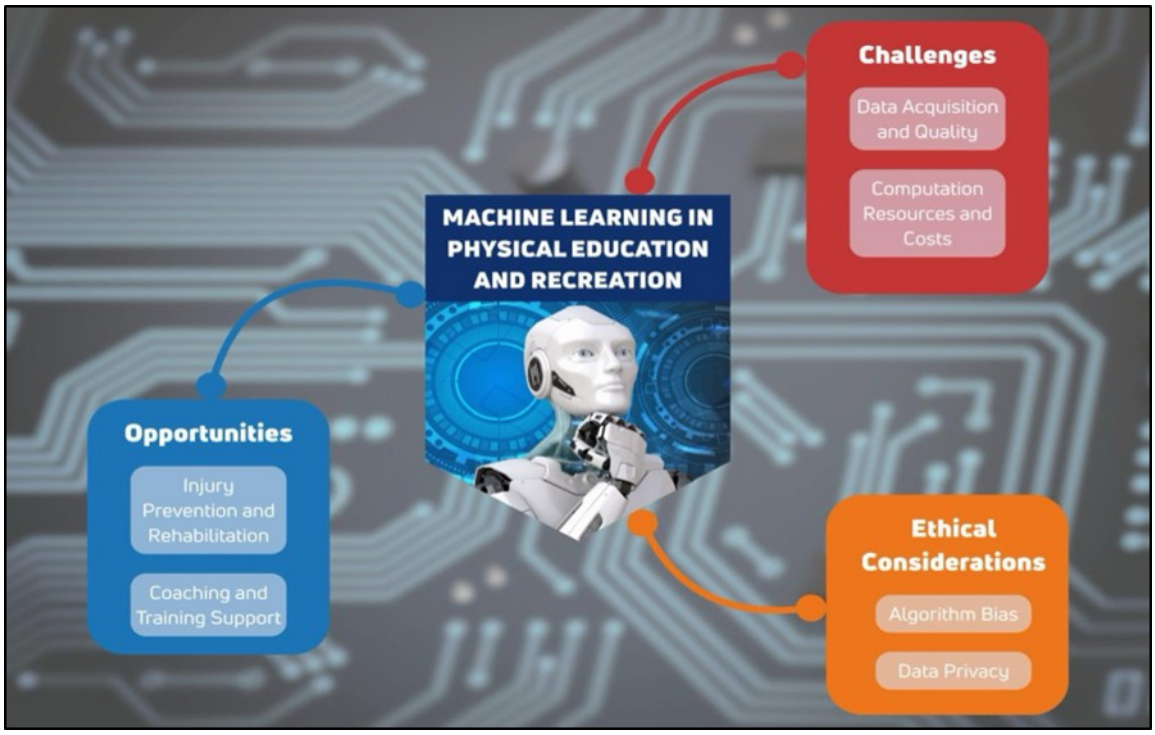

Figure 2. Fadsteps' Conceptual Model

The picture illustrates the potential, challenges, and ethical implications of machine learning in the context of physical education and recreation, with a primary focus on integrating this technology into the field. Opportunities: Machine learning offers significant possibilities for injury prevention and rehabilitation through data-driven analysis and personalized training programs. It can also provide teaching and training support, enhancing the efficiency and effectiveness of training methods. Challenges: Implementing machine learning faces hurdles related to data collection and quality, requiring extensive and reliable datasets. Additionally, the computational resources and costs associated with advanced algorithms and processing power pose substantial challenges. Ethical Considerations: The ethical use of machine learning in this area demands careful examination of algorithmic bias to ensure fairness and avoid discriminatory outcomes. Data privacy is crucial, requiring strict measures to protect sensitive personal information. The graphic illustrates the numerous potential benefits, practical limitations, and ethical responsibilities related to the deployment of machine learning in physical education and recreation. The connections among the three sections—Opportunities, Challenges, and Ethical Considerations—highlight that successful implementation requires simultaneous attention to all aspects.

The authors emphasizes the importance of responsibly and inclusively applying machine learning (ML) in physical education and recreation. ML should be applied not only to elite athletes or well-funded institutions but also to educational settings and grassroots programs. If implemented ethically, ML can democratize opportunities by enabling personalized learning, supporting injury prevention, and enhancing inclusivity for individuals of all abilities. The success of ML depends on striking a balance between technological potential, practical challenges, and ethical responsibilities.

Opportunities of Machine Learning in Physical Education, Sports, and Recreation

Performance Enhancement

Machine learning (ML) offers significant opportunities for performance enhancement across various sports and physical activities. ML can be used for skill acquisition and training optimization, enabling athletes to reach their full potential.[10,12] By analyzing vast amounts of data on athlete performance, biomechanics, and physiological responses, ML algorithms can identify the most effective training strategies and provide personalized feedback to athletes. This personalized approach can lead to more efficient skill development, improved technique, and enhanced overall performance.[13]

ML enables personalized training plans tailored to individual athletes' needs, taking into account their strengths, weaknesses, and training goals.[14,15] By analyzing an athlete's historical performance data, ML algorithms can identify patterns and correlations that inform the design of customized training programs. These programs can be adjusted in real time based on an athlete's response to training, ensuring that they are constantly challenged and optimized. ML improves sports performance forecasting and optimizes athlete training by assisting coaches and medical professionals in making more informed decisions. [16]

ML algorithms, such as linear regression, K-means, and random forest, can analyze player performance to identify key factors that contribute to success.[17,18] These algorithms can be used to predict an athlete's future performance based on their past performance, training data, and other relevant variables. Random forest regression can improve talent identification and performance prediction in sports, allowing coaches and scouts to identify promising athletes and develop targeted training programs.[19,13] By leveraging ML for talent identification, sports organizations can improve their recruitment strategies and build stronger teams.

In team sports, ML can be used to analyze player interactions, team dynamics, and game strategies to identify opportunities for improvement. For instance, ML algorithms can scrutinize passing patterns, player positioning, and defensive formations to pinpoint vulnerabilities in the opponent's game plan. This information can then be used to develop customized game strategies that exploit these weaknesses and maximize the team's chances of success. The use of machine learning algorithms enables physical education teachers to gather and analyze data on student performance and behavior, which in turn allows them to create personalized learning experiences that cater to the unique needs of each student.[20,21] This personalized approach can lead to increased engagement, improved skill development, and a greater appreciation for physical activity.

Injury Prevention and Rehabilitation

Machine learning (ML) plays a crucial role in injury prevention and rehabilitation by enabling the identification of key patterns for injury prediction.[22] ML algorithms can analyze vast amounts of data, including athlete demographics, training load, biomechanics, and medical history, to identify risk factors for specific types of injuries. By identifying these risk factors, coaches and medical professionals can develop targeted prevention strategies to reduce the likelihood of injuries.[18]

AI models improve the accuracy and reliability of injury risk assessments by tailoring prevention strategies to individual athlete profiles and processing real-time data.[23] This personalized approach to injury prevention is more effective than traditional methods that rely on general guidelines and recommendations. Personalized rehabilitation programs using ML can modify technique and recommend recovery protocols based on an athlete's specific injury and recovery progress.[24] Machine learning can help athletes heal from injuries faster and more securely by keeping track of their progress and changing the rehabilitation regimen as needed.

Decision tree models can evaluate injury risk based on athletes' physical and psychological conditions, giving researchers valuable information about the factors that contribute to injuries.[15,23] These models can identify athletes who are at high risk of injury based on their self- reported perceptions of their physical and psychological well-being. AI-driven models can enhance injury management through strategic rest periods during recovery, ensuring that athletes are not pushed too hard before they are fully recovered.[16] By leveraging data analytics to monitor athletes' health continuously, these models offer sports managers a predictive tool for a proactive and preventative approach to injury management.[25]

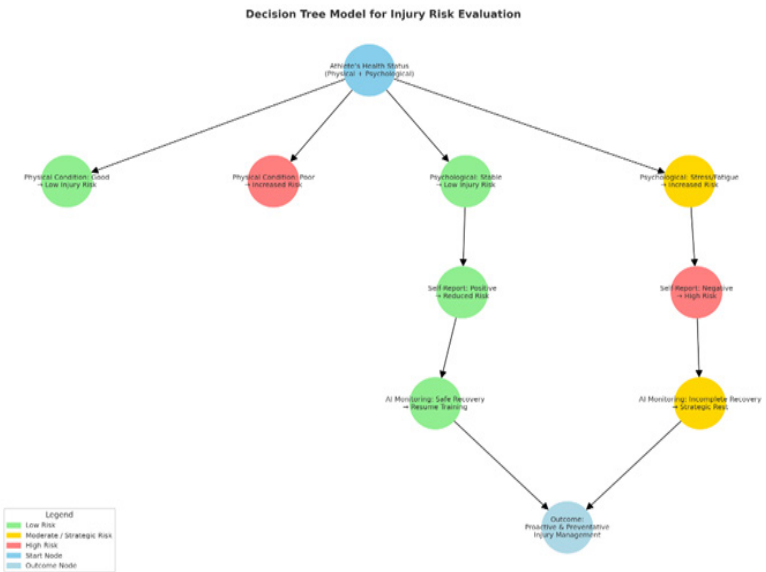

Figure 3. Decision Tree Model for Injury Risk Evaluation

*Green = Low Risk
*Yellow = Moderate Risk / Strategic Management
*Red = High Risk
*Blue = Starting & Final Outcomes

ML can also be used to analyze movement patterns and identify biomechanical risk factors for injuries. For example, ML algorithms can be used to analyze video footage of athletes performing specific movements to identify deviations from optimal technique that may increase the risk of injury.[26] This information can then be used to provide athletes with feedback on their technique and to develop training programs that correct these deviations. The use of machine learning algorithms enables physical education teachers to gather and analyze data on student performance and behavior, which in turn allows them to create personalized learning experiences that cater to the unique needs of each student.[27] This personalized approach can lead to increased engagement, improved skill development, and a greater appreciation for physical activity. All of these findings point to the possibility that ML and AI could change the way we avoid injuries, treat them, and care for athletes as a whole. AI-driven methods use predictive analytics, targeted interventions, and continuous monitoring to create a complete system for protecting athletes' health, improving performance, and improving educational outcomes.

Coaching and Training support

Artificial intelligence (AI) and machine learning (ML) provide coaches and trainers with powerful tools to enhance their decision-making, offer real-time feedback, and design effective training programs.[28,12] AI can assist coaches in making data-driven decisions by analyzing vast amounts of data on athlete performance, opponent strategies, and game conditions. This information can be used to develop customized game plans, adjust training schedules, and make informed substitutions during competitions.

ML can design effective training programs based on athlete data, taking into account their individual strengths, weaknesses, and training goals.[20,22] These programs can be adjusted in real time based on an athlete's response to training, ensuring that they are constantly challenged and optimized. Automated video analysis and player tracking systems can assist coaching by providing detailed information on athlete movement, positioning, and technique.[17] This information can be used to identify areas for improvement and to develop targeted training drills.

ML can analyze vast amounts of data, enabling coaches to design personalized training programs tailored to each athlete's unique characteristics and needs.[29] This personalized approach can lead to more efficient skill development, improved technique, and enhanced overall performance. Performance analytics dashboards provide coaches with valuable insights into athlete performance, allowing them to track progress, identify trends, and make informed decisions about training and game strategies.[30]

The use of ML in coaching and training support is not limited to elite athletes. ML can also be used to improve physical education programs in schools and to provide personalized feedback to recreational athletes. By leveraging the power of AI and ML, coaches and trainers can help athletes of all levels reach their full potential. The use of machine learning algorithms enables physical education teachers to gather and analyze data on student performance and behavior, which in turn allows them to create personalized learning experiences that cater to the unique needs of each student.[13] This personalized approach can lead to increased engagement, improved skill development, and a greater appreciation for physical activity.

By facilitating data-driven decision-making and performance optimization, machine learning (ML) is transforming coaching and training. It enables coaches to create more intelligent tactical plans and make wise in-game adjustments by analyzing vast datasets on player performance, opponent strategies, and environmental factors. Additionally, ML serves as the basis for customized training plans that adjust to the progress, weaknesses, and strengths of each athlete. Technique and positioning adjustments can be made instantly thanks to motion tracking, automated video analysis, and real-time feedback. Coaches can track progress, identify areas for improvement, and learn about long-term trends with the help of performance analytics dashboards. Additionally, ML optimizes training plans by dynamically modifying volume and intensity to preserve a balance between recovery and progress.

Challenges of Machine Learning in Physical Education, Sports, and Recreation

Data Acquisition and Quality

Challenges of Machine Learning in Physical Education, Sports, and RecreationOne of the primary challenges in applying machine learning (ML) to physical education, sports, and recreation is ensuring the acquisition of high-quality data. The effectiveness of ML models depends heavily on the reliability and completeness of the data used to train them.[31,32] However, sports and educational contexts often involve data that are incomplete, noisy, or inconsistent, which significantly undermines model accuracy and predictive value. Data may be

collected from multiple sources such as wearable sensors, video recordings, and self-reported questionnaires, yet each of these methods has inherent limitations. For instance, wearable devices may generate inaccurate readings due to technical malfunctions or user error, while video recordings can be affected by poor lighting, unfavorable camera angles, or background interference.[33,34]

Similarly, self-reported questionnaires may suffer from recall bias and social desirability bias, resulting in inaccurate or incomplete responses. These limitations illustrate the value of addressing data quality as a foundational requirement for robust ML applications in physical education and sports.To address these issues, researchers emphasize that there must be standardized protocols for data collection across institutions and contexts to minimize measurement error and improve consistency.[19,35] Without standardized methods, the generalizability of ML models remains limited, as variations in equipment or procedures may distort outcomes. Another proposed solution is the integration of multi-modal data sources—for example, combining sensor data with video and self-reported measures—so that the weaknesses of one source can be offset by the strengths of another.

Alongside this, the development of automated ML-based data cleaning and preprocessing tools could significantly reduce the burden on practitioners, detecting and correcting missing values, inconsistencies, and noise more efficiently than manual approaches.Beyond technical difficulties, researchers also identify ethical and equity-related challenges. Data storage systems must not only be secure and reliable to prevent loss or corruption but also designed to protect athlete and student privacy, particularly when dealing with youth or school-based populations. Questions of consent and transparency in data use must be prioritized to build trust in ML applications. In addition, disparities in access to high-quality data collection technologies raise concerns about equity: resource-constrained schools or community programs may lack access to advanced wearables or performance-tracking systems, which limits their ability to benefit from ML-driven insights.

A further challenge lies in the gap between real-world and controlled data environments. Many ML models are trained on experimental or laboratory datasets that may not reflect authentic sports or physical education conditions, where unpredictable variables such as lighting, space limitations, or environmental factors are common. Researchers argue that developing more robust datasets that simulate real-world contexts is crucial for improving the ecological validity of ML applications.

Finally, the sustainability of ML models depends on longitudinal data collection, as short-term datasets often fail to capture developmental patterns, training effects, or seasonal variations. Long-term monitoring allows for richer, more stable insights into athlete and student performance trends.Despite these challenges, ML continues to offer promising opportunities in physical education and sports. When supported by rigorous data collection, cleaning, and ethical management practices, ML can enable teachers and coaches to gather and analyze data on student or athlete performance, ultimately supporting personalized learning experiences that foster greater engagement, skill development, and appreciation for physical activity.[36,38] Addressing these challenges not only strengthens the predictive power of ML models but also ensures their application is both equitable and sustainable.

Computational Resources and Costs

Developing and implementing machine learning (ML) solutions in physical education, sports, and recreation requires substantial computational resources and incurs significant costs. Complex ML models, particularly those involving deep learning and large-scale datasets, demand high-performance computing capabilities. Training such models may take several hours or even days on advanced hardware, requiring access to specialized processors, extensive memory, and tailored software environments.[37] For many institutions, especially those in educational or community-based contexts, such an issue represents a considerable barrier. The expenses associated with ML deployment extend beyond computing power to include hardware procurement, software licensing, secure data storage, and the hiring or training of personnel with technical expertise.

These costs can be prohibitive for organizations with limited budgets, raising questions about whether the benefits of ML applications outweigh their financial and logistical demands.[38] To address these barriers, researchers highlight the role of cloud-based computing services, which provide scalable access to computational resources on demand.[39] Cloud systems can reduce upfront infrastructure costs and make advanced ML tools more accessible to institutions that lack in-house capacity. However, this shift introduces new challenges, including concerns about data security, privacy, and long-term sustainability of costs. Continuous reliance on cloud subscriptions can become expensive over time, particularly for organizations requiring constant access to analytics. This raises a broader issue of cost-effectiveness and sustainability, as not all schools, universities, or sports organizations can commit to ongoing operational expenses.Emerging researcher ideas suggest several strategies for overcoming these resource-related limitations. One approach is the development of lightweight and efficient ML models that require less computational power, making them more practical for institutions with limited resources.

Another involves fostering collaborative resource-sharing initiatives, such as partnerships between

universities, government agencies, and private organizations, which could pool infrastructure and expertise to make ML more widely accessible. Researchers also emphasize the importance of open-source platforms and software frameworks, which can reduce licensing costs and democratize access to ML tools. In addition, capacity-building initiatives—such as training educators and coaches in basic data analytics—can reduce reliance on expensive external consultants and strengthen local expertise.

Finally, researchers underscore that the cost-benefit balance of ML adoption must be critically assessed. While ML offers substantial potential for personalized learning, performance optimization, and data-driven coaching, its effectiveness is dependent on whether institutions can sustain the necessary infrastructure and expertise over time. For example, while ML enables physical education teachers to collect and analyze data on student performance to deliver personalized instruction, this benefit will only materialize if the supporting technological and financial structures are in place.[8] Thus, the integration of ML in sports and physical education and Recreation must move beyond technical innovation alone and incorporate strategic planning, financial feasibility, and ethical responsibility to ensure its long-term success.

Ethical Considerations

The use of machine learning (ML) in physical education, sports, and recreation raises several ethical considerations that must be carefully addressed. Data privacy, algorithmic bias, and the potential misuse of ML technology are ethical concerns that can have significant implications for athletes, students, and other stakeholders.[3,4,13] Transparency and fairness in AI applications are of significant importance to ensure that ML is used in a responsible and ethical manner.[40,41]

Ethical implications and data privacy must be considered when using AI in sports training to ensure that athletes' personal information is protected and that their rights are respected.[42] The reliance on AI can lead to a lack of human connection and intuition in coaching relationships, potentially undermining the importance of personal interaction and mentorship.[43] Ensuring responsible and effective use of AI requires addressing these concerns and developing ethical guidelines for the application of ML in physical education, sports, and recreation.[44]

Algorithmic bias can occur when ML models are trained on biased data, leading to unfair or discriminatory outcomes for certain groups of individuals. For example, if an ML model is trained to predict injury risk based on data from a predominantly male population, it may not accurately predict injury risk for female athletes. The use of machine learning algorithms enables physical education teachers to gather and analyze data on student performance and behavior, which in turn allows them to create personalized learning experiences that cater to the unique needs of each student.[45] This personalized approach can lead to increased engagement, improved skill development, and a greater appreciation for physical activity.

Data privacy is a critical ethical consideration in the application of machine learning (ML) to physical education, sports, and recreation. Collecting and analyzing athletes' personal data raises privacy and security issues, as this data may include sensitive information about their health, performance, and training habits.[12] Transparency and fairness in AI applications are essential to ensure that data is collected and used in a responsible and ethical manner.

CONCLUSIONS

Limitations of ML Models

Machine learning (ML) models in sports and physical education face limitations in generalizability, particularly when trained on specific populations or contexts. Incomplete, noisy, or biased datasets can lead to inaccurate predictions, limiting the reliability of ML applications across diverse scenarios. To ensure generalizability, use diverse and representative datasets during model development, validate models on independent datasets, and incorporate domain expertise and contextual factors. Continuous model retraining with updated data ensures relevance and accuracy over time. Transfer learning is a key technique to address data scarcity and improve model adaptability, particularly in sports applications where data may be limited or fragmented. ML in physical education can support personalized learning by analyzing student performance and behavior data, fostering higher engagement, improved skill acquisition, and a more inclusive environment.

Summary, Conclusions, and Implications of Key Findings

Machine learning (ML) has emerged as a crucial tool in sports training, performance optimization, and injury prevention, offering transformative applications in physical education, sports, and recreation. Through models such as Random Forest, Extreme Gradient Boosting, and Logistic Regression, ML has demonstrated effectiveness in analyzing athlete performance, predicting injury risks, and informing training strategies. Its ability to generate data-driven insights enables coaches to make more precise decisions, while physical education teachers can utilize ML to personalize learning experiences that foster engagement, skill development, and appreciation for physical activity.

In addition, AI-assisted tools are reshaping athlete safety and medical decision-making by reducing human error and enhancing monitoring processes. Despite these opportunities, several critical challenges remain. Issues related to data acquisition and quality—including incomplete, inconsistent, or biased data—limit the reliability of predictions and training recommendations.

Similarly, the high computational resources and costs required for ML applications create barriers to accessibility, particularly for institutions with limited budgets or technical expertise. Ethical concerns regarding data privacy and equitable access also persist, which points to the importance of careful governance when integrating ML into educational and athletic contexts. These challenges highlight that while the potential of ML is substantial, its implementation is neither straightforward nor universally attainable.

These findings conclude that while ML holds significant promise, careful planning, resource allocation, and ethical safeguards must support it. Its long-term impact in physical education and sports will depend not only on technological innovation but also on the ability of schools, universities, and sports organizations to establish robust data management practices, develop cost-effective computational strategies, and ensure equitable access to ML tools.

The outcome indicates that machine learning enhances physical education and athletics by improving performance analysis, reducing injury risk, and enabling coaches to personalize training. Although there are challenges such as data quality and ethical concerns, the effective use of machine learning can significantly support athlete development. The combination of machine learning with coaching and educational methods fosters inclusive, data-driven strategies that improve skill acquisition, ensure safety, and promote the long-term well-being of athletes.Researchers also emphasize the need to design lightweight, efficient models and promote collaborative partnerships that can reduce costs and expand accessibility.

The implications are far-reaching

For coaches and trainers, ML can enhance decision-making and optimize training programs, provided that reliable data and sufficient infrastructure are in place. For educators, ML offers opportunities to design adaptive and student-centered learning experiences, though this requires training and institutional support. For policymakers and administrators, the findings emphasize the need to continue investing in infrastructure, data governance, and teacher development to fully realize the benefits of ML in sports and physical education.

Finally, for researchers, the gaps identified point to future directions such as improving data quality protocols, developing ethical frameworks for educational AI, and creating computationally efficient ML models tailored for low-resource environments.In sum, ML represents a powerful but complex innovation in physical education, sports, and recreation. Its adoption must be guided by a balance between technological potential and practical realities, ensuring that its benefits are both sustainable and inclusive.

RECOMMENDATIONS

Future research should expand beyond performance outcomes to explore the psychological and behavioral impacts of machine learning (ML) in sports and physical education.

Ethical concerns such as data privacy, bias, and inclusivity must be addressed to ensure fairness across diverse populations.

Coaches and educators require targeted training and user-friendly tools to effectively integrate ML into their practices.

Finally, continuous validation, retraining, and personalization of ML models are essential to enhance engagement, accuracy, and long-term impact.

Future researchers should aim to build upon this study by addressing another research gap.

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AUTHORSHIP CONTRIBUTION

Conceptualization: Stephen A. Fadare, Maria C. Fadare, Jay-R L. Beterbo, Frederick Ybanez, Sittie Aina T. Pandapatan, Jack Ryan Abdulrajak Isahac, Edris Aloy Barahimin.

Data curation: Stephen A. Fadare, Maria C. Fadare, Jay-R L. Beterbo, Frederick Ybanez, Sittie Aina T. Pandapatan, Jack Ryan Abdulrajak Isahac, Edris Aloy Barahimin.

Formal analysis: Stephen A. Fadare, Maria C. Fadare, Jay-R L. Beterbo, Frederick Ybanez, Sittie Aina T. Pandapatan, Jack Ryan Abdulrajak Isahac, Edris Aloy Barahimin.

Methodology: Stephen A. Fadare, Maria C. Fadare, Jay-R L. Beterbo, Frederick Ybanez, Sittie Aina T. Pandapatan, Jack Ryan Abdulrajak Isahac, Edris Aloy Barahimin.

Supervision: Stephen A. Fadare, Maria C. Fadare, Jay-R L. Beterbo, Frederick Ybanez, Sittie Aina T. Pandapatan, Jack Ryan Abdulrajak Isahac, Edris Aloy Barahimin.

Drafting - original draft: Stephen A. Fadare, Maria C. Fadare, Jay-R L. Beterbo, Frederick Ybanez, Sittie Aina T. Pandapatan, Jack Ryan Abdulrajak Isahac.

Writing - proofreading and editing: Stephen A. Fadare, Maria C. Fadare, Jay-R L. Beterbo, Frederick Ybanez, Sittie Aina T. Pandapatan, Jack Ryan Abdulrajak Isahac,Edris Aloy Barahimin.