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**Review Article**

# Applications of Artificial Intelligence in Sport Medicine: A Review

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## Abstract

Artificial intelligence (AI) is transforming the field of sports medicine, bringing forth innovative solutions to enhance athletic performance, prevent injuries, and optimize recovery processes. This literature review explores the diverse applications of AI in sports medicine, highlighting its role in injury prediction, wearable health devices, and its influence on imaging and diagnostics. A brief overview of AI, along with the subfields of machine learning and deep learning, is provided to help understand their relevance and contribution to the field. The review aims to offer a comprehensive understanding of how AI is revolutionizing sports medicine by improving injury prevention strategies, allowing for more accurate diagnostics, and supporting recovery through personalized treatment plans. As AI continues to evolve, its potential to further shape the future of sports medicine is immense. This review looks forward to the continued advancements in this fast-growing technology and its implications for healthcare, rehabilitation, and overall performance optimization in the world of sports. The integration of AI in sports medicine is paving the way for a more efficient, data-driven approach to athlete care.

**Keywords**: machine learning; deep learning; sports injury; AI applications

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## Introduction

Artificial intelligence (AI) is the field of computer science focused on creating systems and machines that can perform tasks typically requiring human intelligence. These tasks include reasoning, learning, problem-solving, understanding natural language, and perception. AI aims to simulate or enhance human-like cognitive abilities in machines. The term "artificial intelligence" came into existence by McCarthy in 1955, [1] and fast forward to this day, AI has been used in many fields, with its ability to learn and evolve, and the field of medicine and rehabilitation was no exception. By using advanced algorithms, machine learning (ML) and deep learning (DL); ML is a branch of AI that focuses on developing systems and algorithms that can learn from and make decisions or predictions based on data without being explicitly programmed. It involves training models using data to identify patterns, improve performance over time, and solve tasks such as classification, regression, and clustering. While DL is a subset of machine learning that uses artificial neural networks with many layers (hence "deep") to process large amounts of data and extract complex patterns. It is particularly effective for tasks like image recognition, natural language processing, speech recognition, and autonomous systems. Deep learning models automatically learn hierarchical features from raw data, often achieving high performance without extensive manual feature engineering. AI enables deep understanding and analyzation of athletes' biomechanics, injury patterns, and injury prediction. For an athlete, maintaining optimal performance and preventing injuries is very important. [2] Many applications of AI, such as wearable technologies, biosensors, and diagnostic imaging, have made athletes performance and health much better. Consequently, the prevention, reduction, and control of sports injuries are paramount goals for both healthcare professionals and society as a whole.

Recently, sports injuries have been viewed through a more complex view. This perspective suggests investigating injuries using computational methods, ML (like classification trees), and neural networks. These approaches aim to understand the interplay of various biomechanical, physiological, social, psychological, and environmental factors in injury etiology. [3]

AI, which includes both ML and DL, is purportedly part of the next industrial revolution where "data is oil". [4] AI, ML, and DL are not only changing the perspective in sports medicine but also changing how injuries are managed and predicted. by using data and advanced analytics to predict risks, speed up diagnosis, and personalize recovery. Wearable devices and smart sensors monitor movement and environmental factors to prevent injuries, while AI-powered imaging tools provide accurate and fast diagnoses. In recovery, AI tailors rehabilitation plans and tracks progress, ensuring optimal outcomes. From supporting athletes to improving workplace safety, AI is redefining how we prevent, treat, and recover from injuries.

Currently, many opportunities are offered to solve and predict problems regarding sports sciences. In a website named Kaggle, a data science competition platform and online community for data scientists and ML practitioners under Google LLC, the American National Football Team (NFL) hosts a competition every year to advance prediction using AI. American Major League Baseball (MLB) also hosted, previously, a competition to predict fan engagement with baseball player digital content.

AI holds great promise, but it faces key challenges. The availability of high-quality data is limited, often due to privacy concerns and fragmented records. Transparency in machine learning (ML) models is another issue, as their complex algorithms can lack the ability to explain. Additionally, the relatively new nature of AI and ML in healthcare makes them difficult for non-experts to understand and adopt, hindering widespread implementation.

The rapid advancements in AI research are unveiling a new era of medicine. DL algorithms, particularly capable of handling large datasets, are surpassing human capabilities and traditional statistical methods. [5] AI is going to revolutionize healthcare, creating a distinct pre- and post-AI era. Physicians and healthcare systems must embrace this transformative technology and adapt accordingly.

This literature review explores the diverse applications of AI in sports medicine, highlighting its role in injury prediction, wearable health devices, and its influence on imaging and diagnostics. A brief overview of AI, along with the subfields of machine learning and deep learning, is provided to



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help understand their relevance and contribution to the field.

## AI and sports medicine

AI is the science of creating intelligent machines that can mimic human behavior and problem-solving abilities. ML is a subset of AI that allows machines to learn from data without explicit programming, enabling them to improve their performance over time. DL is a further specialization of ML that utilizes artificial neural networks with multiple layers to process and learn from vast amounts of data, leading to highly accurate predictions and decisions. [figure 1]

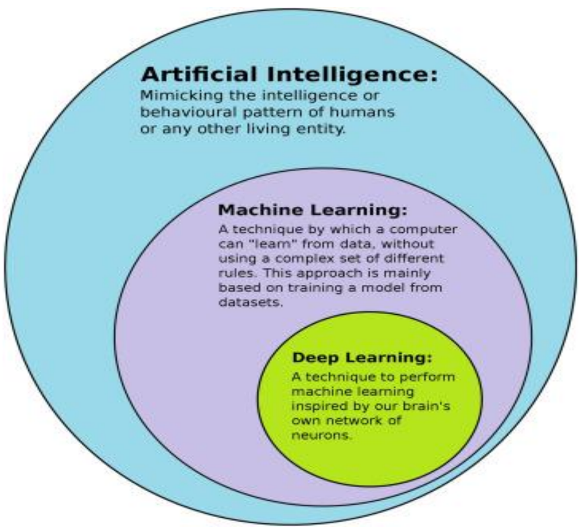


**Fig. 1. Machine learning and deep learning are subsets of a larger field called artificial intelligence. Figure adapted from. [6]**

## Artificial Intelligence

A key milestone for AI was in the 1950s when Alan Turing's Turing Test proposed a way to measure machine intelligence, and early AI programs were developed to solve simple problems. [7,8] In 2000s, Advancements in computing power and the availability of large datasets fueled the rise of ML and DL techniques. This led to breakthroughs in image recognition, speech recognition, and natural language processing. In the present day, AI is now integrated into various aspects of our lives, from self-driving cars to medical diagnosis. It continues to evolve rapidly, with new applications and innovations emerging constantly.

## Machine Learning

ML can be used to recognize patterns within the data that human may not usually be able to observe; it can analyze data such as medical images, patient records, and genetic information. All of these features can lead to advantageous applications, e.g., improved medical diagnosis, personalized treatment plan, drug discovery and development, and analyzing medical images to detect abnormalities.

ML is divided into three sections: supervised, unsupervised, and reinforcement learning, as shown in figure 2.

*Supervised Learning*

Supervised learning is a type of machine learning where a model is trained on labeled data. In this approach, the dataset contains input-output pairs, where each input (features) is associated with a known output (label). The model learns to map inputs to outputs by minimizing the error between its predictions and the actual labels. Once trained, the model can predict outputs for unseen inputs.

Supervised learning constitutes the most prevalent form of ML applied in medical research. In sports medicine, supervised learning methodology has been applied to predict several outcomes of interest. It has demonstrated utility in predicting clinical outcomes. Nwachukwu et al.[10] applied regression algorithms to a dataset of nearly 900 hip arthroscopy patients with femoroacetabular impingement syndrome (FAIS) to forecast 2-year post-operative



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outcomes. Anterior shoulder instability (ASI) is a common cause of functional limitation in the young and athletic population, with a reported annual incidence as high as 169 per 100,000 person-years. [11] In a recent study, Lu et al.[12] investigated the application of supervised ML models to predict the recurrence and development of osteoarthritis following initial shoulder instability events in a cohort of 654 patients. Boosted algorithms demonstrated promising performance, achieving an AUC of 0.86 for recurrence prediction and an AUC of 0.78 for osteoarthritis prediction. The most influential features identified by these models were time elapsed since the initial instability, age at the time of initial instability, and involvement in sports.

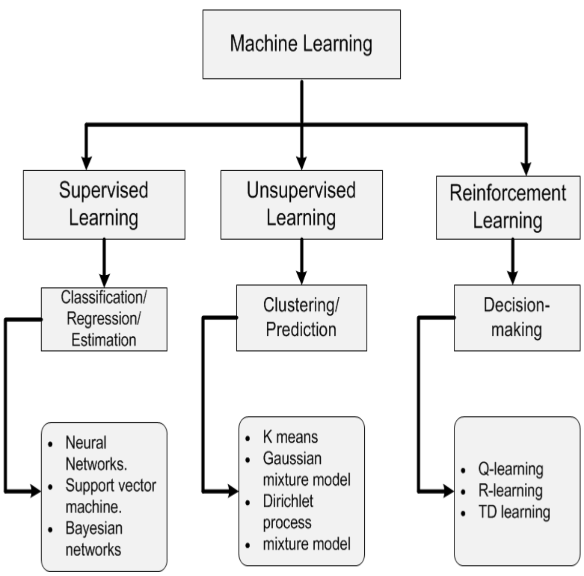


**Fig.2 Comparison of different types of machine learning.[13]**

*Unsupervised Learning*

Unsupervised learning is a type of machine learning where the model is trained on unlabeled data, meaning there are no predefined outputs or labels. The goal is to identify patterns, structures, or relationships within the data. An example of a technique that is related to unsupervised learning is principal component analysis (PCA), which transforms complex ("high-dimensional") data into linear functions, therefore simplifying data. In a recent study, Yocum et al. [13] used the PCA unsupervised learning method to assess knee joint biomechanics in patients after arthroplasty and applied this to kinematic data. People who underwent unilateral total knee arthroplasty (TKA) exhibited altered gait patterns characterized by increased knee flexion and adduction throughout the stance phase, along with decreased sagittal plane range of motion. Bilateral TKA patients demonstrated further limitations, including decreased sagittal plane range of motion, increased adduction range of motion, and reduced push-off ground reaction force compared to unilateral TKA patients. These findings suggest that TKA, particularly bilateral TKA, can induce significant alterations in gait biomechanics, resulting in a stiff knee gait, frontal plane instability, and reduced quadriceps muscle activation. [14]

Another type of technique is k-means clustering: it is an algorithm that partitions data into distinct and non-overlapping clusters. In a recent study of bloodborne markers of joint tissue turnover, K-means clustering of biological markers was used to identify subgroups of patients with distinct osteoarthritis sub-phenotypes. [45]

*Reinforcement learning*

Reinforcement learning (RL) is a type of machine learning where an agent learns to make decisions by interacting with an environment. The agent takes actions and receives feedback in the form of rewards or penalties based on the outcomes of its actions. The goal is to learn a strategy, or policy, that maximizes cumulative rewards over time. It is a less commonly used ML technique in healthcare, likely due to its



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complexity and inherent unpredictability. RL algorithms learn to make a series of decisions in a complex environment with the goal of maximizing rewards. This learning process is similar to trial and error, where the algorithm is rewarded for correct actions and penalized for mistakes. [15] Unlike other ML techniques, RL algorithms are not explicitly guided towards the solution but must independently discover the optimal strategy.

Wood et al. [46] found that reinforcement learning plays a key role in the acquisition and retention of new gait patterns. In line with the reinforcement learning framework, individuals explore various movements until discovering the most rewarding one. Once identified, the most rewarding action is repeated and refined through practice. This framework effectively explains behavior across diverse species, including human bipedal locomotion, where our environment is filled with both risks (e.g., tripping on a cracked sidewalk) and rewards (e.g., successfully clearing a hurdle to win a race).

## Deep Learning

DL uses artificial neural networks with multiple layers to process and learn from vast amounts of data. DL models can recognize complex patterns in data, such as images, text, and sound, enabling them to perform tasks like image recognition, natural language processing, and speech recognition with high accuracy. Deep learning, especially related to computer vision, has become more prominent throughout musculoskeletal radiology because of the ability to make tasks more efficient. [9] For athletes, an ACL (Anterior Cruciate Ligament) injury can have a profound impact on their careers. It often requires surgery and a lengthy rehabilitation process. Y. Jeon et al. used DL to detect ACL tears on MRI with an AUC of nearly 0.98 [16]. Recent developments in DL have the potential to revolutionize medical image analysis. Astuto et al. [17] showcased this potential by developing a model capable of automatically detecting multiple abnormalities (cartilage, bone marrow, menisci, and ACL) in knee MRI scans, which could significantly aid in clinical diagnosis and treatment planning.

## Applications in sports medicine

## AI and injury prediction

Injury prediction has a key role in sports field, and understanding its risk factors is an essential part of it. Some studies used typical tools to predict some injuries like hamstring strain and patellar tendinopathy, but these tools didn't give consistent identification of risk factors. [18,19] To add, the complexity of injuries needs more complex approaches to give better results [20] ML methods can be successfully applied for sport injury prediction. In a study to assess injury risk in elite-level youth football players based on anthropometric, motor coordination, and physical performance measures with an ML model, XGBoost (Extreme Gradient Boosting Algorithms). it showed high accuracy of 85%, In addition, injuries could be classified as overuse or acute with accuracy of 78%. [21] As well, Karnuta *et al.* [22] analyzed hockey player data to predict future injuries using ML algorithms. XGBoost, the top-performing model, achieved an accuracy of 94.6% in predicting next-season injuries. Kautz T. et al. [23] used the monitoring data from wearable sensors in beach volleyball players to model injury risk using artificial neural network with accuracy of 83.2%.

For injury risk assessment, the artificial neural network, decision tree classifier (Tree-based models are currently the most popular ML models in sports medicine, [24] and support vector machine have been used in soccer, basketball, American football, Australian



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football, and handball. [25] While the full potential of AI and ML in this field is yet to be realized, it offers a promising future for uncovering new insights into the relationship between workload and injury, which could ultimately lead to more effective injury prevention strategies. [26]

## Wearable health technology and biosensors

The increasing use of wearable health devices has created a wealth of data that can be leveraged by AI to optimize training programs and improve performance. This has the potential to revolutionize the way athletes train, leading to significant performance gains and reduced injury risk. These devices can collect data on physiological parameters like blood pressure, heart rate, body temperature, ECG, EEG, sweat analysis, and movement data (displacement, velocity, and acceleration). In a study aimed to assess the efficiency of using ML on long-term data from fitness bands with biosensors to detect issues regarding mental health, Classification accuracy of up to 85% was achieved. [27] Novatchkov et al. [28] utilized sensor technology to track force, displacement, velocity, and duration during resistance training. This data-driven approach can help weight-lifters refine their technique and maximize performance. Chen *et al.* [29] designed a wearable heat-stroke-detection device to prevent heat stroke while exercising in high temperatures.

Following a sports injury, athletes often undergo a period of rehabilitation, physiotherapy, and medical treatment. During this time, wearable technology can be employed to monitor patient progress and recovery. For example, Bloomfield *et al*. [30] utilized ML algorithms (unsupervised clustering) to analyze data collected from wearable devices in patients recovering from total knee arthroplasty to correlate higher PROMS (patient-reported outcome measures) in the cohort that also had better post-operative functional clinical outcomes.

FocusMotion, an AI-powered system, remotely monitors patients post-knee surgery using Bluetooth-enabled braces. These devices collect objective and subjective data, which is then transmitted to an ML algorithm. The algorithm analyzes the data to identify potential warning signs and track parameters such as mobility, range of motion, PROMs, and home exercise compliance.[30-32] This information is presented on a central dashboard accessible to both patients and healthcare providers, leading to increased patient engagement and motivation during the rehabilitation process.

In a recent paper, [44] a novel smartphone-based approach using a pose estimation algorithm to evaluate the quality of the movements and provide feedback is presented, allowing patients to perform autonomous recovery sessions. By using MediaPipe to extract the coordinates of 33 key points on the patient's body [check figure 3] and comparing them with reference videos made by professional physiotherapists using cosine similarity and dynamic time warping.

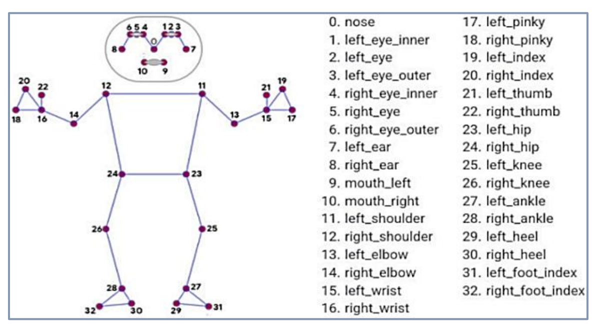


**Fig.3 MediaPipe's 33 key points [44]**

In general, wearable health technology has become a massively popular industry, with a market size of just over USD 13 billion in 2019. [33] In 2024, The global wearable



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technology market, valued at USD 117.5 billion in 2024, is projected to reach USD 390.2 billion by 2031. [34]

## Medical imaging and diagnostics

AI is transforming medical imaging and diagnostics in sports medicine by enhancing the accuracy, speed, and personalization of injury detection and treatment. AI systems can classify different types of sports injuries, such as ligament tears, fractures, and muscle strains, by analyzing imaging data.

In a recent study, ML models were used to detect ACL injury from MRI with an AUC (area under curve) result of 0.894 for the injury-detection problem and 0.943 for the complete-rupture-detection problem, [35] which is considered a high result. In another study to detect distal radial fractures using convolutional neural networks (CNNs) to analyze images, [36] 2,340 wrist radiographs from 2,340 patients were enrolled in this study, and the AUC of the CNN for this test was 0.96. Kang YJ *et al.* [37] developed an ML–based implant recognition program of hip arthroplasty via X-ray. a total of 170 X-ray images were collected for this study; the recognition model structure consisted of two steps: object detection and clustering. Femoral stem identification in patients with total hip arthroplasty was very accurate (AUC of 0.99).

## limitations & Future

## challenges and limitations

Although the great success of AI in many areas, there are some limitations that AI faces. The first challenge that faces AI is the availability of high-quality data, [38-40] due to inaccurate or incomplete medical data, which is due to hospitals having different standards for medical data, there are no uniform standards. This can be solved by Implementing uniform data standards across healthcare systems to improve accuracy and consistency. Another reason is fragmented and inconsistent data due to privacy concerns. The second challenge is transparency in ML, [38,41] users have access to input and output of algorithm but not the inner workings, which creates a "black box" phenomenon. [41] Therefore, in some cases we are not able to know exactly how the decision was made. This can be improved by Using simpler, interpretable models like decision trees or linear models where possible and providing improved documentation for the models used. Third challenge is that ML and AI technology are relatively new to healthcare and can be challenging for non-experts to understand. [9] Also, medical AI is a complex field that requires expertise in both medicine and AI, but there is a significant shortage of professionals with this dual skill set. [40]

## Future perspective

Some concerns are related to the patient-health care provider relationship and that it may get affected after the increasing usage of AI in medicine, but in contrast, AI has the ability to do redundant tasks which allow the health care provider to spend more time with patients. [41,43] AI doesn't cover all aspects of the treatment process, e.g., empathy and proper communication, [42] so we can consider AI more as a useful assistant.

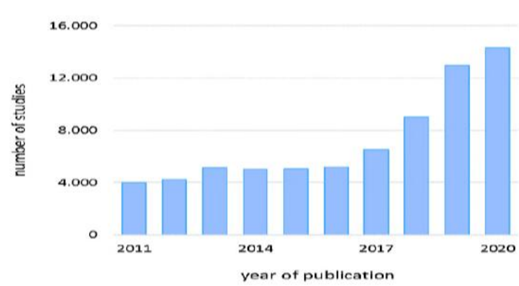


**Fig.4 Global evolution of research in artificial intelligence in medicine. [47]**



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The future of AI in healthcare holds immense promise. As more research papers are being conducted through the years [figure 4], and as AI technology continues to advance, we can expect to see even more groundbreaking applications in sports medicine. This includes the development of more sophisticated AI-powered diagnostic tools that can detect subtle injuries with unparalleled accuracy. Additionally, AI-driven personalized treatment plans will optimize recovery time and minimize the risk of re-injury. Furthermore, AI-enabled wearable devices will provide real-time monitoring of vital signs and performance metrics, allowing for early intervention and proactive care. As AI becomes more integrated into sports medicine, we can anticipate significant improvements in athlete performance, injury prevention, and overall healthcare outcomes.

## Conclusion

Artificial intelligence is revolutionizing sports medicine by offering innovative solutions for injury prevention, diagnosis, and rehabilitation. Advancements in wearable technologies, imaging tools, and personalized treatment plans are transforming athlete care and recovery processes. To address current limitations, implementing uniform data standards, developing explainable AI models, and providing interdisciplinary training for professionals in both AI and healthcare are essential steps forward. The author encourages future studies to build on these solutions, unlocking AI's full potential to elevate sports medicine. As AI continues to evolve, it will pave the way for improved outcomes and a new era in healthcare.

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