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ARTIFICIAL INTELLIGENCE IN SPORTS MEDICINE: ADVANCING ATHLETE SCREENING, INJURY PREDICTION, AND REHABILITATION

M. Karthik Prakash*[1], Duggirala Subhashini[2], D. Kalidoss[3] A. Sandhya Rani[4]

[1]Ph.D. Research Scholar, Department of Physical Education, Kalinga University, Raipur, Chhattisgarh, India.

[2]Ph.D. Research Scholar, Department of Physical Education, Kalinga University, Raipur, Chhattisgarh, India.

[3]Associate Professor, Department of Physical Education, Kalinga University, Raipur, Chhattisgarh, India.

[4]Research Scholar, Department of Physical Education, Kalinga University, Raipur, Chhattisgarh.

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***Corresponding Author: M. Karthik Prakash**
Ph.D. Research Scholar, Department of Physical Education, Kalinga University, Raipur, Chhattisgarh, India.

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ABSTRACT

Background: Artificial intelligence (AI) is increasingly embedded across the sports medicine pipeline, from pre-participation screening through injury forecasting to post-injury rehabilitation. Advances in machine learning (ML), deep learning (DL), computer vision, and wearable sensor technology now allow clinicians and performance staff to process volumes of physiological, biomechanical, and imaging data that were previously impractical to analyse manually.Objective: This narrative review synthesises recent literature on the use of AI across three interconnected domains of sports medicine practice: (i) athlete screening, particularly cardiovascular and musculoskeletal pre-participation assessment; (ii) prediction of injury risk using machine learning models trained on training-load, biomechanical, and wearable-sensor data; and (iii) AI-supported rehabilitation, including robotic exoskeletons and virtual reality-integrated recovery systems.Methods: Findings from peer-reviewed narrative reviews, scoping reviews, and primary studies indexed in PubMed, Scopus, Web of Science, and IEEE Xplore were synthesised, with an emphasis on studies published between 2020 and 2025. Reported quantitative outcomes were extracted where available to illustrate the comparative performance of AI approaches across the three domains.Results: Across the reviewed literature, AI-enhanced electrocardiogram (ECG) analysis, convolutional neural network (CNN)-based movement assessment, and random forest (RF) injury-prediction models consistently reported high classification accuracy and agreement with expert assessment. Robotic exoskeleton research is dominated by artificial neural network (ANN) and adaptive control architectures, while integrated AI monitoring systems have been associated with meaningful reductions in reinjury rates and improvements in training-load management.Conclusion: AI offers substantial promise for more precise, individualised, and proactive sports medicine care. Realising this potential at scale will depend on resolving persistent challenges around model interpretability, data standardisation, external validation, and equitable access to the underlying technology.

KEYWORDS: Artificial Intelligence; Machine Learning; Sports Medicine; Athlete Screening; Injury Prediction; Rehabilitation; Wearable Sensors; Deep Learning.

1. INTRODUCTION

Sports medicine sits at the intersection of preventive screening, in-season performance monitoring, and post-injury care, all of which generate large and heterogeneous streams of data: electrocardiographic recordings, motion-capture and video, force-plate and inertial-sensor output, training-load logs, and imaging studies. Traditional analytic approaches, which rely heavily on clinician experience and univariate statistical thresholds, are increasingly complemented, and in some contexts superseded, by AI methods capable of detecting non-linear and multivariate patterns across this data.

Interest in AI-enabled sports medicine has grown rapidly over the past decade, driven by three converging trends: the proliferation of low-cost wearable sensors capable of continuous physiological and biomechanical monitoring; the maturation of deep learning architectures for image, signal, and time-series analysis; and mounting clinical and financial pressure to reduce the burden of sports-related injury, which remains a leading cause of athlete attrition and a substantial direct cost to professional sports organisations.

This review synthesises current literature across three domains that, taken together, span the athlete's journey through sport: pre-participation screening, in-season injury-risk prediction, and post-injury rehabilitation. Rather than treating these as separate technical problems, the review highlights how the same underlying AI methods, most notably ensemble tree-based models, convolutional neural networks, and adaptive control algorithms, recur across all three domains, and considers the shared methodological challenges that limit their translation into routine clinical practice.

2. Review Approach

This is a narrative rather than a systematic review. Sources were identified through targeted searches of PubMed, Scopus, Web of Science, and IEEE Xplore for recent (predominantly 2020-2025) reviews and primary studies combining terms related to artificial intelligence, machine learning, and deep learning with sports medicine, athlete screening, injury prediction, and rehabilitation. Priority was given to peer-reviewed systematic and scoping reviews, which were used to synthesise the state of the field, supplemented by primary studies reporting quantitative model-performance data. The aim is to provide an integrative, non-exhaustive overview rather than a formal, protocol-driven systematic synthesis.

3. AI-Enabled Athlete Screening

Pre-participation examination (PPE) aims to identify athletes at elevated risk of adverse cardiovascular or musculoskeletal events before they occur. Conventional PPE protocols, including resting 12-lead electrocardiography, are constrained by inter-observer variability and the difficulty of distinguishing benign, exercise-induced cardiac remodelling ('athlete's heart') from pathological findings that predispose to sudden cardiac death.

3.1 Cardiovascular Screening

AI-assisted ECG interpretation has been explored as a means of improving the sensitivity and consistency of cardiovascular PPE. In one study evaluating a random forest classifier trained on annotated ECG recordings across six sports (handball, football, athletics, weightlifting, judo, and karate), the model achieved high overall accuracy, specificity, and precision in stratifying athletes into low-, moderate-, and high-risk categories based on QTc interval, PR interval, QRS duration, and related parameters, although sensitivity for the rarer, higher-risk classifications was comparatively lower, reflecting the class-imbalance challenges typical of screening datasets in which serious pathology is uncommon. Reviews of AI applications in sports cardiology similarly report growing use of deep learning for automated detection of hypertrophic cardiomyopathy, channelopathies, and arrhythmias from ECG and imaging data, though most authors emphasise that these tools remain adjuncts to, rather than replacements for, clinician judgement.

3.2 Musculoskeletal and Biomechanical Screening

Beyond cardiovascular assessment, computer-vision and inertial-sensor-based systems are increasingly used to screen movement quality, asymmetries, and biomechanical risk factors historically assessed through functional movement screens. Markerless computer-vision systems have been reported to approximate marker-based motion-capture accuracy for selected biomechanical measures, expanding the feasibility of biomechanical screening outside specialised laboratories.

Table 1. Selected AI applications in pre-participation athlete screening.

Screening Domain	Representative AI Technique(s)	Screening Task	Reported Strength / Limitation
Cardiovascular (ECG)	Random forest, convolutional neural networks	Classification of cardiovascular risk from resting 12-lead ECG parameters	High specificity and precision; sensitivity for rare high-risk cases lower due to class imbalance
Cardiac imaging	Deep learning on echocardiography / CMR	Differentiating physiological athletic remodelling from cardiomyopathy	Improves consistency vs. manual reads; validation cohorts often small
Movement / biomechanics	Markerless computer vision, CNNs	Assessing movement quality and technique against expert benchmarks	Approaches marker-based accuracy for some tasks; sensitive to camera setup and lighting
Musculoskeletal imaging	Deep learning image classifiers	Detecting structural abnormalities (e.g., tendinopathy) on ultrasound/MRI	Promising early accuracy; limited external validation across populations

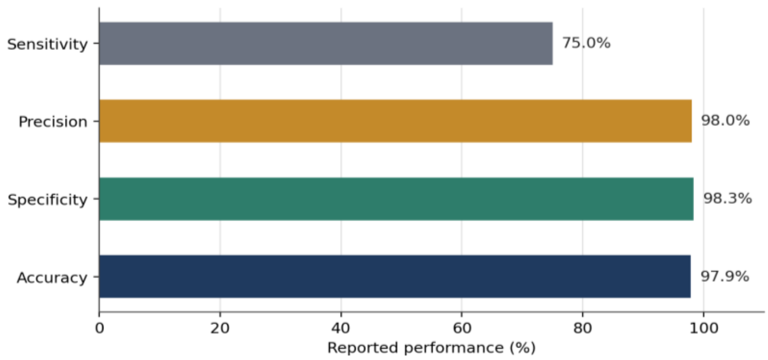

Figure 1. Performance metrics of a random forest ECG-based cardiovascular risk classifier evaluated across a six-sport athlete cohort.

4. AI in Sports Injury Prediction

Injury-risk prediction has attracted the largest volume of AI sports-medicine research, reflecting both the scale of the problem (use and overuse injuries account for a substantial share of athlete time-loss) and the relative maturity of the underlying data, principally training-load logs, GPS and inertial-sensor streams, and historical injury records.

4.1 Machine Learning Approaches

Across reviewed literature, tree-based ensemble methods, particularly random forests and gradient-boosted trees, are the most frequently applied algorithms for injury-risk classification, valued for their ability to handle mixed categorical and continuous features and to produce interpretable feature-importance rankings. Neural network and deep learning approaches, including long short-term memory (LSTM) and convolutional architectures, are increasingly applied to raw time-series sensor data, such as running kinematics or GPS-derived training load, where they can capture temporal dependencies that simpler models cannot. K-nearest neighbour, support vector machine, and clustering methods (e.g., k-means) also feature in the literature, generally as comparison baselines against tree-based or deep learning models.

4.2 Wearable Sensors and Real-Time Monitoring

Wearable inertial measurement units (IMUs), GPS trackers, and smart textiles allow continuous capture of training load, running mechanics, and fatigue-related movement changes outside the laboratory. When combined with AI models, these streams support individualised, near real-time risk flags rather than static, population-level thresholds, an approach reviews describe as a shift from reactive to proactive injury management.

Table 2. Machine learning approaches commonly applied to sports injury-risk prediction.

Algorithm Family	Typical Input Data	Example Application	Notable Consideration
Random forest / gradient boosting	Training load, GPS, questionnaire and historical injury data	Predicting hamstring, ACL, and general overuse injury risk	Strong, interpretable performance; risk of overfitting on small cohorts
Convolutional neural networks	Video, image, and structured time-series data	Movement-technique assessment and pattern recognition	High agreement with expert raters reported in several studies
Recurrent	Sequential sensor /	Modelling cumulative	Captures temporal

Algorithm Family	Typical Input Data	Example Application	Notable Consideration
networks (e.g., LSTM)	GPS time-series	fatigue and load progression over a season	dependency; requires larger longitudinal datasets
K-nearest neighbour / SVM	Structured tabular features	Baseline classification of injury vs. non-injury cases	Simpler and faster; generally lower ceiling performance than ensembles

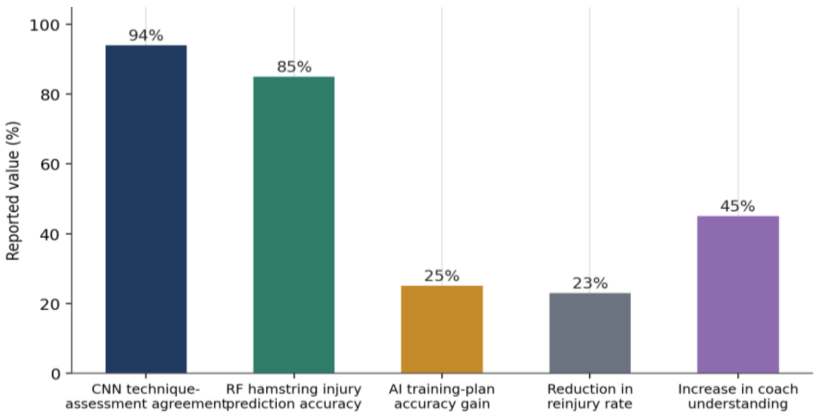

Figure 2. Selected reported outcomes from a scoping review of AI applications in sports biomechanics and injury prediction (73 studies, 2015-2024); each bar reflects findings from a distinct subset of the reviewed literature and should not be read as a single unified result.

5. AI in Rehabilitation

Following injury, AI is applied both to guide clinical decision-making (e.g., return-to-play readiness) and to power assistive devices that actively support the recovery process.

5.1 Robotic Exoskeletons

AI-controlled wearable robotic exoskeletons are the most extensively reviewed rehabilitation technology, particularly for upper-limb motor recovery. A systematic review of thirty studies published between 2016 and 2020 found that artificial neural networks were the dominant intelligent control technique, used exclusively in roughly a third of included studies and appearing in some form in around forty percent, with adaptive control algorithms and mixed AI approaches accounting for the remainder. The same review noted that the majority of research effort was concentrated on wearable device development rather than dedicated neuromotor rehabilitation outcomes, suggesting substantial room for growth in clinically focused evaluation.

5.2 Virtual Reality and Sensor-Integrated Rehabilitation

Beyond exoskeletons, AI-driven virtual reality (VR) systems and adaptive hand exoskeletons incorporating AI-based assessment engines have been proposed as holistic neurorehabilitation tools, coupling motion tracking with automated, individualised feedback on movement quality and effort during recovery.

Table 3. AI-enabled approaches used across sports rehabilitation modalities.

Rehabilitation Modality	Role of AI	Reported Focus in Literature	Key Limitation
Upper-limb robotic exoskeletons	ANN and adaptive control for movement assistance and human-robot interaction	Predominantly wearable device engineering	Relatively few studies target neuromotor rehabilitation outcomes specifically
Lower-limb exoskeletons	Reinforcement learning, SVM, decision trees for gait assistance	Human-robot interaction and control strategy design	Reinforcement-learning approaches require extensive, safe training data
VR-integrated systems	AI-based movement assessment engines paired with VR feedback	Neurorehabilitation and engagement/adherence	Evidence base still emerging; small sample sizes common
Wearable monitoring for return-to-play	ML models integrating load and biomechanical data	Supporting graded return-to-sport decisions	Limited standardisation of readiness criteria across studies

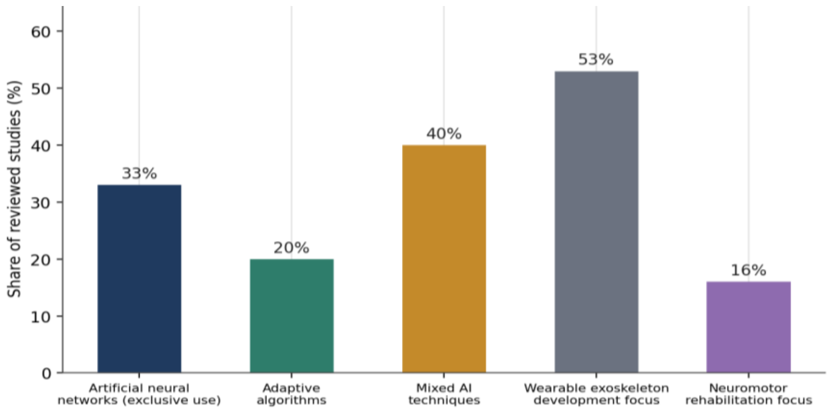

Figure 3. Distribution of AI techniques and research focus areas reported in a systematic review of AI-based wearable robotic exoskeletons for upper-limb rehabilitation (30 studies, 2016-2020).

6. CHALLENGES AND LIMITATIONS

- Interpretability: Many high-performing models, particularly deep neural networks, function as 'black boxes', complicating clinical trust and shared decision-making with athletes.
- Data standardisation: Injury definitions, training-load metrics, and sensor placement vary substantially across studies, hampering direct comparison and pooled analysis.
- External validation: Reported accuracies are frequently derived from small, single-cohort, or single-sport datasets and may not generalise across age groups, sexes, or competition levels.
- Class imbalance: Injury and serious cardiac events are comparatively rare, which can inflate apparent accuracy while masking weaker sensitivity for the outcomes of greatest clinical concern.
- Integration into practice: Translating validated models into coach- and clinician-facing workflows requires attention to usability, trust, and training, not only predictive performance.

7. Ethical Considerations

The deployment of AI in athlete care raises questions that extend beyond technical performance. Continuous physiological and biomechanical monitoring generates sensitive personal health data whose storage, ownership, and downstream use (including by clubs, sponsors, or insurers) require clear governance. Algorithmic risk flags can also influence high-stakes decisions, such as playing time or contract status, underscoring the importance of transparency about model limitations and avoiding over-reliance on automated outputs in place of clinical judgement. Equitable access to AI-enabled screening and rehabilitation technology, which remains concentrated in well-resourced professional and collegiate settings, is a further consideration as the field matures.

8. Future Directions

Several directions appear likely to shape the next phase of AI-enabled sports medicine. Explainable AI methods that expose feature contributions in clinician-interpretable terms may help bridge the trust gap associated with complex models. Federated and multi-site data-sharing approaches could enable larger, more representative training datasets while preserving athlete data privacy. Closer integration of screening, injury-prediction, and rehabilitation data into unified athlete-monitoring platforms may also allow AI systems to track an athlete's trajectory continuously, rather than treating each domain in isolation. Finally, prospective, sport- and sex-specific validation studies remain a priority to establish whether promising retrospective performance translates into genuine reductions in injury incidence and improved rehabilitation outcomes.

9. CONCLUSION

Artificial intelligence is reshaping sports medicine across the full arc of athlete care, from AI-enhanced cardiovascular screening and biomechanical assessment, through machine learning-based injury-risk prediction, to AI-controlled rehabilitation technologies such as robotic exoskeletons and VR-integrated recovery systems. The literature reviewed here points to consistently strong performance for specific, well-defined tasks, alongside shared and unresolved challenges around interpretability, validation, and equitable access. Continued progress will depend less on further gains in raw predictive accuracy and more on the disciplined, transparent, and ethically grounded translation of these tools into everyday sports medicine practice.

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