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Artificial Intelligence in Sport: Applications, Evidence, Limitations, and Directions for Responsible Implementation

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Abstract: ***Artificial intelligence (AI) is increasingly embedded in sport through machine learning, computer vision, wearable sensing, predictive modelling, and automated analytics. This narrative review synthesizes evidence on AI applications in athlete performance analysis, movement recognition, training support, injury-risk modelling, return-to-sport decision support, talent identification, tactical analysis, officiating, and fan-facing systems. Foundational reviews demonstrate substantial research activity: a 2019 review identified 58 studies across 12 team sports and a pooled sample of 6,456 participants, while a systematic review of sport-specific movement recognition included 52 studies. More recent evidence shows rapid growth in injury prediction research but also persistent methodological limitations. A 2025 scoping review included 38 injury-risk studies and reported that tree-based approaches achieved the highest statistical performance in 60% of studies; however, small datasets and heterogeneous injury definitions limited clinical utility. A 2026 systematic review of 18 empirical injury-prediction studies found that only one study (5.6%) had low overall risk of bias, with external validation remaining uncommon. Collectively, the literature supports AI as a promising decision-support technology rather than an autonomous replacement for coaches, clinicians, sports scientists, or officials. Future work should prioritize external validation, representative athlete cohorts, transparent reporting, explainability, privacy protection, and prospective evaluation in real-world sporting environments.***

Keywords: artificial intelligence; machine learning; sports analytics; performance analysis; injury prediction; computer vision; athlete monitoring; sports technology

1. Introduction

Artificial intelligence has moved from a specialized computational approach to a practical component of contemporary sport. High-performance environments now generate large volumes of data through global positioning systems, inertial measurement units, optical tracking, video, force platforms, wellness questionnaires, and competition databases. AI methods can identify patterns in these data, automate classification tasks, estimate probabilities, and support decisions that would otherwise require extensive manual analysis.

The attraction of AI is particularly strong in sport because performance is multidimensional. Technical execution, physical capacity, tactical context, training exposure, recovery, psychological state, and environmental conditions interact dynamically. Machine learning may capture nonlinear relationships across these variables, while computer vision can automate aspects of movement recognition and video analysis. Nevertheless, predictive performance reported in development datasets does not automatically translate into real-world usefulness.

This review therefore evaluates AI in sport from both an application and an evidence-quality perspective. It asks where AI is currently useful, where claims exceed the available evidence, and what methodological and ethical requirements should guide responsible implementation.

2. Review Aim and Questions

The aim of this narrative review is to synthesize major applications of AI in sport and critically evaluate the strength, limitations, and practical implications of the evidence.

- What are the principal applications of AI in sport?
- What does the published review literature indicate about model performance and research maturity?
- What methodological, ethical, and implementation barriers limit translation into practice?
- What priorities should guide future research and responsible adoption?

3. Methodology

This manuscript is a narrative review informed by targeted literature searching and evidence synthesis rather than a de novo systematic review or meta-analysis. Priority was given to peer-reviewed systematic reviews, scoping reviews, and established foundational papers addressing AI, machine learning, movement recognition, sports analytics, injury prediction, and return-to-sport modelling. Recent evidence through 2026 was used to update the discussion of injury-prediction research.

Because the present paper does not claim exhaustive database coverage, formal PRISMA reporting, duplicate screening, or quantitative pooling were not undertaken. Numerical findings are reported only when they were explicitly provided by the cited review literature. The synthesis emphasizes external validity, risk of bias,

interpretability, population representation, and practical relevance in addition to headline model accuracy.

4. Evidence Base and Research Maturity

The published literature shows both rapid expansion and uneven methodological maturity. Claudino et al. (2019) identified 58 studies applying 11 AI techniques across 12 team sports. The pooled sample comprised 6,456 participants, 97% of whom were male, and 76% were professional athletes. This concentration in male and elite cohorts raises an important generalizability issue.

Cust et al. (2019) included 52 studies of machine and deep learning for sport-specific movement recognition. Kernel support vector machines were used in 53% of inertial-sensor studies and 50% of vision-based studies, while 12 studies used convolutional neural networks. The review also documented substantial variation in preprocessing, model development, and evaluation.

Recent injury-prediction literature reinforces the need for methodological caution. Leckey et al. (2025) reviewed 38 studies and found that area under the curve was reported in 71%; tree-based methods provided the highest statistical predictive performance in 60% of studies, but small datasets and methodological heterogeneity limited clinical utility. A 2026 systematic review of 18 empirical studies reported that only one study (5.6%) had low overall risk of bias, with most models relying on internal validation. These findings indicate that strong development-set performance should not be equated with readiness for routine clinical or coaching use.

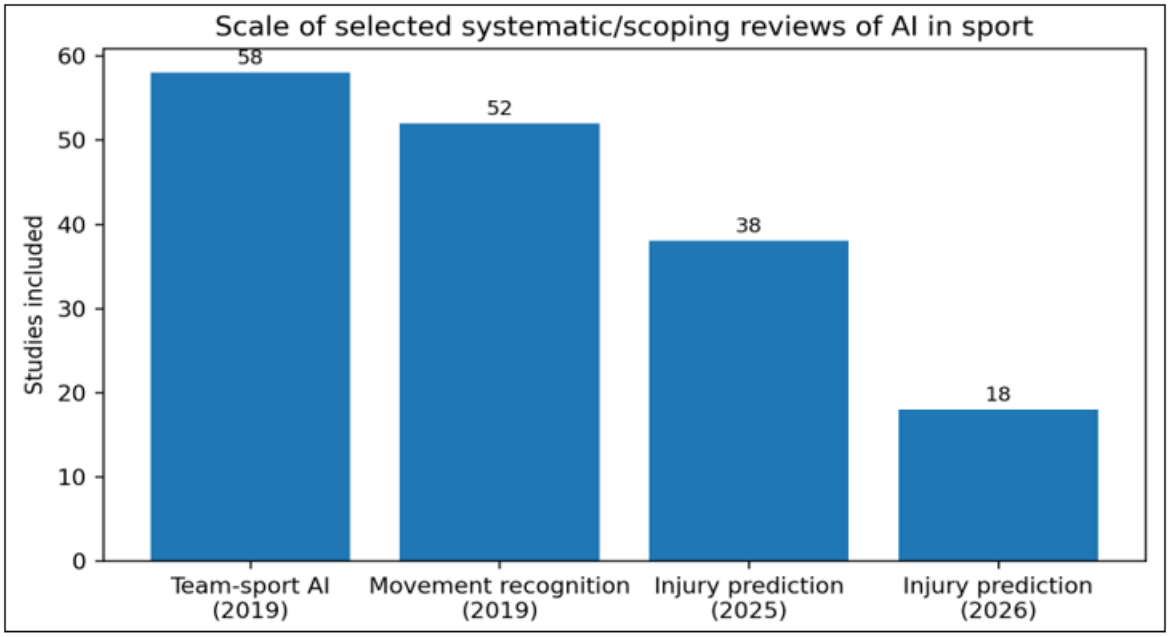


Figure 1: Number of included studies in selected reviews used in this synthesis.

5. Applications of AI in Sport

5.1 Performance analysis and tactical modelling

AI can automate event detection, player tracking, pattern recognition, and the organization of large video or tracking datasets. In team sports, these tools can support analysis of spatial organization, transitions, possession patterns, workload, and opponent tendencies. Their primary value is analytical scale and consistency, while tactical meaning still depends on expert interpretation.

5.2 Movement recognition and biomechanics

Computer vision and inertial sensors allow automated recognition of sport-specific movements and estimation of movement characteristics. Applications include running, jumping, throwing, lifting, and sport-specific technical actions. However, model outputs should not automatically be treated as laboratory-grade biomechanical measurements; calibration, occlusion, camera geometry, sensor placement, and population-specific validation remain important.

5.3 Training and athlete monitoring

AI can integrate workload, wellness, fitness, and performance data to support individualized training decisions. Such systems may help identify unusual changes or patterns across repeated sessions. They should complement athlete feedback and coaching judgment rather than prescribe training autonomously.

5.4 Injury-risk prediction

Machine learning is increasingly used to model multidimensional injury risk. Predictors include training load, previous injury, biomechanical variables, neuromuscular characteristics, anthropometrics, and psychological or biological indicators. Although recent reviews report promising discrimination in some studies, the evidence remains heterogeneous and often lacks external validation. Injury-risk estimates should therefore be interpreted probabilistically rather than as deterministic predictions.

5.5 Return-to-sport decision support

Recent review evidence suggests growing use of machine learning for return-to-sport modelling after injury. Random forest has been frequently applied, and some studies report high AUC values. Yet definitions of successful return, feature selection, and modelling procedures vary considerably, limiting generalizability. Clinical decisions should remain multidisciplinary.

5.6 Talent identification

AI can assist scouting by screening large athlete datasets and detecting unusual performance profiles. The principal risk is that models reproduce historical selection biases or overvalue easily measured attributes. Late maturation, learning capacity, motivation, and contextual opportunity remain difficult to quantify.

5.7 Officiating and event detection

Computer vision and tracking technologies can support officials by identifying relevant spatial or temporal events. These systems may improve consistency for measurable decisions, but interpretive rules and ambiguous situations still require human governance.

5.8 Fan engagement and media

AI supports automated highlights, personalization, statistical storytelling, and content generation. These applications can increase accessibility and engagement but create additional questions about user profiling, transparency, and data governance.

6. Quantitative Evidence Summary

Review	Scope	Key quantitative finding	Interpretation
Claudino et al., 2019	Team-sport AI	58 studies; 6,456 participants; 97% male; 76% professional	Broad activity but limited demographic representation
Cust et al., 2019	Movement recognition	52 studies; SVM used in 53% of IMU and 50% of vision studies	Strong interest with heterogeneous pipelines
Leckey et al., 2025	Injury prediction	38 studies; AUC reported in 71%; tree-based models best in 60%	Performance promising; clinical relevance constrained
2026 systematic review	Sports injury prediction	18 empirical studies; 5.6% low overall risk of bias	External validation and reporting remain major weaknesses
2026 meta-analysis	Sports injury prediction	Pooled sensitivity 0.79; specificity 0.71	Potential predictive value, but methodological differences remain

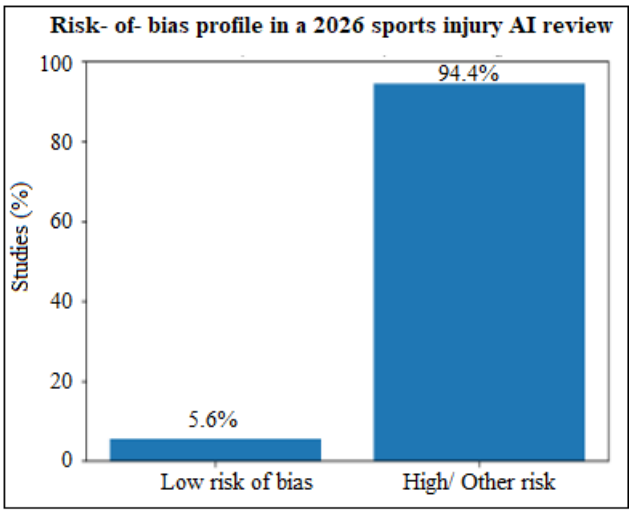


Figure 2: Risk-of-bias profile reported in a 2026 systematic review of 18 empirical AI injury-prediction studies

7. Methodological Challenges

7.1 External validation

A recurring limitation is reliance on internal validation. Models can perform well within the dataset from which they were developed but fail when applied to another team, season, competition level, sex, or age group. Prospective external validation should therefore be a central requirement before high-stakes implementation.

7.2 Class imbalance and metric selection

Injury datasets often contain many more non-injury than injury observations. Accuracy alone can therefore be misleading. Sensitivity, specificity, precision, F1-score, calibration, and AUC should be considered according to the intended decision context.

7.3 Small samples and overfitting

Complex models trained on small datasets may learn noise rather than generalizable patterns. Recent reviews continue to identify small cohorts as a major barrier, especially where very high performance is reported.

7.4 Heterogeneous outcome definitions

Different definitions of injury, exposure, performance, and return to sport make direct comparison difficult. Standardized definitions and transparent reporting would improve reproducibility and evidence synthesis.

7.5 Explainability

A model that cannot communicate why a prediction was generated may be difficult to trust in coaching or clinical practice. Explainable AI methods can help, but explanations themselves require validation and should not be mistaken for causal proof.

8. Ethical and Governance Considerations

Athlete data can be sensitive, commercially valuable, and career-relevant. Responsible implementation requires informed data governance, security, proportional data

collection, clear access rules, and transparency about how automated outputs influence decisions. Particular caution is warranted when AI affects health management, selection, contracts, scholarships, or youth development.

Bias is both a technical and ethical concern. The heavy representation of male and professional athletes in parts of the literature means that apparently high-performing models may not generalize to women, youth athletes, para-athletes, recreational populations, or resource-limited settings. Fairness assessment should therefore be treated as part of model validation, not as an optional addition.

9. Implications for Practice

Current evidence supports a human-in-the-loop model of AI adoption. Coaches can use AI to reduce repetitive analytical work and identify patterns; sports scientists can use it to integrate monitoring data; clinicians can use risk estimates as one component of assessment; and organizations can use automated tools to improve workflow. In each case, the model should provide evidence for a decision rather than become the decision-maker.

Before deployment, organizations should define the intended use, target population, acceptable error profile, validation requirements, responsible decision-maker, and procedure for reviewing incorrect or uncertain outputs. These governance questions are as important as model selection.

10. Future Research Priorities

- Prospective, multi-site external validation across seasons and competition levels.
- Greater inclusion of female athletes, youth, para-athletes, and non-elite populations.
- Transparent reporting of missing data, class imbalance, preprocessing, feature selection, calibration, and uncertainty.
- Direct comparison of AI models with simpler statistical baselines and expert judgment.
- Evaluation of whether AI changes real-world decisions and outcomes, not only whether it predicts a label.
- Explainability methods that are understandable and useful to coaches and clinicians.
- Privacy-preserving and federated approaches where appropriate for sensitive athlete data.
- Cost-effectiveness and implementation research in schools, universities, community sport, and lower-resource settings.

11. Limitations of This Review

This paper is a narrative review and does not claim exhaustive systematic coverage. The search and selection process was targeted toward influential and recent review literature, so publication counts should not be interpreted as a complete census of the field. The manuscript also spans diverse sporting applications whose datasets, outcomes, and validation standards differ substantially. Accordingly, quantitative findings are used to characterize the evidence base rather than to rank algorithms across incompatible tasks.

12. Conclusion

AI has clear potential to improve analytical efficiency and decision support in sport, particularly in performance analysis, movement recognition, athlete monitoring, and the integration of complex datasets. Yet the maturity of the evidence varies sharply by application. Recent injury-prediction research illustrates the central challenge: promising statistical performance coexists with limited external validation, heterogeneous methods, risk of bias, and uneven population representation.

Publication and implementation should therefore move beyond headline accuracy. The next phase of sports AI research should demonstrate reproducibility, generalizability, calibration, fairness, explainability, and measurable benefit in real sporting environments. The most defensible future is not athlete or coach versus algorithm, but carefully governed collaboration between domain expertise and validated computational tools.

Declarations

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Informed consent: Not applicable.

Data availability: No new dataset was generated. All quantitative values presented in the manuscript are derived from cited published sources.

Author contributions: To be completed according to the target journal's authorship requirements.

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