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Kavita Vats¹, Kumari Seema²,

¹Assistant Professor, Department of Physical Education, Shyama Prasad Mukherji College for Women, University of Delhi, Delhi, India

²Assistant Professor, Department of Physical Education, Shyama Prasad Mukherji College for Women, University of Delhi, Delhi, India

Corresponding Author: Kavita Vats

kavitavats820@yahoo.com

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Artificial Intelligence Technology in Indian Sports: Applications, Opportunities, Challenges and Future Directions

Kavita Vats¹, Kumari Seema²,

Abstract

Artificial Intelligence (AI) is increasingly changing the way sporting performance is measured, interpreted, and managed. The convergence of machine learning, computer vision, wearable sensors, predictive analytics, natural language processing, and multimodal data systems has created new possibilities for athlete assessment, talent identification, tactical analysis, injury-risk estimation, rehabilitation, officiating, and fan engagement. In India, this technological transition is particularly relevant because of the country's large and diverse athlete population, expanding sports infrastructure, professional leagues, and growing emphasis on scientific talent identification. The Sports Authority of India has already incorporated AI-enabled assessment concepts into the proposed Khelo India Rising Talent Identification (KIRTI) portal, including video-based assessment, automated measurement, standardized evaluation, and centralized athlete reporting. At the research level, AI has demonstrated potential in performance prediction, injury-risk assessment, cricket analytics, wearable-based monitoring, and adaptive sports. However, the evidence also shows important limitations, including small and unrepresentative datasets, insufficient external validation, limited interpretability, privacy concerns, algorithmic bias, and unequal access to advanced technology. This article critically examines the current and emerging role of AI in Indian sports and proposes a human-centred framework in which AI functions as a decision-support technology rather than a replacement for coaches, sports scientists, physicians, and athletes. Particular attention is given to the Indian sporting context, including talent identification, performance optimization, injury prevention, cricket analytics, sports medicine, adaptive sports, and governance. The article concludes that the effective integration of AI into Indian sports will depend not simply on acquiring advanced technology but on developing high-quality Indian datasets, interdisciplinary expertise, ethical governance, explainable models, and affordable systems that can operate across both elite and grassroots sport.

Keywords: Artificial intelligence, machine learning, Indian sports, sports analytics, athlete performance.

1 Introduction

Sport has progressively evolved from an activity primarily guided by observation and experience into a data-intensive scientific domain. Contemporary athletes generate information through competition statistics, video recordings, wearable sensors, physiological testing, biomechanical assessment, training-load monitoring, and medical records. The growing volume and complexity of these data have created a need for computational approaches capable of identifying patterns that may not be readily visible through conventional analysis. Artificial Intelligence provides one such approach by allowing computational systems to learn relationships within large datasets and generate predictions, classifications, or decision-support information.

AI should not be regarded as a single technology. It represents a broad family of computational approaches that includes machine learning, deep learning, computer vision, natural language processing, reinforcement learning, and other data-driven methods. In sports, these techniques can process temporal, spatial, physiological, biomechanical, and contextual information simultaneously. Earlier systematic evidence demonstrated applications of artificial neural networks, decision trees, support vector machines, and Markov models in team-sport performance and injury research. More recent research has expanded this landscape to include deep neural networks, transformers, multimodal systems, and AI-enabled wearable technologies.

The Indian sporting environment provides a particularly important setting for examining the potential of AI. India has a large youth population and an increasingly diversified sporting ecosystem encompassing cricket, hockey, football, badminton, wrestling, athletics, shooting, boxing, weightlifting, kabaddi, archery, tennis, and numerous other disciplines. At the same time, sporting opportunities and access to advanced sports science are not distributed equally across geographical regions or socioeconomic groups. Consequently, AI could potentially assist India not only in improving elite performance but also in scaling objective assessment and talent identification to a much larger population.

The transition is already visible at the institutional level. The Sports Authority of India has proposed AI-enhanced assessment within the Khelo India Rising Talent Identification (KIRTI) portal. The proposed system includes video capture and AI analysis, automated generation of assessment results, standardized evaluation criteria, automated data entry, and centralized athlete-performance reporting. This indicates that AI is increasingly being considered not merely as an experimental research technology but as a component of large-scale sporting infrastructure.

The objective of this article is therefore to critically examine the role of AI technology in Indian sports, with particular emphasis on its applications, scientific basis, opportunities, limitations, ethical considerations, and future research directions.

2 Conceptual Foundation of Artificial Intelligence in Sports

At its simplest level, an AI system attempts to learn a function that maps available information to an outcome of interest. In a supervised learning problem, the general relationship can be expressed as:

$$\hat{y} = f_{\theta}(X) \quad (1)$$

where $\hat{y}$ represents the predicted outcome, X represents the input variables, f_{θ} represents the learned model, and θ represents the model parameters.

In sports, X may contain variables such as training load, heart-rate measures, movement characteristics, sleep indicators, previous injuries, anthropometric variables, technical actions, opponent characteristics, and environmental conditions. The outcome $\hat{y}$ may represent performance, injury occurrence, fatigue status, match result, or another sport-specific variable. The value of AI lies primarily in its ability to integrate multiple information streams. Traditional statistical analysis may focus on a relatively small number of predetermined relationships, whereas machine-learning systems can model nonlinear interactions among numerous variables. Nevertheless, increased computational complexity does not automatically guarantee scientific validity. A model can achieve excellent performance on a development dataset while performing poorly when applied to athletes from another population, sport, institution, or competition level.

This distinction is important in sports because athletes are highly heterogeneous. Age, sex, training history, playing position, genetics, environmental conditions, competition level, and

coaching practices can influence the relationships observed in performance data. Therefore, AI systems intended for Indian sports must be developed and validated using populations that adequately represent the athletes on whom the systems will ultimately be used.

3 Artificial Intelligence for Athlete Performance Analysis

Performance analysis represents one of the most established applications of AI in sport. Video footage, positional data, event data, physiological measurements, and wearable sensors can be processed to generate information concerning movement efficiency, tactical behaviour, workload, technical execution, and performance trends.

Computer vision is particularly important because video is one of the richest sources of information available in sports. Deep-learning models can detect athletes and sporting objects, estimate body position, track movement, recognize actions, and quantify spatial relationships. Recent reviews of sensor-based sports intelligence describe applications ranging from athlete and ball perception to pose estimation, action recognition, trajectory analysis, fatigue monitoring, injury-risk prediction, rehabilitation, and return-to-play support [?].

For Indian athletes, computer vision could be particularly valuable in sports where technical execution is critical. In cricket, for example, video analysis can potentially quantify bat trajectory, bowling mechanics, release characteristics, foot placement, body alignment, and shot selection. In athletics, computer vision can examine running mechanics, stride characteristics, joint positions, and movement symmetry. In wrestling and kabaddi, automated movement analysis could help quantify tactical actions and positional behaviour.

A performance index can be conceptually represented as:

$$PI = \sum_{i=1}^n w_i z_i \quad (2)$$

where PI represents a composite performance index, z_i represents standardized performance variables, and w_i represents the relative contribution assigned to each variable.

Such an index should not be interpreted as an absolute measure of sporting ability. Rather, it can provide an additional source of evidence for coaches and sports scientists.

4 AI-Based Talent Identification in India

Talent identification is one of the areas in which AI could have substantial implications for Indian sport. Conventional talent identification often depends on physical testing, coach observation, competition results, and subjective judgment. These approaches remain valuable but can be affected by assessor experience, environmental conditions, maturation, and differences in access to competition.

AI can potentially integrate anthropometric, physical-fitness, technical, psychological, and performance data to identify athletes who display promising characteristics. The KIRTI portal's proposed AI-enhanced assessment process is particularly relevant in this context because it envisages video-based assessment, standardized testing, automated results, and AI-assisted identification of candidates for subsequent stages [?].

A conceptual talent-identification model can be expressed as:

$$T = f(A, P, B, S, C) \quad (3)$$

where T represents predicted talent potential, A represents anthropometric characteristics, P represents physical-performance variables, B represents biomechanical characteristics, S represents sport-specific skills, and C represents contextual factors.

However, talent identification should not become synonymous with algorithmic selection. Adolescents develop at different rates, and an AI model trained on mature athletes may incorrectly classify younger athletes whose performance potential has not yet emerged. Growth and maturation therefore need to be incorporated into Indian talent-identification systems.

5 AI and Cricket in India

Cricket provides an unusually rich environment for AI research because of the enormous volume of structured and unstructured data generated during matches. Ball-by-ball records, player statistics, video footage, pitch conditions, weather information, player movements, and commentary can all be analyzed computationally.

A systematic review of machine-learning applications in cricket reported substantial growth in research using machine-learning approaches across different cricket-related problems [?]. Recent research has investigated AI-based prediction using Indian Premier League data, including venue, weather, team, player, and pitch information [?].

AI can support cricket in several areas, including match-outcome prediction, player-performance forecasting, field-placement optimization, opposition analysis, pitch assessment, automated video analysis, and decision support.

A match-outcome probability can be represented using a logistic model:

$$P(Y = 1|X) = \frac{1}{1 + \exp[-(\beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_k X_k)]} \quad (4)$$

where $Y = 1$ represents the predicted occurrence of an outcome such as winning, $X_1, \dots, X_k$ represent match variables, and β_i are model parameters.

However, predictive accuracy should not be confused with strategic certainty. Cricket contains substantial randomness, and an AI prediction represents a probability rather than a predetermined outcome. Coaches and analysts should therefore interpret AI outputs in combination with tactical knowledge and situational information.

6 AI for Injury Prevention and Sports Medicine

Injury prevention is one of the most scientifically promising but methodologically challenging applications of AI. Athletic injury is generally multifactorial, involving training load, previous injury, biomechanics, recovery, physical characteristics, psychological factors, and environmental conditions. AI provides an opportunity to integrate these variables into predictive models.

A systematic review of AI applications in sports injury prediction identified considerable potential but also important methodological limitations. The literature has highlighted issues related to external validation, reporting quality, generalizability, and representation of female athletes [?]. Earlier research similarly documented the use of tree-based methods, support vector machines, and artificial neural networks for sports-injury prediction [?].

The basic concept of injury-risk prediction can be expressed as:

$$P(I = 1|X) = f(X_1, X_2, \dots, X_n) \quad (5)$$

where $I = 1$ represents injury occurrence and X includes relevant risk variables.

For Indian athletes, a useful model could incorporate training load, previous injury, strength asymmetry, sleep, recovery measures, competition density, environmental heat, travel, and sport-specific biomechanical variables.

Importantly, AI should not tell an athlete that an injury is certain to occur. A prediction

should be interpreted as a risk estimate that can stimulate further assessment. Recent sports-medicine research indicates that AI systems frequently demonstrate promising predictive performance but remain dependent on retrospective datasets and require stronger prospective and external validation [?].

7 Wearable Technology and AI-Based Athlete Monitoring

Wearable devices have significantly expanded the amount of physiological and biomechanical information that can be collected outside conventional laboratories. Heart rate, heart-rate variability, acceleration, movement intensity, sleep, recovery indicators, workload, and other signals can potentially be monitored continuously.

AI can combine these data streams to construct individualized athlete profiles. Recent literature on AI and wearable technology in sport has highlighted applications in performance optimization, injury-risk estimation, return-to-play support, and athlete well-being, while emphasizing the importance of data quality, model validation, contextual interpretation, and practitioner expertise [?].

For Indian sports science laboratories, this creates an opportunity to move from periodic assessment toward longitudinal monitoring. Instead of assessing an athlete only during a laboratory visit, researchers can combine laboratory measurements with daily field data.

A conceptual recovery score can be expressed as:

$$RS = w_1HRV + w_2SQ + w_3TR + w_4PR - w_5FL \quad (6)$$

where HRV represents heart-rate variability, SQ represents sleep quality, TR represents training recovery, PR represents perceived recovery status, and FL represents accumulated fatigue or workload.

The weights w_i should be empirically derived rather than arbitrarily assigned. Such models could be useful for individualized training, but subjective athlete feedback should remain part of the assessment because physiological measurements are indirect indicators rather than complete representations of recovery.

8 AI in Biomechanics and Movement Analysis

Biomechanics provides another important area for AI implementation. Traditional biomechanical analysis often requires specialized laboratory equipment, force platforms, motion-capture systems, or expert observation. Computer vision and machine learning may reduce some of these barriers by allowing movement characteristics to be estimated from video.

Pose-estimation algorithms can identify anatomical landmarks and calculate joint angles, segment velocities, movement symmetry, and temporal characteristics. Deep-learning approaches are increasingly being investigated for vision-based and multimodal sports monitoring [?].

This technology has considerable potential for Indian sports because many institutions may not have access to sophisticated motion-capture laboratories. A smartphone or camera-based system could potentially provide preliminary movement analysis at a lower cost.

Nevertheless, low-cost does not mean automatically accurate. Camera position, lighting, clothing, occlusion, frame rate, lens distortion, and athlete morphology can influence measurement quality. AI-based biomechanical systems should therefore be validated against accepted reference methods before being used for high-stakes clinical or performance decisions.

9 AI and Adaptive Sports in India

AI also has the potential to contribute to inclusive sports. Athletes with disabilities may benefit from personalized training feedback, assistive technologies, movement analysis, classification support, and health monitoring.

Research involving athletes with disabilities has reported potential benefits of AI-based technologies for sports performance, physical health, and psychological well-being [?]. AI-based systems may also contribute to individualized training and assistive solutions in Paralympic sport.

For India, AI-based adaptive sports technologies could help address the shortage of specialized expertise in some regions. However, accessibility must remain a central design principle. An AI system that is technologically sophisticated but financially inaccessible to most athletes will have limited public-health or sporting value.

10 AI in Coaching and Decision Support

The traditional coach-athlete relationship is based on observation, experience, communication, and accumulated knowledge. AI does not necessarily need to replace this relationship. Its more appropriate role is to increase the amount and quality of information available to decision-makers.

An AI coaching system could provide information regarding changes in performance, training load, technical execution, opponent behaviour, or recovery status. The coach can then integrate this information with contextual knowledge about the athlete.

This relationship can be represented conceptually as:

$$Decision = f(AI\ Data, Coach\ Expertise, Athlete\ Feedback, Context) \quad (7)$$

The equation emphasizes that AI should be one component of the decision-making process rather than the sole decision-maker.

This human-in-the-loop approach is particularly important because an algorithm may recognize statistical patterns without understanding important contextual factors such as motivation, examination stress, illness, family circumstances, tactical changes, or the athlete's subjective experience.

11 AI and Officiating

AI-assisted officiating has become an important component of modern professional sport through technologies capable of tracking trajectories, detecting events, and supporting officials. Computer vision can potentially assist with line decisions, movement detection, object tracking, and event classification.

In India, such systems may be particularly relevant for sports where human observation becomes difficult because of the speed of play. However, technological assistance should remain transparent and subject to appropriate human oversight.

The objective should not be to eliminate officials but to reduce avoidable errors and provide additional evidence during decision-making. The final implementation should establish clear procedures for system failure, disagreement between AI and officials, and review of algorithmic decisions.

12 AI for Sports Broadcasting and Fan Engagement

The impact of AI extends beyond athletes and coaches. Natural language processing, automated video editing, recommendation systems, computer-generated statistics, and multi-modal systems can change how spectators interact with sport.

AI can generate personalized content based on a viewer's interests, identify important moments in matches, summarize player performances, and support automated commentary. Research has investigated deep-learning approaches for automated cricket analytics, player classification, and commentary generation.

For the Indian sports industry, this could be particularly significant because of the enormous audiences associated with cricket and the growing popularity of other professional leagues. AI-enabled media systems could increase the visibility of less-commercialized sports by lowering the cost of content production and analysis.

13 Benefits of Artificial Intelligence for Indian Sports

The potential advantages of AI in Indian sports can be summarized across several interconnected dimensions. First, AI can improve *objectivity* by converting observational information into measurable indicators. Second, it can improve *scalability*, particularly for large talent-identification programmes. Third, it can support *personalization* by identifying individual patterns rather than applying identical training recommendations to all athletes.

Fourth, AI can facilitate *early detection* of potentially concerning changes in workload, performance, or health indicators. Fifth, it can improve *decision support* by combining large numbers of variables that are difficult to process manually. Sixth, it can strengthen *longitudinal athlete management* by maintaining continuous records of performance and recovery.

These benefits are particularly relevant to India's need to expand sports science beyond a relatively small group of elite athletes.

14 Challenges and Limitations

Despite its potential, AI should not be presented as a universal solution to the problems of Indian sport. One of the most significant limitations is *data quality*. Machine-learning models learn from the information supplied to them. If datasets are incomplete, biased, incorrectly labelled, or collected under inconsistent conditions, the resulting model may produce unreliable predictions.

A second challenge is *population representativeness*. Many sports AI datasets are dominated by professional athletes, particular sports, or male participants. Recent systematic evidence has highlighted limited external validation and underrepresentation of female athletes in injury-prediction research [?].

A third problem is *overfitting*. A model may perform extremely well on its development dataset but fail when applied to new athletes. This makes external validation essential.

A fourth challenge is *interpretability*. Complex deep-learning systems may function as black boxes. A coach or sports physician may need to understand why a model has identified an athlete as high-risk rather than simply receiving a numerical prediction.

A fifth challenge concerns *privacy*. Athlete data can include health information, biometric characteristics, location information, psychological information, and detailed performance records. Improper collection or sharing of such information could create substantial risks.

A sixth challenge is *digital inequality*. Elite teams may be able to purchase sophisticated sensors, computing systems, and analytical services, while schools and community-level programmes may have very limited resources. If technology is introduced without an equity

strategy, AI could widen rather than reduce existing inequalities.

15 Ethical and Responsible AI in Indian Sports

The ethical dimension of AI deserves particular attention because sporting decisions can influence selection, scholarships, contracts, medical decisions, and career opportunities. An incorrect algorithmic decision can therefore have consequences beyond a simple prediction error.

NITI Aayog's framework for responsible AI in India identifies principles including safety and reliability, equality, inclusivity and non-discrimination, privacy and security, transparency, accountability, and protection of positive human values [?]. These principles have direct relevance to sports.

For example, an AI-based talent-identification model should not systematically disadvantage athletes because they come from a particular region or socioeconomic background. Similarly, injury-prediction systems should not be used to exclude athletes automatically from competition without professional assessment.

Athletes should also be informed about what data are being collected, why they are collected, who can access them, and how long they will be retained. AI systems used in high-stakes decisions should undergo regular auditing for accuracy, fairness, reliability, and demographic bias.

16 Proposed Framework for AI Integration in Indian Sports

A sustainable Indian AI ecosystem in sport should be developed through a staged approach. The first stage should involve *data infrastructure*. Standardized protocols should be established for anthropometry, physical fitness, biomechanics, physiological monitoring, training load, injuries, and sport-specific performance.

The second stage should involve *model development* using Indian athlete datasets. Models developed primarily from foreign populations should not automatically be assumed to have equivalent validity in Indian athletes.

The third stage should involve *validation*. Models should undergo internal validation, external validation, prospective validation, and, where appropriate, field-based implementation studies.

The fourth stage should focus on *explainability*. Coaches and clinicians should receive interpretable outputs rather than unexplained numerical scores.

The fifth stage should establish *human oversight*. AI predictions should be reviewed by appropriately trained professionals before major decisions are made.

The sixth stage should establish *governance and athlete protection*, including consent, privacy, cybersecurity, data ownership, access control, and mechanisms for challenging automated decisions.

The overall framework can be represented as:

$$\text{Data Quality} \rightarrow \text{AI Model} \rightarrow \text{Validation} \rightarrow \text{Explainability} \rightarrow \text{Expert Review} \rightarrow \text{Sporting Decision} \quad (8)$$

Such a model would position AI as an augmentation technology rather than an autonomous authority.

17 Future Directions for India

The future of AI in Indian sport is likely to move from isolated analytical applications toward integrated athlete ecosystems. One promising direction is the development of *athlete digital twins*, in which physiological, biomechanical, technical, and performance data are combined to create individualized computational representations of athletes. Such systems could potentially simulate training responses and assist with individualized decision-making, although substantial validation will be required before they become practically reliable.

Another important direction is *multimodal AI*, where video, wearable, physiological, contextual, and textual data are analyzed simultaneously. Recent reviews emphasize multimodal sensing and deep learning as emerging directions in sports intelligence while also highlighting challenges involving data heterogeneity, generalization, interpretability, and privacy [?].

India should also invest in *open and standardized sports datasets*. High-quality datasets covering Indian athletes across age groups, sexes, regions, sports, and competition levels could become a major national research resource.

The integration of AI with *sports genomics* is another emerging area. Recent research has examined the potential of combining AI and genomic information to support precision sports science and individualized approaches to performance and injury risk [?]. Such research, however, requires particularly strong ethical safeguards because genomic information is highly sensitive.

Finally, AI education should become part of sports-science training. Coaches, physical-education professionals, physiotherapists, sports physicians, and strength-and-conditioning specialists do not necessarily need to become programmers, but they should understand fundamental concepts such as model accuracy, sensitivity, specificity, false positives, overfitting, validation, bias, and interpretability.

18 Conclusion

Artificial Intelligence is emerging as an important technological component of modern sports science and has considerable potential for the Indian sporting ecosystem. Its applications extend from athlete performance analysis and talent identification to injury-risk assessment, biomechanics, wearable monitoring, cricket analytics, adaptive sports, officiating, coaching, and fan engagement.

The Indian context is especially important because AI offers the possibility of scaling scientific assessment to a large and geographically diverse athlete population. The proposed AI-enhanced assessment components of the KIRTI portal demonstrate how video analysis, standardized testing, automated reporting, and AI-supported talent identification could become part of large-scale national sports development [?].

However, technological adoption should not be equated with sporting progress. The current scientific literature demonstrates that promising AI performance can coexist with weaknesses in external validation, dataset quality, representativeness, interpretability, and real-world implementation [?].

Therefore, the future of AI in Indian sports should be based on a *human-centred, evidence-based, and ethically governed model*. AI should assist coaches, athletes, sports scientists, and medical professionals rather than replace their expertise. Investment in Indian datasets, interdisciplinary training, validation research, affordable technologies, explainable AI, and athlete data protection will be more important than simply purchasing advanced computational systems.

If these principles are followed, AI can contribute not only to the production of elite champions but also to a broader transformation of Indian sports science—from observation-driven

practice toward *evidence-informed, individualized, scalable, and scientifically accountable athlete development*.

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Conflict of Interest

The authors declare that there is no conflict of interest associated with this article.

Use of Artificial Intelligence

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ORCID iDs

Kavita Vats: 0009-0003-0175-1068

Kumari Seema: 0009-0005-9862-3840

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