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Emerging Technologies in Sports

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ABSTRACT

Technology is no longer an add-on; it is the backbone of modern sport. From training sessions to club management, and from the fan experience to injury prevention, emerging technologies in sport are reshaping every link in the chain at an unprecedented pace. Advances in artificial intelligence, wearable devices, robotics, virtual reality, data analytics, biotechnology, and smart equipment are creating new possibilities for improving performance and reducing injuries. As these technologies continue to develop, sports are becoming increasingly intelligent, connected, personalized, and data-driven. In the future, these technologies are expected to become even more sophisticated and integrated into virtually every aspect of the sporting world. This paper explores the critical role of emerging technologies in sports.

KEYWORDS: *technology, emerging technologies, sports, sport industry, entertainment.*

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INTRODUCTION

Sports technology is the use of digital tools, software, equipment, and systems to improve athletic performance, elevate fan engagement, and optimize sports business operations. It encompasses innovations such as artificial intelligence, machine learning, wearable technology, virtual and augmented reality, blockchain, and data analytics. Sports organizations are prioritizing technologies that create compounding value across performance, engagement, and monetization. Emerging technologies are transforming the world of sports by changing how athletes train, coaches make decisions, officials enforce rules, and fans experience sporting events. Technologies such as artificial intelligence (AI), wearable devices, the Internet of Things (IoT), virtual reality (VR), augmented reality (AR), robotics, drones, advanced analytics, and smart equipment are increasingly becoming part of modern sports. These innovations are being applied at both professional and amateur levels to improve performance, enhance safety, support decision-making, and create more engaging experiences for spectators [1,2].

WHAT ARE EMERGING TECHNOLOGIES?

Technology may be regarded as a collection of systems designed to perform some function. It can help alleviate some of the challenges facing business today. Emerging technology is a term generally used to describe new technology. The term often refers to technologies currently developing or expected to be available within the next five to ten years. Any imminent, but not fully realized, technological innovations will have some impact on the status quo.

Emerging technologies are shaping our societies. They continue to affect the way we live, work, and interact with one another. Emerging technology (ET) lacks a consensus on what classifies them as "emergent." It is a relative term because one may see a technology as emerging and others may not see it the same way. It is a term that is often used to describe a new technology. A technology is still emerging if it is not yet a "must-have" [3]. An emerging technology is the one that holds the promise of creating a new economic engine and is trans-industrial. ET is used in different areas such as media, healthcare, business, science, education, or defense.

The characteristics of emerging technologies include the following [4]:

- *Novelty:* Emerging technologies are typically new or novel, meaning they have yet to be widely adopted or used. They often represent a significant departure from existing technologies or processes.
- *Potential for Disruption:* Emerging technologies have the potential to disrupt existing markets, industries, or ways of doing things. They may also displace existing businesses or industries.
- *Uncertainty:* Because emerging technologies are still in the early stages of development, there is often a high uncertainty surrounding their future potential and impact. It can be challenging to predict how they will evolve.
- *Rapid Change:* Emerging technologies often evolve rapidly, with new developments and innovations emerging frequently. It can make keeping up with the latest trends and advancements challenging.
- *Interdisciplinary*: Emerging technologies often involve multiple disciplines or fields of study, such as computer science, engineering, and biology. They may require collaboration across different fields and industries to develop their potential fully.

Emerging technologies are worth investigating. They are responsible for developing new products or devices. As emerging technologies continue to evolve, engineering is poised for a transformative future. Emerging technologies have driven innovation and progress in today's rapidly evolving digital landscape. The collective impact of emerging technologies such as artificial intelligence, machine learning, big data, and the Internet of things is undeniably transformative. Some emerging technologies are shown in Figure 1 [5].

EMERGING TECHNOLOGIES IN SPORTS

Technology has become an important force in the transformation of modern sports. The sports industry is rapidly evolving, with technology playing a pivotal role in transforming how athletes train, develop team strategies, and engage with fans. From professional leagues and international competitions to amateur athletics and personal fitness, emerging technologies are changing how athletes train, how coaches make decisions, how officials enforce rules, and how spectators experience sporting events. The most important sports technology innovations include artificial intelligence, computer vision, wearable devices, advanced analytics, virtual and augmented reality, robotics, drones, smart equipment, digital twins, biotechnology, advanced connectivity, and intelligent stadiums. These technologies are transforming athlete performance, coaching, operations, broadcasting, and fan experiences. Emerging technologies in sports include the following [1,6-8]:

1. *Artificial Intelligence:* Artificial intelligence (AI) is one of the most influential emerging technologies in sports. AI systems can analyze enormous quantities of information collected from games, training sessions, wearable devices, and video recordings. Machine-learning algorithms can identify patterns that may be difficult for coaches or analysts to recognize manually. For example, AI can evaluate an athlete's speed, movement, positioning, passing patterns, shooting performance, and tactical decisions. Coaches can use this information to develop individualized training programs and adjust strategies for particular opponents. AI can also analyze an opposing team's previous performances and identify tendencies that may provide a competitive advantage. Generative AI is expanding these possibilities further. It can help summarize performance information, generate scouting reports, explain complex statistics, and assist coaching staff in exploring possible tactical scenarios.
2. *Robotics:* Robotics represents another developing area of sports technology. Robots can assist athletes during training by providing consistent and repeatable practice conditions. Robotic systems can deliver balls in tennis, table tennis, baseball, and other sports at controlled speeds and trajectories. Robotics may also support rehabilitation. In addition, autonomous robots are increasingly capable of assisting with stadium operations, broadcasting, field maintenance, equipment transportation, and other sporting activities. Figure 2 shows robots playing basketball on a futuristic court [9].
3. *Drones*: Drones are providing new opportunities for sports broadcasting, training, and event management. Equipped with high-resolution cameras, drones can capture aerial footage that would be difficult or expensive to obtain using conventional cameras. They are particularly valuable in outdoor sports such as cycling, skiing, surfing, motorsports, and athletics. Coaches can also use aerial recordings to analyze team formations and player positioning. Drones may additionally assist organizers with crowd observation, venue inspection, and large-event management, although their use must comply

with aviation, privacy, and safety regulations. Figure 3 shows the use of a drone in American football [10].

4. *Internet of Things (IoT):* IoT has transformed the sports world, with many connected devices helping to gather real-time data on health, performance, and game metrics. The Internet of things can improve the safety of athletes and fan convenience, from smart wearables to many connected stadiums.
5. *Wearable Technology*: Wearables are transforming the way training sessions are planned and monitored. Wearable technology has become an important component of athlete monitoring. Smartwatches, GPS trackers, heart-rate monitors, smart clothing, and biometric sensors can collect information while athletes train or compete. These devices can measure variables such as heart rate, distance traveled, acceleration, workload, sleep patterns, body temperature, and recovery. Coaches and sports scientists can use this information to determine whether an athlete is training appropriately or experiencing excessive physical stress. Wearable technology also supports personalized training. Rather than requiring every athlete to follow exactly the same program, coaches can modify training intensity according to individual performance and recovery data. This approach can potentially improve performance while reducing unnecessary physical strain. Figure 4 shows wearable technologies on an athlete [11].
6. *Computer and Image Recognition:* Computer vision allows computers to obtain meaningful information from photographs and video. It has become particularly valuable in sports because cameras can capture detailed information without requiring athletes to wear additional equipment. Computer-vision systems can track players and balls, analyze body movements, measure distances, recognize events, and evaluate techniques. In football, basketball, tennis, baseball, athletics, and many other sports, these systems can help analysts understand exactly how athletes move and interact during competition. Image recognition can also automate the analysis of large collections of sporting footage.
7. *Immersive Technologies*: Virtual reality (VR) creates computer-generated environments in which users can experience simulated situations. In sports, VR can allow athletes to practice decision-making without experiencing the physical demands of repeatedly performing the actual activity. A quarterback, goalkeeper, racing driver, or basketball player, for example, can experience simulated competitive situations and practice responding to them. This can be especially useful for tactical training, reaction development, and mental preparation. Augmented reality (AR), in contrast, adds digital information to a person's view of the physical environment. AR may provide athletes or coaches with visual instructions and performance information during training. For spectators, AR can display statistics, player information, and interactive content alongside live sporting events.
8. *Digital Twins:* Digital twins are virtual representations of physical objects, systems, or environments that can be updated using real-world data. In sports, digital twins may eventually be created for athletes, equipment, stadiums, or playing environments. An athlete's digital model could combine information about movement, workload, physical condition, and performance. Sports scientists could potentially use such models to explore different training scenarios before applying them in practice. Digital twins of stadiums could similarly help organizations simulate crowd movements, energy consumption, emergency procedures, and facility operations.
9. *Biotechnology:* Advances in biotechnology are contributing to increasingly personalized approaches to sports performance and recovery. Researchers are studying biomarkers, metabolism, nutrition, hydration, sleep, muscle function, and other physiological factors to understand individual differences among athletes. When combined with AI and wearable sensors, these technologies may allow training and recovery programs to become more individualized. However, biological information is highly sensitive. Its collection and use therefore raise important questions about privacy, informed consent, fairness, and ownership of athlete data.
10. *Injury Prevention Technologies:* One of the most valuable applications of emerging sports technology is injury prevention. Motion sensors, computer vision, force plates, wearable devices, and AI can help identify unusual movement patterns or excessive workloads that may indicate elevated injury risk. Technology is also transforming rehabilitation. Virtual reality, robotic systems, motion-tracking equipment, and digital rehabilitation platforms can help professionals monitor exercises and track recovery progress.
11. *Blockchain:* Blockchain technology has also attracted attention in sports. Its potential

applications include ticket verification, digital collectibles, athlete records, contracts, and authentication of sporting merchandise. One particularly useful application is ticketing. Blockchain-based systems may help verify ticket ownership and reduce certain forms of counterfeiting or unauthorized duplication. However, not every sports application requires blockchain, and organizations must determine whether it provides meaningful advantages over conventional databases.

12. *Predictive Analytics*: The power of predictive analytics is that it removes guesswork. Instead of making decisions based on intuition or incomplete information, teams make decisions backed by data models built from thousands of data points. Predictive analytics uses historical and current information to estimate possible future outcomes. Teams can use predictive models to evaluate player performance, identify promising recruits, analyze opponents, optimize lineups, and estimate injury risks. However, such predictions should generally support rather than replace professional judgment. Predictive systems should not be viewed as perfect predictors of injury. Injuries often result from complex combinations of physical, environmental, and situational factors. Technology should therefore complement rather than replace professional judgment.

Other emerging technologies include 5G, digital ticketing, sports analytics, smart stadiums, and smart sports equipment.

APPLICATIONS OF EMERGING TECHNOLOGIES IN SPORTS

The applications of emerging technologies in sports extend across nearly every aspect of the sporting environment. For example, AI applications have the potential to enhance traditional sports performance analysis methodologies. It has enabled video analysis to become faster, more precise, and comprehensive, supplanting time-consuming and potentially biased manual reviews. Common applications of emerging technologies in sports therefore include the following [1,2]:

- *Athlete Performance Monitoring*: One of the most important applications of emerging technologies in sports is athlete performance monitoring. Wearable technologies such as smartwatches, fitness trackers, GPS devices, and biometric sensors can collect information about an athlete's heart rate, speed, acceleration, distance traveled, workload, sleep, and recovery. Coaches can use this information to understand how athletes respond to training and competition. Instead of relying entirely on observation, they can use measurable data to determine whether an athlete is improving, becoming fatigued, or requires additional recovery. This data-driven approach can help training programs become more individualized and effective.
- *Sports Analytics*: Artificial intelligence has become an important tool for analyzing large amounts of sports data. AI systems can identify patterns that may be difficult for human observers to recognize. They can analyze player movements, team formations, previous performances, opponent behavior, and numerous other variables. For example, AI can help identify patterns associated with successful plays and recommend possible strategies. Machine learning can further support predictive analytics. However, such predictions should generally support rather than replace professional judgment.
- *Injury Prevention*: Sports injuries remain a critical challenge worldwide, causing substantial physical, psychological and financial burdens. Emerging technologies are increasingly being used to improve athlete safety. Sensors, motion-capture systems, computer vision, and AI can analyze an athlete's movements and identify potentially harmful patterns. Abnormal running mechanics, excessive workload, poor landing technique, or muscular imbalance may indicate an increased risk of injury. Wearable sensors can also help medical and performance teams monitor workload and recovery.
- *Officiating and Decision-making:* Technology has significantly changed sports officiating. Video replay systems, electronic sensors, computer vision, and automated tracking technologies can assist officials in making difficult decisions. Examples include goal-line technology in soccer, electronic line-calling systems in tennis, video review in basketball and football, and timing technologies in athletics and swimming. These systems can improve the accuracy of decisions and reduce some forms of human error.
- *Fan Engagement*: Emerging technologies are transforming the spectator experience. Mobile applications allow fans to receive live scores, statistics, highlights, player information, and personalized notifications. AI can help digital platforms recommend sports content according to individual interests. Virtual and augmented reality may provide more immersive experiences. Fans who cannot attend a sporting event physically

may increasingly be able to experience games through interactive digital environments.

- *Sports Broadcasting*: Sports broadcasting is one of three main sources of income for sports organizations. Emerging technologies have also revolutionized sports broadcasting. High-definition cameras, drones, automated camera systems, computer vision, AI, and advanced graphics can provide viewers with more detailed coverage. AI systems can assist broadcasters in identifying important moments, generating highlights, organizing video footage, and producing statistical graphics. For example, ESPN, an American broadcaster, implemented an AR application that helps viewers to visualize data collected during the match.
- *Talent Recruitment*: Sports organizations increasingly use technology to identify promising athletes. Traditional scouting depends heavily on human observation, but data analytics can complement scouting by comparing large numbers of performance indicators. AI systems can analyze statistics, video recordings, physical measurements, and other information to identify athletes who meet particular performance requirements.
- *Personalized Coaching:* Digital platforms and AI systems are making personalized coaching more accessible. Mobile applications can analyze workouts and recommend training activities according to an individual's goals and performance. For recreational athletes, these systems may function as digital training assistants by providing exercise instructions, progress reports, and motivational feedback. At elite levels, coaches can combine biometric, technical, tactical, and historical information to create highly individualized training programs.
- *Stadium Management*: The Internet of things is contributing to the development of smart stadiums. Connected sensors and digital systems can be used to manage lighting, energy consumption, security, parking, crowd movement, ticketing, and maintenance. Data can help stadium operators understand where crowds are forming and improve movement through entrances, concessions, and transportation areas.
- *Esports*: Emerging technologies have contributed to the rapid development of esports. Competitive gaming depends on advanced computers, high-speed networks, cloud infrastructure, streaming technologies, and sophisticated gaming platforms. Technologies such as VR and AR may further expand esports by creating new forms of immersive competition. Traditional sports organizations are also increasingly incorporating gaming, simulation, and digital fan experiences into their activities.
- *Sports Medicine:* Emerging technologies have important applications in sports medicine. Advanced imaging, biomechanical analysis, wearable sensors, AI, and rehabilitation technologies can help professionals evaluate injuries and monitor recovery. Computer-based analysis can combine different sources of information to support decisions concerning rehabilitation and return to activity.
- *Sports Management*: Emerging technologies are also transforming the business side of sports. AI and data analytics can assist organizations with ticket pricing, marketing, sponsorship analysis, merchandise planning, and customer engagement. Sports organizations can analyze fan behavior to understand which events, athletes, or products attract the greatest interest. Digital platforms also allow teams and athletes to communicate directly with global audiences, creating new commercial opportunities.

BENEFITS

Emerging technologies are providing significant benefits throughout the world of sports. They can improve training, enhance tactical decision-making, reduce certain injury risks, support rehabilitation, improve officiating, and create richer experiences for fans. Other benefits of emerging technologies in sports therefore include the following [1,12]:

- *Greater Accessibility*: Technology can make sports more accessible to people who face geographical or physical barriers. Digital broadcasting and streaming platforms allow people to follow sporting events from almost anywhere. Assistive technologies can also improve accessibility for people with disabilities. Technology can therefore contribute to the broader social goal of making sports more inclusive.
- *Customer Satisfaction*: The way we consume sports has changed. Young fans especially are not sitting down for scheduled broadcasts. They want matches streamed on demand, highlights available immediately, and the ability to watch on their phone, tablet, or whatever device they are holding. The best sports tech innovations are not impressive because they are cool. They are impressive because they solve real problems for

athletes, coaches, fans, and sports organizations. They meet customer satisfaction.

- *Increased Efficiency*: The benefits of emerging technologies extend beyond athletes and coaches. Sports organizations can use digital systems to improve administration, ticketing, scheduling, marketing, venue management, security, and communication. Artificial intelligence can automate repetitive administrative processes, while data analytics can help organizations understand audience behavior and business performance. These applications can reduce costs, improve efficiency, and allow organizations to provide better services to athletes and spectators.
- *Improved Athletic Performance:* One of the greatest benefits of emerging technologies in sports is their ability to improve athletic performance. Traditionally, coaches evaluated athletes mainly through observation, experience, and basic statistics. Modern technologies allow much more detailed analysis. Wearable sensors, GPS trackers, smart watches, and other monitoring devices can collect information about speed, distance, acceleration, movement, workload, and other aspects of performance. Coaches can use this information to identify strengths and weaknesses and develop training programs suited to individual athletes.
- *Personalized Training*: Emerging technologies make personalized training easier and more effective. Athletes differ in physical condition, skill level, recovery rate, playing position, and training needs. Therefore, the same training program may not produce the same results for everyone. Data collected from wearable technologies and performance-monitoring systems can help coaches develop individualized programs. Training intensity and workload can be adjusted according to an athlete's performance and recovery.
- *Injury Prevention*: Another important benefit is injury prevention. Sports injuries can negatively affect athletes, teams, and organizations. Emerging technologies allow coaches and sports professionals to monitor factors associated with physical stress and excessive workloads. Wearable sensors can track movement patterns and training loads. When collected over time, these data can help identify unusual changes that may indicate excessive fatigue or an increased risk of injury. Technology cannot eliminate injuries completely, but it can provide useful information for reducing preventable risks.
- *Better Rehabilitation*: Technology is also improving recovery and rehabilitation. After strenuous training or competition, athletes require sufficient recovery before returning to demanding physical activity. Monitoring technologies can provide information that helps athletes and their support teams evaluate readiness for additional training. When an athlete is injured, motion-analysis systems, wearable sensors, and rehabilitation technologies can help track progress. Instead of relying solely on subjective impressions, rehabilitation programs can incorporate measurable information about movement and functional performance.
- *Better Coaching:* Modern sports produce enormous amounts of data. Advanced analytics can transform these data into useful information for coaches and managers. Coaches can analyze individual and team performance, tactical patterns, opponent tendencies, and historical results. AI can assist by processing large datasets quickly and identifying relationships that may otherwise be overlooked. For example, a team may use analytics to determine which tactical formation has been most effective against a particular type of opponent. Coaches can combine such technological insights with professional experience to make better decisions about training, strategy, and competition.
- *Enhanced Fan Experience:* Emerging technologies are also transforming the experience of sports fans. Fans increasingly expect interactive and personalized experiences rather than simply watching a competition. Augmented reality can overlay statistics and other information on live sporting events. Virtual reality can provide immersive experiences that make viewers feel closer to the action. These technologies can strengthen the relationship between sports organizations and their audiences.
- *Improved Strategy*: Data analytics, AI, and computer vision provide teams with new methods for studying opponents. Video footage can be analyzed to identify patterns in movement, positioning, tactics, and decision-making. Coaches can use these insights to prepare strategies for upcoming competitions. Instead of manually reviewing hours of footage, automated systems can help identify relevant events and patterns more quickly. This can save time while providing deeper tactical insights.
- *New Economic Opportunities*: Emerging technologies are creating new business opportunities within the sports industry. Sports

analytics companies, wearable-device manufacturers, streaming services, gaming businesses, software developers, and technology startups are developing products and services specifically for sports. Digital platforms also create new opportunities for sponsorship, advertising, subscriptions, online merchandise, interactive broadcasting, and fan engagement. The combination of sports and technology has therefore created an expanding ecosystem of businesses and careers.

CHALLENGES

Although emerging technologies offer significant benefits, their adoption also creates important challenges. Challenges involving cost, privacy, cybersecurity, fairness, inequality, algorithmic bias, reliability, employment, ethics, and excessive dependence on technology must be carefully addressed. Other challenges of emerging technologies in sports therefore include the following [1,2,8]:

- *High Cost*: One major challenge is the high cost of acquiring and maintaining new technologies. High implementation costs are a major barrier to adopting sports technology. Advanced cameras, biometric sensors, AI systems, sophisticated training equipment, and data-analysis platforms can require substantial investment. Professional teams and wealthy sporting organizations may be able to afford these technologies, while schools, community organizations, developing countries, and smaller clubs may struggle to obtain them. This technological gap can create inequality because athletes with access to advanced tools may receive better training, injury monitoring, and performance analysis than competitors without similar resources. An effective approach to overcome this is to adopt new technologies incrementally and collaborate with outsourced software development companies to manage costs and scale solutions over time.
- *Data Privacy*: Another important challenge is data privacy. Modern sports technologies can collect enormous amounts of information about athletes, including heart rate, sleep patterns, movement, fatigue, body temperature, location, and other physiological measurements. Some systems may also collect medical and psychological information. Questions therefore arise concerning who owns the information, who is permitted to access it, how long it should be stored, and whether athletes can meaningfully control its use. Sensitive information could potentially affect contract negotiations, team selection, sponsorship opportunities, or an athlete's reputation if it is improperly disclosed.
- *Ethical Concerns*: There are also ethical concerns surrounding genetic, biomedical, and human-enhancement technologies. Advances in biotechnology may eventually make it increasingly possible to alter or enhance aspects of human performance. Such developments raise fundamental questions about the meaning of athletic achievement. Sport traditionally celebrates disciplined training, talent, perseverance, strategy, and teamwork. If technology substantially modifies human capabilities, society may have to reconsider where legitimate preparation ends and artificial enhancement begins.
- *Fairness:* A further challenge concerns fairness and competitive advantage. Technology can improve athletic performance through advanced equipment, clothing, footwear, prosthetics, training systems, and data analytics. However, sporting authorities must determine when technological assistance becomes an unfair advantage. If a particular piece of equipment substantially enhances performance, athletes who can afford or access it may gain an advantage unrelated to their natural ability, training, or effort. Governing bodies must continually establish rules that distinguish legitimate innovation from technology that threatens fair competition.
- *Accuracy*: Another challenge is the accuracy and reliability of technology. Although electronic officiating systems, video review, sensors, and AI can improve decision-making, technology is not infallible. Cameras can have limitations, sensors can malfunction, algorithms can produce incorrect conclusions, and communication systems can fail. Poor-quality data can also result in poor recommendations. If coaches or officials assume that computerized information is always correct, technological errors can have serious consequences. Human judgment therefore remains important even in highly technologically advanced sports.
- *Accessibility*: Emerging technologies additionally raise questions concerning accessibility and the digital divide. Technological innovation should ideally make sports more inclusive, but unequal access can have the opposite effect. Athletes in economically disadvantaged communities may lack high-speed internet, sophisticated equipment, advanced facilities, or expert technological support. If access to technology becomes

increasingly important for athletic development, existing social and economic inequalities may become more pronounced.

- *Overdependence on Technology*: There is also concern about overdependence on technology. Coaches once relied heavily on observation, experience, communication, and personal knowledge of athletes. While technology can strengthen these abilities, excessive reliance on numerical measurements may reduce appreciation for factors that are difficult to quantify. Motivation, courage, leadership, teamwork, determination, creativity, and emotional condition cannot always be completely represented by statistics. The best sporting decisions often require combining technological information with human experience and judgment.
- *Job Displacement*: Another challenge is the possibility of job displacement and changing professional roles. Automated cameras, AI analysis, robotic systems, and digital platforms can perform tasks that previously required human workers. Some roles in broadcasting, performance analysis, administration, security, and officiating may therefore change significantly. At the same time, new occupations will emerge in areas such as sports analytics, cybersecurity, AI management, digital media, and sports engineering. The challenge is to retrain workers so that technological development complements human expertise rather than simply eliminating employment opportunities.
- *Cybersecurity*: Closely related to privacy is the problem of cybersecurity. As sports organizations become increasingly dependent on connected technologies and cloud-based information systems, they may become targets for cyberattacks. Hackers could attempt to steal confidential information, interfere with organizational systems, obtain athletes' personal data, or disrupt sporting operations. Connected stadiums and Internet of things devices can also increase the number of possible points of attack. Sports organizations therefore need strong cybersecurity policies, secure networks, access controls, encryption, employee training, and effective procedures for responding to security incidents.
- *Regulation*: Emerging sports technologies can create legal and regulatory challenges. Questions may arise regarding responsibility when technology fails, ownership of athlete-generated data, intellectual property rights, discrimination caused by automated systems, and consent for biometric monitoring. Because professional sports frequently cross national borders, organizations may also encounter different privacy, technology, and data-protection laws in different countries. Effective governance will therefore require cooperation among sporting organizations, governments, technology companies, athletes, and legal experts.
- *Integration*: Sports organizations often rely on legacy software and established workflows that were not built to support modern digital solutions. Integrating new technologies into these environments can be complex and time-consuming. Without proper planning, teams may face data silos, duplicated processes, or inconsistent performance insights, which reduces the overall value of innovation.
- *Resistance to Change*: Technology adoption in sports is a cultural as well as technical challenge. Coaches, athletes, officials, and staff may resist tools that change established routines or decision-making. Overcoming this challenge requires clear communication, education, and pilot programs that demonstrate measurable value and build trust through practical results.
- *Female Athletes*: Historically, women were significantly underrepresented in sports science studies. However, product development, sports science, and athlete care are finally catching up to the unique needs of female athletes. Wearables are evolving to reflect female-specific metrics. A US-based startup (eir) develops a physiology-focused training platform to support female athletes through individualized, data-driven insights. It combines menstrual cycle tracking, physiological signal analysis, and wearable sensor data to generate real-time performance feedback.

FUTURE OF EMERGING TECHNOLOGIES IN SPORTS

The future of emerging technologies in sports will be characterized by greater personalization, automation, accuracy, connectivity, and data-driven decision-making. It will likely involve greater integration among technologies rather than the isolated use of individual systems. Artificial intelligence (AI) is likely to become one of the most influential technologies in the future of sports. AI systems can process enormous quantities of information and identify patterns that may be difficult for human beings to recognize. AI may analyze information obtained from wearable sensors, computer vision, smart equipment, and medical assessments simultaneously. Coaches and athletes will increasingly use AI to analyze performance, develop

strategies, evaluate opponents, and make training decisions.

Technology will continue to influence sports officiating. Video review, electronic line-calling systems, goal-line technology, and sensor-based systems have already demonstrated how technology can assist officials. Perhaps the greatest question surrounding the future of sports technology is how innovation can be embraced without diminishing the human qualities that make sports meaningful. People admire athletes not simply because of their statistics but because of their courage, discipline, perseverance, teamwork, creativity, and ability to perform under pressure. Technology should therefore serve human performance rather than replace it. The future of sports will therefore depend not simply on developing more powerful technologies but on using them responsibly. When innovation is balanced with ethics, fairness, athlete welfare, and the traditions of competition, emerging technologies can help create a sporting environment that is safer, more informed, more accessible, and more engaging while preserving the human character that gives sport its enduring value [1].

CONCLUSION

Technology has revolutionized sports, enhancing athlete performance and injury prevention through innovations like wearables, AI-based analytics, and sensors. Emerging technologies are transforming nearly every dimension of sports. As these technologies continue to develop, sports will become increasingly connected, data-driven, personalized, and interactive. However, technology should be regarded as a tool for enhancing human ability rather than simply replacing human participation. The greatest value of these technologies lies in their ability to provide better information and new capabilities to the people involved in sports. Coaches can make more informed decisions, athletes can understand their performance more precisely, officials can improve the accuracy of difficult decisions, and fans can enjoy more interactive experiences. The most successful applications will be those that combine technological innovation with the experience of athletes, coaches, officials, medical professionals, and sports administrators.

When applied responsibly, emerging technologies have the potential to make sports safer, fairer, more competitive, and more engaging for participants and spectators alike. The future of sports will therefore depend not simply on adopting more technology, but on using technology wisely to make sports safer, fairer, more engaging, and more accessible. Emerging technologies can make sports safer and more engaging, but the heart of sports will continue to be human achievement, competition, teamwork, discipline, and the desire to excel. Teams that leverage sports technology and athletic performance tools are not just staying competitive they are lapping the competition [12]. More information about emerging technologies in sports can be found in the books in [13-16].

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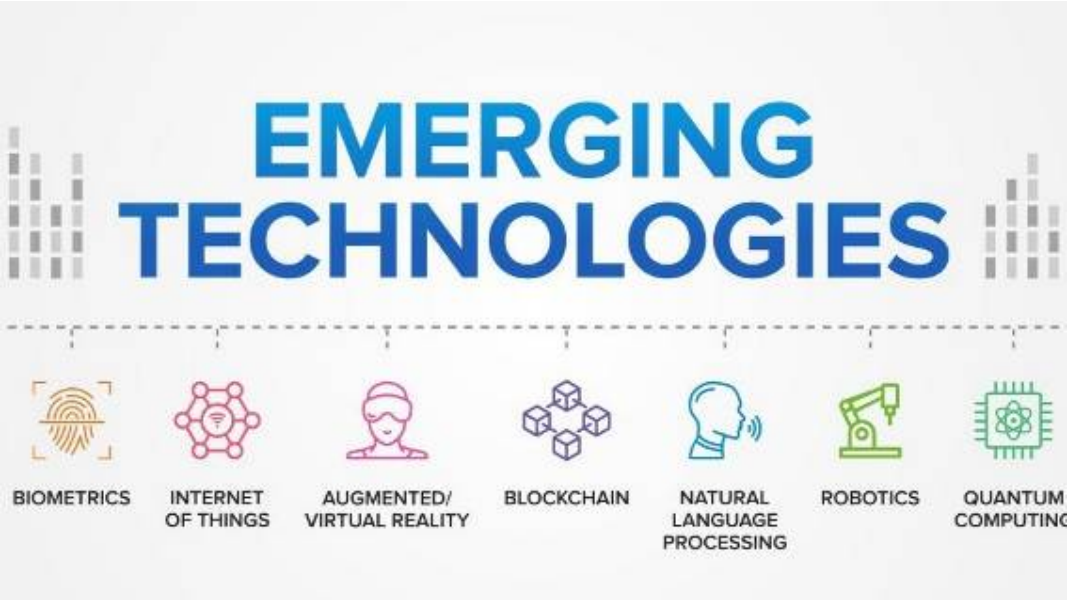


Figure 1 Some emerging technologies [5].



Figure 2 Robots playing basketball on a futuristic court [9].



Figure 3 Use of a drone in American football [10].

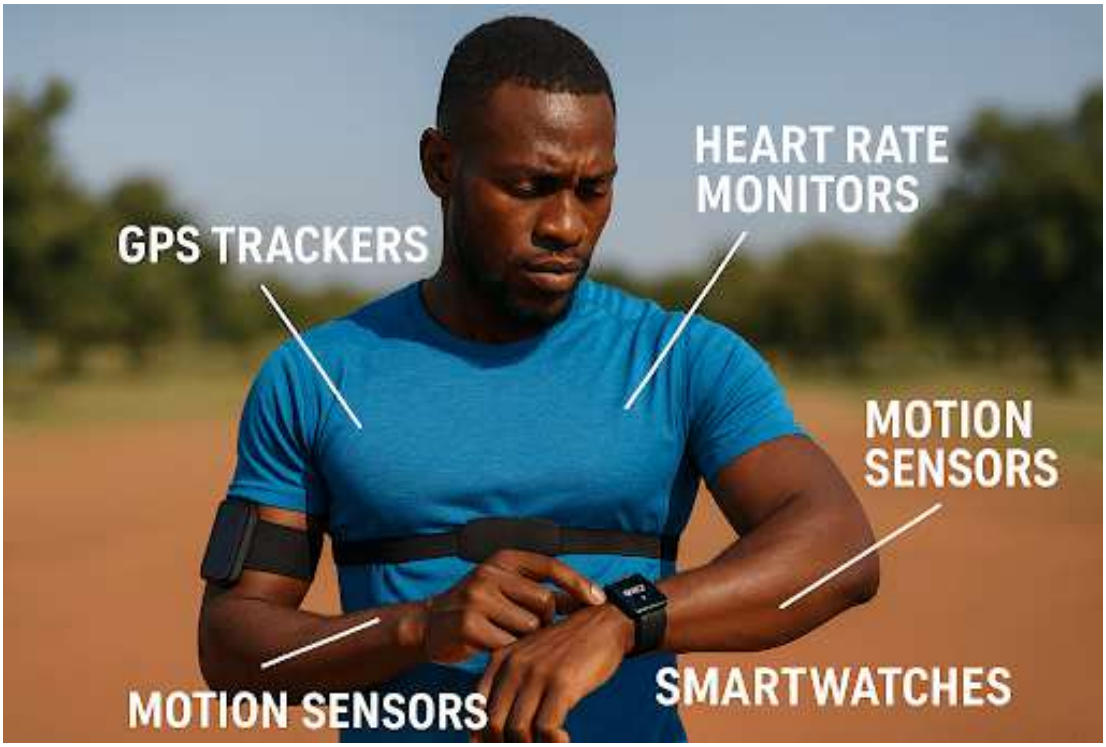


Figure 4 Wearable technologies on an athlete [11].