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Uses Of Artificial Intelligence In Personalizing Sports Training

Usos De La Inteligencia Artificial En La Personalización Del Entrenamiento Deportivo

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REVISTA TECNOLÓGICA
ciencia y educación
Edwards Deming

ISSN: 2600-5867

SUMMARY

This research addresses, from a global analytical approach, the transformative capacity of artificial intelligence (AI) in the personalization of physical training, including both its own basic technological principles, as well as its broad socio-sporting implications. To explore the topic ontoepistemically, a methodological strategy is constructed that pursues the definition and conceptualization of AI, the analysis of its influence on physical-sports practice, the description of its applications and the characterization of emerging technologies in this line; for this purpose, AI models applied to the following sports are reviewed in different websites: athletics, basketball, baseball, gymnastics, soccer, fitness, swimming and field tennis. The applications consulted show AI-based platforms that enable the creation of personalized training routines, adapted to the needs and personal training objectives of athletes, support for referee decisions and injury prevention, projecting a holistic and rigorous margin of a field in continuous development that warns of a serious risk between sports organizations with an abundance of resources and sports organizations with limited resources that do not have the means to acquire the latest technology.

Keywords: Sports, Artificial intelligence, Health, Technology.

Edited by: Tecnológico Superior Corporativo Edwards Deming

July - December Vol. 9 - 2 - 2025

https://revista-edwardsdeming.com/index.php/es

e-ISSN: 2576-0971

Received: March 31, 2025

Approved: May 3, 2025

Page 70-95

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Articles
Revista tecnológica ciencia y educación Edwards Deming
ISSN: 2600-5867

RESUMEN

En la presente investigación se aborda, desde un enfoque analítico global, la capacidad transformativa que presenta la inteligencia artificial (IA) en la personalización del entrenamiento físico, incluyendo tanto sus propios principios tecnológicos de base, como sus amplias implicaciones socio deportivas. Para explorar ontoepistémicamente el tema, se construye una estrategia metodológica que persigue la definición y conceptualización de la IA, el análisis de su influencia en la práctica físico-deportiva, la descripción de sus aplicaciones y la caracterización de las tecnologías emergentes en esta línea; para ello, se revisan, en diversos sitios web, modelos de IA aplicadas a los deportes: atletismo, baloncesto, béisbol, gimnasia, fútbol, fitness, natación y tenis de campo. Las aplicaciones consultadas evidencian plataformas basadas en IA que posibilitan la creación de rutinas de entrenamiento personalizadas, adaptadas a las necesidades y al objetivo de entrenamiento personal de los atletas, apoyo a las decisiones arbitrales y prevención de lesiones, proyectándose un margen holístico y riguroso de un campo en continuo desarrollo que advierte un grave riesgo entre las organizaciones deportivas con una abundancia de recursos y las organizaciones deportivas con recursos limitados que no disponen para adquirir tecnología de última generación.

Palabras Clave: Deporte, Inteligencia artificial, Salud, Tecnología.

Articles
Revista tecnológica ciencia y educación Edwards Deming
ISSN: 2600-5867

INTRODUCTION

The research explores the implementation and benefits of AI in the personalization of sports training. From the methodological perspective, a qualitative and documentary approach was adopted by conducting a comprehensive review of scientific and technical literature published between 2015 and 2025. The search strategy focused on keywords such as "AI", "sport", "technologies", "physical activity" and "health". The critical analysis of the selected texts allowed categorizing the different technologies and methodologies, synthesis of comparison results on advantages and limitations in the optimization of physical activity. The theoretical framework reflected how AI uses a set of techniques that simulate the cognitive processes developed by people in order to carry out the automation of functions and thus improve the efficiency of the various sports fields in which it is used.

This scenario shows that AI can process significant volumes of data that are collected through sensors and wearable devices, thus personalizing workouts and preventing injuries. The research contemplates the use of AI applications in athletics, basketball, baseball, fitness, soccer, gymnastics, swimming and table tennis, indicating that in these sports AI is used in sports training to improve performance by analyzing biometric data and tracking athletes in 3D. In refereeing, semi-automated systems improve the efficiency of decision making, while in sports health, AI enables accurate diagnosis and injury prevention through analysis of training patterns. In conclusion, AI redefines the practice to which athletes are exposed, improves performances, prevents injuries and promotes healthy lifestyles, modifying the sports practice and the experience of the professional athlete or practitioner.

MATERIALS AND METHODS

The research has an exploratory and descriptive character, as well as a qualitative-documental approach, on the analysis of the benefits and implementation of artificial intelligence in personalized sports training. For this purpose, a systematic review of scientific and technical literature was conducted, which collected from specialized websites, to academic articles and technical reports, published between 2015 and 2025, to ensure the timeliness and relevance of the information compiled.

As a search strategy for the selection, the following keywords were used: artificial intelligence, sport, technology, physical activity and health, both in Spanish and English, and with the support of Boolean AND/OR operators.

For the first search, a preliminary filter was carried out based on the chosen titles, selecting only those web pages whose information was relevant to the subject matter. Likewise, only documents on the specific application of artificial intelligence in sport and physical activity were selected, paying special attention to studies on the

personalization of training, biometric data analysis, injury prevention and improvement of sports performance. In this way, sources without scientific support or those that were not available in full text were eliminated.

Next, we moved from the critical reading and precision of the chosen texts to the categorization of the different technologies, methodologies and applications found. Thus, based on the analysis, the results were synthesized in order to compare advantages, limitations and success cases in the use of artificial intelligence for the optimization of sports training. Finally, these findings were mixed in an informative structure that combined theoretical foundations with practical examples, in order to support the conclusions of the study.

Artificial intelligence in sport and physical activity

Artificial intelligence (AI) is commonly defined as a branch of computer science involved in the development of systems or machines that are capable of performing tasks that normally require human intelligence; these tasks include learning, decision making, pattern recognition, language understanding and complex problem solving. Artificial intelligence is based on algorithms, neural networks, systems theory, *machine learning* and, more recently and especially, *deep learning*, which allows machines to refine their performance based on experience and data.

From an academic point of view, AI can be defined as the set of techniques and methods that allow computers to simulate human cognitive processes and are aimed at automating functions that optimize efficiency, precision and speed in various fields of knowledge and industry. Its development has modified numerous sectors, from medicine to engineering, and is having a clear influence in the field of physical activity and sports.

The relationship between artificial intelligence and physical activity is increasingly close and multidimensional. AI in sport is, as Sanabria et al (2024) point out, the tool that corrects errors, contributes to decision making, gives rise to new strategies in sports training and competition, helps prevent sports injuries, helps study opponents and gives rise to top quality sports situations; this is so because, in the first place, AI is present in the analysis and improvement of sports performance from the processing of large volumes of data obtained from sensors, cameras and electronic and wireless devices. The results of these data allow the analysis of biomechanical, physiological and tactical aspects of athletes, favoring the design of training and injury prevention. For example, AI, based on algorithms, can recognize movement patterns that predispose to injury or can suggest adjustments to a technique to optimize energy efficiency.

In addition, AI is used for the development of applications and platforms that encourage sports practice in the non-athletic population, and does so, for example, with virtual coaches that are intelligent, "personalized" training programs or gamification systems that are used to obtain a practice that generates motivation to

have healthy habits by adapting to their needs and their individual progress. In competition, AI is likewise used for the tactical analysis of opponents, the simulation of match status or the evaluation of the performance of teams and athletes, becoming a tactical advantage that can turn a high-level competition in the direction of a particular team and athlete.

In short, Artificial Intelligence has become a tool that redefines the way of understanding and practicing physical activity and sport, and that can give rise to new possibilities to optimize performance, prevent injuries and encourage the practice of healthy lifestyles; but the continuous integration of it in the field of physical activity and sports promises not only to continue to evolve, but also to give rise to a new style of experience between the professional athlete and the athlete who seeks to improve his personal well-being, based on physical activity.

Uses of artificial intelligence in physical activity and sports.

The applications of AI in sports are varied. Technological progress is growing rapidly and incessantly, constantly increasing the production of information that is stored in large databases that give rise to sets of information that exceed the cognitive capacity of human beings. The practice of physical activity and sports as an enhancer of the human being generates a high production of information on a daily basis. In this regard, Carrio (2024), points out that AI collaborates in this field in the following three areas or sectors:

In training and sports preparation

When analyzing the topic of AI in sports, it should be taken into consideration that improving sports performance and individual skills is one of the main purposes of training. There are different AI applications that can be used online, such as the 3D Athlete Tracking (3DAT) proposed by Intel, which offers different metrics to help high-performance athletes improve their performance by analyzing factors such as speed or body position. I believe that this technology will become increasingly important in different sports, since, on the one hand, it offers objective evaluations without human bias, and, on the other hand, it allows offering personalized training plans. Undoubtedly, it thus becomes an invaluable tool for athletes of all levels who wish to achieve excellence in the disciplines they are involved in.

In arbitration

In the field of sports arbitration and jurisdiction, Carrio (2024) highlights the relevance of the refereeing activity being carried out with the help of artificial intelligence. This same author expresses that in championships such as the FIFA World Cup 2022, the implementation of the semi-automated technology system (SOAT), the use of data analysis and artificial intelligence algorithms to assist in making decisions with better accuracy in offside situations, with respect to traditional video arbitration systems

(VAR), is subordinated. This new technology not only makes decisions faster, but also tries to correct as much as possible the human error that has plagued refereeing.

However, as automated competitions increase, a critical analysis of the appropriateness and integrity of sports governance is prompted. Stakeholders must address the question of the appropriateness of machine versus human decision making and whether changes in refereeing may eventually alter the natural competitive nature of the various disciplines. While AI may offer a number of important improvements in the accuracy of refereeing practice, its application should be approached with great care to ensure that its principles are matched and respected in practice.

In health

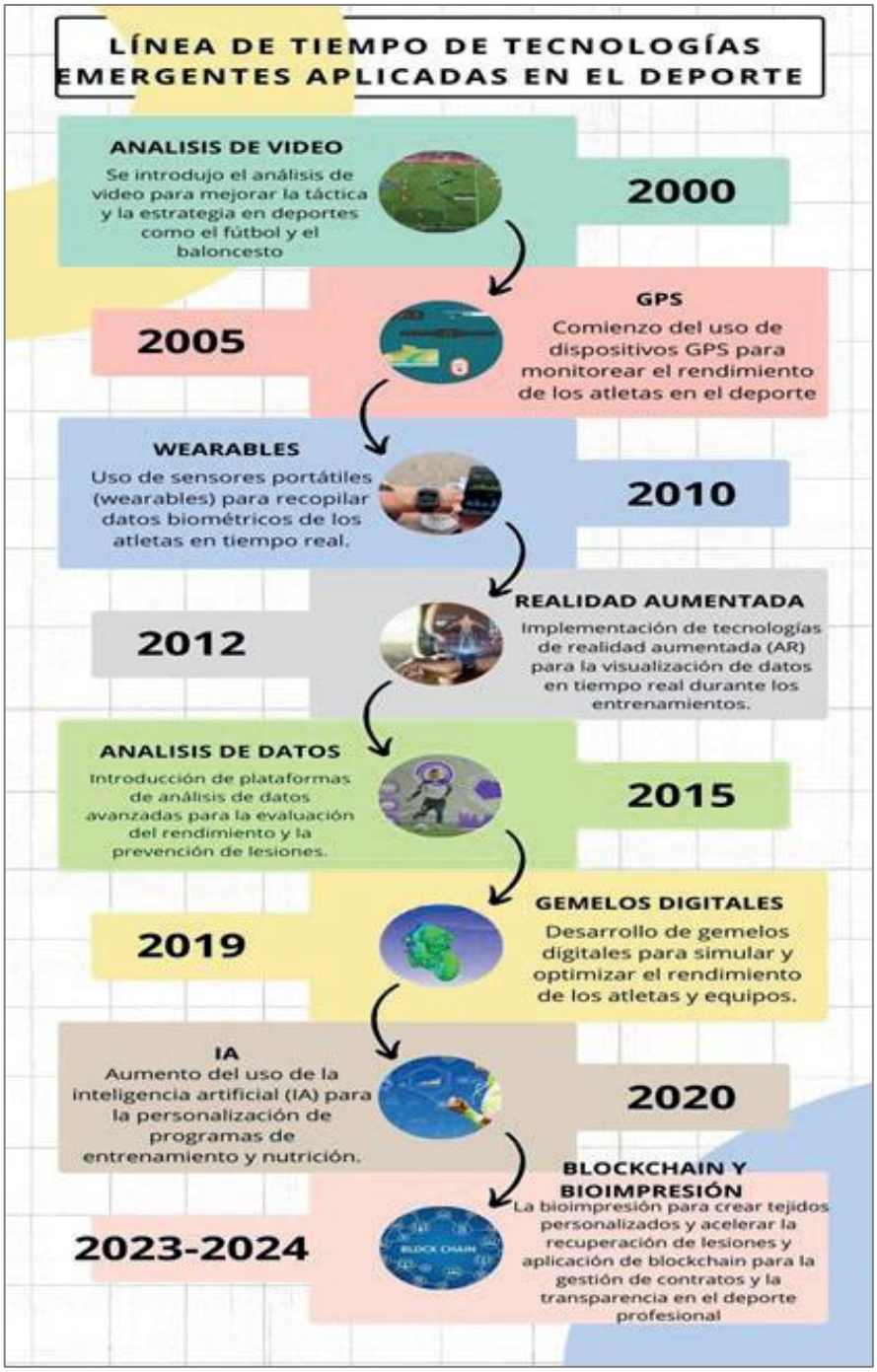
The intersection of artificial intelligence and athlete health is a rapidly evolving discipline that brings to bear both the potential advantages, as well as the limitations that are present in professional sport. While it is clear that physical exercise is a health benefit, it is recognized that high-performance athletes are often faced with high-demanding subjections that are risky to health, particularly injury. Artificial intelligence technologies have increasingly become a fundamental tool in this field because they provide accurate information about the athlete's health while delivering timely information of value for performance tuning that, in turn, protects the athlete's health.

Machine learning algorithms can perform a scan of extensive training data to identify patterns that indicate when an athlete should experience injury relative to their trajectory. This prompts coaches to adjust training regimens, employing pre-exercise performance analysis in order to detect or prevent injury to the athlete or to supplement the diagnosis in the event that injury cannot be avoided, with artificial intelligence being used as an imaging technology technique to facilitate diagnosis, for example.

Emerging technologies that are revolutionizing sports

Innovative technologies linked to artificial intelligence are generating in the field of sports practice a radical change insofar as they transform all training and competition methodologies, but also the way in which sports data are managed and processed and their analysis. Through complex algorithms and intelligent systems, athletic performance can be improved, injuries can be prevented and/or a personalized strategy can be carried out simultaneously, which in turn represents a major change in the usual functioning of a sport. This convergence between technology and sports gives rise to new ways of interacting with each other and with devices, which represents a turning point in the history of current sports practices.

Figure 1. Chronology of emerging technologies in sport.



Source: Caballero & Nuñez (2022)

Articles
Revista tecnológica ciencia y educación Edwards Deming
ISSN: 2600-5867

Among the emerging trends identified by Caballero & Nuñez (2022), the following represent some of the most relevant milestones in the combination of artificial intelligence and sport. On the one hand, the analysis of massive data (Big Data) makes it possible to evaluate the performance of athletes with levels of precision never seen before, which allows decisions to be made. On the other hand, personalized training systems based on machine learning adapt to the individual characteristics of each athlete in their routines and strategies. Likewise, the use of intelligent sensors and wearable devices provides real-time information on certain physiological and biomechanical parameters that are related to improving injury prevention.

Finally, augmented reality and virtual simulation present new ways of preparation and experience for athletes and fans with the inclusion of artificial intelligence in the creation of immersive and highly interactive scenarios.

The combination of these trends will redefine the future of sport from multiple perspectives. Figure 1 presents the timeline of emerging technologies applicable to physical activity and sports; there it can be seen, according to Caballero & Nuñez (2022), from its birth, with video analysis in 2000, to the inclusion of advances in blockchain in 2024.

Cases of artificial intelligence technologies and models applied to physical activity and sports.

Athletics

Artificial intelligence (AI) has made a strong entry into the world of athletics, transforming the way in which athletes' performance is measured and analyzed. One of the most important applications is that which makes use of inertial measurement units (IMUs), which consist of sensors placed on the athlete's body that capture real-time data on acceleration, angular velocity and orientation. This data is further processed by AI-based algorithms that allow for a highly accurate and rigorous assessment of the athlete's biomechanics, exposing technical aspects that can be improved to maximize performance in disciplines such as sprinting, race walking, jumping and throwing. Perceptible feedback through visual, auditory or kinesthetic signals constitutes a mechanism for almost instantaneous adjustment of technique and, in this sense, represents a step forward, without a doubt, in the process of personalization of training.

In addition, AI can be used as a component of GPS tracking systems and physiological measurement systems for endurance sports, such as long-distance running. Deport-Tec (2024) and KGW News (2021) agree that one of the automation systems that Word Atletics is using is the 3D Athletics Tracking System, a system that continuously reports on parameters such as incorporating postural angles, heart rate, speed, distance covered, which are then processed by intelligent models to adjust the load and duration of training, thus preventing overtraining and making the information a

method of minimizing the risk of injury by keeping athletes within safe exertion zones. At the same time, fatigue can be anticipated and, based on this foresight, the timing of a recovery period can be indicated, thus contributing to more efficient long-term performance management.

At the tactical level, AI aids in talent detection and proper training scheduling. From large volumes of historical and current data, AI can identify patterns of results and athletic potential, helping coaches and federations to make decisions. In Spain, this technology has been implemented in projects in different athletics disciplines, proving that artificial intelligence can transform sport through the combined use of intelligent sensors, information processing and real-time feedback. AI will not only improve individual performance, but will also allow the general evolution of athletics to reach other types of technological practices.

Basketball

Artificial intelligence (AI) has changed the ways basketball is played by integrating complex systems for analyzing player and team performance. One of the most notable applications has been the real-time tracking of player movements with the use of cameras and sensors that capture precise data on the position, speed, and on-court movements of ball-handlers. This information is converted into a data set that is processed by AI algorithms and allows coaches and analysts a more detailed and comprehensive picture with which they can make more accurate tactical decisions, stabilize lineups and make tactical adjustments during a match. According to the website Noeliagorod (2023), companies such as Second Spectrum have developed technologies that allow them to track every single action taken on the pitch, thus facilitating an understanding of the game that was not possible before.

In addition, we can establish that AI is also used for the training of technical aspects of players, whether mechanical or not. Tools such as ShotTracker analyze, by means of sensors on the ball, on the players or another form of sensor, the shape of a shot, the accuracy of a shot, shot selection, etc., generating immediate feedback that serves to correct and perfect the mechanics of the shot. Figure 2 shows the "visible" behavior of this platform, which can be expanded with the parallel metrics of the teams or player being worked with. This form of analysis, in combination with AI for the operation of predictive models, increases the ability to anticipate the performance that can achieve as the training of players progresses and the design of efficient training to enhance strengths and minimize weaknesses.

Articles
Revista tecnológica ciencia y educación Edwards Deming
ISSN: 2600-5867

Figure 2. Example of ShotTracker firing technology

Source: Noeliagorod (2023)

The website StatsPerform (2025), with more than 40 years of collecting and archiving sports data, also applies artificial intelligence to detect opponents' patterns of play, developing game plans and tactics that exploit their weaknesses and nullify their strengths.

On the other hand, AI also accompanies the integral management of the player and the sports career. Applications such as QB-BCA.AI are intelligent assistants that monitor the evolution of the athlete from the beginning, recommending exercises, habits and strategies that enhance performance and prevent injuries. At the same time, computer vision technologies, such as Ultralytics YOLO11, enable real-time analysis of matches in which infractions, offsides or fouls can be identified, thus favoring fairer and more effective refereeing. The combination of these advances means transforming the game of basketball not only on the court, but also making it much more enriching for spectators, as well as improving decision making in the different instances of professional basketball.

Nor can we ignore progress in the field of robotics. Lázaro (2024) points out, in the digital portal Inspenet, how a robot produced by Toyota, named CUE, has managed to set a Guinness record by performing the farthest basketball throw made by a humanoid robot, nothing more and nothing less than at a distance of 24.55 meters. The feat was accomplished in September 2024 in Nagakute, Japan. This is a remarkable breakthrough in robot mechanics when it comes to being able to execute precise and technical movements in highly demanding sports. CUE makes use of artificial intelligence and makes real-time adjustments to its posture, strength and arm position, learning with each throw. Toyota's intention is for this robot to make more

complex movements in the future, such as running or feinting, getting closer and closer to human movements. This breakthrough not only demonstrates that machines can replicate complex, high-precision movements, but also opens the door to new forms of training and sports analysis.

Baseball

The irruption of artificial intelligence (AI) on the baseball field is bringing about a sincere and notorious transformation that reveals, on the one hand, better decision making by umpires, while, on the other hand, it favors the work done by players. A clear example of this transformation is the Automated Ball and Strike System (ABS). This system was introduced in development leagues such as the Atlantic League and the Pioneer League and was subsequently tested in the 2023 and 2025 Spring Trainings. As explained in Nestoraltuve.com (2025), ABS makes use of a high-speed camera system and complex computer vision algorithms; this technology is capable of tracking the path of all pitches with such accuracy that it can easily determine whether it is a ball or a strike. The implementation of its hybrid version, which gives teams the right to request immediate reviews of unclear plays, has proven to be effective in this regard and has led to a reduction in on-field disputes, increasing umpiring accuracy from 88% to 90%. This technological innovation is so important that Major League Baseball (MLB) is considering its full implementation for the 2026 regular season, a move that will undoubtedly remain a key episode in the modernization of this sport with a long and deep tradition.

However, the projection that AI captures in baseball is not limited to umpiring, it has also asserted itself as a basic tool that accompanies predictive analytics and the formulation of game strategies. Technological platforms are available that have the function of managing a large amount of data that can range from those we have in the historical database to those we receive in real time (speed in the throw, ball spin, location of a player, etc.), with the purpose of making predictive models that help us to improve elements of the game such as adjusting the position of the defensive alignment, the choice of the pitch that the pitcher will execute, the execution of the offensive tactic that we are going to develop, etc. These types of systems, as Toolify.ai (2024) expresses, allow the technical staff to anticipate the opponent's game patterns and, consequently, to modify their planning, using probability calculations to increase the possibility of achieving a good outcome of the game. At the same time, immersive simulation tools using virtual reality technology have the added advantage of being able to reproduce complex game scenarios and thus provide deeper and safer cognitive training for players.

On the other hand, health and injury prevention in athletes also benefit considerably from technology. Wearable devices or biometric sensors that are discreetly incorporated into players' sports equipment allow uninterrupted monitoring of the most relevant variables: accumulated muscle fatigue, total physical workload, etc.,

which have a direct impact on the probability of injury. AI is in charge of analyzing this constant stream of data, which makes it possible to predict the risk of injury earlier.

The anticipated analytical capacity to be acquired translates practically into the possibility of fine-tuning and fine-tuning training routines, even including tailor-made recovery programs for each athlete. Moreover, such functionality not only predicts that players' careers can be extended over time, but that their performance can also be improved by incorporating a balance between required effort and recovery-oriented rest; the Dodgers and the Yankees, for example, are some elite teams that are already making active use of these technologies in their day-to-day work, combining very specific physiological data with machine learning procedures to support their conclusions regarding strategic management and training decisions.

Of course, the arrival of AI in a sport with such a deep historical significance as baseball has logically reopened a controversy between the defense of the traditional and the innovative proposals in search of a new model of sport. There are some sectors more anchored to a purist vision that consider that the elevation of automation could to some extent lead to a loss of the very human essence so characteristic of baseball. They attribute to elements such as the subjectivity of the umpires' decisions or the unpredictability of the games themselves, aspects that were historically factors that explain baseball's idiosyncratic appeal. But MLB seems to have opted for a transition that seeks coexistence between technology and sufficient human intervention, understanding the delicate balance that has to exist between improved accuracy and deeply rooted traditions. This hybrid model could be seen as a first step towards a sport that is perceived to be fairer and more asymmetrical, but without losing sight of the condition of maintaining a fan base that is very friendly to the more classic aspects of baseball. Well, the intensity of the strategic confluence that exists between AI, Big Data and emerging technologies is undoubtedly taking baseball into a new era, an era in which innovation becomes a fact of life within the field that pertains to sports. To conclude, the question remains: will baseball preserve its soul through algorithms and predictive metrics?

Soccer

Historical situations of strong and enduring controversy, such as Diego Maradona's mythical goal known as the "hand of God", decisive for Argentina to advance to the quarterfinals of the 1986 World Cup in Mexico, or the disputed "ghost goal" attributed to Geoff Hurst, which ended up favoring England in the final of the 1966 World Cup, have led to significant technological investment in the sport, the one that ended up going in England's favor in the 1966 World Cup final, have led to a significant technological investment in the sport, marking the development and evolution of a soccer that today is notably different from the one practiced just a few decades ago. The demand for greater objectivity in refereeing decisions was a fact observed a

posteriori, after those episodes, which served as a starting point for the technological process we are currently experiencing.

In the context of today's soccer, the implementation of advanced technologies has drastically changed the on-field experience and the strategic management of the game. According to the article on the Ndmarketingdigital (2025) website, artificial intelligence, above all, is the driving force behind this revolution. AI exerts its influence on multiple fronts: from customizing training plans and improving individual and team practice, to collecting and analyzing data to prevent injuries, to influencing advertising, the way matches are broadcast or even optimizing sports infrastructures. Likewise, AI is used to better evaluate players' skills and create performance reports, also to facilitate the detection of other talents and predictions about the possible outcome of matches. There is no denying that all these reforms are radically transforming the way soccer is played, the way athletes are prepared and the way refereeing is managed in the most followed sport in the world.

In the refereeing field, one of the systems whose implementation has given more visibility and controversy has been the VAR (Video Assistant Referee or video assistant referee) as we currently understand it. A system that is understood as a support for the referee himself on the field of play, where conflicting or dubious actions are reviewed with various shots and instant replays. It has proven to be effective in correcting human errors of great magnitude, helping to make decisions fairer and promoting transparency in the context of matches. The use of VAR has played a fundamental role in ensuring that the rules of the game are applied from as many objective facts as possible. However, as is often the case with innovations of such caliber, it has also brought with it a debate about its influence on the fluidity and dynamism that characterize traditional soccer.

On the other hand, and beyond the systems designed to improve refereeing, there is an innovation to take into account: the arrival of "smart" balls. Equipped with high-frequency sensors, these balls are expected to become a standard in future top-level international events. They feature sensory and capture technology aimed at retaining and communicating incredibly accurate, real-time data on their trajectory, speed and exact position. The information generated is quickly sent to referee support systems (for example, VAR), greatly increasing accuracy in cases where ball placement is a determining factor: think of offside or checking whether or not the ball has crossed the goal line. The aerodynamic and technological design of these balls increases performance, allowing for better stability and greater consistency of play.

Beyond refereeing, modern soccer has incorporated various technological systems that specialize in a series of processes that are more dedicated to the analysis and comprehensive review of players' physical and tactical performance. Electronic performance tracking devices (EPTS) and different motion sensors allow the collection of a lot of detailed information: from total distance and maximum speed, to

acceleration and other relevant physical parameters of both training exercises and official matches; these data are subjected to an analysis process with computer tools that provide coaches and physical trainers with key information to customize their training plans, fine-tune their tactical strategies and prevent, in the sense of properly managing the workload of soccer players and, therefore, decrease the risk of injuries. Artificial intelligence is also actively used to analyze these large volumes of data and provide tactical analysis with predictions about future performance, complex simulation of scenarios that require extensive analytical work to individually use the strengths in the process of adapting individualized training and the specific weaknesses of each footballer. For their part, immersive technologies, such as virtual reality and augmented reality, are booming as tools to simulate real game situations, working on improving the decision-making capacity under the demands of competition, thus increasing the preparation of soccer players in the digital era.

Artistic Gymnastics

Artistic gymnastics is a sport in which the evaluation of performance depends, fundamentally, on the criteria of a group of referees. Indeed, it is these professionals who evaluate the difficulty and quality of each exercise, a circumstance that has historically given rise to numerous controversies and complaints from gymnasts who consider that the score is disproportionate to the effort made. For this reason, the International Gymnastics Federation (FIG) has sought a solution that aims to increase the reliability and transparency of scoring in artistic gymnastics. The FIG, together with Fujitsu Limited, presented in 2019 an innovative system based on artificial intelligence technology. This technological innovation uses highly sophisticated 3D detection systems to capture, in a very precise way, the gymnasts' execution and obtain a comprehensive analysis of it. This method is called JUDGING SUPPORT SYSTEM (abbreviated to JSS) and is based on 3D sensors coupled to cameras that continuously record the performance and generate and project in parallel a three-dimensional graphic representation of the gymnast performing the exercise in question, as shown in Figure 3. The artificial intelligence of JSS can recognize the body posture, the relative position of the apparatus used and the type of movement performed, but it can also identify very reliably the technical element that is being executed.

Figure 3. *Image of Fujitsu's support system using 3D sensing technology for gymnastics evaluation*

Source: Fujitsu Limited (2019).

The JSS is able to offer considerable benefits to the sport. Mainly, it makes the function of a fundamental tool to support the judges, since the system calculates in an objective way the difficulty value of the elements executed by the athletes, to work as an excellent pillar that has the function of reducing the risk of human error and, therefore, of erring in the final scores and, in this way, narrowing the disputes around the final sketch, but always without giving up the much needed function and judgment offered by human judges.

In addition, the system generates an extremely exhaustive numerical analysis with data that allows to know, with accuracy, the body angles performed in the turns or specific acrobatic elements, which contributes to a more objective and, moreover, quantifiable assessment of the performance. It must be accepted that the recognition capacity is considerable; there is a database that already identifies more than 800 elements in men's artistic gymnastics and more than 500 in women's artistic gymnastics. On the other hand, and no less important, is the training assistance tool, which has become a fundamental pillar that both gymnasts and their coaches can use as a JSS to rehearse the construction of new elements, improve technique by correcting the errors detected numerically and, ultimately, improve technical performance for competition.

Once tested on selected apparatus at the 2019 World Championships, this new system was formally implemented and used at the Paris 2024 Olympic Games. The International Gymnastics Federation considers the JSS as one of the most representative technical developments introduced in the sport in the last couple of decades and, also, believes that it will have a positive impact on both the fairness of refereeing and the overall improvement of the quality of competitions and the training process. FIG President Morinari Watanabe has publicly highlighted the importance of this technology, pointing out the fundamental reasons behind its development and its potential to shape the future of evaluation in artistic gymnastics, seeking that delicate balance between technological precision and the inherent artistry of the performances, this is what he said:

The people we should always keep in mind are the gymnasts. They dedicate their youth to this sport, which gives them dreams and sees them thrive. We cannot accept that all those years of hard work and all those dreams can be destroyed by a single error in judgment. Scoring controversies must be a thing of the past, and the technology that Fujitsu has been developing will reinforce confidence in judging.(Ubergism, 2019)

In line with the perspectives expressed by FIG President Morinari Watanabe regarding the need to strengthen referee judgment support systems through technology, a recent example that highlights the inherent complexity of scoring in artistic gymnastics is the controversial definition of the medals in the women's floor exercise final at the Paris 2024 Olympic Games. In that competition, Brazil's Rebeca Andrade won the gold medal, followed by the United States' Simone Biles, with the silver medal. Controversy arose over the third position, initially awarded to American Jordan Chiles, while Romanian Ana Barbosu was placed fourth.

The controversy escalated when, after a review by the High Court of Judges and Referees, an error was identified in Jordan Chiles' score. This error caused the initial decision to be suspended, awarding the bronze medal to Ana Barbosu eleven days after the competition. This event sparked a great debate on the legitimacy of the appeals process and the significant emotional cost that these situations produce to the athletes involved. Moments like this can clearly illustrate how, despite the experience and greater professionalism of the judges, human error can appear in relevant parts and how technology could intervene as a possible solution.

The Judging Support System (JSS), in this sense, is an innovative system, which shows the path of artificial intelligence as a support for the field of sports disciplines as highly subjective as Gymnastics, because it favors objectivity, transparency and, thus, accuracy in the evaluation of performance. Events such as Paris 2024 clearly show the convenience of having tools for the verification of the starting marks of gymnastic compositions, this being a clear precedent that could lay the groundwork for the implementation of similar technological support systems in other sports that rely on human assessment evaluations.

Swimming

One of the most striking applications of artificial intelligence (AI) in swimming are devices that integrate sensors in the aquatic environment together with underwater cameras, which make it possible to obtain highly nuanced information containing details of the swimmers' technique or movement pattern. This information is then processed through AI algorithms that contain procedures suitable for the analysis of essential biomechanical aspects, such as the position adopted by the body in the water, the frequency and good execution of the strokes or the optimization of each of

Articles
Revista tecnológica ciencia y educación Edwards Deming
ISSN: 2600-5867

the moments of the swimming cycle. This detailed technical information is of great value for coaches and athletes, since it facilitates the correct identification of the susceptible areas to improve technique and maximize performance in this sport (Turbo Swim, 2024).

In addition, artificial intelligence has become a fundamental component of the platforms of the physical control systems, sensorization and study of the training cycles that operate in athletes who perform their training or competition sessions. These systems are responsible for capturing data in real time: heart rate information, blood oxygen level saturation or muscle fatigue that is accumulated by athletes who perform continuous and repeated very intense training sessions. With the help of predictive models, these systems make it possible to anticipate with maximum precision the risk of overtraining or predisposition to injury, and enable physical trainers and coaches to program the workload to promote recovery processes and thus long-term performance.

A tangible example of these resources are *smart glasses*, some of which even integrate augmented reality technology. A paradigmatic model is that of the SwimAR brand, seen on the website Wwwhatsnew (2018) (see Figure 4), smart glasses that are able to collect data on swimming experience, to propitiate directionality indications useful in open water and to display values of heart rate that allow to control the cardiovascular training zone through this physiological indicator that specifies the intensity of training.

Figure1 . Smart swimming lenses.

Source: Computer Today (2023)

The ability to adapt exercise plans in a dynamically tailored way based on the physiological response and progress of each swimmer is undoubtedly a breakthrough in improving injury prevention and sustained competitive performance training. And there are also specific tools that function as data aggregation centers that obtain data from different smart devices and generate personalized training routines that are dynamically updated with the goals and improvement of each swimmer, thus optimizing the quality of training and risk reduction.

On the other hand, artificial intelligence is also increasingly present in the action of tactically analyzing swimming competitions, thus informing from the use of technologies such as computer vision or machine learning so that information on different metrics of each event can be well controlled and recorded. While, for example, from the Nagi Smartpool application, as indicated by CIDE (2025), it is possible to monitor, among other parameters: the swimming speed, the distance swum and the remaining distance, the count of the lengths that are being completed, sending all these data in real time to electronic devices.

These innovations make it possible to have an "intelligent" aquatic environment through the use of sensors that, together with intelligent devices, configure an ideal environment to enhance training, ensure conditions and improve the performance of swimmers. This undoubtedly gives rise to a revolution towards the mutation of sport management models and towards technical improvement in swimming; after all, the ability to apply artificial intelligence, in a recurrent way, is forcing aquatic sport to change towards a sport that is more science-assisted, more efficient in its processes and more personalized in the development of the swimmers.

Field tennis

The so-called artificial intelligence (AI) is taking the field tennis to the current transformations derived from the adoption of advanced technologies that are associated with a comprehensive analysis in real time of the tennis players. One of the most relevant applications of artificial intelligence in the practice of tennis is the existence of some algorithms that manage to process large amounts of data that are recorded by different sensors and cameras installed strategically. This information is essential to keep track of the stroke, the position of the player on the court and also the trajectory of the ball during training and competitions.

These systems, therefore, are not only able to identify highly complex patterns of play, but also establish highly personalized strategic recommendations capable of enabling tennis players to anticipate their opponents' shot sequencing while, in parallel, also optimizing the execution of their own shot sequencing, which makes AI also act directly in contributing to the planning and execution of a more efficient training that

facilitates much more the way in which tennis players can make decisions on the court.

Meanwhile, smart rackets have also been one of the technologies that have been gaining relevance in the field of tennis training. These work from the implementation of sensors inside the racquet that can collect accurate information on aspects such as the type of stroke made, the force of the blow on the ball or the point of contact itself. In addition, these devices are often connected to mobile applications so that both players and coaches can help perform a more comprehensive technical analysis off the court that warns about technical aspects that need to be reviewed to help identify where they require more attention to perfect the techniques of the game. The growing acceptance by sports authorities of these tools has facilitated their integration into professional training activities and they are very useful for generating detailed and tailored analysis of the progress of each tennis player, or for making objective comparisons of the progress that each player's technical aspects may have over time.

In addition, the combination of sensors and AI systems allows for improved analysis and the generation of training programs and results based on the specific needs of the player. A fundamental element for the technological modernization of tennis is undoubtedly the Hawk-Eye system. Inventa S.A. (2023) describes that the also called "Hawk-Eye", is a system that uses several high-speed cameras as sensors to track the movement of the ball in order to know if it has touched inside or outside the regulatory limits. This system, based on triangulation principles and real-time image processing, has revolutionized refereeing by providing faster and more objective decisions, reducing controversies in matches.

Hawk-Eye not only fulfills an umpiring (match) function, it also provides other data that can be used in statistical or strategic analysis by players and coaches, and thus enters a technological ecosystem that enhances both sports fairness and performance. Indeed, all these innovations supported by artificial intelligence represent an evolution for field tennis, improving the competitive standard and, at the same time, the training and competition experience. The ability to monitor, analyze and predict on-court behavior allows players to gain a competitive advantage, while coaches have access to more fine-tuned tools for designing highly personalized programs. The integration of intelligent sensors, data analysis and computer vision systems will undoubtedly continue to further the development of tennis in an era of increasing technology and efficiency.

Beyond tennis itself, Hawk-Eye has found application in sports as diverse as cricket, soccer, volleyball and badminton, as can be seen on the Hawk-Eye Innovations Ltd (2025) website. In each of the sports the system is tailored to meet the specific needs of the discipline in order to follow the game or analyze it. Its ability to provide objective, real-time information has changed the way matches are refereed and has improved the experience of athletes and the public at matches.

Articles
Revista tecnológica ciencia y educación Edwards Deming
ISSN: 2600-5867

Fitness

The incorporation of artificial intelligence (AI) into fitness technology systems is profoundly revolutionizing the way we train, monitor health and achieve fitness goals. AI-based systems use advanced algorithms to process large volumes of user data, such as performance, body composition and pulse rate, with the goal of providing individualized training recommendations and plans that change with individual progress.

This power of continuous readjustment translates into an obvious advantage over traditional systems, as it allows, dynamically, to adapt the exercise program over time and increase motivation for the user. In this regard, some of the most obvious applications pointed out by the website Unite.ai (2025) are the Fitbod and FitnessAI platforms, which make use of AI to provide specific training routines dynamically, using the person's performance and recovery to adjust sets, reps and weights; they also include large libraries on exercises, bring in demonstration videos and intelligent recovery tracking, so that the whole experience is satisfying, complete and safe from beginners to experienced athletes.

Interconnection with wearable devices and health applications also allows for further data collection in real time, which enriches and increases the possibilities for personalizing training sessions. One of the most relevant innovations is the application of 3D sensors and artificial vision in devices such as Peloton Guide and Tempo, which make it possible to ensure user tracking during the training itself. These devices ensure feedback and information regarding the user's technique and attitude, improving not only the adequacy of the exercise but also the prevention of injuries, correcting, in situ, its execution, automatically. Another use of AI allows the creation of tools for the evaluation of daily readiness (training readiness) to adjust the intensity of the training load based on the quality of sleep or fatigue, optimizing performance and recovery.

Another application of AI put into practice in fitness is the one established by the digital portal iidca.net (2023), which describes how AI has also allowed the democratization of access to virtual personal training, available 24 hours a day through chatbots and/or intelligent assistants, which can motivate, answer questions and adapt exercise plans under the action of the user's comments and results. Thus, this continuous availability of the application and the personalization of the system favored AI technology systems to become a viable alternative to traditional gyms, which must adapt to an increasingly digital and user-focused industry.

In short, AI technology systems have revolutionized the fitness industry by offering individuals personalized workouts, contextualized health monitoring, and immediate feedback, all of which are grounded in real-time interpretation of accurate data. Although there are challenges such as minimizing discomfort and some ethical

concerns, the positive impact of AI on the personalization, effectiveness and accessibility of fitness is undeniable.

DISCUSSION

Artificial intelligence (AI) has established itself as a tool that can transform and streamline processes in many areas, such as sports. In this study, we inquired about the applications and benefits that AI provides when it comes to personalizing sports training, especially those ranging from performance measurement, the important prediction of injuries or improving the health of athletes. AI, which academically we can analyze as the method or set of techniques with which we can simulate, with computers, the processes that humans have developed in cognitive terms, definition generated from iidca.net (2023), has made it clear that it is able to provide much efficiency, quality and speed to sports training.

From this perspective, Sanabria et al. (2024) state that artificial intelligence, at the sport level, adjusts errors, supports decision-making, optimizes training strategies and can help prevent injuries. This capacity is supported through processes of analysis of a lot of information that comes from the use of sensors, video, wearables, etc., and allows the analysis of biomechanical, physiological or tactical aspects of athletes. A concrete example among the many applications that are launched every day in sports is Intel's 3D Athlete Tracking System (3DAT), which provides specific metrics to improve athletic performance by analyzing speed and body position. To this end, technology, objective assessments and individual training designs are offered. All in all, the use of AI in sport also presents significant ethical and moral opportunities.

One of the most relevant aspects is to ensure equity and equality of opportunity, both for the athletes themselves regardless of access to technology. Thus, if AI becomes an exclusive element of elite athletes or teams with great resources, then existing inequalities will be maximized and an even greater gap may open up between the haves and have-nots. As highlighted by Carrio (2024), it is critical to critically analyze the implications of technology automation for the equity and ethics of sport.

Another important ethical issue has to do with the transparency and applicability of AI algorithms. Athletes and coaches must understand how such algorithms work; what data is used to make decisions that affect their performance and career. The potential lack of transparency in AI systems can cause hesitation in sport, slow down the adoption of AI and ultimately discard its contribution to the improvement of every dimension of sport; i.e., the life of sport. In this sense, it is necessary to ensure the irreproachable defense and protection of the privacy of sensitive data generated by athletes, but also ensuring that the use of such data is subject to good ethical and responsible practices.

Irrefutably, artificial intelligence is changing sports refereeing, a transformation that was intensely observed during the 2022 FIFA World Cup which, during its course, had a semi-automated offside detection system or SOAT. The model under study is based on advanced data analysis and AI algorithms to enhance the efficiency and accuracy of refereeing decisions around this particular soccer rule (Carrio, 2024), finding its justification, moreover, in that implementing this type of technology highlights the need to continue reflecting on the implications that automation can have on the fundamental principles of fairness and integrity in sport.

In the context of athlete health, AI can be useful, as it provides valuable and objective information on different health metrics and gives feedback at the right time. On the one hand, it improves performance and, on the other hand, it contributes to maintaining the athlete's fitness. Machine learning algorithms can analyze complex patterns in training data that could show a high risk of injury and thus serve as a foundation for coaches to change and adapt training plans in a preventive and personalized way.

Technological innovations in sport through AI have modernized training and competition methodologies, management methodology and data analysis methodology. According to Caballero and Nuñez (2022), the functionalities that are ratified as trends are massive data analysis, training personalization, intelligent sensors and augmented reality. In the field of athletics, the use of AI is presented through inertial measurement units (IMUs), devices that instantly collect large volumes of data on acceleration, angular velocity and orientation, favoring biomechanical assessment and personalized training (Deport-Tec, 2024; KGW News, 2021). AI in basketball also enables full, real-time, and highly accurate player tracking, providing both coaches and analysts with a wealth of information for tactical game decision-making.

It should be noted that all technologies in the field of sport are based fundamentally on the constructivist field of sport biomechanics. The biomechanical principles that study both human movement and those (gravitational) forces that affect the human body provide both the theoretical and practical basis for the development of sensors, algorithms and data analysis systems that today underpin AI in sport.

Finally, it is worth asking what impact the emergence of AI has on the nature of sport; that is, can AI be used in sport to its fullest extent? Can this be to the detriment of a fundamental aspect of sport such as creativity, improvisation, etc. and of the competitive spirit itself? Or, to put it another way, would an over-reliance on the use of AI in sport lead, irremediably, to a homogenization of playing styles and the consequent loss of the very nature of sport itself?

These are questions of great complexity and, therefore, require further reflection by all actors involved in the debate. As Caballero & Núñez (2022) conclude, we need the

right balance that allows us to take advantage of all the benefits of AI and find the right place for it in sport without losing sight of the most fundamental aspects of sport.

From a detailed analysis of the information available in the technical and scientific literature, it is clear that artificial intelligence (AI) is emerging as a fundamental driver of change in the transformation of modern sports training. The impressive capacity for the interpretation and development of large volumes of data from sources such as body sensors, super high-speed cameras and wearable devices allows for extremely accurate assessments covering fundamental aspects of athletes, such as: the biomechanics of their movements, their physiological responses and the application of game tactics. This capability, which is truly enriching to read, allows for unprecedented customization of training programs and, therefore, the possibility of proactively preventing injuries.

Logically, the impact of AI goes beyond the mere objective of being able to offer an optimization of individual performance by analyzing and improving skills, but it is also understood that this impact is located in all those areas that are no less relevant than refereeing or the health care of the athlete. In the same sense of refereeing, the use of systems that rely on AI, such as SOAT, shows that such technology increases the accuracy when making decisions for the competitive dispute. In terms of sports health, on the other hand, machine learning algorithms make it possible to detect complex patterns in athlete data that could foreshadow a high possibility of injury in a short period of time, leading technical teams to preemptively modify training regimens.

Innovative technologies, aided by the development of artificial intelligence, are radically changing both training and competition procedures as well as the management and analysis of information in the field of sport. Big Data, the application of hyper-personalized training systems, the introduction of intelligent sensors and the growing use of augmented reality technology are, without a doubt, the trends that show what the future of high performance sport will be like. Some cases of their implementation in sports such as athletics and basketball turn these strategies into best practices that make it possible to evaluate, based on resources such as inertial measurement units (IMUs) and real-time tracking systems, in a highly accurate way the biomechanics of the athletes and the tactical strategy formulated in the sport. In short, AI is presented not only as a tool to take the personalization of sports training to levels hardly imaginable, but also as a way to favor the path of continuous improvement for high competition.

But it should not be forgotten that this rapid technological transformation is neither far from nor exempt from major ethical and moral dilemmas that deserve such consideration. The massive collection of biometric data, although very useful for improving performance and health, also raises serious questions about privacy, information security and, above all, the informed consent of athletes (Carrio, 2024). It is thus important that athletes are not only aware, but also participants in the

management, control and use of their data; thus, the issue of equity in access to these emerging technologies is also added as an important problem.

Finally, there is a serious risk of further widening the gap between resource-rich and resource-constrained sport organizations. In turn, this could lead to inequality between these organizations, which could jeopardize the integrity and fairness that must be observed within the context of competitive sport, according to Seed-Sport(2023) . In this sense, sport governing bodies have the capacity and are responsible for establishing clear, ethical and strong regulatory frameworks that lead to the promotion of responsible and equitable use of AI, without ever overriding the values that should govern sport, while also ensuring the protection and general welfare of the athlete.

Finally, it also sets out a necessary reflection on how an increasing reliance on artificial intelligence could have effects on the very essence of sports practice. Although the automation of processes and the search for extreme performance optimization offer benefits, there is also the concern that they limit spontaneity, the ability to create and all that highly human dimension that is in charge of the very practice of sport, which, after all, is the driving force behind sporting competition. So, the path, possibly, is the search for a balance between the use of technology and human experience; a balance to enhance performance from science, but without leaving aside the human experience itself: the emotion that gives life and meaning to sport (Caballero & Nuñez, 2022; Carrio, 2024).

Artificial intelligence offers the possibility of accessing a fantastic opportunity to raise performance standards in sport, provided that its use is in line with sound ethical principles and with a holistic vision that not only contemplates sporting *performance*, but above all, deals with the dignity and human development of the sport being exhibited.

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