Una revisione sistematica sulle tecnologie digitali sulla scienza dello sport: Didattica dello Sport
A Systematic Review on Digital Technologies on Sport Science: Didactic of Sport

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ABSTRACT

Background. Several reviews have analyzed studies on the effect digital technologies have had on sports science from a didactic point of view. This research seeks to review select studies on digital technologies in sports science.

Methods. A systematic search for studies published up to November 25, 2021, was carried out on Sportdiscus, Science Direct, PsycINFO, and Medline bibliographic. The search and review process was carried out following steps provided in the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) 2009 guidelines.

Results. The initial database search returned 3256 results for inclusion in the systematic review. After removal of duplicates and non-full-length texts, scanning title and abstracts, and full-text analysis, 13 articles were selected for inclusion.

Discussion and Conclusion. Digital technologies have been very impactful in the development of sports science. This advancement has occurred in teaching (didactic of sport) and helping the population learn about the principles of exercising and sport science.

Background. Diverse review hanno analizzato gli studi sull'effetto che le tecnologie digitali hanno avuto sulla scienza dello sport da un punto di vista didattico. Questa ricerca mira a rivedere studi selezionati sulle tecnologie digitali nella scienza dello sport.

Metodi. Una ricerca sistematica degli studi pubblicati fino al 25 novembre 2021 è stata effettuata su Sportdiscus, Science Direct, PsycINFO e bibliografia Medline. Il processo di ricerca e revisione è stato eseguito seguendo i passaggi forniti nelle linee guida Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) 2009.

Risultati. La ricerca iniziale nel database ha restituito 3256 risultati da includere nella revisione sistematica. Dopo la rimozione di duplicati e testi non integrali, la scansione del titolo e degli abstract e l'analisi del testo completo, sono stati selezionati 13 articoli per l'inclusione.

Discussione e conclusione. Le tecnologie digitali hanno avuto un grande impatto nello sviluppo della scienza dello sport. Questo progresso è avvenuto

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nell'insegnamento (didattica dello sport) e nell'aiutare la popolazione a conoscere i principi dell'esercizio e della scienza dello sport.

KEYWORDS
Technologies, exercise health, sports applications, sport science, sport science technology
Tecnologie, salute fisica, applicazioni sportive, scienza dello sport, tecnologia della scienza dello sport

1. Backgroung

Technology is rapidly changing, with newer and better processes being developed each day. The field is quickly expanding, resulting in significant improvement in machine learning and artificial intelligence. Scientists are even estimating that the world is just three decades away from reaching a singularity. This is defined as a situation where machine intelligence will surpass human intelligence. According to Loland (2009), the advancement of technology has been in all fields, and sport science has not been left behind. The development and continuous improvement of artificial intelligence and technologies such as wearable devices with multi-sensor systems and intelligent analytics have set a center stage in research and innovation. It has provided a stepping ladder for human society to achieve higher relevance in the field of sports science.

Compared to post-practice review and whiteboards, technology has significantly increased athletic potential. Technology is revolutionizing sports science by enhancing live-tracking performances, improving communication and the virtual elimination of injuries, and perfecting the performance of athletes. Sports science is a discipline that studies how the human body works during exercise and how sport and physical activity promote health and performance from cellular to whole body perspectives. To gain knowledge of the body's response during exercise, monitoring is required. In the previous years, monitoring was done through paper measurements and graphs that had to be drawn by analysts or trainers. The trainer and trainee would analyze these drawings later, meaning a lot of time and energy was lost. Over the past few decades, the involvement of technology in sport science has enabled the development of intelligent sensor systems and modern information analytics systems, automatically revolutionizing sports efficiency. With artificial intelligence integrated into the systems, the information produced is utilized to expand knowledge in sports science to all stakeholders. Artificial intelligence (AI) systems are presently widely used to provide information for monitoring the body's responses to exercise stimuli under different study conditions across various study groups.

With the influx of technology in sports, the field of sport and exercise science has dramatically changed (Ratten, 2020). The understanding of the human body during exercise has significantly improved, and advanced research is enabling the gradual elimination of aspects such as injury (Vera-Rivera et al., 2019). Several studies on the effect of digital technologies on sports science exist, some quantitative and most qualitative. The problem is that they do not summarize in detail the di-

dactic impact of digital technologies on sport sciences. This raises the issue of indirect inferences and hence poor advancement in research. This paper sought to resolve such issues by analyzing the impact of sports technology on sports training, sports performance, and sports competitions. This was done considering top improvements in machine learning and artificial intelligence.

2. Methods

Eligibility Criteria
The studies selected for the systematic review were both quantitative and qualitative. The studies had to have been published later than 2010, and only studies were written in the English language. The articles had to majorly focus on sports science technologies associated with the improvements in machine learning and artificial intelligence. The studies conducted on aspects of sports science had to have been reported objectively based on the technology under question.

Search Strategy
The systematic review was carried out following steps provided in the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) 2009 guidelines. This approach was modified by incorporating the article screening process as each article was individually identified. Articles from 2010 – 2021 were considered for the analysis. The search strategy involved a systematic search of e-databases, including Sportdiscus, Science Direct, PsycINFO, and Medline bibliographic. The article selection excluded articles not published in the English language. The reference lists of selected papers were also searched for as per the PRISMA protocol to find and include relevant articles. The search was restricted to scholarly articles hence no gray literature was included. The keywords used in the search were digital technologies, exercise apps, exercise health, sports applications, sports apps, sport science, and sport science technology. The titles and abstracts of the selected articles were scanned to identify eligibility, considering the given inclusion criteria. After their selection, full-text reading was done to justify their inclusion in the review and analysis.

Data Extraction, Quality Assessment, and Synthesis
Independent authors extracted the data. The information from included articles was extracted into pre-defined excel extraction spreadsheets using a pre-defined list of variables. The name of the authors, year of publication, and type of study and/or technology, data measuring approaches, and outcomes in sports were recorded. Microstates of play and significant findings were extracted and collected from each included article. The Crowe Critical Appraisal Tool (CCAT) was utilized to assess the quality of reporting of each of the included studies. The approach was considered as it can accommodate an extensive range of study designs. The quality assessment approach also entails eight independently scored domains. These are preamble, introduction, Design, Sampling, Data Collection, results, ethical considerations, and discussion. Every domain received a score ranging from 0-5, with 5 being the highest possible score and 0 the lowest. The Research and Quality Scoring Method was also used to determine the quality of the included articles. The approach used an excel spreadsheet with selected variables. The range of the total quality score ranged from 0 to 9, with 9 representing the highest quality. Scores from 6-9 represented high quality, while those below six were re-

garded as low quality. Synthesis of the data involved analysis of the discussion to establish the reports of the impact of technology on sports science.

3. Results

The initial database search returned 3256 results to be considered for inclusion in the systematic review. Of the results, 1987 were excluded as duplicates, and 697 were not full-length original research articles. The majority of the 697 articles excluded were theses, books, and government reports. Of the remaining 572 articles, 76 were excluded from not being available in English. The remaining articles were scanned based on their abstracts to satisfy inclusion criteria. During this process, 437 studies were eliminated, and the remaining 59 studies were further evaluated through full-text analysis, through the search of their reference lists, and in data extraction. 13 studies were considered for review considering that they utilized technology, carried out a quantitative measure or analysis of exploration, had English full-text and focused on sports science technology.

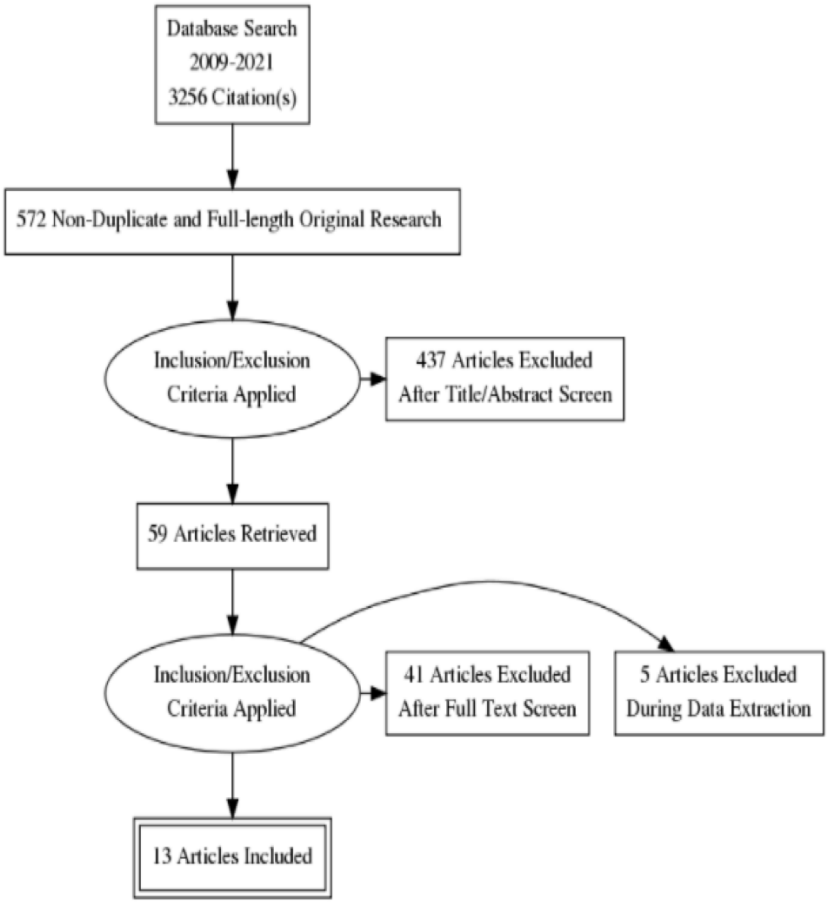

Figure 1: Study Characteristics

Author and Year	Study aim	Technology	Population	Findings and recommendation
(Mataruna-Dos-Santos et al., 2020)	Analysis of the most critical technologies that are currently allowing significant progress in sports performance and in the impartiality of competitions through the study of the collected data	Video-assisted data collectors, wearable technologies, and scouting tech-based techniques	Amateurs and professional athletes	Innovations in the field of materials and tools for the verification of proper training have revolutionized training and performance.
(Ráthonyi et al., 2018)	Determine the interlocks of sports and information technology and show how to increase fan experience with digital technologies under-propping them with practical examples	Augmented reality, big data, virtual reality, and social media	Athletes and sports fans	Four macro-areas show the linking between sport and informatics: athletic performance, sports club, event management, fan experience. Mobil fan experience augmented (AR), and virtual reality (VR), big data, social media are those technologies that even popular are these days in order to enhance the fan experience in sport
(Hughes et al., 2021)	Address some of the novel technologies being increasingly utilized within sports biomechanics and highlight critical factors to be considered in best practice	Wearable sensors and smartphone sensors	Athletes	Emerging technological developments that are applicable to movement analysis offer exciting opportunities for biomechanics to bridge the gap between research and practice and allow Biomechanists to move away from the laboratory increasingly and to the field where athletes train and compete. They could provide a chance to increase the ecological validity of measurements
(Loland, 2009)	Present a normative the framework within which to reason systematically about where to draw the line between valuable, acceptable, and nonacceptable technologies in sport	Sport technology	Athletes	Technology policies are generally linked to more or less clearly articulated normative theories of sport. Narrow theories challenge the attitudes and preconceptions of people. Therefore, critical reflection in the utilization of technology in sports can never be made to focus on progress and records alone.

(Vera-Rivera et al., 2019)	Analyze through research results in some sports how the application of technology affects the diagnosis and planning of sports training	Sport machines such as contact platforms, linear encoders, sports preparation software, tablets, and mobile devices	Athletes	The use of technology applied to sports training represents a significant advance in reducing costs, time, and processes in the training of athletes with a view to professional sports.
(Dyer, 2015)	Conduct a systematic review of peer-reviewed literature to identify any case studies of controversial events surrounding the implementation or use of sports technology	Sport technology	Athletes	Long periods without intervention or resolution by a governing body often increase the peer-reviewed attention paid to such cases.
(Haake, 2009)	assess the effect of technology on sports by analyzing performance statistics for four disciplines: the 100-m sprint, pole vault, javelin, and cycling.	Sports technology in the javelin, 100-m sprint, cycling, and pole vault	Athletes	The performance improvem index could be extended to amateur as well as elite spo where distance or time is us as a measure of performanc For instance, technological advancements in simple equipment such as pole vau and javelin affected the performance improvement i by about 30%
(Strenge et al., 2020)	Outline Cognitive Interaction Technology (CIT) area of research, address ethical issues, and present an empirical study in the context of a new measurement and assessment system for karate training.	Cognitive interactive technology	Karate athletes	The potential benefits of such an assistance system for intermediate and advanced practitioners include more effective and flexible practice, as well as supportive effects and more flexible training schedules.
(West et al., 2020)	Detail the challenges and contextual factors that must be considered when interpreting training load data. Highlight the complexity associated with the use of training load in the management of injury risk.	Sport technology	Athletes	Monitoring of athletes is an essential tool in modern-day sports science. At the same time, recent framing has extensively emphasized medicalized rationale for athlete monitoring. Maximization of performance may help sports scientists, players, and coaches buy-in.

(Wei et al., 2021)	Explore three specific cases of AI application in sports training and explains the main principles. Discuss the strong relationship between AI technology and physical education training and highlights the advantages of AI, including utilization, convenience, and innovation	Artificial intelligence	Athletes	Artificial intelligence in sports science can be considered as assistive technology. Therefore, the technology can be used to provide specific support to training during the physical education of athletes. This can be in the form of data analysis and simulation of training scenarios.
(Fong & Chan, 2010)	Review the literature related to the usage of inertial sensors in human lower limb biomechanics studies	Wearable motion sensors consisting of accelerometers, gyroscopes, and magnetic sensors	Athletes	Motion sensors are critical tools for the analysis of human motion in sports. Wearable inertial motion sensors are highly transportable. For the devices, no stationary units, as for the case of cameras and receivers, are required in data collection. Advancement in the development of micro-electro-mechanical systems has made them efficient for lower limb joint kinematics studies. However, data logging, data processing, and fixation method are the areas to be improved in the near future
(Aroganam et al., 2019)	Discuss the trends and projections for wearable technology in the consumer sports sector (excluding professional sport)	Wearable technologies for different users (specifically Inertial measuring unit (IMU) and Global Positioning System (GPS) sensors)	Consumer sports sector excluding professional sport)	Sensors are influential in the delivery of different readings, which are critical in various ways in sports science. By integrating technology, wearables are increasing in function, and users can utilize them to collect data about themselves. With improvements in technology, different sensors can be customized for various other needs.
(De Pasquale & Ruggeri, 2019).	Provide a general description of the technologies relating to wearable sensors that have been adopted in medicine and sport, and to review device typologies, sensing strategies, and future perspectives	Non-invasive wearable devices (Focus on wearable sensing systems)	Subjects in medical and sports disciplines	Non-invasive wearable devices allow real-time evaluation of the physiological conditions of patients. The sensors allow monitoring of the body, including aspects such as heart rate, heart rate variability, skin temperature, metabolic parameters, body motion, and breathing. However,

				to allow efficiency in use, warble systems must provide excellent and 4 acceptable accuracy, repeatability, and noise.

4. Discussion

This systematic review was done to establish the implications of technology on sports science over the past few years. Technological advancement in the past three decades has had a huge developmental impact on the field of sports science. The progress has brought changes making athletes (both professional and amateurs) and fitness enthusiasts to integrate technological solutions to improve their performance (Mataruna-Dos-Santos et al., 2020). According to Ráthonyi et al. (2018), performance enhancement has been the pivotal play of new technologies. This means athletes have been made to provide their best possible performance. Hughes et al. (2021) mention that gadgets used in sports have become smaller, more resilient, and less burdensome over recent years. Such advancements have created new opportunities for athletes.

According to Mataruna-Dos-Santos et al. (2020) and Rathonyi et al. (2018), the development of wearable technologies with sensors has been critical in improving sports safety. Sensors presently convey real-time information to the devices of athletes. Conveying of such information to devices such as smartwatches, for instance, enables the pinpointing of optimal performance positions resulting in the prevention of injuries. When compared to tools such as paper charts and graphs that were used before, the performance of the athlete is significantly increased. An advancement in motor learning by athletes with the aid of sensors sports activity signal acquisition and metric analysis of signals has dramatically improved the quality of sports and, consequently, elevated competition standards (Loland, 2009).

Overall, the application of digital technologies was a consistent topic in all articles, with a considerable proportion terming the application positively. Four major themes emerged from the review of the studies: Sports training, artificial technologies, data analysis, biomechanics, and wearable technologies. Most articles contained not just one theme but had overlaps in several themes. The articles had to be categorized into the most agreeable groups with the article contact.

5. Sports training

The introduction of newer technology can influence how a game is played and how the participants prepare for competing (Vera-Rivera et al., 2019). The author alludes that the utilization of technology in sports training represents a considerable advancement in reducing costs, time, and processes in athletes' training. The authors in their study obtained reliable information for the realization and control of various training plans. This resulted in the generation of inputs for decision-making that brought out a clear picture of aspects of computerized management of sports. Preparation is critical, and as stated by Dyer (2010), most athletes who train with technological aids have a winning edge over athletes using traditional means of training. The author claims that any significant gains in the future will

be majorly due to sports technology made possible by technical innovation. However, the author notes that the merits of non-human-based decision-making systems are still not resolved in various sports, and this will need to be considered in the future.

Haake (2009) states that technology plays a growing role in supporting professional athletes, amateur runners to compete. The author assessed the effect of technology on sports by studying four disciplines: a 100-m sprint, javelin, pole vault, and cycling. The following improvements were reported having been measured using indices: 100-m sprint, 24% over 108 years; pole vault, 86% over 94 years; javelin, 95% over 76 years; 4-km individual pursuit, 35% over 32 years; one-hour cycling record, 221% over 111 years. This demonstrates that sports technology, to a great extent, can improve training and allow the realization of the best possible performance in sports events.

Use of sensors placed on the body, a trainer can measure and track the performance of the trainee. Strenge et al. (2020) studied cognitive interactive technology and established that it offers a range of benefits. One aspect of these is smart clothing, an activewear sports clothing with inbuilt sensing fibers woven into it (Strenge et al., 2020). This type of clothing can help the trainer track performance of the status of the trainee in real-time. Overall, the authors concluded that the potential benefits of technical assistance in sports for intermediate and advanced practitioners include flexibility and effectiveness of practice. However, they emphasize that the development of such systems should strictly consider ethical concerns. Vitals such as heart and breathing rates, amount of body moisture or hydration levels, and even both exothermal radiations and temperatures can be measured (Ráthonyi et al., 2018). Some innovative kits are even capable of helping the trainer to trainer to predict the outcome of a hypothetical competition based on the trainee's results during a training session (Hughes et al., 2021).

With the acquired data from live metrics being analyzed, the trainer can determine which aspects the athlete needs to focus on more and which factors negatively affect the desire for improvement (West et al., 2020; Wei et al., 2021). West et al. (2020) allude that training load monitoring is a primary aspect of modern-day sports science practice. They indicate that with improved investment in training load monitoring, practitioners can be able to transform data into informed and valuable decisions. Some kits are athlete tailored, and if they are not, the real-time data generated by biometric sensors are unique to the individual athlete or trainee (Wei et al., 2021). The authors mention this after analyzing three practical examples of the use of artificial intelligence in physical education training. The authors note that through data analysis and simulation, artificial intelligence provides avenues for training and thus performance improvement. Such results help the trainer or coach create a detailed training timetable or scheme for that athlete, incorporating individual resting time and durations, recommended diet and bodybuilding routine, either calisthenics or gym blocks.

6. Artificial Intelligence and Data Analysis

Training load monitoring is an essential aspect of modern-day sports science practice (West et al., 2020). This aspect includes collecting, cleaning, analysis, interpretation, and dissemination of data. Data analysis and interpretation are made to improve athlete or player performance and manage injury risk (West et al., 2020; Wei et al., 2021). Performance analysis in sports has undergone dramatic changes over the past three decades, from shorthand notations to the use of analysis soft-

ware (O'Donoghue, 2014). Modern study has incorporated advanced statistical modeling and new analytical frameworks and technologies like GPS tracking and time-lapsed notational analysis software.

Performance analysis is an observational analysis task that includes data collection and analysis and feedback delivery. Performance data analysis aims to improve sports performance by involving coaches, trainers, analysts, and athletes. Most performance analysis is in real-time, using specialized software, such as SportsCode, Dartfish, or Nacsport, as Mataruna-Dos-Santos et al. (2020) presented. In their study, statistical reports were generated to summarize key performance metrics and highlights during the sport. A post-session analysis is also essential as it allows for a detailed evaluation of performance using complementary data sources. O'Donoghue (2014) alludes that in a post-session analysis, data beyond the analysts' observation is incorporated in the system for analysis using artificial intelligence. Such data include qualitative statistics, video playbacks, and athletes' vitals measurements, including breathing rates, heart rates, blood lactate levels, aspiration and respiration levels, speed, and GPS location metrics collected through wearable technology devices.

7. Biomechanics

A proficient understanding of how living organisms move with regard to mechanical laws has been a must-know for most elite athletes and trainers or coaches. Advancement in technology has led to the development of new types of sports equipment that adhere to the principles of biomechanics. Most of the pieces of equipment are wearables and can measure motion and inertial forces acting on the athlete during body movement (Fong & Chan, 2010). The authors mention that wearable inertial motion sensors, for instance, are highly transportable and do not require additional stationary units, as in the case of cameras and receivers. Due to technological advancement, power consumption, size, and designs of these devices have been greatly improved, making them even more efficient for sport utilization. However, there are challenges that more improvements will need to resolve. These challenges include data processing, logging, and fixation frameworks (Fong & Chan, 2010). Generally, though, the technology is critical in ensuring reduction of costs and easy attachment on users for ambulatory concerns.

There are more established and used sports technologies that are based on inertia (Inertial Measurement Units [IMUs]) which are used often together with magnetic field sensors (MIMUs) (Aroganam et al., 2019). The authors mention that these developments are trends and projections or wearable technology in the consumer sports sector. They claim that wearable technology is about tracking if performance and can also be used as a health monitoring system. Sensors can give players and doctors more significant interaction using technology in monitoring live time health status. Wearable tech clothing has, for instance, been found to improve the biomechanics of a baseball pitcher. This benefits the performance of the pitcher and minimizes the chances of potential injuries. With innovations in medical and training wearable technology, injury tracking and performance will be improved (Aroganam et al., 2019). De Pasquale & Ruggeri (2019) agrees with this and mention that the main application of this area of sports mechanics is performance improvement and injury risk prevention and mitigation. These new technologies in biomechanics are essential to the athlete in that they are cost-effective and efficient in the provision of results.

8. Wearable technologies

Wearable technologies have been around for quite a while, but never have they been sport-oriented as they are now (De Pasquale & Ruggeri, 2019). These wearable technologies have become a part of daily life for professional athletes and fitness enthusiasts. They measure the physical and physiological quantities of the individual wearer for the predetermined range of time. These simple devices output statistical values that will later need analyzing (Aroganam et al., 2019). The provided analysis needs to be timely, spatial, and productive. The wearable devices can collect data due to multivariable system sensors incorporated into the machines and the presence of logarithms that compute secondary data based on the primary input data (from inbuilt sensors). Sport wearables contain real-time biofeedback systems for conveying data to the wearer or trainer's tablet as vitals change in real-time (Aroganam et al., 2019; Fong & Chan, 2010).

Some examples of wearable devices are fitness trackers. They can monitor steps taken, heart rate, breathing rate, calories burned, and a bunch of other fitness metrics (Mataruna-Dos-Santos et al., 2020). Implantable devices have also gained popularity in the field of sports science. Proteus had produced sensor-containing pills that could monitor blood pressure and other health metrics, so patients had to swallow the pill (Aroganam et al., 2019). Implantable devices make contact with the user's body from the inside and, via communication, produce data from within the body that can be monitored using an external device (De Pasquale & Ruggeri, 2019). The author mentions that while the relevance of wearable and implantable devices has tremendously increased in the recent past years, developers must focus on the performance effectiveness of the devices if they are to promote efficiency in sports science. In this case, the author mentions that the basic requirements for wearable devices are low power consumption, reliability, flexibility, and lightness. Therefore, manufacturers should focus on appropriate innovations to develop products with acceptable noise, accuracy, and repeatability.

Conclusion

In conclusion, technology in sports science has changed things significantly. Teams and athletes can presently get real-time data on performance, flexibility, technique, endurance, injury, and more. Advancement in technology can also allow stakeholders in sports science to compare such data with previous benchmarks to understand the condition of athletes' bodies and situations in sports. New medical technologies mean that recovery from training sessions, games, and injuries is better than ever. Also, advances in medical technologies mean that improvements will be made in terms of the prevention of such injuries. The sports science technological trends receiving prominence over the past decade include injury recovery systems, analytics to prevent injuries, wearable technologies, sweat analysis.

Most of the technology developments incorporate big data and artificial intelligence, meaning that their efficiencies and functions will keep improving with time. Wearable technologies, for instance, play a critical role in how athletes are evaluated in real-time and during training sessions. With continued advancement in sensor technology, these devices will give athletes and coaches more ability to understand performance, prevent injuries, and ensure quick recovery in case of injury. Recovery from injuries and improvement in performance is about the body and the mind. Future technologies must incorporate aspects of mental and emotional support to athletes to enhance performance.

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