

جامعة عمار ثليجي الأغواط
معهد علوم وتقنيات النشاطات البدنية والرياضية
قسم النشاط الرياضي التربوي



مطبوعة لمحاضرات في:

التطبيقات والبرمجيات التكنولوجية في الرياضة

من إعداد الأستاذ: شاشو أحمد

المستوى: السنة الثانية أستاذ تربية بدنية

السنة الدراسية: 2025-2026

University Amar Thelidji-Laghouat

Institute of Science and Technology of Physical and Sports Activities



Title of the scientific publication

Applications and software specific to sports

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Department: Physical activities and sports education

Division : Physical activities and sports education

Specialization : Physical education and sport

Level: 2nd year Licence

Academic year: 2025-2026



Ministry of Higher Education and Scientific Research
Institute of Physical Activity Sciences and Techniques

Teacher information sheet

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reception day:

Cycle: Licence degree

Level: 2nd year

Field: Physical education and sports

Specialisation: Physical Education and Sports

Module: Applications and software specific to sports

Hours per week: 1h15 hours of Theory / 4 hours of Practical Work (14 weeks =77h)

Coefficient: 4

Credits:6

Presentation of the course

This STAPS bachelor's course, "Applications and software specific to sports," introduces students to essential digital tools to modernize sports training. It combines theory (software features, data protocols) and practice (hands-on workshops with Kinovea, basic Python for ML, VR simulations via Unity), over 45-60 hours per semester (30% theory, 50% practical sessions, 20% projects).

Divided into thematic units—video analysis, GPS/biometric tracking, AI for fatigue prediction, VR for rehearsal—it enables the creation of customized dashboards (e.g., Google Sheets + wearable APIs) and data-driven session management. Main objective: link these tools to STAPS core knowledge for career entry in digital coaching, physical preparation, or performance analysis. Assessment: applied projects (70%), MCQs (30%).

The general objectives

- Master the main software and applications dedicated to sports to analyze performance (e.g., Kinovea for biomechanics, Hudl for video tagging).
- Develop practical skills in using digital tools to quantify training loads (external/internal) and prevent injuries via predictive AI.
- Know how to integrate mobile apps (Garmin Connect, Strava) and VR/AR platforms into personalized training planning.
- Evaluate and select software suited to different audiences (elites, amateurs, schoolchildren) to optimize data analysis and real-time feedback.
- Promote autonomy in exploiting sports data for professional reports and digital transformation in coaching.

Assessment method:

- **A diagnostic assessment (assessment of prerequisites)**

- **A summative/certification assessment**

a final written examination covering the concepts covered in the course during the semester. During this examination, which accounts for 60% of the final mark, you will also be required to:

- **Solve problem situations similar to those dealt with in tutorials and practicals.**

- Answer summary questions (via multiple-choice questions).

Formative or continuous assessment:

This is carried out through occasional activities (remote or face-to-face) to help you pass your final examination.

This continuous and regular assessment accounts for the remaining **40%** of your mark and allows you to earn points throughout the semester or even the year. It takes various forms, with each activity accounting for a quarter (1/4) of the overall mark.

These are:

- **an individual project** on the basic concepts of volleyball training: the assessment will take into account compliance with instructions, relevance and organisation of the work.

- **a group project** on the physical and sporting activities of the specialities carried out in practical classes.

- **Practical work** scheduled each week throughout the semester, covering each point covered during the course. The practical work is divided into two parts: a theoretical part to be prepared at home and a practical part to be carried out in the field. The assessment of the practical work is based on the preparation of the theoretical part, combining it with the practical part. The report summarises the theoretical and experimental parts.

A practical work examination is planned at the end of the semester, covering all the points covered during the practical work sessions.

Support arrangements

Support for this course will be provided in person and remotely.

Summary

The first axis : Sports Digital Transformation and History of the Renovation and Revolution of Modern Technological Applications in the Field of Sports

Axe 2: Program analysis of information and Digital Transformation in Sports

Axis 3: Athletic physical monitoring program.

Axis 4: Wearables and Fitness Tracking (GPS, Heart Rate)

Axis 5: Training Load Management Using Digital Tools

Axe 6: Numerical data analysis in sports

Axis 7: Foundational Studies

Axe 8: Training load planning using digital devices

Axe 9: Systems of simulation and virtual training

Introduction générale

The COVID-19 pandemic clearly exposed the vulnerabilities of the sports industry. Once social distancing restrictions and lockdowns took effect in most countries, this industry experienced a terrifying period of stagnation, and many major sports entities are still suffering to this day. However, at the same time, it served as a driver for clubs to seek innovative ways to support the increasingly complex and challenging sports business landscape, with digital transformation being one such approach.

Sports digital transformation offers clubs and entities tremendous opportunities that were not previously available. Despite its importance, most club owners and managements lack full awareness of the associated losses and benefits. In this article, we will clarify what digital transformation for sports clubs entails and its advantages.

First Axis : Sports Digital Transformation / History of the Renovation and Revolution of Modern Technological Applications in the Field of Sports

Lecture 1: Sports Digital Transformation

I- Définition

What is Meant by Sports Digital Transformation?

It is the disruptive process undertaken by clubs to make radical changes in the key organizational and cultural aspects of sports facilities, reshaping their operational, administrative, and management models to rely on digital technologies. This aims to improve performance levels, reshape value creation methods for customers, generate new revenue streams, and reduce long-term costs.

1- Importance of digital transformation in sport

Knowing the history of renovation and revolution in modern sports technology applications is essential for athletes, coaches, fans, and industry professionals to leverage data-driven performance gains and anticipate future innovations. This understanding bridges past milestones with current tools like AI coaching apps, ensuring safer, more inclusive sports participation amid rapid evolution.

2- Performance Optimization

Grasping technological timelines—from 2000s GPS trackers like Nike+ to 2020s AI platforms like Garmin Connect—enables precise training adjustments based on real-time biometrics, reducing injury risks by up to 30% through predictive analytics. Coaches can replicate elite strategies, such as VR simulations used by pros for tactical drills, democratizing access for amateurs. Historical context reveals how wearables evolved from basic step-counters (Fitbit 2007) to holistic recovery systems, maximizing endurance and output.

Historical revolutions, like Strava's 2009 social features expanding to metaverse integrations by 2025, highlight tech's role in boosting global participation—fitness app

users surpassed 1.5 billion by 2026. Knowing this progression informs AR/VR broadcasts that enhance viewing with live stats overlays, fostering inclusivity for remote fans. It underscores equitable growth, countering digital divides by promoting affordable apps in underserved regions.

3- Strategic and Ethical Insights

Industry leaders benefit by tracing Hawk-Eye's 2001 debut to modern blockchain fan NFTs, guiding investments in sustainable tech like solar wearables. Awareness of dual-sided models (wearables + data sales) flags privacy risks, urging regulations for biometric data. This knowledge fosters ethical innovation, balancing performance edges with fair play.

Stakeholder	Key Benefit
Athletes	Injury prevention
Coaches	Data-driven tactics
Fans	Immersive experiences
Managers	Revenue via analytics

4- Benefits of Sports Digital Transformation

Digital transformation offers countless benefits, as the symbiotic relationship between humans and technology profoundly impacts all industries. We could easily list dozens of advantages it adds to your sports club, but let's now explore the following key benefits:

- Integrating digital business models with traditional ones to future-proof operations.

- Leveraging the power of digital content and adapting to new consumer content habits.
- Creating new income and revenue sources for the club through digital technologies.
- Expanding content reach for sports institutions via digital media to enhance direct fan engagement (consumers).
- Utilizing Industry 4.0 technologies, such as virtual reality and augmented reality (**AR & VR**), to create innovative consumer experiences.

In the digital world, organizations can access vast amounts of data, giving club sponsors broader insights into ad types that suit audiences. Digital tools can also provide sponsors with more fan information to customize marketing messages for greater effectiveness.

5- Activating Digital Transformation Initiatives in Sports Entities

Digital transformation has become an urgent necessity and an unavoidable decision for all entities across sizes and sectors. Meanwhile, the sports industry has begun catching up and adapting to developments in recent years. Here are some steps sports institutions should take to activate transformation initiatives within their entities:

- Conduct analyses to assess the current state of the institution, identify strengths and weaknesses, study strategies of larger entities, infrastructure, operations, and culture.
- Define priorities for the digital transformation process and what it aims to achieve.
- Design and develop a digital transformation strategy that aligns with the institution's overall strategy.
- Talk to employees to understand their ideas and perspectives on transformation, helping gauge needs for change management training programs.

- Identify key projects that achieve the institution's transformation goals and start them immediately.
- Finally, define key performance indicators.

6- Areas of Digital Transformation for Sports Clubs

No organization can claim to have fully achieved digital transformation. It is not limited to a single initiative but is an ongoing journey as long as business goals evolve with emerging digital technologies and trends, lest the organization stagnate and exit the market. Currently, digital transformation can enhance three key areas in sports entities and organizations, as follows:

Organizational Structure: New technologies and digital innovations can change and simplify business operations, disrupting the entire organization. Sports entities often need to create new roles and departments focused on innovation, new technologies, and digital transformation overall.

Performance: Digital transformation also impacts athletic performance. Data, in particular—with greater volumes processed faster and better—can enhance performance.

Enhancing Fan Experiences: Digital transformation can improve fan experiences, whether in stadiums or on digital platforms.

7- Success Factors for Sports Clubs' Digital Transformation

With the right strategies and capabilities, sports institutions can activate digital transformation initiatives to achieve business goals. Here are three critical success factors:

1. Prepare the club's culture for change: Change will inevitably face resistance from employees and stakeholders. Ensure passage through all change process stages during project implementation and understand drivers for different employees.

We always advise starting with the most change-ready departments, then sharing their positive results and experiences with resistant ones to influence behavior and address resistance causes.

2. Clearly define pursued goals: You cannot start implementing digital transformation and integrating technologies without clear goals and a guiding vision. For sports digital transformation to succeed, precisely identify processes to transform and steps to digitize.
3. Choose the right platforms and tools: In a sports club's digital transformation journey, avoid chasing trends without studying needs. What works for one organization may not suit another. The right choice must always start with future-proofing. Ask: What does your institution plan to achieve from digital transformation?

Often, organizations choose between the cheapest or best tool without mapping their digital ecosystem and integration. It's also illogical to pick the priciest if you'll use only 10% of its features!

In conclusion, our key advice to all leaders: Don't let technology drive the digital transformation. Conduct a comprehensive entity analysis, make data-driven decisions based on precise objective studies, and develop a digital transformation strategy and framework to guide decisions. You must fully understand how digital technologies help the entire sports organization grow.

Lecture 2: History of the Renovation and Revolution of Modern Technological Applications in the Field of Sports

1- Pre-Digital Origins

Early technological innovations in sports date back to the 19th century, with bamboo poles evolving to fiberglass vaulting poles in the 1960s, marking a material shift toward greater flexibility and performance. In the 20th century, electronic stopwatches and stop-motion cameras enabled precise movement analysis, laying the groundwork for quantifying athletic performance. These "pre-digital" advancements paved the way for digitalization by making the previously subjective measurable.

2- 2000s: Birth of Wearables

Elite wearables emerged commercially in 2006 with Catapult's minimaXx GPS device, adopted by Australian football teams to track distances and movements. Fitbit launched its first tracker in 2007—a clip-on device measuring steps, distance, and calories—democratizing fitness tracking for the masses. Strava and Nike Run Club arose in the late 2000s as pioneering mobile apps for running and cycling, integrating communities and social sharing.

3- 2010s: Mobile Apps - Sensor Boom

From the 1990s onward, physiology and physiological sensors revolutionized physical preparation and recovery, extending to all sports in the 2010s. Integrated biometrics (shoes, clothing) analyzed strengths/weaknesses, guiding pro training. Precise video analysis and AI enhanced sensors for live physical performance measurement.

Civilian GPS access in 1996 accelerated smartphone integration, peaking with devices like the Nokia 5500 in 2006 for activity tracking via 3D accelerometers. Apps like Strava (2010s) and Nike+ optimized real-time training, while Hawk-Eye (2006) revolutionized officiating in tennis and cricket using high-speed cameras. Connected watches (Garmin, Polar) added heart rate and sport-specific analytics, boosting adoption among amateurs and pros.

Application/Tech	Key Year	Main Innovation
Fitbit Classic	2007	Step/calorie tracking
Strava	Late 2000s	Cycling/running community
Nike Run Club	2010s	Social coaching integration
GPS Wearables	2006	Elite distance/movement

4- Modern Revolution (2020s) and AI and Immersion

Since 2020, AI has enabled live performance analysis, VR provides immersive training simulations, and 5G enhances fan apps with real-time stats and betting. LPS (Local Positioning Systems) extend indoor tracking for basketball and hockey, while blockchain and metaverses redefine fan engagement. By 2025, apps integrate Nike Training Club with Strava for cross-platform communities, embedding sports into daily life via personalized data. Since 2020, generative AI has personalized training (Strava, Garmin Connect, Apple Fitness+), alerting on health and adapting programs. Virtual reality simulates matches (Meta Quest, Apple Vision Pro), optimizing tactics and post-trauma recovery. In 2025-2026, VRWorkout and boxing VR apps match HIIT energy levels; fitness gyms integrate AI for holistic recovery profiles.

Innovation	Period	Main Impact
GPS/Sensors	2000s	Distance tracking
Biometrics AI	2010s	Body analysis
VR/AI Coach	2020s	Immersive simulations
Fitness+/Strava	2025+	Health personalization

2026 Trends

By 2026, AI hyper-personalizes group classes and fitness advice in sports gyms; fitness machines generate electricity. Mixed reality boosts physical e-sports (EVA arenas) and fan marketing via generative AI. Sports-health explodes with VR rehab and autonomous coaches.

5- Impacts and Challenges

These technologies have "revolutionized" sports by optimizing training (AI sensors, video analysis) and engaging fans through mobiles. However, dual-sided business models (wearable sales + data monetization) raise ethical issues like privacy of sensitive health and location data . Adoption remains skewed toward young urban users, with high dropout rates (up to 50%) .

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Axe 2: Program analysis of information and Digital Transformation in Sports

Introduction

In sports, a "Program analysis of information" refers to a structured curriculum or module focused on processing and interpreting sports-related data to enhance performance, training, and decision-making.

Core Concept

It involves systematic techniques for collecting (e.g., GPS tracking, video footage), analyzing (e.g., statistical modeling, pattern recognition), and visualizing sports data (e.g., player movements, workload metrics) to provide actionable insights for coaches and athletes. This aligns with performance analysis in STAPS programs, where students learn to evaluate technical skills, tactical patterns, and physiological responses using tools like Kinovea or Hudl.

Key Applications

- **Technical Analysis:** Breaking down biomechanics (e.g., serve efficiency in volleyball) via notational coding.
- **Tactical Evaluation:** Assessing team strategies, opposition scouting, and in-game adjustments.
- **Load Management:** Quantifying internal (heart rate) vs. external (distance covered) loads to prevent injuries.
- **Digital Integration:** Using AI/ML for predictive modeling, linking to your interests in wearables and VR simulations.

This course element equips students to turn raw data into feedback loops, much like modern sports analytics in elite training.

The sports industry is one of the most robust and competitive sectors in the world. Over the last decade, the integration of technology into sports has dramatically transformed the dynamics of how the sports industry operates. Sports analytics (i.e.,

the integration of data science and sports) is at the forefront of this digital transformation. Sports analytics encompasses the applications of innovative technologies and advanced analytical techniques to assess and enhance performance of players and teams, improve decision-making across diverse aspects, and bolster competitive advantages and strategies.

Digital Transformation in Sports explores the key driving forces and emerging trends that are fueling the digital transformation of the sports industry. It presents a collection of chapters that delve into state-of-the-art research and real-world applications of sports analytics, providing a diverse perspective on its transformative impact across different sports sectors. It showcases how advanced technologies such as the Internet of Things (IoT), machine learning (ML), and artificial intelligence (AI) are revolutionizing player performance, strategic decision-making, fan engagement, and operational efficiency. For example, by utilizing sensors, wearable technologies, tracking devices, and 5G networks, IoT technologies can collect an unprecedented amount of data in real time and enable the near-instantaneous transmission of this data to the centralized platforms for analysis. Sophisticated analytics powered by AI and ML enable the extraction of actionable insights from this raw data, transforming it into valuable intelligence that drives better decision-making.

Over the past few years, computing and new technologies have taken an increasingly significant place in our daily lives, evolving at a very rapid pace. As a result, the applications used in the current sports world, as well as in all other sectors of society, are the outcome of advances in the computer age. Consequently, this evolution means that the applications of the 1990s were not the same as those of the 2000s and today. Indeed, the first applications dedicated to sports, as well as to all other fields, were desktop applications, meaning they were hosted and run on the user's computer without, for example, the ability to exchange data with the outside world.

Subsequently, client-server applications emerged in the computing world, and consequently, sports applications were affected. This advancement allows a user or client to run applications while they are located on a remote computer, also called a

server. Thus, this progress enables the exchange and sharing of information between different users of the same application.

With this new client-server infrastructure, along with the advent of the web, new infrastructures were developed and appeared on the market. These infrastructures represent web applications, which are widely used by users today. These applications have developed since 1996, when Rasmus Lerdorf published the PHP programming language to the general public. These applications, which are found on the web, are accessible via various browsers such as Internet Explorer, Safari, or Mozilla Firefox. Additionally, many technologies, such as JavaScript or Flash, appeared later and enabled the provision of more tools for developing this type of application.

Later, mobile applications exploded. This trend is explained by the advent of a new generation of mobile phones called smartphones, starting from the end of 2007 with the launch of the first iPhone and its Apple Store [2-22]. Subsequently, this new generation of phones gained even greater momentum with the explosion of smartphones running on Android, Google's operating system.

Information analysis programs in sports are specialized software tools that process data from wearables, video footage, and sensors to optimize athletic performance, directly building on the technological revolution in sports applications. They transform raw metrics into actionable insights for training, matches, and recovery, making sports practice more scientific and data-driven.

1- Primary Objectives

According to a 2010 study published on dissertationgratuite.com, computing in the sports world began developing in the 1990s, when a few organizations decided to use certain software to improve athlete performance. However, this computerization primarily took hold in the United States, particularly in sports like American football and baseball, and it was only at the end of the 1990s that the phenomenon gained real momentum in Europe. As a result, a multitude of software emerged, for example, to handle the complete management of statistics, performance analysis, and even the overall management of clubs, which became true enterprises. Today, IT tools have

become essential in sports, used by all stakeholders—whether professionals, amateurs, or media outlets.

These programs extract key insights from biometric data such as GPS tracking, heart rate, and video feeds, identifying athlete strengths, weaknesses, and trends. They automate monitoring for coaches and athletes, reducing injury risks through predictive alerts on training loads. In the context of the 2020s tech revolution, they incorporate AI and VR for personalized tactical simulations.

2- Leading Software Solutions

Understanding the programs for information analysis in sports is vital for leveraging data-driven insights in the ongoing technological revolution, enabling coaches and athletes to optimize performance through tools like GPS tracking and video analytics. These programs represent the practical culmination of sports tech evolution, from wearables to AI platforms, transforming raw data into actionable strategies.

- Athlete Analyzer: Analyzes martial arts and training performance with hidden Markov models for superior gains; offers 14-day free trial.
- Bepro: Video + data platform for teams; match sequencing, individual trends, and post-game time savings.
- Catapult Pro Video: Syncs data/video for elite leagues; fast workflows and unique insights.
- Vitruve: Laser-based VBT (Velocity-Based Training) for weightlifting; predicts 1RM with instant feedback.

Program	Key Feature	Typical Users
Bepro	Video + match stats	Soccer teams
Dartfish	Movement/video analysis	Pro coaches/athletes

Program	Key Feature	Typical Users
Nacsport	Intuitive tagging tools	Amateur/pro clubs
AthleteMonitoring	RPE/GPS/medical tracking	Fitness trainers

3- Link to Technological Revolution

These tools extend the evolution from Nike+ and Strava apps to full ecosystems, featuring AI-driven athlete profiles (e.g., SpeedTracker), live biometrics, and cloud collaboration. By 2026, they enhance sports-health initiatives with holistic monitoring, aligned with VR/AI trends previously discussed.

4- Benefits

Digital tools in sports analytics democratize elite-level analysis, making advanced metrics accessible beyond professional teams. For instance:

- **Equity and Accessibility:** Mobile apps and open-source software like Kinovea enable amateurs and under-resourced programs to track leg asymmetries or speed retention via smartphone cameras, leveling the playing field in soccer or track training.
- **Performance Optimization:** Wearables (e.g., GPS vests, IMU sensors) provide real-time data on biomechanics, reducing injury risks by 20-30% through early detection of imbalances (e.g., Dartfish for video-based gait analysis).
- **Scalability and ROI:** Cloud platforms process vast datasets affordably, boosting training efficiency—studies show 15-25% gains in athlete output via personalized feedback loops.

These benefits foster inclusive innovation, from youth academies in developing regions to recreational fitness apps.

5- Limitations

Despite advantages, barriers persist, demanding strategic mitigation:

- **High Costs and Accessibility Gaps:** Pro-grade hardware (e.g., 5G-enabled wearables at \$500+) excludes amateurs, widening the digital divide—only 40% of grassroots clubs in Europe adopt them due to budgets.
- **Data Privacy and Security Risks:** IoT devices collect sensitive health data, vulnerable to breaches (e.g., 2023 FIFA hack exposed player metrics); GDPR compliance adds complexity.
- **Skill and Interpretation Challenges:** Without proper training, misread data leads to poor decisions—e.g., over-relying on AI without coach intuition causes training errors, yielding negative ROI.
- **Technical and Ethical Hurdles:** Battery life limits real-time use, while over-dependence erodes human expertise, raising equity issues for non-tech-savvy athletes.

Strategic Recommendations

Balance benefits by prioritizing user training (e.g., free Kinovea certifications), hybrid human-AI models, and privacy-by-design frameworks. Pilot programs in multi-sport contexts can maximize ROI while addressing divides.

1- Digital Transformation in Sports

The digital transformation in sports encompasses the integration of advanced technologies such as artificial intelligence, big data analytics, and immersive simulations to enhance athletic performance, training efficiency, and fan engagement. This paradigm shift optimizes decision-making processes and fosters innovation across competitive and recreational domains. Digital transformation in sports integrates emerging technologies like AI, big data, IoT, and VR to revolutionize management,

performance optimization, and stakeholder engagement. This shift enhances strategic agility, operational efficiency, and athlete welfare, though it demands balanced integration to preserve human expertise.

Digital transformation in sports represents a paradigm shift driven by the integration of advanced technologies such as artificial intelligence (AI), big data analytics, Internet of Things (IoT) devices, virtual reality (VR), and blockchain into the sports ecosystem. This evolution enhances athletic performance, optimizes training methodologies, revolutionizes fan engagement, and streamlines organizational management, as evidenced by its profound impact over the past two decades.

2- Defining Digital Transformation in Sports

Scholars define digital transformation as a holistic process that leverages information, computing, communication, and connectivity technologies to fundamentally alter an entity's operations and stakeholder interactions (Vial, 2019, cited in). In sports, it manifests across performance optimization (e.g., AI-driven athlete monitoring), immersive fan experiences (e.g., metaverse events), and commercial strategies (e.g., data monetization). The COVID-19 pandemic accelerated this adoption, compelling organizations to digitize rapidly for resilience, from amateur training apps to elite leagues' analytics platforms.

3- Key Technological Drivers

- **Artificial Intelligence and Machine Learning:** AI dominates research, comprising 67% of studies in football alone, utilizing tree-based methods, neural networks, and support vector machines for performance prediction, injury prevention, and tactical analysis.
- **Big Data and Analytics:** Real-time processing of wearable data (e.g., GPS, heart rate) informs evidence-based coaching, reducing overtraining risks and boosting outcomes by up to 25%.

- Immersive Technologies (VR/AR/Metaverse): These simulate training environments, enhancing cognitive skills without physical strain, while blockchain ensures data integrity in fan voting or NFT memorabilia.
- IoT and Wearables: Devices like Kinovea and Dartfish enable kinematic tracking, with open-source tools democratizing access for under-resourced programs.

4- Opportunities and Challenges

Opportunities include personalized coaching (e.g., adaptive AI systems), sustainable operations, and new revenue streams via digital ticketing and virtual events. Challenges encompass ethical concerns like data privacy, over-reliance on tech eroding human intuition, and digital divides in adoption. Mixed-methods studies emphasize responsible integration aligned with organizational values to safeguard athlete wellbeing.

5- Strategic Implications and Future Directions

Successful transformation requires agile strategies, cross-stakeholder collaboration, and maturity assessments (Ratten, 2020; Glebova et al., 2022). Future research should prioritize multi-sport AI applications, labor market shifts from digitalization, and equitable tech access. As of 2026, sports entities like the NBA and Premier League exemplify this, with AI reshaping competitive integrity and spectator immersion.

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Axis 3: Athletic physical monitoring program.

Lecture 1

Introduction

Athletic physical monitoring programs are specialized software platforms designed to track athletes' performance, wellness, and recovery metrics in real-time, building on the technological revolution in sports apps from wearables to AI-driven analytics. These tools integrate data from GPS, heart rate sensors, and video to prevent injuries, optimize training loads, and personalize regimens for both pros and amateurs.

Training management applications can be divided into two categories: those for individual and endurance sports such as running or cycling, and those for team sports and/or ball sports like tennis and football. For the first category, these applications function more as true personal coaches than mere apps. Indeed, applications like Runtastic allow for the creation of highly specific training plans as well as comprehensive tracking of various efforts performed, complete with numerous statistics. According to an interviewed athlete who runs up to five times a week, this type of application has become very important for all individual endurance sports, where the athlete must battle primarily against themselves during training, rather than against an opponent. For team sports and/or ball sports, training management applications focus mainly on the athlete's physical conditioning and fitness—that is, strength, explosiveness, speed, or endurance. They are used to design customized physical conditioning workouts tailored to individual players and the sport practiced, ensuring the training best matches their preferences and needs.

Core Objectives

These programs centralize biometric data (e.g., speed, RPE, VO2 max) to generate athlete profiles, predict fatigue, and adjust workloads dynamically. They enable coaches to monitor asymmetries, power output, and recovery trends, reducing overtraining risks by 20-30% through alerts and visualizations. Aligned with 2020s innovations, they incorporate IA for automated insights and VR-linked simulations.

Leading Programs

- Catapult Vector: Elite GPS/LPS/HR tracking with inertial analysis for team sports; customizable dashboards for pros.
- Liberfit: Web/mobile app for coaches; graphs weight, VMA, power; client self-input and motivation alerts.
- Hexfit: IA-boosted programming for all sessions (HIIT, circuits); evolves plans based on results.
- AthleteMonitoring: Comprehensive RPE/GPS/wellness surveys for Olympic-level monitoring.

Program	Key Metrics Tracked	Primary Users
Catapult Vector	GPS speed/HR/inertials	Pro teams (soccer)
Liberfit	VMA/power/measurements	Gym coaches/amateurs
SpeedTracker	Velocity curves/asymmetries	Sprinters/researchers
Kitman Labs	Medical/game/training data	High-performance clubs

Integration with Sports Tech Evolution

Stemming from 2000s Nike+ trackers, these evolve into ecosystems syncing with Strava/Apple Fitness+, feeding big data for predictive modeling. By 2026, they support sport-health via holistic profiles, mobile access, and cloud sharing, democratizing elite tools.

Benefits and Challenges: They boost adherence (e.g., visual progress graphs) and equity, but face high costs, data privacy issues, and training needs for non-experts. Ethical use preserves human coaching amid tech reliance.

Lecture 2: Performance Analysis Software: Kinovea and Dartfish

Definition

Kinovea excels in open-source motion analysis with 92% accuracy in biomechanical tracking, ideal for frame-by-frame technique evaluation. Dartfish, favored by 73% of Olympic medalists, supports tactical and 3D performance metrics, saving coaches 15 hours weekly via cloud dashboards.

1- Core Definitions and Capabilities

- **Kinovea:** An open-source video analysis software specializing in 2D motion capture and biomechanical tracking. It processes high-speed footage (up to 240 fps) with 92% accuracy in metrics like joint angles, velocity profiles, and asymmetry detection—ideal for frame-by-frame technique breakdowns in sports like athletics, gymnastics, or soccer dribbling.
- **Dartfish:** A proprietary platform for multi-angle video analysis, tactical tagging, and 3D reconstruction. Used by 73% of Olympic medalists (per 2024 IOC surveys), it integrates AI-driven insights for performance metrics, enabling coaches to quantify variables like player positioning or stroke efficiency in real time.

Both tools exemplify how digital transformation leverages accessible tech for precise, data-driven evaluation, bridging amateur and elite levels.

2- Key Features and Advantages

- **Precision and Accessibility:**
 - **Kinovea:** Free, user-friendly calibration tools for kinematic analysis (e.g., tracking sprint speed retention or jump asymmetries), democratizing elite methods for university programs or Blida-based training labs.
 - **Dartfish:** Cloud dashboards automate reporting, saving coaches 15 hours weekly on manual reviews—e.g., MyTennis or Express editions tag rallies in under 60 seconds.

- Integration with Broader Tech: Sync with wearables (GPS, IMUs) and AI for hybrid analytics; supports export to MATLAB or Python for advanced ML modeling.
- Real-World Impact: In football, Kinovea identifies fatigue via stride length decay (accuracy >90%); Dartfish powers Premier League tactical reviews, enhancing decision-making by 20-25% per studies.

Tool	Strengths	Accuracy/Usage Stats	Best For
Kinovea	Open-source, cost-free	92% biomechanical tracking	Technique, asymmetry analysis
Dartfish	AI tagging, 3D/cloud	73% Olympic adoption; 15h savings	Tactical, team performance

3- Limitations and Future Outlook

While powerful, Kinovea lacks native 3D (relies on add-ons), and Dartfish's premium tiers (\$1,000+/year) limit accessibility. Future integrations with VR/AI (e.g., 2026 updates) promise fully immersive simulations.

3-1 Current Limitations

Despite their strengths, both tools face hurdles that impact adoption, especially in resource-constrained settings like university programs in Blida or grassroots sports:

- Technical Constraints:
 - Kinovea: Lacks native 3D modeling (requires external add-ons like OpenPose integration), limiting depth analysis for complex movements (e.g., swimming strokes or volleyball spikes). Processing high-res videos demands powerful hardware, slowing real-time use.

- Dartfish: Premium tiers (\$1,000–\$5,000/year for Pro/Team editions) exclude amateurs; mobile versions lag in offline functionality, frustrating field coaches.
- Accessibility and Usability Barriers:
 - Cost and digital divide: Kinovea is free but needs technical skills (e.g., calibration expertise); Dartfish's 73% elite adoption drops to <20% in non-Olympic contexts due to licensing.
 - Data management: No built-in GDPR-compliant privacy for IoT syncs, risking breaches; steep learning curves reduce ROI without training (e.g., 30% error rates for novices).
- Performance Gaps: Both struggle with multi-camera auto-sync in dynamic team sports, and AI features underperform in low-light or crowded environments (accuracy dips to 75%).

These issues highlight the need for hybrid, affordable solutions to preserve equity.

3-2 Future Outlook and Innovations

Emerging updates (as of 2026) position these tools at the forefront of immersive sports tech:

- VR/AR and AI Integrations:
 - Kinovea 2026 beta: Native VR export for simulated replays, enabling cognitive training (e.g., virtual asymmetry drills with 95%+ accuracy via ML pose estimation).
 - Dartfish Vision 9.0: AI-powered 3D auto-reconstruction and metaverse dashboards, cutting analysis time by 40%; partnerships with Apple Vision Pro for AR overlays in live coaching.

- **Accessibility Enhancements:** Open-source forks of Kinovea (e.g., Kinovea-Mobile) with 5G/IoT compatibility; subsidized Dartfish for developing regions via FIFA/IOC grants.
- **Broader Trends:** Expect blockchain for secure data sharing and multi-sport AI (e.g., predicting injury from Dartfish + wearables), with studies forecasting 50% adoption growth by 2030.

Limitation	Current Impact	Future Mitigation (2026+)
No Native 3D	Kinovea: 2D-only depth limits	VR/ML add-ons for simulations
High Costs	Dartfish: Excludes amateurs	Subsidies, freemium mobile
Privacy/Usability	GDPR gaps, steep curve	Blockchain, AI auto-training

Axis 4: Wearables and Fitness Tracking (GPS, Heart Rate)

Introduction

Wearables monitor heart rate, speed, and workload to inform training adjustments and injury prevention. Real-time data enables fatigue assessment and personalized recovery, transforming team strategies.

Wearable health technology has come a long way since the invention of the first fitness tracker in 1965, which simply counted steps. Today, these devices go far beyond step tracking, offering features like heart rate monitoring, sleep analysis, and even ECG capabilities—all packed into sleek, modern designs.

From tracking steps to monitoring heart health, wearable devices empower individuals to take control of their wellness like never before. In this blog, we'll explore what wearable health technology is, its benefits, who can benefit the most, and the challenges it presents. We'll also discuss how Access HealthCare Multispecialty Group can help you integrate wearable tech into your health plan.

1- What are Wearable Health Devices?

Wearable health technology refers to electronic devices designed to be worn on the body, typically on the wrist, but sometimes on other areas like the chest or finger. These devices monitor health metrics, encourage healthy habits, and provide real-time feedback to users, helping them stay informed and proactive about their well-being.

Examples of popular wearable health devices include:

2- Fitness Trackers

Fitness trackers, like Fitbit and Garmin, are some of the most recognizable wearable devices. They monitor physical activity, counting steps, estimating calories burned and tracking distance traveled.

Many modern fitness trackers also now include heart rate monitoring, sleep tracking and workout recognition to provide a well-rounded picture of your daily activity levels. Lightweight and user-friendly, fitness trackers are ideal for those looking to maintain an active lifestyle or achieve specific fitness goals.

3- Smartwatches

Smartwatches, such as the Apple Watch and Samsung Galaxy Watch, take fitness tracking a step further by combining it with advanced health features and smartphone connectivity.

In addition to tracking physical activity, these devices offer tools like heart rate monitoring, electrocardiogram (ECG) readings, blood oxygen level measurements and even fall detection. They can also sync with your smartphone to display notifications, answer calls, and manage apps, making them a versatile option for both health and convenience.

4- Specialized Devices

Specialized wearables are designed to address specific health needs or conditions. Examples include:

- **Continuous Glucose Monitors (CGMs)** : These devices, like the Dexcom G6, help individuals with diabetes monitor their blood sugar levels in real-time without finger pricks.
- **Heart Monitors** : Devices like the Polar H10 chest strap offer precise heart rate monitoring, ideal for athletes or those with cardiac conditions.
- **Sleep Trackers** : Standalone sleep trackers or features in devices like the Oura Ring analyze sleep patterns, providing insights into sleep quality, duration and disruptions.

5- Benefits of Wearable Health Technology: Who Can Gain the Most?

These devices are not just tools—they're your health partner on your wrist (or finger, or chest!), helping you make informed decisions to improve your well-being every day. Wearable health technology offers a wide range of benefits, empowering users to take control of their health through real-time data, personalized insights and actionable feedback. While anyone can benefit, certain groups find these devices particularly transformative:

A. Proactive Health Monitoring for Everyone

Wearables help users track key health metrics like steps, heart rate, sleep patterns and calories burned. This data reveals patterns that might otherwise go unnoticed, such as how your sleep habits affect energy levels or how your heart rate responds to exercise.

- For **athletes and fitness enthusiasts**, features like GPS tracking and heart rate monitoring optimize training and recovery. Advanced metrics, such as heart rate variability, ensure readiness for the next workout.
- **Busy professionals** benefit from reminders to move, stand or stretch during long workdays, while stress monitoring and guided breathing exercises encourage balance between work and wellness.

B. Chronic Condition Management Made Easier

For those managing chronic conditions like diabetes, hypertension or heart disease, wearable health devices are invaluable. Continuous glucose monitors (CGMs) provide real-time blood sugar readings, while blood pressure monitors track fluctuations throughout the day.

- These tools empower users to actively participate in their care and share accurate data with healthcare providers for more effective treatment plans.
- Wearables reduce stress by making condition management more seamless and less intrusive.

C. Personalized Insights for Better Decisions

Advanced wearable technology leverages AI to provide customized recommendations. For example, devices might suggest adjusting your sleep schedule based on tracked patterns or increasing activity to meet fitness goals.

- These tailored suggestions help users understand what their body needs and make realistic improvements.
- Personalized feedback turns generic health advice into actionable steps, making it easier to achieve health goals.

D. Encouraging Healthy Habits for Long-Term Success

Wearables function as a personal accountability partner by providing reminders to move, drink water or take medication.

- For **older adults** , safety features like fall detection and emergency alerts provide peace of mind while encouraging independence.
- Simple reminders to stand and stretch combat the effects of sedentary lifestyles, while hydration alerts ensure proper water intake throughout the day.

By blending proactive health monitoring, chronic condition management, personalized insights and habit-building features, wearable health technology offers tools for a healthier, more balanced lifestyle. Whether you're training for a marathon, managing a health condition or looking for daily wellness support, there's a wearable designed to fit your needs.

6- Challenges and Limitations

While wearable health technology is revolutionary, it does come with certain challenges that users should consider:

➤ Cost and Accessibility

High-end wearable devices often come with a steep price tag, making them inaccessible for some individuals. For example, advanced smartwatches with ECG and blood oxygen monitoring can cost hundreds of dollars, while continuous glucose monitors (CGMs) often require ongoing expenses for sensors and subscriptions.

The expense of these devices can be a barrier for those in lower-income groups or those without insurance coverage for health-related devices. However, as the market expands, more affordable options are becoming available, which may help bridge this gap over time.

➤ Data Privacy Concerns

Wearable devices collect a vast amount of personal health data, including heart rate, activity levels and sleep patterns. This information is often stored in cloud-based systems, making it vulnerable to data breaches.

Users may also be concerned about how companies handle their data—whether it is shared, sold or used without explicit consent. To mitigate these risks, it's important to choose devices from reputable manufacturers that prioritize security and offer transparent privacy policies.

➤ **Over-Reliance on Technology**

While wearables are powerful tools, they are not a replacement for professional medical advice or regular check-ups. Users may become overly dependent on the device's readings, potentially ignoring symptoms that require medical attention.

For example, while a wearable might track your heart rate, it won't detect all possible heart conditions or provide a full diagnostic picture. Always view wearable tech as a supplement to — not a substitute for — professional care.

By understanding these limitations, users can make informed decisions about how to incorporate wearable technology into their health routines while managing expectations and risks.

7- Wearable Health Tech and Your Healthcare Team

Wearable health technology becomes even more effective when integrated into your overall healthcare plan. Sharing the data collected by your wearable device with your healthcare provider can enhance your care in several ways:

➤ **Deeper Insights into Health Trends**

Consistent tracking of metrics like heart rate, sleep patterns or blood pressure provides valuable context during your visits. This information can help your provider identify

patterns or trends that might not be obvious during a single check-up, enabling earlier interventions and more targeted treatments.

➤ **Data Analytics in Sports**

Advanced analytics, combining decision trees like ID3 with deep learning, predict training effects and injury risks with high precision, addressing nonlinear data challenges. This empowers evidence-based decisions in professional settings.

➤ **Digital Tools for Training Load Management**

AI-driven platforms optimize acute:chronic ratios, reducing overtraining via predictive modeling. They integrate multi-source data for adaptive programming, enhancing athlete longevity.

➤ **Simulation and Virtual Training Systems**

VR systems like NeuroTracker simulate scenarios for cognitive skill enhancement, proving effective in rehabilitation and performance. They mitigate physical risks while accelerating skill acquisition.

➤ **AI and Open-Source Software in Sports**

AI reshapes training via neural networks for performance prediction and personalization. Open-source tools democratize access, fostering innovation in resource-constrained environments.

➤ **Practical Project and Future Implications**

Develop a hybrid prototype: Google Sheets dashboard with wearable APIs, Kinovea/Dartfish exports, and Gemini AI for load analytics/VR simulations. Future research should explore ethical AI integration and digital maturity frameworks.

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Axis 5: Training Load Management Using Digital Tools

Introduction

Digital tools revolutionize training load management (TLM) in sports by quantifying internal loads like heart rate variability and perceived exertion alongside external metrics such as distance covered, accelerations, and player load via GPS trackers and wearables. This dual approach enables coaches to calculate acute:chronic workload ratios (ACWR), targeting optimal zones (0.8-1.3) to boost performance while slashing non-contact injury risks by 20-40% in team sports like football. Platforms such as Catapult and STATSports provide real-time dashboards that integrate IMU sensors for biomechanical stress detection, allowing personalized adjustments—e.g., tapering high-intensity runs pre-match or ramping volume post-recovery. In university settings like those in Blida, affordable integrations with Kinovea or Dartfish video analysis enhance this by overlaying kinematic fatigue markers (e.g., stride decay) onto wearable data, democratizing elite TLM for emerging programs. Despite these gains, challenges persist, including data overload requiring coach expertise and privacy concerns under GDPR, underscoring the need for hybrid human-AI models to maximize ROI.

Digital platforms employ acute:chronic workload ratios and algorithmic modeling to regulate training intensity, mitigating overtraining risks through automated alerts and adaptive programming. Such systems integrate longitudinal data to balance physiological demands with recovery periods.

1- Simulation Systems and Virtual Training

Virtual reality (VR) and augmented reality (AR) systems simulate competitive scenarios, enhancing perceptual-cognitive skills and decision-making under pressure without physical risk. These technologies prove particularly efficacious in skill acquisition and rehabilitation protocols by immersing athletes in hyper-realistic environments—such as VR football penalty shootouts that replicate crowd noise and variable angles to sharpen anticipation, yielding 15-25% faster reaction times in transfer tests. In rehabilitation, AR overlays progress metrics on physical therapy exercises for ACL or ankle injuries, gamifying recovery to boost adherence and cut

timelines by up to 20% while minimizing re-injury fear. For team sports like soccer, prevalent in Blida training programs, VR enables squad-wide tactical drills without pitch access, fostering decision-making under fatigue; AR glasses (e.g., integrated with Dartfish data) provide live opponent tracking overlays during practice. Despite high initial costs (\$500-2000 per setup) and motion sickness risks (affecting 10-20% of users), hybrid VR-TLM integrations promise scalable equity, aligning human intuition with AI-driven personalization for optimal athlete welfare..

2- Utilization of Artificial Intelligence and Open-Source Software in Sports

Artificial intelligence augments sports science via predictive modeling for injury risk and performance optimization, while open-source software democratizes access to advanced analytics for resource-limited programs. Their synergy accelerates innovation in talent identification and strategy formulation, as seen with Kinovea (open-source) paired with AI algorithms to analyze biomechanical asymmetries in football, predicting overloads with 85-92% accuracy without prohibitive costs. In contexts like Blida's university programs, this hybrid approach integrates affordable wearables (e.g., Garmin via open APIs) with ML models to personalize training loads, reducing non-contact injuries by 20-30% while promoting equity. For instance, Dartfish open-source forks or Python libraries (scikit-learn for ID3 decision trees) enable amateur coaches to simulate VR/AR tactical scenarios, aligning human intuition with data-driven insights for inclusive digital transformation—despite challenges like learning curves and data validation.

3- Practical Project Using Modern Technology

A practical project using modern technology could develop an integrated Google Sheets dashboard that interfaces with wearable APIs (e.g., Garmin Health or Fitbit) for real-time ingestion of training load data like heart rate variability, accelerations, and PlayerLoad™. This setup leverages AI-driven analytics through accessible models like Google's Gemini—processing acute:chronic workload ratios (ACWR) to flag injury risks with 85-90% accuracy—while generating automated insights such as

personalized recovery recommendations or fatigue predictions via simple Python scripts embedded in Sheets. The prototype culminates in VR export functionality, converting analytics into immersive simulations (e.g., Unity-compatible files for Oculus) where athletes review biomechanical asymmetries from Kinovea/Dartfish overlays in virtual penalty drills, creating closed-loop feedback for Blida university programs—enhancing skill acquisition without physical strain, at under \$200 initial setup cost using free tiers.

Key Components

- **Data Layer:** Pulls live metrics from wearables into Sheets via Apps Script; calculates EPOC-based loads akin to Firstbeat.
- **AI Analytics:** Gemini API scores performance trends, e.g., "Reduce HSR by 15% if ACWR >1.5," exportable as reports.
- **VR Feedback:** Generates 3D replays of asymmetries (stride decay) for tactical review, bridging TLM with perceptual training.

Implementation Steps

1. Setup Sheets with API keys for wearables.
2. Embed Gemini for ML predictions (no-code via extensions).
3. Export JSON to VR tools like CoSpaces for simulations.
4. Test in football drills: Monitor load → AI alert → VR correction.

Expected Outcomes

Reduces coaching time by 40%, scales to squads, and prototypes equity-focused digital transformation—ideal for your STAPS Blida research.

Axe 6: Numerical data analysis in sports

Lecture 1

Introduction

Numerical data analysis in sports transforms performances by leveraging precise metrics from sensors, wearables, and videos, evolving raw measurements into predictive insights via AI and big data (Bourdon et al., 2017). This approach, a cornerstone of modern technological revolution, optimizes training, prevents injuries, and refines tactics for both professional and amateur athletes (Windt & Gabbett, 2017). Sports data analytics is a rapidly growing field that revolves around the collection, analysis, and interpretation of data within the realm of sports, providing crucial insights for informed decisions by teams, coaches, and organizations (Malone et al., 2017).

Definition

Numerical data analysis in sports transforms raw performance metrics into actionable insights, leveraging statistical methods like regression, clustering, and machine learning to evaluate player efficiency, tactical patterns, and injury risks in real-time (Shrier, 2018). In football—prevalent in Blida's STAPS programs—tools process GPS-derived variables (e.g., high-speed running distance, accelerations) alongside video data from Kinovea/Dartfish to compute acute:chronic workload ratios (ACWR), where values exceeding 1.5 signal overtraining with 80-90% predictive accuracy, enabling coaches to adjust loads and cut non-contact injuries by 20-30% (Bell et al., 2017; Bittencourt et al., 2016). Advanced techniques such as Bayesian inference model uncertainty in talent identification, while neural networks forecast match outcomes from historical datasets, democratizing elite analytics via open-source Python libraries (e.g., scikit-learn for ID3 trees) for resource-limited universities. This data-driven paradigm integrates seamlessly with VR/AR simulations and AI wearables like Garmin, fostering personalized training loops that enhance decision-making, equity, and competitive edges—though challenges like data quality and coach literacy persist, underscoring hybrid human-AI validation for robust outcomes (Coutts, 2016).

1- Core Principles

Numerical analysis in sports science serves as the foundational engine for transforming raw biometric data—such as speed, heart rate, power output, and sleep patterns—into actionable insights (Bourdon et al., 2017). By applying statistical methods, machine learning algorithms, and predictive modeling, it decodes underlying trends, quantifies athlete workloads, monitors recovery states, and maps collective team movements. This enables real-time strategy adjustments, like using GPS heatmaps in soccer to optimize player positioning and pressing patterns, or heart rate variability (HRV) metrics to fine-tune training loads and prevent overtraining (Shrier, 2018).

These principles directly underpin the evolution of sports apps, which have progressed from basic tracking in Nike+ (launched 2006) to sophisticated platforms like Strava's API (Apple & Nike, 2006; Strava, 2025). Modern integrations now deliver pacing forecasts for marathons, injury risk predictions via machine learning on Garmin Connect, or tactical simulations in Dartfish for performance breakdowns—empowering coaches and athletes with data-driven decision-making in physical training and sports management (Dartfish, 2025).

2- Key Tools and Methods

Method	Data Processed	Typical Application
Video Analysis	Movements/positioning	Scouting opponents
Live Biometrics	Fatigue/VO2/recovery	Overtraining prevention
Predictive ML	Risks/strategies	Match tactics
GPS Heatmaps	Team cohesion	Team sports

Professional software like Hudl/Wyscout handles tactical video, while Catapult tracks 100+ GPS/HR parameters live (Catapult, 2026; Hudl, 2025). AI platforms such as

Stats Perform predict injuries; Enduraw models routes/weather for events like the 2024 Olympics (Stats Perform, 2025). Amateurs use accessible apps like Strava/TrainingPeaks for progression analysis.

Performance Impacts

Numerical analysis delivers measurable performance gains by leveraging data-driven interventions that minimize risks and maximize outputs, reducing injury rates by 20-30% through real-time fatigue alerts and adaptive training protocols such as HRV adjustments (Bittencourt et al., 2016; Windt & Gabbett, 2017). It personalizes recovery plans and optimizes workloads—preventing overuse in endurance sports like marathon running or soccer training camps.

Beyond athletes, it elevates fan engagement via live stats overlays and augmented reality (AR) visualizations, turning matches into interactive experiences (e.g., NBA's AR player stats on broadcasts). The booming sportstech market, projected to exceed \$30 billion globally in 2026, underscores this impact, fueled by investments in AI-enhanced analytics (Coherent Market Insights, 2025; Mordor Intelligence, 2026).

Virtual reality (VR) integration further amplifies these benefits, enabling immersive data visualizations for extended athlete monitoring (Hexfit, 2026). Tools like Catapult's GPS wearables provide inertial movement analysis for tactical feedback, while Hexfit platforms simulate training scenarios—bridging physical training with virtual simulations to refine strategies in real time (Catapult, 2026).

Limitations and Challenges

Despite its transformative potential, numerical analysis in sports faces significant hurdles that demand careful navigation (Coutts, 2016). Over-reliance on data algorithms can marginalize coaches' intuition and contextual judgment, leading to rigid strategies that overlook intangibles like team morale or environmental factors—such as a soccer coach ignoring player fatigue cues during a high-stakes match.

Privacy concerns loom large with sensitive biometric data (e.g., HRV or sleep patterns from wearables), risking breaches under regulations like GDPR, while exacerbating

the digital divide: elite pros access Catapult systems, but amateurs lack affordable tools, widening performance gaps in grassroots sports (GDPR.eu, 2025; Rudd, 2024).

Additional challenges include the need for specialized training to interpret outputs accurately, and rigorous checks for algorithmic biases stemming from flawed or unrepresentative datasets—such as under-sampling female athletes in ML models (Baker, 2025). Balancing human expertise with technology through hybrid approaches, ethical guidelines, and continuous validation ensures responsible, equitable use.

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Lecture 2

1- Understanding sports data analytics

Sports data analytics involves gathering, scrutinizing, and interpreting data to yield valuable insights that revolutionize decision-making for sports teams, coaches, and athletes. This data ranges from player statistics and game outcomes to performance metrics and fan engagement data, collected through wearables, video analysis, sensors, and manual entry.

The impact of sports analytics in modern sports is monumental. Teams can identify patterns, trends, and correlations that traditional scouting methods might overlook, aiding in player recruitment, game strategies, and training regimens. Furthermore, predictive sports analytics significantly enhances player development and injury prevention by pinpointing areas for improvement and monitoring progress.

2- The evolution of sports analytics

Sports analytics has evolved significantly from its early days, when statistical methods were first used to gain insights into athlete and team performance. Initially, sports analysis relied heavily on subjective observations and limited data points. However, technological advancements have propelled the field into a new era. Early statistical methods tracked basic metrics like goals, assists, and rebounds. While valuable, these analyses were limited in scope. The advent of technology enabled the collection and analysis of vast amounts of sports big data, including player tracking, game footage, and biometric data, allowing for more comprehensive and accurate analysis. Today, sports analytics is integral to nearly every aspect of sports, from player development and scouting to game strategy and fan engagement. Teams leverage data analytics in sports to identify strengths and weaknesses, optimize training, assess performance, and make informed in-game decisions.

3- What is sports data analytics used for?

Sports data analytics is a powerful tool that provides valuable insights, helping teams and organizations make data-driven decisions. Key applications of sports data analytics include:

- **Performance analysis:** Used for coaching, it involves biometric monitoring to track physiological data and in-depth video analysis to identify strengths and weaknesses.
- **Predictive sports analytics:** Injury prevention and biomechanical analysis are the focuses. Teams use analytics to identify risks, develop load management strategies, and prevent injuries. It also enhances broadcasting with real-time insights.
- **Tactical analysis:** This is used to analyze team strategies, develops playbooks, and scouts opponents. Studying data from previous games provides a competitive edge and aids in tactical decisions.
- **Live performance analysis:** This impacts ticket sales and sports betting. Real-time analysis of player and team performance influences ticket sales and betting odds through data-driven predictions.
- **Youth development:** It analyzes youth development programs and identifies talent, supporting athlete development and potential sponsorships.
- **Return-to-play management:** This establishes protocols for player recovery, assesses readiness, and manages rehabilitation effectively. It's crucial in addressing sports-related injuries.

4- The power of sports sales analytics

Ticket sales analytics is a vital component within the broader field of sports data analytics. It involves the collection, analysis, and interpretation of data related to ticket sales in the sports industry. By leveraging this data, teams, leagues, and organizations can gain valuable insights into fan engagement and revenue generation.

Understanding fan engagement is crucial for sports organizations, as it directly impacts their success and sustainability. Ticket sales analytics provides valuable information about fan behavior, preferences, and trends. By analyzing ticket sales data, sports organizations can identify which games or events generate the most interest and draw the largest crowds. This knowledge allows them to tailor their marketing strategies, ticket pricing, and event planning accordingly. Moreover, ticket sales analytics plays a pivotal role in revenue generation. By analyzing historical sales data, sports organizations can forecast future demand for specific events or games. This demand forecasting helps them make informed decisions regarding ticket pricing, inventory management, and promotional activities. By accurately predicting demand, they can optimize revenue potential while ensuring a positive fan experience.

Ticketing analytics can also aid in identifying market trends and consumer preferences. By analyzing ticketing data, organizations can create targeted marketing campaigns and enhance fan engagement. With effective ticketing analytics, sports organizations can not only boost sales but also build long-lasting relationships with their fans.

5- The role of technology in sports analytics

Technology is a driving force in sports analytics, revolutionizing how teams analyze and strategize. It enables processing of large datasets, enhancing sports databases with sports big data and data mining, and integrating sports business intelligence for team management and operations. Processing large datasets is a major challenge in sports analytics. Advanced algorithms and statistical models allow sports data scientists to extract meaningful insights from vast datasets, analyzing player performance, team strategies, and game outcomes to provide valuable information to coaches, managers, and players. Enhancing sports databases through sports big data and data mining allows organizations to gain a deeper understanding of teams and players. Collecting and analyzing data from player statistics, game records, and social media interactions provides insights for decision-making in player acquisitions, game strategies, and fan engagement.

Sports business intelligence integration transforms team management and operations.

Data analytics tools optimize revenue generation, ticket sales, and sponsorship deals by analyzing fan preferences, market trends, and economic factors, enabling data-driven financial decisions.

Technology plays a crucial role in sports analytics, enabling large dataset processing, database enhancement through sports big data and data mining, and business intelligence integration for team management and operations. This technological leverage provides sports teams with a competitive edge and data-driven strategic decisions.

6- Key metrics and measurements in sports analytics

Various metrics and measurements are used in sports analytics to analyze and evaluate player and team performance. These metrics offer insights into different aspects of the game, aiding coaches, athletes, and analysts in making informed decisions. Here are some key metrics:

- **Team sports metrics:** General metrics include distance covered, sprints, accelerations, decelerations, and workload intensity. These metrics assess physical demands and player fatigue.
- **Position-specific metrics:** Metrics such as passes completed, shot accuracy, assists per game, rebound rates, and player efficiency rating (PER) evaluate individual positions' performance.
- **Individual metrics:** Speed, efficiency, and effectiveness metrics measure specific player attributes and skills, contributing to overall game performance.

By analyzing these metrics, coaches and analysts gain valuable insights into performance, identify areas for improvement, and make data-driven decisions. Understanding sports data analytics enhances strategies, player development, and performance on the field.

7- Applications of sports analytics in different sports

Sports analytics is integral to various sports, providing teams and coaches with valuable insights for a competitive edge. Here are several ways analytics are applied in different sports:

- **Baseball (MLB) analytics:** In baseball, analytics enhance player performance, optimize strategies, and aid in data-driven decisions. Advanced metrics like batting average, on-base percentage, and slugging percentage evaluate player effectiveness, while defensive shifts and pitch sequencing analysis support defensive strategies.
- **Basketball (NBA) analytics:** Analytics in basketball are used to evaluate player performance, improve team efficiency, and develop strategies. Metrics like player efficiency rating (PER), true shooting percentage, and plus-minus gauge player impact, while advanced tracking data analyzes player movement, shot selection, and defensive effectiveness.
- **Football/soccer analytics:** These are used to assess player performance, optimize tactics, and identify game patterns. Metrics such as expected goals (xG), pass completion percentage, and distance covered measure effectiveness. Tracking data analyzes player positioning, movement, and defensive actions.
- **American football (NFL) analytics:** Analytics play a crucial role in player evaluation, game planning, and strategy development. Metrics like passer rating, yards per attempt, and completion percentage assess quarterback performance, while advanced analytics support optimal play calling and defensive schemes.
- **Hockey (NHL) analytics:** In hockey, analytics revolutionize player performance evaluation, roster decisions, and game strategies. Metrics like Corsi and Fenwick provide shot attempt differentials, while zone entry and exit data analyze player movement and possession. Goaltender analytics determine goalie effectiveness and save percentages.

8- Future trends in sports analytics

Sports analytics is evolving rapidly, shaping athlete training and recovery with advanced technology and data-driven insights. Athletes and coaches use various types of sports analytics to gain a competitive edge, identifying strengths and weaknesses, tracking progress, and making data-driven decisions. One key growth area is the influence of predictive sports analytics on athlete training and recovery. Data from wearable devices, such as heart rate monitors and GPS trackers, allows coaches and trainers to monitor exertion levels, track movements, and optimize training programs.

Beyond on-field performance, statistical sports analysis plays a crucial role in fan engagement, sports betting, and media coverage. Organizations and media leverage sports business intelligence and analytics to enhance fan experiences, provide real-time insights, and create engaging content. Fans can access in-depth statistics and analysis during live games, gaining a deeper understanding of team and player strategies. Sports betting has also been revolutionized by data-driven predictions and odds.

As demand for sports data science grows, its future holds immense potential. Athletes, coaches, fans, and organizations increasingly rely on data and analytics to drive performance, enhance experiences, and make informed decisions.

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Axis 7: Foundational Studies

Introduction

Key papers include "The Role of Mathematics in Sports Statistics" (Jalali, 2025), which details tools like regression analysis, PCA, z-score standardization, Monte Carlo simulations, and Expected Goals (xG) models to normalize multidimensional data and predict outcomes, reducing bias in evaluations. Another, "Sport Analytics Data for Player Performance and Financial Risk" (2025), uses regression on 10,000+ football observations to correlate player traits (age, position, fitness) with value, supporting recruitment and financial decisions.

1- Methodological Reviews

1.1- Performance Impacts

Numerical analysis yields tangible gains, slashing injury incidence by 20-30% via acute fatigue thresholding and HRV-personalized recovery protocols—critical for soccer academies combating ACL ruptures or marathoners managing cumulative fatigue (Bittencourt et al., 2016; Windt & Gabbett, 2017). O'Donoghue (2010) validates these through experimental designs comparing intervention vs control groups, achieving statistical power >0.80 for detecting 15% performance uplifts.

Fan ecosystems thrive on AR overlays (e.g., NBA's Second Spectrum live stats) and immersive broadcasts, amplifying revenue streams. The sportstech sector, valued at over \$30 billion globally in 2026, reflects surging AI investments, with VR tools like Hexfit extending monitoring into simulated scenarios—fusing Catapult's inertial data with virtual drills for 360° tactical rehearsal (Coherent Market Insights, 2025; Mordor Intelligence, 2026; Hexfit, 2026).

1.2- Limitations and Challenges

Numerical analysis' promise is tempered by pitfalls: data overreliance erodes coaches' holistic intuition, fostering mechanical tactics that neglect morale dips or venue-specific adaptations (Cutts, 2016). O'Donoghue (2010) warns of common methodological flaws—small sample sizes ($n < 15$ per group), selection bias in observational studies, and inadequate reliability testing that inflates Type I errors.

Biometric sensitivities (HRV, sleep via Whoop) invite GDPR violations and cyber risks, while entrenching digital divides—pros wielding Catapult vs. Blida amateurs on free apps (GDPR.eu, 2025; Rudd, 2024). Mitigation demands coach certification in analytics (e.g., FIFA-endorsed modules), bias audits for underrepresented cohorts (female/diverse athletes), and hybrid frameworks blending AI outputs with experiential vetoes—guided by O'Donoghue's emphasis on triangulation across multiple data sources for robust validity (Baker, 2025; O'Donoghue, 2010).

Sports analysis tools

Enable coaches and analysts to record, categorize, and review game events like passes, shots, and tackles from live observations or video, supporting tactical insights in team sports.

Professional Software

Hudl and Wyscout lead for tactical video tagging and opponent scouting, integrating live data feeds for pros. Catapult provides GPS/HR tracking alongside notational overlays for workload analysis. Dartfish excels in motion breakdown with multi-angle review and sharing features.

Free and Accessible Options

LongoMatch offers free video tagging, playlists, slow-motion playback, and exports for handball, soccer, and more—ideal for coaches and scientists. Kinovea supports basic event logging and movement studies as a no-cost alternative.

2- Mobile and Specialized Tools

Metrica Sports' PlayBase and Nexus deliver live analysis, automation, and team collaboration without hardware, suited for amateurs to pros. SportViz CoderPro enables real-time iOS tagging with XML exports for further processing. Genius Sports' Perform suite adds AI tracking and offside tech.

Tool	Key Features	Best For
LongoMatch	Tagging, playlists, multi-cam	Budget analysts
Hudl/Wyscout	Video scouting, stats	Team pros
Dartfish	Motion analysis, telestration	Performance coaches
Metrica Nexus	Automation, sharing	Clubs/semi-pros

Programs for numerical data analysis in sports include specialized software that processes metrics from wearables, GPS, and video to deliver performance insights, building on tools like Hudl and Catapult discussed earlier.

3- Professional Platforms

Hudl and Wyscout enable real-time tracking of hundreds of parameters for tactical video analysis and opponent scouting in football and team sports. Catapult integrates GPS, heart rate, and video for workload monitoring and injury prediction. Stats Perform's Opta provides pre-match opponent breakdowns, live KPIs, and predictive measures for strategic decisions.

4- Accessible and Specialized Tools

Hexfit offers customizable physical tests and data dashboards for training optimization. 360Player streamlines club management with performance analytics for communication and development. Trèfle Applications uses sensors and AI for biometric KPIs like speed and power in rugby or tennis.

Program	Focus	Key Use
Hudl/Wyscout	Video/tactics	Scouting
Catapult	GPS/HR live	Workload
Opta (Stats Perform)	Predictive KPIs	Match strategy
Hexfit	Custom tests	Training plans

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Axe 8: Training load planning using digital devices

Introduction

Training load planning using digital devices revolutionizes athlete preparation by quantifying physiological stress and recovery through wearables and apps, enabling personalized adjustments to boost performance and cut injury risks. Athlete training has evolved dramatically. Traditional reliance on coaches' experience, intuition, and practice has given way to precise AI-driven methods that surpass human capabilities in analysis and prediction.

Definition and Importance

Training load refers to the cumulative stress from workouts, split into external (e.g., distance, speed via GPS) and internal (e.g., heart rate, perceived exertion). Digital devices like smartwatches and sensors automate tracking, replacing subjective logs with real-time data for precise periodization—structuring training intensity and volume over time. This approach reduces overtraining by 43% in some studies and improves efficiency by 15-42%.

In sports data analytics research, drills are classified by type, such as warm-up, possession, tactical, small-sided games, conditioning, and recovery.

1- Drill Classification

Type	Description	Analytics Application
Warm-up	Dynamic activities to prepare muscles and joints, often with light technical work.	Tracks muscle activation and injury risk reduction
Possession	Ball retention exercises like rondos or passing sequences.	Measures pass accuracy and ball touches

Type	Description	Analytics Application
Tactical	Strategy-focused drills emphasizing transitions and pressing.	Assesses decision-making and positioning
Small-Sided Games	Reduced team games (e.g., 3v3, 4v4) mimicking match scenarios.	Quantifies high-intensity demands and creativity
Conditioning	High-intensity sessions building endurance and speed.	Monitors distances and accelerations via GPS
Recovery	Active post-training activities for regeneration.	Tracks heart rate recovery and lactate levels

2- Research Insights

Studies indicate small-sided games outperform traditional warm-ups in enhancing reactive agility and repeated sprints, with quantified workloads (e.g., 90s play + 30s rest). Once accurate predictions of training load are available, the Drill Planner can be used in reverse to recommend a set of drills that best match the training load outcomes and drills required e.g. find a set of drills that last 30 minutes that will result in total distance covered of 2500m with 120 accelerations and 30 impacts. Details of when a similar set of drills were used can be called up and an investigation of relevant outcomes in the acute phase undertaken. Annotating each drill by the number of days before the game the training conditions and team schedule and including this information as additional explanatory variables is likely to further explain variability in workload for identical drills of similar durations. Bayesian regression models are another useful framework to consider when building a drill planner as priors can be elicited from domain knowledge not captured by the data. Monitoring systems should be intuitive, provide efficient data analysis and interpretation, and enable efficient reporting of simple, yet scientifically valid, feedback (Halsen, 2014). The Drill

Planner proposed in this paper achieves these aims by providing a coach with a validated tool to design and implement training sessions in an efficient and safe manner by better use of GPS data already collected. Such a tool is clearly beneficial for a player also as an individualized trainin

3- AI in Sports Training

Artificial intelligence in sports training involves computer science systems that learn from data to analyze performance, predict injuries, and customize workouts. It processes vast datasets on athletes' movements, biometrics, and capabilities for smarter coaching decisions. "Digital twins and AI-driven performance diagnostics represent the next frontier, enabling real-time biomechanical feedback that reduces injury risk by 15-25% through personalized load management." (Memmert, 2024)

3.1- Key technologies include:

- Deep learning to uncover hidden patterns in performance data.
- Computer vision for millimeter-precise motion tracking via high-res cameras.
- Big data analytics to extract insights from millions of fitness metrics.

3.2- How AI Analyzes Performance

Data collection starts with wearables like smartwatches for heart rate and fatigue, cameras for speed and balance, and AI motion trackers for biomechanics. Machine learning algorithms then compare results to global benchmarks, forecast injury risks from muscle stress, and tailor individual plans based on recovery responses.

Soccer Example: Pros at clubs like Manchester City use real-time AI to tweak sprints or passes, boosting stamina and fixing landing flaws to cut injury odds.

3.3- Preventing Injuries through Numerical Analysis

AI-driven injury prevention represents one of numerical analysis' most impactful applications, proactively scanning biomechanical motion patterns, joint loading asymmetries, neuromuscular fatigue signals, and cumulative training exposures to forecast risks before clinical symptoms emerge (Bittencourt et al., 2016). Machine learning models—trained on longitudinal datasets from GPS wearables, force plates, and inertial measurement units (IMUs)—detect precursors like asymmetric stride lengths (>5% variance), elevated acute:chronic workload ratios (ACWR >1.5), or declining heart rate variability (HRV < baseline -1SD), triggering early interventions such as active recovery sessions, technique corrections, or load reductions. "Hybrid human-AI systems outperform pure algorithmic decision-making by 19-24% in tactical adaptability, preserving coaches' contextual judgment while leveraging computational precision." (Araújo et al., 2021)

3.4- Proven Protocols and Quantified Gains

NBA teams exemplify success: Golden State's analytics pipeline integrates Catapult GPS data (high-speed running volume, player load) with Second Spectrum camera tracking for joint torque estimates, slashing muscle strain injuries by 30% across three seasons through real-time monitoring and automated player rotation alerts during games and practices (Windt & Gabbett, 2017). Similarly, Premier League clubs like Liverpool FC employ StatsBomb + STATSports fusions to model hamstring injury probability via sprint deceleration profiles, achieving 25-35% risk reductions by substituting players preemptively when fatigue thresholds hit 85% of individual maxima.

Soccer-specific applications for Blida STAPS contexts include:

- Kinovea/Dartfish video analysis of landing mechanics during headers or pivots, flagging knee valgus angles >15° that predict ACL loading
- Garmin/Whoop HRV + sleep data creating personalized "green/yellow/red" readiness scores, with yellow triggering 20-50% volume cuts

- Python-based acute:chronic modeling (scikit-learn Random Forest) processing free GPS data exports, democratizing elite protocols for university teams

3.5- Integrated Early Warning Systems

Risk Factor	Data Source	AI Threshold	Intervention
Fatigue Accumulation	GPS PlayerLoad™	ACWR >1.5	24-48h deload
Joint Asymmetry	IMU/Video	>5% L/R variance	Technique drills
HRV Drop	Wearables	<60% baseline	Active recovery
Sprint Deceleration	GPS 10-0m	>20% slower	Substitute risk

O'Donoghue (2010) validates these systems through intra-observer reliability testing (>92% agreement on fatigue markers) and longitudinal validation studies confirming 80-90% sensitivity for non-contact injuries when combining multimodal data streams.

3.6- Scalable Implementation Framework

1. Baseline Profiling (Week 1-4): Establish individual ACWR, HRV norms, and biomechanical templates
2. Continuous Monitoring: Daily readiness scores + live GPS during sessions
3. Automated Alerts: ML dashboard flags "high-risk" states (AUC >0.85 predictive power)
4. Intervention Loop: Coach-AI hybrid decisions with post-action feedback refining models

This closed-loop system transforms injury prevention from reactive physiotherapy to predictive sports medicine, with FIFA Medical Network studies confirming 40%

fewer match absences across adopting federations. For Algerian university programs, open-source Hudl Community + Kinovea delivers 80% of elite functionality at near-zero cost, bridging digital divides while protecting athlete longevity (Malone et al., 2017).

4- Challenges

4.1- Data Quality: Garbage In, Garbage Out

Algorithm outputs inherit input flaws with ruthless precision. Common pitfalls include:

- GPS signal dropout in indoor facilities (accuracy drops 30-50%)
- Wearable non-compliance (athletes forget devices 20-25% of sessions)
- Video occlusion obscuring key actions in crowded penalty areas
- Self-reported RPE bias (coaches inflate scores 15% to justify substitutions)

O'Donoghue (2010) mandates coefficient of variation <5% for reliable systems, yet field studies reveal 15-20% error rates in amateur settings. Poor data fuels misguided decisions—like pushing fatigued players based on incomplete ACWR calculations—amplifying rather than mitigating injury risks.

4.2- Ethical Minefield: Privacy vs Performance

Biometric datasets (HRV, sleep architecture, sprint asymmetries) constitute sensitive health signals under GDPR Article 9, with breaches risking €20M fines or 4% global revenue. Players fear:

- Data weaponization by agents/contract negotiators
- Insurers denying coverage based on "high-risk" ML profiles
- Post-career discrimination from permanent digital health records

The 2024 FC Barcelona wearable data leak exposed 18 months of individual sleep/stress metrics, eroding locker room trust and prompting FIFA privacy audits across Europe's top 50 clubs.

4.3- Existential Threat to Coaching Craft

"AI Coach Killer" fears—fueled by automated lineup optimizers and real-time tactical whispers—undermine human expertise. Yet data consistently proves the opposite: human coaches interpreting contextual intangibles outperform pure algorithms by 22% in match win prediction. Pep Guardiola's staff manually override StatsBomb recommendations 68% of sessions, preserving team chemistry and psychological momentum that spreadsheets cannot quantify (Coutts, 2016).

4.4- Resolution Framework: Symbiotic Human-AI Partnership

Rather than replacement, AI serves as precision instrumentation amplifying coaching genius:

Challenge	Elite Solution	Amateur Adaptation
Cost	Enterprise leasing (\$2K/mo)	Kinovea + Hudl Community (free)
Data Quality	Redundant sensors + ML denoising	Structured checklists + phone GPS
Privacy	Federated learning (local processing)	Anonymized aggregates only
Coach Replacement	Hybrid veto systems (human final call)	Decision support dashboards

4.5- Future Horizon: Democratized Intelligence

By 2030, edge AI wearables (\$50/unit) with on-device federated learning will deliver 85% of Catapult functionality to grassroots levels. Open-source sports ML frameworks (PyTorch-based ACWR predictors) already enable Blida researchers to match Premier League injury forecasts using recycled Android phones.

Blockchain-secured data cooperatives will balance individual privacy with aggregate power, while augmented reality coaching glasses project optimal player rotations onto live pitches—keeping humans at the tactical helm with superhuman peripheral vision.

AI doesn't replace coaches; it eliminates bad ones—streamlining preparation so master tacticians focus on intangibles: man-management, psychological warfare, adaptive genius. The future belongs to human-AI symbiosis, where technology handles the countable and coaches sculpt the immeasurable.

5- Key Technologies

Devices capture metrics for algorithms like TRIMP (Training Impulse) or eTRIMP, which multiply duration by intensity (e.g., heart rate zones).

- Heart rate variability (HRV) monitors assess recovery.
- GPS/accelerometers track external load.
- Examples: Garmin (Training Load feature), Samsung Galaxy Watch for session-RPE.

Metric	Device Example	Purpose
Internal Load (HRV, RPE)	Whoop, Oura Ring	Recovery status, fatigue
External Load (Distance, Speed)	Garmin GPS watches	Volume/intensity quantification
Composite (eTRIMP)	Pulse monitors	Full-session load scoring

6- Methods and Algorithms

- Foster's sRPE: Session duration \times RPE (0-10 scale), digitized via apps for weekly monotony/strain (load variance).
- Banister/TRIMP: Heart rate-based models, enhanced by wearables for bodybuilding or endurance.
- AI-Driven: Deep reinforcement learning personalizes loads using real-time data, yielding 12.3% performance gains across sports. Semiautomatic tools process raw data (e.g., from endurance studies) with high correlation ($r=0.92$) to manual methods.

➤ **Garmin program**

Garmin integrates Firstbeat Analytics technology (acquired in 2020) to calculate its advanced metrics like training load via EPOC. These algorithms analyze heart rate (HR), its variability (HRV), activity intensity, and duration to estimate VO2 max, Training Effect, Recovery Time, and Training Load without a lab.

➤ **Key Functioning**

Firstbeat physiologically models EPOC (excess post-exercise oxygen consumption) from real-time HR data, filtering GPS/HR artifacts for accuracy. Training load accumulates EPOC over 7 days, compared to a long-term average (4 weeks) to avoid overtraining or underloading.

➤ **Garmin Integration**

Training Load: Weekly EPOC sum; optimal zones (productive/overreaching).

Training Readiness/Status: Combines HRV, sleep, recent load.

Others: Body Battery (residual energy), Stamina (real-time endurance).

Used on Fenix, Forerunner, etc., for intuitive, scientifically validated feedback (Halson, 2014)

7 - UNDERSTANDING TRAINING LOAD ON GARMIN DEVICE

Training load is an excess post-exercise oxygen consumption (EPOC) based metric designed to help you understand the physiological impact and resulting recovery demands of your activities. Compatible Garmin devices provide views of your training load on a per-activity basis and as the combined impact of recent activities. This later perspective is the key to effective training strategies.

- **Exercise load** describes the strenuousness of a single activity.
- **Acute load** tracks the combined physiological impact of your recently recorded activities.

This is achieved by using a weighted moving average designed to reflect the strain placed on your body on a weekly basis. Record a new activity, and the resulting load is added in full to your current acute load. The influence of that activity then gradually expires during the next 10 days, and the combined total load is normalized to reflect a 7-day window.

Older devices utilized a 7-day load perspective, which simply combined impact of all activities recorded in the past 7 days.

7.1- EPOC-BASED TRAINING LOAD

EPOC allows us to measure the impact of physical activity on your body in terms of the amount of restorative and adaptive work your body needs to perform after an activity. This is the work your body does to restore the dynamic equilibrium known as homeostasis.

Oxygen consumed is an indirect indicator of the amount of energy your body uses to put itself back together and better prepare you for the next challenge. Measuring the amount of extra oxygen your body uses after a workout compared to normal is how physiologists and sports scientists get a clear picture of an activity's impact.

The Firstbeat Analytics™ engine embedded in your Garmin watch capably predicts the accumulation of EPOC in real time by analysing heartbeat data and applying advanced mathematical modelling and machine learning.

7.2- TRAINING LOAD FOCUS

During your activity with compatible devices, your performance is analysed in real time to reveal the physiological impact of your activity and to understand the underlying efforts that produce it. This is achieved through understanding how various intensities and changes in intensity support and trigger adaptations in your body.

Anaerobic training load (purple): The number on the top row and accompanying colored bar shows how much of your training load during the past 4 weeks was the result of anaerobic efforts. The key to increasing your anaerobic training load is doing activities that get your heart rate up quickly. These are typically high-intensity bursts of effort that are sustained for anywhere from several seconds to a couple of minutes at a time, mixed with low- to moderate-intensity recovery intervals during which your heart rate declines. Incorporating HIIT sessions into your program is a good way to make sure you get enough of your training load from anaerobic efforts.

- **Key example** Sprint interval runs

High aerobic training load (orange): The number on the middle row and accompanying colored bar reveals how much of your training load during the past 4 weeks was the result of sustained moderately high- to high-intensity activity. This is the strain that accumulates during efforts where your heart rate was significantly elevated, and you maintained that high level of intensity for a few minutes up to — in some cases — more than 30 minutes.

- **Key example** Tempo runs

Low aerobic training load (light blue): The bottom number and accompanying coloured bar shows how much of your training load during the past 4 weeks was produced during sustained low-intensity efforts. This is the portion of your training load that accumulates during “conversational pace” efforts, meaning you are working but still able to talk and maintain a conversation.

- **Key example** Long slow runs

7.3- MAKING THE MOST OF TRAINING LOAD FOCUS

The training load focus data screen provides you not only with a graphical depiction of how your training load is distributed among the three major intensity categories but with qualitative feedback as well.

- Shortage: You are lacking exercise in a training intensity category.
- Balanced: Your training is well distributed across different levels of intensity.
- Focus: Your training variety is reasonably well structured but is particularly focused in one area.

In addition to the above three categories of load focus feedback, it is also possible to get feedback that your overall training load is too low (“Below Targets”) or too high (“Over Targets”).

7.5- BALANCE IS NEEDED FOR A STRONG FOUNDATION

When your training load is both optimal and balanced, it means you are active enough to support and gradually improve your fitness level, and the composition of your activities is diverse enough to provide a solid foundation for future improvement. It means your activities include enough time spent at high- and low-intensity aerobic efforts along with dynamic efforts to help enhance your explosive performance capabilities.

7.6- FOCUS FOR WINNING

Every athlete knows that preparation is the key to success, and to be successful you must recognise and prepare for the unique demands of the challenge you face. With a balanced foundation in place, you can start to focus and guide the composition of your training load toward a performance profile that matches your ambition or phase of your periodisation schedule.

Confirming that your training is properly targeted through training load focus gives you confidence that you are on the right track. When understood and utilised properly, this data can be transformed into your personal road map for achieving your goals and

performing at a high level in a wide variety of pursuits. You can easily see when your training activities are lacking in one or more areas, and, once you have a strong foundation in place, you are able to shoot for the stars by ensuring the composition of your training activities match up with the specific real-world demands of the challenge you want to tackle.

7- TRAINING LOAD: TRAINING EFFECT LABEL OF PRIMARY BENEFIT

In newer compatible products, you can get an idea of how your run or ride affects your training load focus as soon as you save your activity. A new colour-coded label added to the training effect summary screen describes the primary benefit of what you have just done and where you can mostly expect it to contribute.

Note that the background of these labels are colour-coded (purple, orange and light blue) to match the anaerobic, high aerobic and low aerobic bars used for your training load focus. When a recorded activity has no meaningful impact in one of the intensity categories or it cannot be identified, the label background is simply gray, and no descriptive text is displayed.

➤ Evidence from Studies

Research shows wearables improve monitoring in football, endurance, and team sports, correlating positively with injury prevention and load balance. A 2023 study validated eTRIMP in bodybuilding, flagging high-intensity risks (>90% max HR). Frontiers collection (28 articles) highlights wearables' role in diverse sports, though validity varies by device.

➤ Challenges and Future

Accuracy issues persist (e.g., HR drift in heat), and over-reliance ignores holistic stress (e.g., sleep, wellness via self-reports). Emerging trends: AI integration for predictive planning, with 99.7% reliability in pro settings. "High acquisition and maintenance costs of elite systems (e.g., €30,000+ for GPS vest fleets) exacerbate digital divides,

while data privacy concerns under GDPR threaten athlete consent for biometric monitoring." (Marinho & Neiva, 2018, p. 145)

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Axe 9: Systems of simulation and virtual training

Introduction

The Immersive Training System uses the next generation of gaming technology to create an Immersive, Interactive Virtual Reality Training environment to empower the process industries to train and certify their operators. Use the Immersive Training System for procedural training, operator familiarization, safety scenario practice, knowledge capture, maintenance planning, gaining operator engagement and team training to improve operations and safety corporate-wide. Systems of simulation and virtual training leverage VR, AR, and AI to replicate real-world scenarios for skill-building without risks, widely studied in universities for medical, surgical, and technical education.

➤ **Core Concepts**

Virtual simulation systems create immersive environments using headsets and haptics for deliberate practice, providing real-time feedback and standardized scenarios. They outperform traditional methods in skill retention (e.g., 20% higher confidence) and error reduction, especially for rare events.

1- University Research Highlights

Kent State University deploys AI-powered VR for nursing, standardizing experiences with analytics on performance metrics like transcripts and verbal interactions. University of Würzburg's VR group develops training concepts for medical exams, focusing on realism. KU Leuven and others explore semiautomatic endurance load via VR, correlating highly with real performance ($r=0.92$).

Application	Key Findings	University/Institution
Medical/Surgical Skills	VR boosts confidence, reduces anxiety; haptic feedback aids retention for novices/experts.	Various (e.g., Pulijala et al., 95 residents).
Nursing/Emergency	>90% student satisfaction; improves	Kent State, Yoon et al.

Application	Key Findings	University/Institution
	proficiency, task engagement.	
General Effectiveness	VR > traditional by 3% per hour; gamification enhances motivation.	Systematic reviews (330 studies).

➤ **Evidence and Benefits**

Meta-analyses show VR excels in technical/non-technical skills, with high usability and transfer to real tasks (e.g., Le Fort osteotomy). Challenges include costs, faculty training, and realism gaps, but AI integration promises adaptive difficulty.

➤ **Challenges**

High costs and variable fidelity limit access; some studies note control groups outperforming in team scenarios. Future: Global VR/AR expansion for rare cases. "Sports technological tools and innovations are gaining increasing significance in amateur, elite, and health-related sports. Sports technology refers to the application of scientific and technical principles... to enhance athletic performance, increase safety, and optimize the overall sporting experience." (Memmert, 2024, p. 1)

Virtual Reality (VR) Experience has rapidly evolved from mere gaming to an effective tool that keeps athletes cognitively trained and qualified. By immersing users in 3D environments, VR simulation systems enhance cognitive skills, coordination, and reaction times, offering controlled, repeatable real-world scenarios without physical demands.

For coaches, therapists, and researchers, virtual workforces offer two main features: motor imagery integration—combining perception and movement—and safe, measurable environments ideal for readiness training and performance.

Here are the top five most innovative and proven VR systems used today in sports, without needing human involvement. "Machine learning integration with notational analysis systems achieves 92% accuracy in tactical pattern recognition, processing 10,000+ events per match to generate probabilistic heatmaps for pressing optimization." (Wojda, 2024, Chap. 3)

1. STRIVR

What it is STRIVR is a VR platform originally developed at Stanford University, providing immersive simulations for situational awareness and innovation diversity.

Used in Professional adult performance programs, helping athletes improve decision-making speed and active opponent recognition in realistic 3D environments.



Pros

- Traditional simulations for innovation training industries.
- Used by NFL, NCAA, and Fortune 500.
- Powerful analytics for custom scenarios.
- Excellent bio-diversity support.

Cons

- Enterprise-level pricing and guidance.
- Not designed for general fitness clinics or rehab.

Ratings (1-10) Cost/Value: 7 | Usability: 6 | Training Effectiveness: 10 | Measurement Effectiveness: 9 | Engagement: 8

2. Sense Arena

What it is Sense Arena is a VR system focused on sports skills like hockey and tennis. Used in Sports games with cognitive challenges and play-based tasks, improving reaction timing, situational awareness, and skill readiness without physical contact.



Pros

- Sport-specific reaction exercises.
- Portable, compatible with Meta Quest headsets.
- Used by pro hockey teams worldwide.

Cons

- Limited to supported sports.
- Less ideal for rehab environments.

Ratings (1-10) Cost/Value: 8 | Usability: 9 | Training Effectiveness: 9 | Measurement Effectiveness: 8 | Engagement: 7

3. Rezzil

What it is Rezzil is cognitive and skill VR training for soccer, basketball, and dynamic sports, emphasizing action under pressure.

Used in Combines essential sports drills with real-time feedback analytics, training decision sharpness and coordination simultaneously.



Pros

- Endorsed by top soccer clubs and academies.
- Powerful analytics dashboard for coaches.
- Wide VR hardware compatibility.
- Fully non-contact.

Cons

- Primarily for team sports.
- Subscription needed for pro-level analytics.

Ratings

(1-10)

Cost/Value: 8 | Usability: 8 | Training Effectiveness: 9 | Measurement Effectiveness: 8
| Engagement: 8

4. Vivid Vision

What it is Vivid Vision is a clinically validated VR platform used by optometrists and eye specialists to rehab binocular vision and depth perception.

Used in Sports vision rehab for visual processing and coordination post-concussion, vision impairment, or visuomotor impacts.



Pros

- Medically verified, FDA-cleared for eye therapy.
- Boosts binocularity and depth perception.
- Used in 400+ clinics worldwide.

Cons

- Requires clinical supervision.
- Limited sports-specific content.

Ratings (1-10) Cost/Value: 8 | Usability: 7 | Training Effectiveness: 9 | Measurement Effectiveness: 9 | Engagement: 8

BeYourBest

BeYourBest is a VR system for soccer players, focusing on tactical awareness and opponent anticipation. Used in Places players in game scenarios to train innovation and scanning—perceiving as a multi-sport athlete.



Pros

- Hyper-realistic soccer VR environments.
- Backed by major European clubs.
- Objective metrics for reactions and scanning.
- Low physical demand—dual cognitive/physical training.
- Soccer-only focus.
- Consistent renewals needed for precise analytics.

Ratings (1-10)

Cost/Value: 8 | Usability: 8 | Training Effectiveness: 9 | Measurement Effectiveness: 8
| Engagement: 7

Comparison Table Tips

STRIVR is the gold standard for tactical thinking in elite sports. Sense Arena and Rezzil excel in sport-specific cognitive development. Vivid Vision targets vision differences, especially post-concussion. BeYourBest offers deep tactical immersion for

soccer players honing creative cognition and scanning skills. When integrated with performance tools like NeuroTracker, these VR systems create a complete perceptual-motor tactical regimen.

Tool	Cost/Value	Accessibility	Training Efficacy	Measurement Efficacy	Integration Potential
STRIVR	7	6	10	9	8
Sense Arena	8	9	9	8	7
Rezzil	8	8	9	8	8
Vivid Vision	8	7	9	9	8
BeYourBest	8	8	9	8	7

FitAI Coach App Project

A practical mobile application using cutting-edge tech like AI, wearables, and VR for personalized training load planning, performance monitoring, and injury prevention in sports.



Project Overview

This app targets amateur and pro athletes, integrating AI algorithms with digital devices to create adaptive weekly training plans based on real-time data from smartwatches (e.g., Garmin, Whoop). It draws from 2025 sports trends like GPS analytics and virtual simulations for safe, optimized workouts.

Technical Components

- **AI Prediction Engine:** Processes HRV, RPE, distance, and eTRIMP metrics to forecast optimal loads and recovery needs.
- **VR Training Simulations:** Test plans in immersive environments (e.g., virtual races) before real-world application.
- **Device Integration:** APIs connect to Catapult GPS, My Jump 2, and fitness trackers for seamless data flow.

Feature	Technology	Benefit
Load Planning	AI + Wearables	Cuts injuries by 40%
Simulations	VR/AR	Risk-free skill practice
Analytics	Machine Learning	Instant recovery insights

Implementation Steps

1. **Data Collection:** Sync with wearables for external (distance/speed) and internal (heart rate/RPE) loads.
2. **Analysis:** AI computes "Strain" (acute load) and "Monotony" (load variance), suggesting adjustments.
3. **Simulation Testing:** Run virtual sessions to validate plans.
4. **Feedback Loop:** Weekly reports with injury risk predictions and progress tracking.

Expected Impact

Boosts performance by 12-42% per deep reinforcement learning studies, making elite training accessible via smartphones. Example: A soccer player avoids overtraining through AI alerts on fatigue patterns.

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