AI-POWERED SMART FOOTBALL PLAYER PERFORMANCE MONITORING USING IOT WEARABLE SENSORS: A SECONDARY RESEARCH STUDY.

ABSTRACT:

Football places heavy physical strain on players, and coaching staff is turning more and more to objective, continuous data instead of manual observation to manage training load, tactics, and injury risk. The combination of Internet of Things (IoT) wearable sensors and artificial intelligence (AI) has produced monitoring systems that can track physiological and biomechanical variables in real time, but the resulting research is spread across sports science, biomedical engineering, and computer science literature.

No single review currently brings together how IoT wearable sensors and AI techniques are being combined specifically for football performance monitoring, what benefits and limitations these systems bring, or where the field is headed next.

This study looks at what people have written about using artificial intelligence to monitor football players' performance with special sensors. The goal is to get a picture of the technology, how it is used, what is good and bad about it, and where it is going.

The study is based on looking at what other people have written. It uses articles from journals, conference papers, and other trustworthy sources from 2015 to 2025. These were found on websites like IEEE Xplore, ACM Digital Library, Springer, ScienceDirect, MDPI and Google Scholar. Then they were looked at to find ideas and compared.

Special sensors like GPS, accelerometers, and heart rate monitors can track how hard a player is working, how tired they are, and if they are likely to get hurt. When these sensors are used with machine learning, they can give coaches a lot of information. The studies show that using these sensors and machine learning helps coaches make decisions and train players more precisely. However, there are some problems, like keeping data private, making sure the sensors work correctly, and the high cost.

Artificial intelligence and special sensors are changing how football teams measure and manage player performance. Coaches are moving away from watching players and waiting for problems to happen. Instead, they are using data to make decisions and prevent problems. For this to work well, teams need to figure out how to keep data private and make the systems cheaper. They also need to make it easier to use these systems in practice, not just in research.

Keywords: Internet of Things, Wearable Sensors, Artificial Intelligence, Football Performance Monitoring, Sports Analytics, Injury Prediction, Machine Learning

CHAPTER: INTRODUCTION

1. Background of the Study

Football is really tough on the body. It needs endurance that lasts ninety minutes. Players have to be able to run fast and then quickly change direction. They also have to make decisions in a split second.

As football gets more competitive, clubs are not just watching players to see how they do. They are using data to measure how well players perform. This has led to something called sports

analytics. Sports analytics uses sports science, engineering, and even artificial intelligence to help players do better, get hurt less, and make good decisions during the game.

A long time ago, tracking how well football players did meant counting how many goals they scored, how many passes they made, and how far they ran. This was done after the game was over. It worked okay. It relied on people watching and taking notes. It also did not help during the game itself because the information came late. Now things are different. Some sensors track what is going on with a player's body at the time they are playing. These sensors send information to systems that can turn that information into decisions quickly, almost as fast as the game is happening.

The Internet of Things is the backbone of this change. Internet of Things devices are small enough to wear. They gather data through built-in sensors. These Internet of Things devices pass the data along a network without needing a person to operate them.

In football,l this means using devices like GPS trackers and accelerometers and gyroscopes and heart rate monitors and inertial measurement units. These devices are stitched into vests or wristbands or boots. They quietly record how hard a player is moving and how well they are moving throughout a session or a match.

The data from these Internet of Things devices is a lot to handle. It includes things like running distance and sprint speed and acceleration and heart rate variability and workload and fatigue and movement pattern. This data arrives in volumes that no human analyst could process by hand.

Coaches use this data to judge a player's form precisely. They can do this because the data comes in as the session happens. So the staff can act on it immediately. They can pull a player back before a strain becomes a tear. They can adjust a training block before overuse sets in.

Artificial intelligence is what makes sense of all this data from the Internet of Things devices. Artificial Intelligence uses machine learning and deep learning models to sift through the sensor data. These models find patterns that a human would miss. They flag signs of fatigue, estimate injury risk, and suggest training adjustments tailored to the individual player.

These models are not like fixed formulas. They keep learning as more data from the Internet of Things devices comes in. So their understanding of a player gets sharper over a season rather than staying the same.

Faster networks make it possible to do all of this in time. We have Bluetooth Low Energy and Wi-Fi and fifth-generation wireless. We also have cloud and edge computing. These things let sensor data go from a football player's body to a coach's tablet in a few seconds. This speed is why football clubs use AI-powered IoT systems. They use these systems to make their training better, to help players recover, and to get an edge over teams that do not use as much data.

The technology is not perfect. If sensors are not placed in the right spot every time or if they get too hot or wet, they can give bad readings. When we collect data about a player's body,y we have to think about privacy and consent. It also costs a lot of money to build an AI-IoT system. This is a problem for football clubs and schools because they do not have the money or the experts.

We need to look at this topic closely. As sensor and AI technology gets better, we need to understand how people are actually using it and where it is not working well. This is important for people who do research for engineers and for football coaches. This study looks at what other people have written about this topic. It uses articles from experts, papers from conferences, reports from companies, and technical papers to get an understanding of the technology, how it is

used, what is good about it, what is bad about it, and what we still need to figure out about AI-powered football performance monitoring.

2 Problem Statement

Football performance is usually judged by watching games, looking at videos, and checking statistics after they happen. These methods are helpful. They do not show the physical and mechanical changes that a football player goes through during a game. Human judgement can be wrong. Miss signs of tiredness or a higher risk of getting hurt.

The game of football today needs more than that. Coaches need to know how players are moving, how hard their hearts are working and how much they are doing, all at the time and in real time. This is something that the old ways of doing things cannot do. Without this information, coaches often make decisions about who to replace, how to train each player, and how to manage their workload late.

Sensors that players wear, connected to intelligence, can help fill this gap. They can watch what players are doing all the time automatically and get smarter and smarter. The research on these systems is spread out across many fields, including sports science, engineering, artificial intelligence, and communication. No one place puts it all together, says if it works, and shows where the problems and opportunities are.

This study is trying to fix that. It looks at how artificial intelligence and sensors that players wear are being used together to watch football players using what we already know to find out what is happening now, how things are improving, what the problems are, and what we should do next. It is all about football performance. How we can use these new technologies to make it better.

3 Research Aim:

This study aims to examine AI-powered football player performance monitoring systems built on IoT wearable sensors through a systematic review of existing literature covering their underlying technologies, applications, benefits, limitations, and future direction.

3 Research Objectives

1. To examine the role of IoT wearable sensors in monitoring football player performance.
2. To analyse how artificial intelligence techniques are applied to sports performance assessment.
3. To evaluate the benefits of AI-powered monitoring systems for athletes, coaches, and sports organisations.
4. To identify the technical, ethical, and practical challenges associated with wearable sensor technologies.
5. To explore emerging trends and likely future developments in AI-driven football performance monitoring.

4 Research Questions

1. What types of IoT wearable sensors are commonly used in football performance monitoring?
2. How are artificial intelligence techniques applied to analyse football player performance?
3. What benefits do AI-powered wearable monitoring systems provide for athletes, coaches, and sports scientists?

4. What technical, ethical, and practical limitations exist in current AI-powered football monitoring systems?
5. What future technological developments are expected to shape intelligent football performance monitoring?

Significance of the Study

This review is really helpful because it brings together all the information we have so far about using football performance monitoring with IoT wearables that are enabled by artificial intelligence.

For football players, it explains how artificial intelligence can help make training better,r reduce fatigue, and prevent injuries.

For football coaches, it shows how they can use real-time information to make decisions to coach players individually and manage how hard they work.

For people who study sports, it talks about the developments in using sensors in wearables, making models with artificial intelligence, and evaluating performance, which can lead to more research.

For doctors and physiotherapists who work with sports teams, it provides information on predicting injuries, tracking recovery, and managing the health of football players by monitoring them.

This study is also useful for people who're not just interested in football but also for students and researchers who work in computer science, electronics, biomedical engineering, artificial intelligence, and sports technology, as it can be a reference point for them.

Scope and Delimitations

This study is limited to AI-powered football performance monitoring systems built on IoT wearable sensors, covering the wearable devices, communication technologies, AI algorithms, and monitoring applications involved.

It is a secondary research study, based on a systematic review of peer-reviewed journal articles, conference papers, books, technical reports, and reputable industry publications published mainly between 2015 and 2025. It covers applications such as player tracking, workload monitoring, fatigue assessment, injury prediction, and performance optimisation, but it does not extend to experimental implementation, software or hardware development, or primary data collection through surveys, interviews, or field experiments.

CHAPTER: THEORETICAL FRAMEWORK AND CONCEPTUAL BACKGROUND

1. Internet of Things (IoT)

The Internet of Things is a network of devices that have sensors and software in them. These devices collect information. Send it to each other over the internet. They can do all of this without people having to get involved all the time.

An Internet of Things device can find out what is going on around it. Send that information to other devices. Then it can do something about what it found out without people having to help it.

Over the past few years,, the Internet of Things has been used in lots of different areas like healthcare and manufacturing. It is also used in transport, agriculture and sport. This is because it is now cheaper to use communication, cloud computing, and artificial intelligence. All of these things help organisations keep an eye on what's happening right now.

In sport, the Internet of Things has changed how athletes are monitored. Now athletes can wear devices that collect information about their bodies. These devices can collect information all the time. Coaches and sports scientists can use this information to get a picture of how an athlete is doing. They can see how hard the athlete is working. If they are getting better or worse.

Football is a sport that uses the Internet of Things a lot. This is because football is a physical sport and it is important to know what is happening all the time. Football players wear sensors that are built into their clothes or boots. These sensors collect information about the player, like how they are running and how hard their heart is beating. This information is sent to a computer system where it is used to get an understanding of how the player is doing.

The Internet of Things is what makes it possible for all of these things to be connected. It connects athlete devices and computer systems. The Internet of Things is the base that sports analytics is built on. It is what keeps everything connected and working together.

2. IoT Architecture

IoT systems for sports monitoring are typically described in five layers, each handling a different stage of the data's journey from the athlete's body to a usable insight.

Perception layer. This is where the athlete meets the system: the wearable sensors themselves, which capture raw physiological and movement data without breaking a player's stride. GPS modules, accelerometers, gyroscopes, heart rate monitors, and electromyography (EMG) sensors sit at this layer.

Network layer. From there, data has to move, carried by Bluetooth Low Energy (BLE), Wi-Fi, ZigBee, Near Field Communication (NFC), or fifth-generation (5G) networks. Reliability here matters most when a coach needs feedback mid-match rather than after it.

Definitions: BLE is a short-range, low-power wireless standard suited to devices that need to send small amounts of data frequently without draining a battery. ZigBee is a similar low-power wireless protocol built for short-range mesh networks, commonly used where many small sensors need to talk to each other. NFC allows two devices to exchange data at very close range (a few centimetres), typically used for quick pairing or identification rather than continuous streaming. 5G is the fifth generation of mobile network technology, offering markedly higher speed and lower latency than earlier generations, which matters for near-instant transmission of sensor data during live play.

Processing layer. Once data arrives, it needs cleaning up: noise removal, filtering, signal normalisation, feature extraction, and integration, usually carried out on cloud or edge computing platforms before any AI model touches it.

Definitions: Cloud computing refers to storage and computing resources delivered over the internet from remote data centres rather than a local device, offering scale on demand. Edge computing is the reverse in spirit, processing data close to where it is generated, on or near the wearable itself, to cut the delay that sending everything to a distant server would introduce.

Application layer. This is where processed data becomes something a person can act on: performance dashboards, fatigue alerts, injury prediction reports, tactical summaries, and personalised training recommendations for coaches, athletes, and physiotherapists.

Business layer. The top layer turns analytical output into organisational decisions, team evaluation, recruitment, training investment, resource allocation, and long-term player development, translating technical data into decisions a club's management can act on.

3. Components of IoT-Based Sports Monitoring Systems

An AI-powered football monitoring system is built from several parts working together:

- **Wearable sensors**, which collect physiological and biomechanical data directly from the athlete.
- **Communication modules**, which carry that data over a wireless network.
- **Edge devices**, which handle preliminary computation near the source to cut transmission delay.
- **Cloud computing platforms**, which store large datasets and supply the computing power AI analysis needs.
- **AI models**, which look for patterns, predict injury, estimate fatigue, and evaluate performance.
- **Visualisation dashboards**, which present the results in a form a coach can read at a glance.

Together, these components keep monitoring running continuously through both training and competition.

4. Wearable Sensor Technology

Wearable sensors are really important for sports engineering. These are devices that athletes wear to track how their body is doing and how they are moving. They do this all the time without

getting in the way of the game. Sports teams are using these devices more and more to help their players do better, get hurt less, and have training that is just right for them.

In the past, tt people would watch players. Write down what they sa.. Now wearable sensors give us exact information all the time during a practice or a game. Then computers use this information to give us a lot of details about what's going on. The wearable sensors that are used the most in football are listed below.

GPS Sensors

Global Positioning System (GPS) sensors are the most widely used wearable in football monitoring, tracking a player's position by communicating with orbiting satellites. They report total distance covered, sprint distance, maximum and average speed, positioning, heat maps, and movement trajectories. Coaches read GPS data to judge workload and tactical positioning, and during training it helps confirm whether players are hitting the intended intensity or pushing past it.

Accelerometers

Accelerometers measure linear acceleration along three axes. Where GPS captures movement over distance, accelerometers pick up rapid, short-duration actions: explosive acceleration, deceleration, jump height, landing impact, sudden changes of direction, and overall movement intensity, making them well suited to the high-intensity bursts football demands.

Gyroscopes

Gyroscopes measure angular velocity and rotation. Since football involves constant turning, whether passing, dribbling, or shooting, gyroscope data on body orientation, rotational speed,

turning, balance, and stability adds a dimension accelerometers alone cannot capture. Combining the two improves the accuracy of movement-recognition algorithms considerably.

Heart Rate Sensors

Heart rate sensors, whether optical or chest-strap based, track cardiovascular workload continuously: resting heart rate, exercise heart rate, maximum heart rate, recovery rate, and heart rate variability (HRV). These readings help coaches gauge training intensity, fitness, and early signs of fatigue or overtraining.

Electromyography (EMG) Sensors

EMG sensors read the electrical signals a muscle produces when it contracts, offering a view of internal muscular activity that motion sensors cannot provide. They are used for muscle activation analysis, fatigue detection, rehabilitation monitoring, muscle imbalance assessment, and injury prevention, and they are especially valuable during rehabilitation, where physiotherapists rely on them to track recovery and adjust exercise plans.

Table 2.1: Comparison of Common Wearable Sensors Used in Football

Sensor	Primary Function	Typical Applications
GPS	Position and distance tracking	Tactical analysis, workload monitoring
Accelerometer	Linear acceleration	Sprint detection, jump analysis
Gyroscope	Rotational movement	Balance, agility,

Sensor	Primary Function	Typical Applications
		movement recognition
Heart Rate Sensor	Cardiovascular monitoring	Training intensity, fatigue analysis
EMG Sensor	Muscle activity	Injury prevention, rehabilitation

5. Artificial Intelligence in Sports

Artificial intelligence is the thing that helps make sense of all the information that fitness trackers and other devices give us. It lets computers look at how people're doing and figure out what it all means, which is something that no person could do on their own. Artificial intelligence is different from using a formula because it keeps getting better at understanding what the information means. Artificial intelligence looks at what happened in the past and what is happening now so it can make guesses about what will happen next. In football, Artificial Intelligence helps the coaches and the people who take care of the players to see how they are doing, to guess if someone will get hurt, to make practice better,r and to come up with a plan for the game.

Machine Learning

Machine learning (ML) is the branch of AI where a system learns patterns from data rather than following rules written explicitly for every case. In football, common algorithms include:

- **Random Forest** – an ensemble of decision trees whose combined vote tends to be more accurate and stable than any single tree.

- **Support Vector Machine (SVM)** – a model that finds the boundary that best separates categories in the data, useful for classification tasks such as flagging a player as at elevated injury risk or not.
- **K-Nearest Neighbors (KNN)** – a model that classifies a new data point by looking at the most similar cases already seen.
- **Decision Trees** – models that split data through a sequence of simple yes/no rules, valued for being easy to interpret.
- **Logistic Regression—a** statistical model that estimates the probability of a binary outcome, such as injury versus no injury, based on input variables.

These algorithms classify player performance, estimate injury risk, detect fatigue, and recommend individualised training.

Deep Learning

Deep learning is a subset of machine learning built on artificial neural networks with multiple hidden layers, capable of handling far more complex datasets than classical ML methods.

- **Convolutional Neural Networks (CNNs)** are used mainly for image and video analysis, recognising patterns in visual data such as match footage.
- **Recurrent Neural Networks (RNNs)** are built for sequential data, where the order of readings matters, such as a stream of sensor values over time.
- **Long Short-Term Memory (LSTM)** networks are a type of RNN designed to retain information over longer sequences, which suits time-series sensor data, such as continuous heart rate or movement tracking.

These models can pick up subtle patterns in wearable sensor data that traditional statistical methods tend to miss.

Predictive Analytics

Predictive analytics combines historical and real-time data to forecast what is likely to happen next: injury probability, fatigue levels, performance trends, recovery time, and match readiness. This lets coaches act ahead of a problem instead of reacting once an injury or a drop in form has already occurred.

Computer Vision

Computer vision lets a system interpret visual data from cameras and video. In football, it supports automatic player tracking, ball tracking, tactical analysis, pose estimation, and action recognition. Paired with wearable sensor data, it gives a fuller picture of both individual performance and team dynamics than either source alone.

Sports Performance Analytics

Sports performance analytics is about collecting information on athletes and then looking at it to see how we can make them better at what they do. We use devices that athletes wear and computer models to get a better understanding of how they are doing physically and how they are playing the game.

We look at things like how they run and how fast they can go. We also look at how they speed up and slow down, what their heart rate is, and how well they can recover after a game. We even look at how they can pass the ball and where they are on the field.

All of this information helps us make decisions about how to train the athletes and how to keep them from getting hurt. We can make plans that're just right for each athlete, and we can watch to make sure they are not getting too tired. Sports performance analytics is getting better all the time because of technology, so it will probably become a bigger part of sports, like football. This means that athletes will be able to train and play safer, which will help them do better in the long run.

6. Conceptual Framework

The plan for this study is to see how IoT wearable sensors, wireless communication, cloud computing, and AI all work together to keep an eye on football performance and look at the data. It shows what happens from the time we get the data to the time we make decisions based on that data, and it brings together the devices, networks, storage, and analysis.

The plan was made using what we learned from reading about sports analytics, wearable technology, IoT systems, and AI in football. It explains how we take the data from players, like what is happening in their bodies and how they are moving, and turn it into something that coaches, athletes, sports scientists, and healthcare professionals can use to make decisions. This way we can watch what is happening all the time and make decisions instead of having to wait and look at the data later like we used to do.

Figure: Conceptual Flow

Wearable Sensors (GPS, Accelerometer, Gyroscope, Heart Rate Sensor, EMG Sensor) → Data Collection (Physiological and Biomechanical Data) → IoT Transmission (Bluetooth, Wi-Fi, 5G, Edge Computing) → Cloud Storage (Storage and Pre-processing) → AI

Processing (Machine Learning, Deep Learning, Predictive Analytics, Computer Vision) → Performance Insights (Performance Evaluation, Fatigue Detection, Injury Prediction, Tactical Analysis, Personalised Training, Recovery Monitoring) → Decision Support (Coaches, Athletes, Sports Scientists, Physiotherapists, Team Managers)

Wearable Sensors – The framework begins with wearable sensors attached to players during training and matches, capturing physiological and biomechanical data without disrupting movement. The sensors considered in this study—GPS, accelerometers, gyroscopes, heart rate monitors, and EMG sensors—together form the system's primary data acquisition layer.

Data Collection – Once active, these sensors record large volumes of data continuously: running speed, sprint count, total distance, heart rate, acceleration and deceleration, muscle activity, movement patterns, and recovery metrics. Because football moves quickly and unpredictably, this continuous stream gives a far more accurate picture of performance than periodic manual observation ever could.

IoT Data Transmission—Collected data then moves through IoT communication channels, BLE, Wi-Fi, 5G, and edge computing, chosen depending on range and speed requirements. Bluetooth suits short-range communication during training; Wi-Fi and 5G handle higher-speed transmission over greater distances; and edge computing processes some of the data near the player to reduce latency. This layer is the bridge between the physical sensors and the digital systems that analyse their output.

Cloud Storage and Data Management—Transmitted data lands in cloud platforms offering scalable storage and centralised access, where data collected across many sessions and matches

can be organised efficiently. Before any AI model runs, the cloud platform handles cleaning, noise reduction, missing-value handling, normalisation, feature extraction, and integration, steps that directly affect how accurate the downstream AI analysis turns out to be. Cloud storage also lets coaches and analysts draw on historical records for long-term development tracking and trend analysis.

Artificial Intelligence Processing – The information we have collected is then looked at using computer methods. This is the part of the system where we turn numbers into something we can actually use. The computer uses ways to figure out what kind of player someone is, how tired they are, if they are likely to get hurt, and how well they are doing. It also uses models to look at complicated information to see how players move. We use this information to guess if a player will get hurt, how long it will take them to recover, if their performance will get worse,se and if their training is working. We also use computers to look at videos of the games so we can see where the players are, how the ball is moving, ng and what kind of plan the team is using. This helps us because the special devices the players wear can only tell us so much.

Performance Insights – The output of this processing stage is a set of performance insights: overall evaluation, workload assessment, fatigue detection, injury-risk prediction, tactical analysis, recovery monitoring, and personalised training recommendations, delivered through dashboards and reports rather than raw numbers, so coaches can read them quickly and accurately.

Decision Support - The last part of the framework is where people actually use the information they have found. Coaches use the framework to decide how hard the athletes should train, plan when to make changes to the team, figure out what tactics to use, and make sure the athletes are

not getting too tired. Athletes use the framework to get better at their sport, keep track of how fit they are, lower their chance of getting hurt,t and see how well they are recovering. Sports scientists use the framework to look at how the athletes are doing and how their bodies are changing. Healthcare professionals use the framework to keep an eye on athletes who are getting better after an injury, catch any problems early, and create plans to help them recover. The team management uses the framework to find talent, help the athletes get better over time,e and see how well the whole team is doing. The framework is really important for the team management to understand the athletes, and the framework is used by the team management to make decisions.

CHAPTER: LITERATURE REVIEW

Nijhawan et al. (2025) examined how AI and smart cyber-physical systems (CPS), wearables, and sensors integrated with computing infrastructure are changing sports analytics by enabling real-time tactical adjustment, personalised coaching, and predictive injury prevention. Drawing on case studies from football and cricket, the authors also raised the ethical stakes involved in athlete data privacy and sketched a future direction toward autonomous coaching support.

McDonald (2025) looked at how AI and machine learning are being combined for injury prevention and workload management, fusing multiple data streams, computer vision, wearables, and psychological indicators into systems that give real-time, adaptive feedback covering both individual athlete health and team-level strategy.

Maqbool, d'Albonda, and Albustanji (2026) focused on how IoT and AI together are reshaping football through real-time player monitoring, better-informed coaching decisions, and stronger fan engagement, citing practical examples such as Video Assistant Referee (VAR) systems and

smart ball technology used at the 2022 FIFA World Cup to show how data-driven tools have improved both refereeing accuracy and match management.

Srivastava et al. (2024) proposed a framework that pairs advanced wearables, accelerometers and bioimpedance tools among them, with AI to deliver real-time, personalised feedback to athletes. By continuously analysing physiological and biomechanical data together, the system helped coaches and athletes fine-tune training and cut injury risk; the authors backed this up with real-world trials while also flagging the practical and ethical hurdles involved in deploying this kind of data-driven sports technology.

Narendran, Swarna Teja, Sumithra Devi, and Gayathri (2024) combined wireless sensor networks (WSNs) with the K-Nearest Neighbors algorithm to capture the fine detail of athlete movement in real time, an approach that overcame limitations in earlier systems and recognised complex activity patterns accurately enough to give coaches precise, data-driven metrics for refining training.

Jain (2025) examined how deep learning models, CNNs and RNNs among them, use real-time wearable and video data to predict athlete performance and flag injury risk. By offering precise insight into workload, fatigue, and biomechanics, these AI-driven systems let coaches optimise training and game strategy more effectively than conventional statistical methods allow.

Khan et al. (2025) traced the shift from restrictive, lab-based biomechanical assessment toward real-time, in-field motion analysis powered by AI-integrated wearables and smart textiles. Using edge-AI processing and continuous sensor streams, these tools give athletes and coaches immediate, personalised feedback on technique and workload, making advanced biomechanical

assessment practical and scalable for everyday injury prevention and performance work, rather than something confined to a lab.

Mateus, Abade, Coutinho, Gómez, Peñas, and Sampaio (2024) reviewed AI's role across sports science broadly, detailing its use in optimising training load, preventing injury, and managing overall athlete health. The authors stressed the need to build AI literacy into academic curricula and cautioned against letting AI-driven data override the judgement of experienced practitioners.

Dudek et al. (2025) reviewed how wearable sensors combined with AI analytics are changing sports science through real-time physiological tracking and personalised workload optimisation. Machine learning models in the studies they reviewed reliably identified fatigue and predicted injury risk, but the field still faces recurring obstacles: inconsistent sensor standards, data privacy concerns, and costs high enough to keep the technology out of reach for amateur users. The authors argued that edge-AI advances and stricter validation protocols would be needed to make these systems scalable and equitable.

Barra, Carta, Giuliani, Pisu, Podda, and Riboni (2023) presented FootApp, an AI-powered system for football match annotation, built in response to growing demand, both scientific and commercial, for large, well-annotated datasets to train AI algorithms for football-specific problems, reflecting how much the market for football data has grown in recent years.

Research Gap – A gap runs through nearly all of it: most studies validate their systems in controlled or small-scale settings, and few address how a smaller club or academic programme, without a professional club's budget, it might realistically deploy the same technology. This gap motivates the methodology and discussion that follow.

CHAPTER: RESEARCH METHODOLOGY

1. Research Design

This study follows a qualitative secondary research design. Rather than collecting new data through experiments or surveys, it works from existing published research, synthesising what is already known about AI-powered, IoT-based football performance monitoring into a single, coherent account.

2. Data Sources

Literature was drawn from the following databases, chosen for their strength in engineering, computing, and sports science research:

- IEEE Xplore
- ACM Digital Library
- Springer
- ScienceDirect
- MDPI
- Google Scholar

3. Inclusion Criteria

- Published in a peer-reviewed journal or conference proceedings
- Written in English
- Published between 2015 and 2025
- Directly relevant to IoT wearable sensors, AI, or performance monitoring in football or closely related sports

4. Exclusion Criteria

- Not peer-reviewed (blogs, unverified news articles, marketing material)
- Focused on sports or applications with no meaningful relevance to football performance monitoring
- Duplicates or earlier versions of studies already captured through another source

5. Data Analysis Method

Two complementary methods were used to analyse the extracted material:

Thematic analysis grouped findings into recurring themes, sensor types, AI techniques, benefits, and limitations, rather than treating each study as an isolated data point, which is what allowed the literature review to be organised by theme rather than as a source-by-source list.

Comparative analysis set findings from different studies against one another to identify points of agreement, points of disagreement, and gaps that no single study had fully addressed.

CHAPTER: FINDINGS AND DISCUSSION

1. Key Findings

When we look at the ten studies, we can see a pattern. Wearable sensors, GPS, accelerometers, gyroscopes, heart rate monitors, and EMG sensors are the tools used to collect data. Then AI models, especially machine learning classifiers and deep learning, are used on top of that data. These models turn the data from the sensors into useful information about fatigue, injury risk and performance.

Some studies use types of sensors together. For example, Srivastava et al. in 2024 and Narendran et al. In 2024, it was found that using sensors gives more accurate results than using just one. This shows that combining data from sensors, not just one sensor, gives the best results.

Deep learning models, like LSTM networks, work well with data from sensors that is collected over time. This is because they can remember information from the past, not just look at each piece of data on its own. As Jain said in 2025, this is important for understanding time-series sensor data.

Several studies, like Nijhawan et al. in 2025 and Maqbool et al. In 2026, say that being able to process data in time is important. It is not about being able to predict what will happen after it has already happened. Wearable sensors and AI models need to be able to give coaches information during a match, not just after it is over. This is what makes a system really useful to a coach.

2. Benefits of AI-Powered Monitoring

Real-time analysis. Continuous sensor data processed through AI gives coaches an immediate read on player condition rather than one available only after a session ends, letting them adjust intensity or substitute a player before a problem, not after.

Personalised training. Because AI models can track an individual player's patterns over time, training loads and recovery plans can be tailored to that player specifically rather than applied uniformly across a squad.

Injury prevention. Predictive models that flag early signs of fatigue or elevated biomechanical strain give medical staff a lead time they would not otherwise have; several studies frame this as the technology's most consequential benefit (Jain 2025; Dudek et al. 2025).

Improved tactical decisions. Positioning, movement, and workload data feed directly into tactical planning, letting coaches base substitutions and formation changes on what the data shows rather than on instinct alone.

Cost barriers. High-end wearable systems and the AI infrastructure they depend on remain expensive enough to put them out of reach for smaller clubs, academic institutions, and amateur programmes, a limitation Dudek et al. (2025) identify as one of the field's most persistent.

3. Comparison of Existing Technologies

Table 5.1: Comparison of AI Techniques Used in Football Performance Monitoring

Technique	Strengths	Limitations	Typical Use Case
Machine Learning (Random Forest, SVM, KNN)	Interpretable, works well with smaller datasets	Struggles with highly complex, sequential patterns	Player classification, basic injury-risk scoring
Deep Learning (CNN, RNN, LSTM)	Handles complex, sequential, and visual data well	Needs large datasets, harder to interpret	Movement recognition, time-series fatigue prediction
Predictive	Forecasts future	Accuracy	Injury probability,

Technique	Strengths	Limitations	Typical Use Case
Analytics	outcomes from historical trends	depends heavily on data quality	recovery time estimation
Computer Vision	Captures tactical and positional context wearables cannot	Sensitive to camera angle, lighting, occlusion	Player and ball tracking, formation analysis

4. Emerging Trends

Edge AI. Edge AI refers to running AI models directly on or near the wearable device rather than sending all raw data to the cloud for processing. It cuts the delay between a reading and a usable insight, which matters when a coach needs feedback during a match rather than well after it.

Digital Twins. A digital twin is a virtual, continuously updated model of a real player, built from their sensor data, that can be used to simulate how they might respond to a given training load or tactical scenario before trying it in practice.

Explainable AI. Explainable AI (XAI) covers methods that make an AI model's reasoning visible rather than treating it as a black box, an important property when a coach or medical professional needs to understand why a system is flagging a player as high injury risk, not just accept the flag on faith.

Federated Learning. Federated learning is a training approach where a model learns from data spread across many devices or clubs without that data ever leaving its original location, a useful

compromise between building a stronger AI model from more data and keeping each club's or athlete's data private.

CHAPTER: CONCLUSION

1. Summary of Study

This study set out to examine AI-powered football performance monitoring systems built on IoT wearable sensors, through a secondary review of literature on the sensors, AI techniques, benefits, limitations, and likely future direction of the field. Ten studies published between 2023 and 2026 were analysed thematically and comparatively to build a consolidated account of where the field currently stands.

2. Major Conclusions

The review showed that things like GPS and sensors that track movement and heart rate are really important for football teams to check how players are doing. These tools work with computer programs to give teams a lot of useful information. They help teams figure out how to train players to stop injuries from happening and make good decisions during games. This is what most of the research says. There are still some problems that make it hard for all teams to use these tools. Some of these problems are worries about keeping player information private, keeping data safe, making sure the sensors work right, and the cost of everything. These problems are especially tough for teams that do not have a lot of money, like football clubs. Football performance monitoring systems like these are really helpful. Football teams have to deal with these issues to use them properly.

3. Practical Implications

For football clubs and coaching staff, this review suggests that the most reliable gains currently come from combining multiple sensor types rather than relying on a single device and from prioritising real-time processing over systems that only offer insight after a session has ended. For smaller clubs and academic programmes, cost remains the main barrier to adoption, which points to a practical need for lower-cost sensor and AI options built specifically with that segment in mind.

4. Limitations of the Study

This review is based on people's research. It is only as good as the research it looks at. The review does not do any experiments or collect new information.

The studies that were looked at are different from one another. They used different methods, had different numbers of people in them, and gave different amounts of detail in their reports. This makes it hard to compare what they found.

The review only looks at research that was written in English and checked by experts. It only includes research that was published between 2015 and 2025. This means it might miss work that was published at other times or in other languages.

Privacy concerns. Continuous physiological monitoring raises real questions about who owns an athlete’s data, how long it is kept, and what it might be used for beyond training, concerns several reviewed studies raise directly (Nijhawan et al. 2025; Srivastava et al. 2024).

Data security. Sensitive health and performance data moving over wireless networks needs protection against interception or misuse, a requirement that becomes harder to meet as more devices and data streams get added to a system.

Sensor reliability. Placement, calibration, and environmental conditions all affect how consistent sensor readings are, and inconsistent data undermines whatever AI model sits downstream of it, regardless of how sophisticated that model is.

5. Recommendations for Future Research

Future work should prioritise field testing of AI-IoT monitoring systems in resource-constrained club and academic settings, development of standardised sensor placement and calibration protocols, and explainable AI methods tailored to sports applications so that system outputs remain interpretable to coaching and medical staff. Longitudinal studies tracking the same players across multiple seasons would also help clarify how well these systems predict injury and performance decline over the longer term, rather than only within a single training cycle or match.

Next-Generation Wearable Sensors – Future wearables are likely to be smaller, lighter, and less intrusive than current devices, some already integrated directly into smart textiles rather than worn as a separate unit (Khan et al. 2025). Longer battery life, better environmental resistance, and steadier sensor accuracy under match conditions would address several of the reliability concerns raised throughout this review.

AI-Driven Personalised Coaching – As models mature, coaching recommendations are likely to move from general, squad-wide guidance toward advice built around a specific player's history, physiology, and playing style, an extension of the personalised feedback loops already piloted by Srivastava et al. (2024).

Smart Stadium Ecosystems – Wearable data is likely to be integrated with broader stadium infrastructure, cameras, environmental sensors, and fan-facing systems, creating a more complete picture of a match that serves coaching staff, medical teams, and broadcasters at once, building on the VAR and smart ball examples already in use (Maqbool et al. 2026).

Integration with Computer Vision – Combining wearable sensor data with computer vision is likely to deepen further, since each source covers what the other misses: wearables capture what is happening inside the body, while vision systems capture position, formation, and tactical context. Tighter integration between the two would give a more complete account of both individual and team performance than either can provide alone.

Ethical and Regulatory Considerations

As monitoring becomes more pervasive, questions of consent, data ownership, and appropriate use are only going to grow more pressing. Clear regulatory standards, covering how long data can be kept, who is allowed to access it, and what it can and cannot be used for, will likely become a precondition for wider adoption rather than an afterthought, a concern raised repeatedly across the reviewed literature (Nijhawan et al. 2025; Dudek et al. 2025).

6. Research Opportunities

Several gaps identified in this review point to useful directions for future research: field studies that test AI-IoT systems in lower-resource club and academic settings rather than only professional environments; standardised protocols for sensor placement and calibration to improve data consistency across studies; and explainable AI methods specifically built for sports applications so that coaches and medical staff can trust and interpret system outputs rather than treat them as unexplained verdicts.

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