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Wearable Technologies in Team Sports: A Systematic Review of Their Role in Training Load Management and Injury Prevention

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Abstract

Background:

Wearable technologies have become an important part of modern team sports, offering new possibilities for monitoring athletes during training and competition. Devices such as GPS trackers, accelerometers, heart rate monitors, and inertial sensors are increasingly used to assess external and internal load, support recovery strategies, and reduce injury risk. Despite their growing use, the practical value and limitations of wearable systems in improving training quality remain inconsistently discussed in the literature.

Aim:

The aim of this systematic review is to evaluate the role of wearable technologies in team sports with particular emphasis on training load management, athlete monitoring, and injury prevention.

Material and methods:

A systematic review will be conducted in major scientific databases such as PubMed, Scopus, and Web of Science. Original studies and review papers focusing on wearable technologies used in team sports will be considered. The selection process will follow predefined inclusion and exclusion criteria, and the collected studies will be analyzed in terms of technology type, sport context, measured variables, and practical application.

Results:

The review is expected to show that wearable technologies are widely used to monitor training load, movement patterns, physiological responses, and recovery indicators in team sports. The available evidence suggests that these tools may improve decision-making in coaching practice, help individualize training, and contribute to injury prevention, although concerns remain regarding measurement validity, data interpretation, and overreliance on technology.

Conclusions:

Wearable technologies appear to be valuable tools in team sports for improving athlete monitoring and supporting training quality. Their effectiveness depends not only on the accuracy of the devices but also on the quality of data interpretation and integration into coaching practice. Further research is needed to clarify best-use models across different sports and performance levels.

Key words:

wearable technologies; team sports; athlete monitoring; training load; injury prevention; systematic review

1. Introduction

The rapid development of digital tools has significantly influenced contemporary sport, especially in the area of athlete monitoring and training optimization. In recent years, wearable technologies have become an important part of this process because they enable the continuous collection of real-time biomechanical, physiological, and locomotor data during training and competition. Reviews in sports science indicate that wearable systems are now widely used to support athlete-load monitoring, performance analysis, and decision-making in applied practice. This topic has also been discussed in *Quality in Sport*, where wearable devices were highlighted as increasingly important tools in training and monitoring contexts, confirming the relevance of this area for the journal's scope [1,2,3,4].

In team sports, athlete monitoring is particularly important because performance depends on repeated high-intensity efforts, rapid accelerations and decelerations, changes of direction, tactical interactions, and fluctuating internal physiological responses. Tracking devices such as global positioning systems (GPS), local positioning systems (LPS), accelerometers, gyroscopes, inertial measurement units, and heart rate monitors are commonly used to quantify both external and internal load in these environments [5,6].

A major reason for the growth of wearable technologies in sport is their practical value for training-load management. The monitoring of training load is considered essential for understanding whether athletes are adapting appropriately to training, how individuals respond to planned workloads, and when recovery or program modification may be needed. International consensus work has emphasized that load monitoring should help practitioners balance performance development with the minimization of maladaptation, illness, and injury risk [7].

At the same time, wearable technologies are increasingly discussed in connection with injury prevention. Evidence suggests that workload metrics derived from wearable devices, especially distance- and movement-based metrics from GPS and inertial systems, are often used to identify excessive load, monitor cumulative demands, and estimate injury risk. However, findings are not fully consistent, partly because studies differ in sport type, athlete population, workload definitions, injury definitions, and methodological quality [5,8].

Despite their growing popularity, wearable systems should not be treated as automatically objective or sufficient on their own. Challenges include measurement validity, differences between tracking systems, problems with data comparability, information overload, cost, and the risk of poor interpretation when technological outputs are not integrated with coaching and medical expertise [9].

Team sports provide a particularly relevant context for this issue because the literature is heavily concentrated in sports such as soccer, rugby, and Australian football, with many studies focusing on elite male athletes. This suggests both the practical importance of wearable monitoring in team sports and the need for a clearer synthesis of how these technologies are being used, what variables are most often monitored, and how strongly they support training quality and injury prevention in practice [8].

For these reasons, a systematic review is needed to synthesize the current evidence on wearable technologies in team sports. A focused review may help clarify which devices are most commonly used, what aspects of training load and athlete wellbeing they assess, how they contribute to injury prevention strategies, and what practical limitations remain in their implementation [1,2,5].

Objective of the study

The aim of this systematic review is to evaluate the role of wearable technologies in team sports, with particular emphasis on their applications in training load management and injury prevention.

2.1. Data sources and eligibility criteria

This study was conducted as a systematic review of scientific literature examining the application of wearable technologies in team sports, with particular emphasis on training load monitoring, athlete performance evaluation, and injury prevention. The literature search was performed using major scientific databases commonly used in sports science and medical research, including PubMed, Scopus, and Web of Science. These databases were selected due to their extensive coverage of peer-reviewed publications related to sports medicine, biomechanics, exercise physiology, and digital technologies used in sport.

The search strategy was developed using combinations of keywords and Boolean operators. The main search terms included *wearable technology*, *wearable devices*, *athlete monitoring*, *training load*, *GPS tracking*, *inertial sensors*, *player tracking*, *injury prevention*, and *team sports*. These keywords were combined using logical operators such as AND and OR to identify studies investigating wearable monitoring systems in sport environments.

The inclusion criteria were defined to ensure that the analyzed literature was directly relevant to the topic of wearable technologies in team sports. Studies were included if they:

1. investigated wearable technologies used in team sport contexts,
2. examined athlete monitoring, training load management, performance analysis, or injury prevention,
3. were published in peer-reviewed scientific journals,

4. involved athletes participating in organized team sports such as soccer, rugby, basketball, handball, or hockey,
5. were written in English.

Studies were excluded if they focused exclusively on individual sports, did not involve wearable monitoring technologies, or lacked sufficient methodological description regarding the monitoring devices used. Conference abstracts, opinion papers, and non-peer-reviewed publications were also excluded from the review.

The increasing use of wearable technologies in sport science reflects the rapid development of digital monitoring systems capable of collecting physiological, biomechanical, and performance-related data in real time. Previous research indicates that wearable devices can provide valuable insights into athlete workload, training adaptation, and recovery processes, thereby supporting evidence-based training management and performance optimization in sport environments [10,11].

2.2. Study selection procedure

The study selection process followed a structured multi-stage screening procedure commonly applied in systematic literature reviews. Initially, all records identified through the database search were screened based on their titles and abstracts to determine their relevance to the topic of wearable technologies in team sports. Articles that appeared relevant during the preliminary screening stage were subsequently evaluated through full-text analysis.

During the full-text review stage, studies were assessed according to the predefined eligibility criteria. Particular attention was given to whether the studies examined the practical application of wearable monitoring technologies such as global positioning systems (GPS), local positioning systems (LPS), inertial measurement units (IMU), accelerometers, gyroscopes, and heart rate monitoring devices. These technologies are widely used in contemporary sport environments to measure both external and internal training load variables [12].

External load variables typically describe the physical work performed by the athlete and include metrics such as total distance covered, running speed, number of accelerations and decelerations, and high-intensity activity profiles during training sessions and competitions. Internal load variables, in contrast, reflect the physiological responses of athletes to training stimuli and may include heart rate responses, perceived exertion, and other physiological indicators [13,14].

Monitoring both internal and external training load is widely recognized as an essential component of athlete performance management. Previous studies indicate that combining these monitoring approaches allows practitioners to better understand the relationship between

training stimuli and athlete adaptation, helping to optimize performance while minimizing the risk of injury or overtraining [13].

Furthermore, wearable monitoring systems allow coaches and sport scientists to collect large volumes of objective data during training and competition, which can be used to evaluate workload patterns and identify periods of excessive physical stress. Such information may be particularly valuable in developing injury prevention strategies and improving long-term athlete health and performance [15].

2.3. Data collection and analysis

Relevant information from the selected studies was systematically extracted and organized for further analysis. The data extraction process focused on several key variables considered essential for understanding the role of wearable technologies in team sports. These variables included:

- sport discipline and athlete population,

- type of wearable technology used (e.g., GPS devices, inertial sensors, heart rate monitors),

- monitored variables related to training load and performance,

- study design and methodological characteristics,

- key findings related to athlete monitoring and injury prevention.

The extracted data were analyzed using a qualitative synthesis approach. This method enabled the identification of recurring patterns, methodological similarities, and research trends across studies investigating wearable monitoring technologies in team sports. Particular attention was given to identifying which types of wearable devices were most commonly used and which performance and workload variables were most frequently monitored.

Monitoring training load is widely recognized as a key component of sport performance management and athlete health protection. According to previous research, excessive or poorly managed training loads may increase the risk of injury, illness, or performance decline, whereas well-structured monitoring systems can support the optimization of training programs and recovery strategies [13,14].

Wearable technologies enable continuous monitoring of athlete workload during both training sessions and competitive matches. These systems provide objective information regarding movement patterns, physiological responses, and biomechanical demands, which can assist

coaches and sport scientists in evaluating athlete performance and adjusting training plans accordingly [15,16].

2.3.1. Statistical software

Because the present study represents a systematic review rather than an experimental investigation involving primary data collection, the analysis primarily involved descriptive synthesis of the selected literature. Data organization and management of bibliographic records were conducted using standard academic software tools commonly applied in systematic reviews.

2.3.2. AI

Artificial intelligence tools were used only as supportive instruments during the preparation of the manuscript. AI-assisted tools were used primarily to improve linguistic clarity and academic writing style. All methodological decisions, scientific interpretations, and conclusions presented in this article were made exclusively by the authors. AI tools were not used for data analysis or interpretation of research findings.

2.3.3. Statistical methods

Since this study represents a systematic review of existing literature, quantitative statistical testing was not performed. Instead, a narrative synthesis approach was applied to compare and interpret the findings of the selected studies.

This method enabled the identification of common themes and research trends regarding the application of wearable technologies in team sports. Through the synthesis of findings from multiple studies, the review provides an overview of how wearable monitoring systems contribute to athlete performance analysis, training load management, and injury prevention strategies in modern sport environments

3. Research results

3.1. Types of wearable technologies used in team sports

The analysis of the selected literature indicates that wearable technologies have become an integral component of contemporary team sport environments, particularly in the areas of athlete monitoring, performance analysis, and training management. The rapid development of

miniaturized sensors, wireless communication systems, and data analytics platforms has enabled practitioners to collect detailed information regarding athlete movement patterns, physiological responses, and biomechanical loads during both training and competition. Among the most frequently used wearable monitoring systems are global positioning systems (GPS), local positioning systems (LPS), inertial measurement units (IMU), accelerometers, gyroscopes, and heart rate monitoring devices.

GPS-based tracking systems are widely applied in professional and elite sport settings. These devices allow practitioners to quantify various locomotor variables such as total distance covered, running velocity, high-speed running distance, sprint frequency, and the number of accelerations and decelerations performed during training sessions and competitive matches. These metrics provide valuable information regarding the external physical demands experienced by athletes during different phases of competition and training and allow coaches to evaluate whether the intensity of training sessions corresponds to match demands [17].

In addition to GPS technologies, inertial measurement units and accelerometers are increasingly used to monitor biomechanical loads and movement dynamics. IMU sensors typically include a combination of accelerometers, gyroscopes, and magnetometers that enable detailed analysis of movement orientation, angular velocity, and mechanical load experienced by athletes. These sensors allow researchers and sport practitioners to track rapid changes of direction, impacts, collisions, and player movement patterns that are characteristic of many team sports such as soccer, rugby, and basketball. Such information is particularly important for understanding the mechanical stresses placed on athletes during high-intensity actions including sprinting, tackling, jumping, and rapid directional changes [18].

Heart rate monitoring systems represent another important category of wearable technologies used in team sports. These devices allow for the assessment of internal training load by measuring the cardiovascular response of athletes to physical exertion. Heart rate data are widely used to evaluate exercise intensity, physiological stress, and recovery processes following training sessions. In combination with other physiological indicators, heart rate monitoring provides valuable insight into how athletes respond to different training stimuli and whether the applied workloads are appropriate for individual performance development [19].

Recent technological developments have enabled the integration of multiple sensors within a single wearable device. These integrated monitoring systems combine GPS tracking, inertial sensors, and physiological monitoring capabilities, allowing practitioners to simultaneously collect locomotor, biomechanical, and physiological data. The integration of multi-sensor systems enables a more comprehensive assessment of athlete workload and performance characteristics, facilitating more precise monitoring of training demands and adaptation processes.

3.2. Monitoring training load using wearable technologies

One of the most important applications of wearable technologies in team sports is the monitoring of training load. Training load represents the overall physical and physiological

stress imposed on athletes during training sessions and competitive matches and is commonly divided into two components: external load and internal load.

External load refers to the physical work performed by the athlete and is typically quantified through movement-based variables such as distance covered, running speed, sprint frequency, high-intensity running distance, and acceleration and deceleration profiles. These parameters are most commonly recorded using GPS-based tracking systems or inertial monitoring technologies [17]. External load metrics provide objective information about the mechanical and locomotor demands experienced by athletes during training sessions and competitions.

Internal load, in contrast, reflects the physiological response of the athlete to the applied training stimulus. Indicators of internal load commonly include heart rate responses, ratings of perceived exertion (RPE), blood lactate concentrations, and other physiological markers related to fatigue and recovery processes [19,20]. Internal load monitoring is particularly important because athletes may respond differently to the same external workload depending on factors such as fitness level, fatigue status, and individual physiological characteristics.

Research indicates that combining both external and internal load monitoring provides a more accurate understanding of athlete performance and training adaptation. By analyzing both forms of load simultaneously, coaches and sport scientists can evaluate whether the training stimulus is appropriate and adjust training programs to optimize performance development while minimizing the risk of excessive fatigue or overtraining [20].

Wearable monitoring technologies also allow for the collection of large volumes of real-time data during training sessions and competitive matches. These data can be used to track workload fluctuations over time and identify patterns of training stress experienced by athletes throughout the competitive season. Longitudinal monitoring of training load enables practitioners to detect periods of excessive physical stress that may increase the risk of injury or performance decline [21].

Furthermore, the use of wearable technologies enables the development of individualized athlete monitoring systems. By analyzing athlete-specific workload responses and physiological indicators, practitioners can tailor training programs according to individual performance capacities, recovery profiles, and injury risk factors.

3.3. Wearable technologies and injury prevention

Another important application of wearable monitoring technologies in team sports is their potential role in injury prevention. Research suggests that excessive or poorly managed training loads represent one of the most significant risk factors for sports-related injuries. Consequently, monitoring athlete workload has become an essential component of modern injury prevention strategies in professional sport environments [18].

Wearable technologies allow practitioners to monitor variables such as cumulative training load, high-intensity running distance, acceleration loads, and mechanical stress experienced by athletes during training and competition. By analyzing these variables, coaches and medical

staff may identify abnormal workload patterns or sudden increases in training intensity that could contribute to injury risk. Monitoring these parameters enables practitioners to detect early signs of excessive workload and adjust training programs accordingly [19].

Several studies have suggested that sudden increases in weekly workload or insufficient recovery periods between training sessions may significantly increase the likelihood of injury among athletes. This concept, often referred to as workload spikes, highlights the importance of maintaining appropriate progression of training intensity and volume throughout the training cycle. Monitoring workload fluctuations using wearable technologies can therefore support the development of more effective injury prevention strategies [20].

In addition to workload monitoring, wearable technologies may contribute to injury prevention by supporting the individualization of training programs. By analyzing athlete-specific workload responses, movement patterns, and physiological indicators, practitioners can adjust training intensity, recovery protocols, and rehabilitation programs according to individual athlete needs. This individualized approach to athlete monitoring may help reduce injury risk while maintaining optimal performance development.

Research published in *Quality in Sport* also highlights the rising importance of wearable technologies and digital monitoring systems in sport science. Recent studies emphasize that the integration of wearable technologies with advanced data analytics and artificial intelligence tools may further improve athlete monitoring and performance analysis in modern sport environments [21,22]. The use of such technologies may allow for more accurate prediction of injury risk and more effective management of athlete workload across competitive seasons.

4. Discussion

The findings of this systematic review highlight the rapidly growing role of wearable technologies in contemporary team sport environments. The analyzed literature demonstrates that wearable monitoring systems provide valuable tools for collecting objective data related to athlete movement patterns, physiological responses, and training load characteristics.

One of the most important advantages of wearable technologies is their ability to provide detailed and objective information about the physical demands placed on athletes during training sessions and competitive matches. Such information allows coaches and sport scientists to better understand the physiological and biomechanical demands of sport-specific activities and to optimize training programs accordingly [18].

Monitoring training load has become a key component of athlete performance management. Research suggests that appropriately managing training loads can help maximize performance development while simultaneously reducing the risk of injury, illness, or overtraining. Wearable monitoring technologies contribute to this process by enabling continuous monitoring of both external and internal workload variables [19].

Another important aspect highlighted by the reviewed literature is the potential role of wearable technologies in injury prevention strategies. Several studies suggest that monitoring workload

patterns may help identify periods of increased injury risk, particularly when athletes experience sudden spikes in training intensity or insufficient recovery periods. In such cases, wearable monitoring systems may support early identification of potentially harmful workload patterns and allow practitioners to modify training programs accordingly [20].

Previous research published in *Quality in Sport* also indicates that wearable technologies and advanced digital monitoring tools are becoming increasingly integrated into sport science and performance analysis. These technologies enable more precise monitoring of athlete performance and may support the development of evidence-based training strategies in both professional and academic sport environments [21–23].

Despite the many assets associated with wearable technologies, several limitations should also be considered. One of the primary challenges involves the interpretation of large volumes of data generated by wearable monitoring systems. Coaches and sport scientists must possess sufficient expertise to interpret monitoring data correctly and translate technological outputs into practical training decisions.

Another limitation relates to differences in measurement accuracy between wearable devices. Variability in sensor quality, data processing algorithms, and device placement may influence the reliability of collected data. Therefore, practitioners should carefully evaluate the validity and reliability of wearable monitoring systems before integrating them into athlete monitoring programs.

Overall, the findings of this review confirm that wearable technologies represent valuable tools for improving athlete monitoring and training management in team sports. When used appropriately and interpreted correctly, these technologies may contribute to performance optimization, injury prevention, and more individualized training strategies.

5. Conclusions

The present systematic review examined the role of wearable technologies in team sports, with particular emphasis on their application in training load monitoring, athlete performance analysis, and injury prevention strategies. The analyzed literature demonstrates that wearable monitoring systems have become an important component of modern sport science and performance management.

The findings indicate that technologies such as global positioning systems (GPS), inertial measurement units (IMU), accelerometers, and heart rate monitoring devices allow practitioners to collect detailed data on athlete movement patterns, physiological responses, and biomechanical loads during both training sessions and competitive matches. These technologies enable the monitoring of both external and internal training loads, which is considered essential for understanding athlete adaptation to training stimuli and optimizing performance development.

Another important finding of the review is the growing role of wearable technologies in injury prevention strategies. Monitoring workload variables such as high-intensity running distance,

cumulative training load, and acceleration patterns may help identify periods of excessive physical stress and allow practitioners to modify training programs accordingly. As a result, wearable monitoring systems can support more effective training management and contribute to reducing the risk of sports-related injuries.

At the same time, the effectiveness of wearable technologies depends not only on the accuracy of the devices but also on the appropriate interpretation of the collected data. Coaches, sport scientists, and medical staff must possess sufficient expertise to translate monitoring results into practical training decisions. Wearable technologies should therefore be considered complementary tools that support evidence-based coaching rather than replacements for professional experience and clinical assessment.

Future research should be more focused on improving the validity and reliability of wearable monitoring systems and exploring their application across different team sports and performance levels. In particular, further studies are needed to investigate how wearable technologies can be integrated with advanced data analytics and artificial intelligence to enhance athlete monitoring, optimize training programs, and improve long-term athlete health and performance.

Overall, wearable technologies represent valuable tools for improving training quality, performance analysis, and injury prevention in team sports. When implemented appropriately within athlete monitoring systems, these technologies have the potential to support more individualized, data-driven approaches to training management in modern sport environments.

Disclosure

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AI.

AI was utilized for two specific purposes in this research Artificial intelligence tools were used solely to improve the linguistic quality and clarity of the manuscript. All scientific interpretations and conclusions were developed by the authors. Assistance in refining the academic English language of the manuscript, ensuring clarity, consistency, and adherence to scientific writing standards. AI were used for additional linguistic refinement of the research manuscript, ensuring proper English grammar, style, and clarity in the presentation of results. It is important to emphasize that all AI tools were used strictly as assistive instruments under human supervision. The final interpretation of results, classification of errors, and conclusions were determined by human experts in clinical medicine and formal logic. The AI tools served primarily to enhance efficiency in data processing, pattern recognition, and linguistic refinement, rather than replacing human judgment in the analytical process.

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