The Role of Physical Rehabilitation in Athletic Performance Recovery in IoT

Dr. S. Jeyakumar[1], Dr. K. Raja Senthil[2]
[1]Professor & Research Coordinator, School of Health Sciences, Garden City University, Bangalore, Karnataka, India.
E-mail: jeyakumar.s@gcu.edu.in
[2]Professor & Research Supervisor, School of Health Sciences, Department of Physiotherapy, Garden City University, Bangalore, Karnataka, India
E-mail: ksrajashenthil2023@gmail.com

Article Info

Article History:

Received Apr 03, 2026
Revised May 06, 2026
Accepted Jun 05, 2026

Keywords:

AI,
IoT,
Sensors,
Healthcare,
Physical rehabilitation,
Medical personnel,
Tracking system

ABSTRACT

The outcomes of clinical research and current neurological rehabilitation medicine demonstrate that impaired limb motor function can be partially restored with scientific rehabilitative training. The physician must regularly evaluate the patient's physical condition and the impact of teaching in order to develop or alter the follow-up rehabilitation exercises plan. This study proposes an IoT-enabled physical rehabilitation framework for athletic performance recovery that integrates wearable sensors, blockchain technology, and neural network-based injury risk analysis. The proposed system continuously acquires physiological and biomechanical data from wearable sensors and employs a blockchain-assisted multi-sensor data fusion mechanism to ensure secure, reliable, and tamper-resistant data management. These technologies enable athletes to maximize their recuperation while reducing the chance of re-injury by constantly tracking physiological and mechanical data. Additionally, remote monitoring and instruction are made possible by the incorporation of wearable technology and IoT sensors into tele-rehabilitation systems, expanding access to specialist care outside of conventional clinical environments. The findings demonstrate the potential of intelligent IoT-based rehabilitation systems to deliver secure, personalized, and efficient recovery solutions for modern sports medicine.

Corresponding Author:

Dr. S. Jeyakumar,
School of Health Sciences,
Garden City University, Bangalore, Karnataka, India.
E-mail: jeyakumar.s@gcu.edu.in

1. INTRODUCTION

The rapid development of wearable technology in sports training, medical management, and rehabilitation therapy is being driven by the increasing convergence of sports science and biomedical engineering across disciplines due to the increasing focus on health and athletic excellence [1]. Specifically, a Photo Plethysmo Graphy (PPG)-based heart rhythm measurement has significantly aided the broad screening of atrial fibrillation. Commercially available wearable devices, such as smart watches, may easily track regular physical activity and basic vital signs. However, the capacity of traditional biophysical sensors to do molecular-level precise monitoring is still restricted [2]. The majority of current clinical standards rely on blood sample, which is laboratory-dependent, ineffective, and time-consuming, limiting individualized applications and dynamic monitoring. Emerging wearable sensor platforms have started to get around these restrictions in recent years by providing high temporal resolution and real-time chemical monitoring through bodily fluids like sweat, interstitial fluid, and breathing.

These gadgets offer great promise in clinical research because they can automatically evaluate data and anticipate health hazards when combined with intelligent interfaces and AI algorithms. For example [3], the noninvasive identification of sweat-based biomarkers like C-reactive protein opens up new possibilities for remote rehabilitation, treatment monitoring, and disease screening. This pattern suggests a paradigm change in wearable technology toward telehealth tracking and early harm warning. Because of their high water content, exceptional softness, biocompatibility [4], and mechanical characteristics akin to those of skin tissue, hydrogels have become essential candidates for flexible electronics and wearable systems. Hydrogels have better adherence, user comfort, and data coupling efficiency than conventional devices made of metals or stiff polymers.

In addition to strain sensing and electrical impulse transduction, hydrogels can acquire intelligent properties like self-healing, stimuli-responsiveness, and multifunctional sensing by adding conductive materials, conductive nanofillers [5], or ionic liquids. These characteristics are gradually turning hydrogels from basic interfacial materials into essential functional elements for flexible sensing and human-machine interactions.

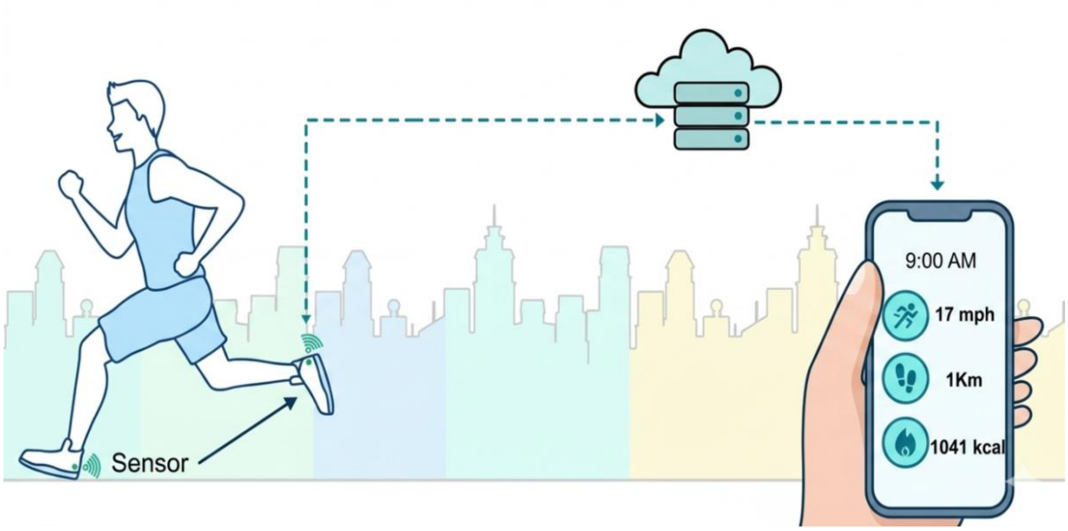

Figure 1. IoT-Based Framework for Athletic Performance Recovery and Sports Rehabilitation

In Figure 1 Shows the proposed IoT architecture integrating wearable sensors, data processing, and rehabilitation monitoring. Hydrogel-based wearable technology makes it possible to track joint mobility, muscle tension, walking patterns, and workout intensity in real time during sports training. This helps to optimize training regimens and minimize fatigue injuries. They continually monitor joint range of motion (ROM) and electromyographic (EMG) signals in preoperative rehabilitation, supporting remote rehabilitation and individualized intervention as well as aiding in the evaluation of healing progression. Intelligent interface with self-healing and reusability, nanocomposite techniques for extremely sensitive strain measurement [6], and dual-network and slide-ring architectures for mechanical support are examples of recent developments.

In the meantime, hydrogel-based wearables are moving closer to multimodal sensing, autonomously feedback, and smart rehabilitation because to the quick advancements in flexible electronics, power storage [7], wireless communications, and artificial intelligence. Building on previous developments, this paper methodically outlines current developments in wearable hydrogel-based sports tracking and rehabilitative technology. In three example scenarios—sports training tracking, injury prevention, and post-exercise rehabilitation—we concentrate on their useful applications and enabling technology while defining future prospects and critically evaluating present issues [8]. The goal is to give researchers and physicians a thorough and forward-thinking resource for developing this new discipline.

2. LITERATURE REVIEW

In order to determine if it is feasible to use SRR to improve the physical capabilities of older people with degenerative disorders, this study examined the impacts and functioning mechanisms of several forms of SRR. 38 of the 633 English-language journal publications that were published during the previous five years were chosen by the study team for a narrative literature assessment [9]. The following was discovered by our summary: (1) End-effector robots, intelligent robotic rolling machines, smart walking machines, and bodysuit robots are the current categories of SRR; Robots with bodysuits were found to be the most well-liked. (2) In the current operating procedures, patients are the primary intermediaries—that is, they control the staff member tools to take part—assistant tools are the primary agents—that is, robots assist patients in participating—and sensors are the agents—that is, myoelectric-powered robots promote patient involvement.

The purpose of conventional wearable sensors is to get over the drawbacks of existing technology so that a user's vital signs can be accurately and non-invasively taken right from the body. Wearable sensors enable athletes to scientifically track their body motions and performance throughout sporting events, surpassing the coach's subjective assessment boundaries [10]. Giving a comprehensive overview of wearable technology and sensing systems to detect and monitor patients' physiological characteristics during post-operative rehab and athletic competition training is the main goal of this review study, as well as to present data demonstrating the system's effectiveness for medical applications.

Additionally [11], a human gait analysis algorithmic that can be used in a variety of sports is proposed through the study of the athlete's human body modelling and motion process, and simulation analysis is used to conduct the gait parameter evaluation and algorithm dependability research. This paper builds a system model using the Internet of Health Things technology, obtains the system's function module structure with the help of the Internet of Health Things technology, and performs standard tests to confirm the system performance after verifying the algorithm's effectiveness. The model developed in this work satisfies both theoretical and practical requirements, as demonstrated by the experimental investigation, and the system can be used in routine in the future.

The physical fitness test design, training layout, training method, training tracking, and effect evaluation are all thoroughly analyzed in this study [12]. The experiment reveals that the training organization still has deficiencies in physical training, diagnostic criteria, training plans and standards, load tracking, uniformity of operation, dietary requirements, and recovery. At all levels of sports teams, there are only 25.40% of professional squad doctors and 23.81% of full-time physical trainers. In all sports squads, there were only 25.40% of professional team doctors and 24.81% of full-time physical fitness trainers. According to the basketball injury study, there were 67 sports-related injuries among basketball players over the course of the year, or 3.25 injuries per person and 2.48 illnesses per 1000 hours. Chronic injuries typically occur in the ankle joint, knee joint, and lumbar back.

3. METHODS AND MATERIALS

3.1 AI and IoT in Healthcare

The next two paragraphs do not represent the original ideas of this paper; instead, they present assertions from the body of current literature. The Internet of Things and artificial intelligence are revolutionary technologies that are changing industries all over the world. A description of these innovations and how they are used in different industries can be found below. AI is the simulation of human intellect in machines that are capable of reasoning, learning, solving problems, and making decisions [13]. It includes technologies that let systems to analyze data, identify patterns, and make predictions or judgments, such as ML, NLP, and machine vision. The IoT is a network of connected devices that collect, share, and analyze data via the internet. These devices, which include wearables, sensors, and smart appliances, enable automation, data-driven decision-making, and real-time monitoring.

Medical services, intelligent cities, production, and agriculture are just a few of the industries that have incorporated AI and IoT technologies. These sectors use sensor data and machine learning techniques for a variety of purposes. IoT and AI work together to improve each of their respective capabilities [14]: Large volumes of real-time data from linked devices are provided via IoT. Smart automated systems, predictive analysis, and better decision-making are made possible by AI's processing of this data to produce actionable insights. In the healthcare industry, for instance, IoT devices gather patient information, which AI then analyzes for early detection. IoT sensors keep an eye on machinery in manufacturing, and AI forecasts maintenance requirements. By increasing productivity, cutting expenses, and enhancing customer experiences, both technologies are spurring innovation across businesses.

3.2 The Impact of the Sports Rehabilitation Robot

The physical and mental traits of senior patients, as well as their unique characteristics, are not given enough consideration in traditional exercise rehab programs, which are designed to concentrate on the features of the patient's ailment. There are numerous obstacles to exercise for older people who are frail [15], such as their physical incapacity to sustain their own physical activity, their unfavorable attitudes toward exercise, and their lack of enough exercise assurance. Sports rehab robots were found to be more successful than traditional rehabilitation techniques in treating degenerative diseases in the elderly, particularly in secondary medical conditions like bone mending, heart disease, respiratory issues, and intestinal dysfunction [16]. Seniors who use a sports therapy robot to aid in their recovery also display positive psychological and behavioral traits.

Additionally, the study demonstrated that older individuals with degenerative conditions benefited from the exercise rehabilitation robot. They showed a notable increase in their balance and coordination, as well as a quicker recovery of their strength and stamina. However, there was no discernible increase in their speed or agility.

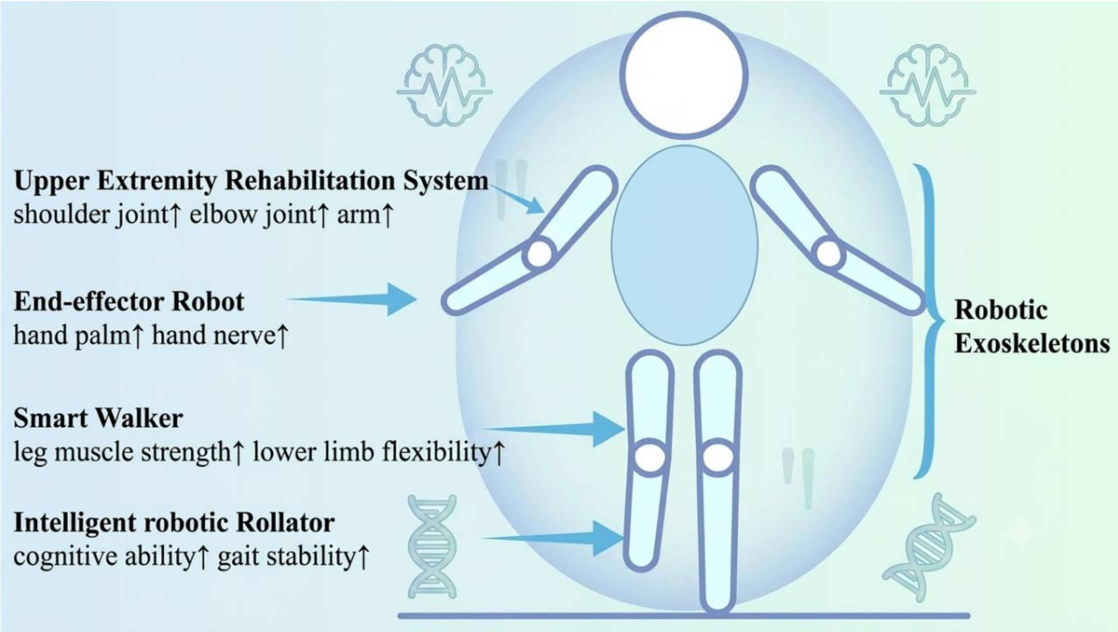

Figure 2. Effects of Various Robot Kinds on Rehabilitation

Figure 2 illustrates the primary body parts that the various rehabilitative robot types target as well as their outcomes.

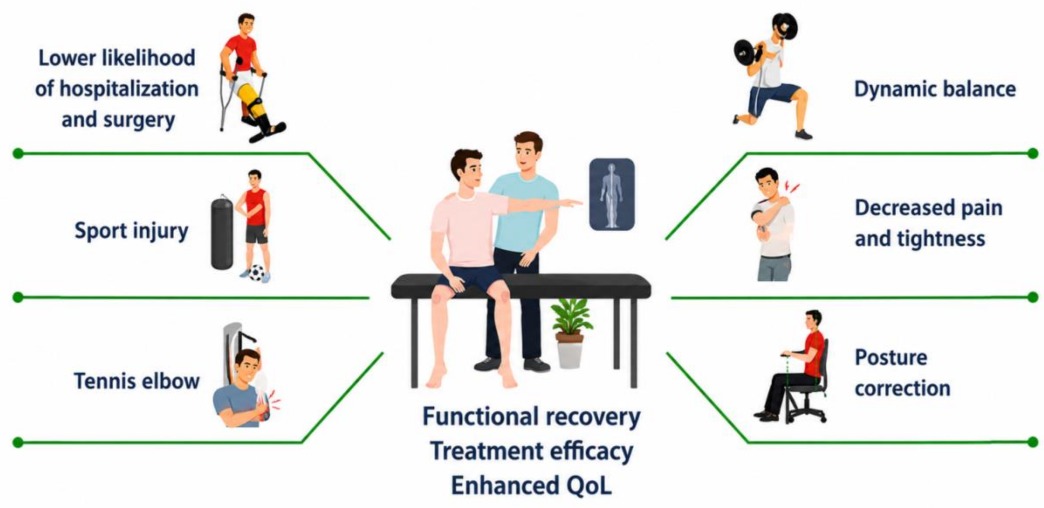

Figure 3. Flow Diagrams for Physical Therapy Rehabilitation

As seen in Figure 3 [17], the physical functioning training system consists of motion mode training, basic strength training, sensitivities and balance training, metabolic system training, and recuperation and regenerative training. Therefore, for many years, professionals from all around the world have been researching ways to lessen knee joint injuries and avoid injuries in basketball. Traditional physical education theories and methods are no longer able to meet the demands of training and competition due to the rapid growth of modern competitive sports. In light of professional sports, a significant advancement in the theory and practice of physical training has been established. The concepts and techniques of functional training, which have garnered international prominence, have dominated the whole physical training system developed in the United States.

Numerous components of body function training [18], when paired with the unique physical strength training qualities of basketball, are always crucial components of body function exercise. Simultaneously [19], China's long-term training period has been validated, and the key to sports technical competence is body muscle strength, prevention is ensured by improvement, and sports level is determined by the management of sports injuries. Consequently, by examining the process and signs of knee joint injuries, the study's findings can be used to teach basketball players how to prevent and treat knee injuries, as well as lessen the number of athletes who sustain knee joint injuries during practice or competition; The knee joint has the potential to decrease the rate of damage, extend the life of athletes, and avoid knee injuries in basketball players. It also serves as a point guide and a conceptual framework for future practical study.

3.3 Building an action tracking system for sports instruction using wearable technology

The system stores a lot of unstructured data in the area of sports injury prevention in physical education instruction, including training data from undergraduates and qualitative information from athletic medicine [20]. To effectively evaluate college students' health and intelligently suggest tailored, scientific training approaches, these data must be processed using data mining algorithms. We must create certain data mining algorithms and theories to handle this unorganized data. To guarantee that the analysis findings are in line with the real scenario, these algorithms and models must take into account the features of the information, such as information size, information type, information quality, etc. In order to accomplish this, we must carry out data preprocessing, which includes procedures like data cleaning, converting data, and information integration to guarantee the correctness and quality of the information.

4. IMPLEMENTATION AND EXPERIMENTAL RESULTS

4.1 IoT and AI in Health Recovery and Rehabilitation

Table 1 shows the allocation of the number of publications pertaining to the health category. The widespread use of IoT and AI in healthcare is covered in the greatest number of papers. When it comes to specific illnesses, physical illness accounts for the greatest number of publications, followed by stroke rehab, cancer, and mental health. Most of the following columns are arranged alphabetically [21].

Table 1. The Quantity of Articles in Each Health Group

Health Category	Number of Records
Cancer	6
Chronic Disease	5
Healthcare in General	30
Heart Disease	5
Mental Health	6
Not Healthcare	3
Ophthalmology	1
Physical Disease	12
Stroke Rehabilitation	7
Traumatic Brain Injury	2
Grand Total	**77**

Table 2 shows the allocation of the quantity of articles pertaining to AI solutions, techniques, and methods that were applied or addressed in the framework of health rehabilitation and recovery. Not all AI solutions, techniques, and seeks are at the same level, as the table illustrates. Artificial neural networks, a subset of deep learning, include convolutional neural systems. Moreover [22], all approaches fall under the general category of artificial intelligence, and deep learning represents a subset of traditional machine learning.

Table 2. Each AI solution, Method, and Approach's Total Number of Papers

AI Solution	Number of Records
AI (General)	70
Artificial Neural Network	8
Augmentation Methods	14
Big Data Analytics	45
Convolutional Neural Network	14
Deep Learning	35
Edge Computing	16
Machine Learning	55
Natural Language Processing	3
Simulations	23
Simultaneous Localization and Mapping (SLAM)	1

Table 3 shows the allocation of IoT devices used to address health recovery and rehabilitation challenges. Wearable's and Wi-Fi devices are the next most popular IoT devices, after sensors (some articles mention the type of sensors [23]; therefore we discovered GPS sensors, vital signs detectors, optical sensors, and more).

Table 3. Each IoT device's number of papers

IoT Device	Number of Records
AR/VR	9
Bed Mat	2
Cameras (2D/3D)	22
Doppler/Ultrasound	2
Floor Sensors	3
GPS Sensors	2
IMU	12
Optical Motion Sensor (Kinect)	2
Robots	11
Sensors	63
Triboelectric Nanogenerator (TENG) Sensors	2
Vital Signs Sensor	28
Wearables	40
Wi-Fi-Enabled Microscopic Device	35

Additionally, we examined every document and classified them according to the state of AIoT device development [24].

Table 4. The quantity of papers for each stage of the development of AIoT systems

Level of AIoT System Development	Number of Records
AIoT Idea	2
AIoT System Design	11
Prototype Description	1
The Application of Prototypes in a Real Environment	29
The Review of Trends (Including Literature Reviews)	34
Grand Total	**77**

We developed a more straightforward scale for this aim because it was difficult to differentiate between levels of some AIoT systems in publications, despite the existence of well recognized technical readiness levels (TRLs) in Table 4.

4.2 AI-powered Rehabilitation Solutions

Wearable triboelectric nanogenerator sensors allow for lower limb rehabilitation by tracking both waist mobility and gait [25]. This project includes two sensors in each insole that record strides; four electronic textile sensors around the waist are used to monitor movements while performing augmented reality/virtual reality exercises, or controlling a robot in real time. An artificial neural network (ANN) achieved a 97.4% accuracy rate in identifying individuals based only on their gait signals. The integrated system, consisting of a rehabilitation robot and an immersive video game, provided strong tracking performance (i.e., moving tracking) and user detection capabilities, enabling gaming-assisted training, which suggests that mixed reality (i.e., AR/VR) and IoT are likely to be promising methods for intelligent rehabilitation. This proposal serves as a prototype for future development of inexpensive, energy-efficient artificial intelligence Internet of Things (AIoT) technology as part of a larger framework for innovative health care delivery methods.

5 CONCLUSION

AIoT-based systems in kinesio-therapy and physical therapy show great promise for enhancing rehabilitation through intelligent intervention, tailored feedback, and ongoing monitoring. Research demonstrates a high degree of accuracy in identifying patient states and favorable health outcomes, such as improved mobility, decreased pain, and improved drug adherence. While cutting-edge sensing technologies allow for real-time progress tracking, AI-driven personalization guarantees that treatments adjust to individual demands.

Despite encouraging outcomes, there are still issues with integration into clinical procedures, inadequate large-scale validation, and data privacy. Many technologies are still at the prototype phase and need to be further improved for mass acceptance, usability, and dependability. To increase efficacy and confidence, future research should concentrate on long-term clinical trials and strong safety precautions.

REFERENCES

[1] De Fazio, R., Mastronardi, V. M., De Vittorio, M., & Visconti, P. (2023). Wearable sensors and smart devices to monitor rehabilitation parameters and sports performance: an overview. *Sensors*, *23*(4), 1856.

[2] Wu, Z., Huang, Z., Tang, N., Wang, K., Bian, C., Li, D., ... & Schmid, F. (2025). Research on sports injury rehabilitation detection based on IoT models for digital health care. *Big Data*, *13*(2), 144-160.

[3] El-Din, T. S., & Kumar, T. (2025). Yoga-Based Interventions for Enhancing Physical Health and Preventing Disease. *International Journal of Yoga, Sports, and Health Sciences*. pp. 1~12.

[4] Li, N., & Zhu, X. (2023). Design and application of blockchain and IoT-enabled sports injury rehabilitation monitoring system using neural network: N. Li, X. Zhu. *Soft Computing*, *27*(16), 11815-11832.

[5] Jiang, Y. (2020). Combination of wearable sensors and internet of things and its application in sports rehabilitation. *Computer Communications*, *150*, 167-176.

[6] Nascimento, L. M. S. D., Bonfati, L. V., Freitas, M. L. B., Mendes Junior, J. J. A., Siqueira, H. V., & Stevan Jr, S. L. (2020). Sensors and systems for physical rehabilitation and health monitoring—A review. *Sensors*, *20*(15), 4063.

[7] Lianzhen, C., & Hua, Z. (2021). Athlete rehabilitation evaluation system based on internet of health things and human gait analysis algorithm. *Complexity*, *2021*(1), 6663224.

[8] Yao, H. (2024). An IoT-based injury prediction and sports rehabilitation for martial art students in colleges using RNN model. *Mobile Networks and Applications*, 1-18.

[9] Jovanov, E., Milenkovic, A., Otto, C., & De Groen, P. C. (2005). A wireless body area network of intelligent motion sensors for computer assisted physical rehabilitation. *Journal of NeuroEngineering and rehabilitation*, *2*(1), 6.

[10] Kolarić, I., Pepelnik, K., Vlahek, D., Oreški, D., Gusić Munđar, J., & Kadoić, N. (2025). Application of Artificial Intelligence and Internet of Things in Rehabilitation and Health Recovery. In *Proceedings of the 36th International Scientific Conference: Central European Conference on Information and Intelligent Systems: CECIIS 2025* (pp. 69-76). Varaždin: University of Zagreb Faculty of Organization and Informatics.

[11] Cui, J., Du, H., & Wu, X. (2023). Data analysis of physical recovery and injury prevention in sports teaching based on wearable devices. *Preventive medicine*, *173*, 107589.

[12] Kos, A., & Umek, A. (2018). Wearable sensor devices for prevention and rehabilitation in healthcare: Swimming exercise with real-time therapist feedback. *IEEE internet of things journal*, *6*(2), 1331-1341.

[13] Sun, P. (2022). Rehabilitation Training and Prevention of Athlete’s Hind Thigh Muscle Injury Based on IoT Intelligent Data. *Journal of Nanomaterials*, *2022*(1), 7678694.

[14] Aziz, R., Jawed, F., Khan, S. A., & Sundus, H. (2024). Wearable IoT devices in rehabilitation: enabling personalized precision medicine. In *Medical robotics and AI-assisted diagnostics for a high-tech healthcare industry* (pp. 281-308). IGI Global Scientific Publishing.

[15] Szabo, D. A., Neagu, N., Teodorescu, S., Apostu, M., Predescu, C., Pârvu, C., & Veres, C. (2023). The role and importance of using sensor-based devices in medical rehabilitation: a literature review on the new therapeutic approaches. *Sensors*, *23*(21), 8950.

[16] Wu, B. (2024). Real Time Monitoring Research on Rehabilitation Effect of Artificial Intelligence Wearable Equipment on Track and Field Athletes. *EAI Endorsed Transactions on Pervasive Health & Technology*, *10*(1).

[17] Yang, J., Hu, J., & Chen, W. (2025). IoT-enabled real-time health monitoring system for adolescent physical rehabilitation. *Scientific Reports*, *15*(1), 17994.

[18] Ju, F., Wang, Y., Xie, B., Mi, Y., Zhao, M., & Cao, J. (2023, January). The use of sports rehabilitation robotics to assist in the recovery of physical abilities in elderly patients with degenerative diseases: A literature review. In *Healthcare* (Vol. 11, No. 3, p. 326). MDPI.

[19] Chen, J., & Liu, W. (2026). Integration of IoT and Sensor Technology in Sports Performance Tracking and Analysis. *Sensors and Materials*, *38*(1), 439-454.

[20] Dobkin, B. H. (2017). A rehabilitation-internet-of-things in the home to augment motor skills and exercise training. *Neurorehabilitation and neural repair*, *31*(3), 217-227.

[21] Zhen, H., Kumar, P. M., & Samuel, R. D. J. (2021). Internet of things framework in athletics physical teaching system and health monitoring. *International Journal on Artificial Intelligence Tools*, *30*(06n08), 2140016.

[22] Geng, J., Wang, J., Wang, T., & Yan, X. (2025). IoT muscle monitoring device based on thermal infrared image monitoring in sports training: real-time analysis of exercise heat consumption. *Journal of Radiation Research and Applied Sciences*, *18*(3), 101788.

[23] Faliagka, E., Skarmintzos, V., Panagiotou, C., Syrimpeis, V., Antonopoulos, C. P., & Voros, N. (2023). Leveraging edge computing ML model implementation and IoT paradigm towards reliable postoperative rehabilitation monitoring. *Electronics*, *12*(16), 3375.

[24] Wilkerson, G. B., Gupta, A., & Colston, M. A. (2018). Mitigating sports injury risks using internet of things and analytics approaches. *Risk analysis*, *38*(7), 1348-1360.

[25] Al-Farouni, M., & Kumar, R. A. (2025). IoT-Enabled performance monitoring Methods, injury prevention Strategies, and tactical Decision-Making in football. *Advances in Sports Science and Technology*, 75-79.