Proceedings of the 6th International Conference on Biological Engineering and Medical Science
DOI: 10.54254/2753-8818/2026.34081

A Review of AI-Enhanced Wearables in Home-Based Rehabilitation after Total Hip Arthroplasty

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Abstract. This study reviews the role of AI-enhanced wearable technology in home-based rehabilitation following Total Hip Arthroplasty (THA). It focuses on gait monitoring and exercise correction. A secondary research approach was adopted, which includes the analysis of existing academic literature, clinical studies and healthcare reports. The findings show that AI-integrated wearable systems can improve postoperative rehabilitation through technologies, such as enabling continuous movement monitoring, real-time feedback and personalised exercise guidance. They can not only improve the accuracy of gait assessment, but also support remote clinical supervision, which will greatly promote patients' participation and compliance with rehabilitation training programs. Compared with traditional methods, AI-driven wearable devices are good at data collection with better continuity, so that abnormal movement patterns can be identified as soon as possible. However, this technology still faces some challenges, including high costs, data privacy issues, technical limitations, and obstacles to widespread clinical use. In general, this technology has great potential to improve rehabilitation and change postoperative care after THA.

Keywords: AI in healthcare, Gait monitoring, Rehabilitation, Total Hip Arthroplasty, Wearable technology

1. Introduction

Total hip replacement (THA) is usually used to treat serious hip diseases, including osteoarthritis and fractures. This technology is very mature, and it can effectively improve the patient's joint function and overall mobility. With the aging of the population and the increasing number of musculoskeletal diseases, the demand for THA is increasing [1]. The success of THA surgery depends greatly on postoperative rehabilitation, which focuses on strength recovery, mobility and normal gait patterns. A scientific rehabilitation plan can improve functional results and reduce the risk of complications. The traditional rehabilitation program is mainly based on physiotherapy. It has several limitations, such as high cost, limited benefits and differences in patients' compliance. In addition, home rehabilitation exercise is usually not self-disciplined, resulting in incorrect exercise performance and less than expected [2]. In the field of digital health, artificial intelligence (AI) and wearable technology have brought new solutions. It can continuously monitor the mobility of patients, while the system can conduct real-time data analysis and feedback. Compared with

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DOI: 10.54254/2753-8818/2026.34081

traditional physiotherapy or non-AI wearable devices, these technologies have high accuracy, high personalization and remote clinical support, which will benefit postoperative rehabilitation of patients. This study outlines the use of artificial intelligence-enhanced wearable technology in home gait monitoring and exercise correction after THA.

2. Literature review

2.1. Total Hip Arthroplasty and rehabilitation challenges

THA is the most widely used orthopedic surgery for the treatment of advanced hip joint diseases, especially for the treatment of osteoarthritis. The operation replaces the damaged hip joint by implanting the prosthesis, which can greatly improve the patient's mobility and reduce pain. The recovery after surgery depends on postoperative rehabilitation. Patients are very likely to have complications such as decreased muscle strength, loss of balance and gait pattern after surgery [3].

Gait recovery is an important part of rehabilitation. Abnormal walking patterns may lead to long-term functional impairment and increase the chance of falling. Even a few months after the operation, some patients cannot fully restore normal gait symmetry. Thus, traditional physiotherapy is still used to help gait recovery. However, the limitations of traditional physiotherapy itself, including dependence on the clinical environment, limited benefits for patients in remote areas, and inconsistency in prescribed exercise, coupled with the lack of continuous monitoring, may delay intervention [4].

2.2. Wearable technology in healthcare

In contemporary health care, the development of Wearable technology provides new ideas and methods for health control and disease monitoring. After being equipped with sensors such as accelerometers, gyroscopes and inertial measurement units (IMUs), Wearable technology can collect real-time physiological and movement data. For example, in rehabilitation application scenarios, it is used to monitor patients' sports, posture and gait patterns [5]. Moreover, wearable technology is widely used in health care, including chronic disease management, fall detection and postoperative rehabilitation. As far as THA is concerned, wearable devices can continuously track patients' movements and provide objective data to support clinical decision-making. Compared with traditional assessment tools, wearable devices can achieve more detailed and accurate monitoring of recovery progress [6].

Despite these advantages, existing wearable devices also have some limitations. For example, some early systems do not integrate intelligent data analysis, so clinicians need to analyze a large amount of data manually. In addition, issues such as equipment accuracy, battery life and user comfort also affect its actual usability. These restrictions have prompted device developers to think about the need to design more advanced systems, hoping that a new generation of systems can provide real-time feedback and more effective analysis.

2.3. Artificial intelligence in rehabilitation

AI has become an indispensable factor in health care, and it plays an important role in advanced data analysis and decision-making. During rehabilitation, AI can help understand the complex data sets generated by wearable devices and make reliable suggestions for developing more accurate and

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customized treatment plans. Now machine learning algorithms have been applied to motion pattern analysis and can measure deviations from normal biomechanics [7].

Studies show that subtle abnormalities in gait and posture can be identified by AI systems, but traditional observation methods cannot be detected, which will benefit for early detection of potential complications and timely clinical intervention. In addition, researchers have also developed an AI-based feedback system that can provide real-time guidance for patients during rehabilitation exercises. The system can use sensor data to evaluate the accuracy of movement and provide feedback, thus improving the effectiveness of practice. AI is also suitable for specifying personalized rehabilitation plans. By analyzing patient data, the AI system adjusts the exercise plan according to personal progress and needs, which improves the effectiveness of rehabilitation and improves the treatment results of patients. In general, the integration of AI solves the limitations of traditional wearable devices and rehabilitation methods [8].

2.4. AI-enhanced wearable systems for gait monitoring

AI-enhanced wearable systems show great potential in improving gait monitoring after THA recovery. Unlike traditional digital prediction, it can not only combine sensor data with artificial intelligence methods, such as machine learning and real-time data analysis, but also measure parameters, including step symmetry, walking speed and joint coordination. It can provide the early identification of abnormal movement patterns and make more accurate tracking and recovery judgments.

Real-time feedback can help patients correct their movements during home exercise, which can improve the effectiveness of rehabilitation exercises and minimize complications. Figure 1 shows a typical workflow. First, patient movement data is collected through sensors, then AI algorithms are used to process it. Following this, feedback is provided to patients and clinicians through digital platforms. In addition, remote monitoring enables clinicians to adjust the treatment plan in time without having to consult in person many times. Compared with the traditional method, this method can improve the patient's gait symmetry, compliance and recovery speed [9].

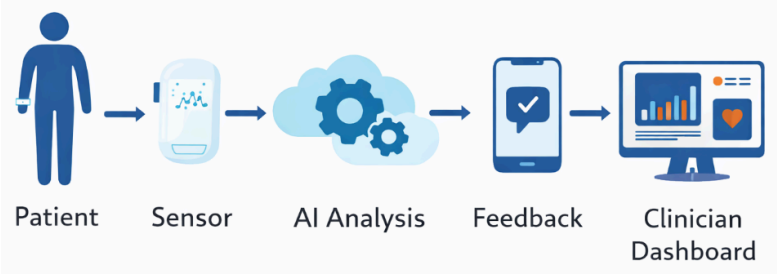

Figure 1. AI-enhanced wearable system workflow [9]

2.5. Patient engagement and compliance

The success of the rehabilitation plan largely depends on the patient's participation and compliance. Studies have shown that many patients find it difficult to stick to the prescribed exercise at home. AI-enhanced wearable technology can make rehabilitation training more interesting and interactive, and patients will be attracted by functions such as real-time feedback, progress monitoring and personalized suggestions after using it. Some systems also incorporate gamified elements, including goal setting and rewards, which enable convalescents to participate more actively in home rehabilitation training programs.

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In addition, through the application of remote rehabilitation and remote monitoring, uninterrupted communication between patients and clinicians has been achieved, and the compliance of rehabilitation has been improved. This continuous interaction provides additional support and accountability. It is reported that patients who use AI to enhance wearable systems have a higher compliance rate. Digital health technologies have shown potential to improve treatment and rehabilitation results by increasing patient participation.

2.6. Challenges and ethical considerations

Although AI-enhanced wearable technology has many advantages, it also triggers many challenges and reflection on ethical issues. Since wearable devices may store sensitive health data, ensuring the safe storage of data and compliance with regulatory standards are very important to protect the privacy of patients. The ease of access and price factors are also major obstacles to the widespread adoption of this technology. Advanced wearable devices and artificial intelligence systems are often accompanied by high costs that only certain groups can afford, and health care inequality and digital divides are likely to occur. The popularization of technology may further affect the performance of these systems. For example, inaccurate sensors, connection problems and low overall system reliability will have some overall effectiveness. In addition, the wider adoption of AI systems requires integration with the current health care infrastructure, which is a complex and resource-intensive task [10].

Ethical considerations related to AI decision-making have also been widely discussed. The transparency, bias, and accountability of the algorithms require more attention to ensure safe use. Moreover, digital literacy has played a critical role in determining user adoption, particularly among older patients who may be less familiar with new technologies. Altogether, while AI-enhanced wearable systems have already demonstrated considerable potential, it is still critical to address these challenges and ensure successful and equal implementation.

3. Methodology

Based on a structured literature review, this study adopts a qualitative secondary research design to analyze existing academic research, clinical trials and industry reports, so as to achieve the purpose of studying the role of AI-enhanced wearable technology in post-THA rehabilitation. This method can identify patterns, trends and relationships across multiple studies, and systematically and comprehensively demonstrate the current development of this field.

The academic database of this study includes PubMed, ScienceDirect, IEEE Xplore and Google Scholar, including journal articles, system reviews and conference papers. In addition, gray literature, such as clinical guidelines, health care organization reports and technical white papers, has also been absorbed to show the latest progress and applications of AI-based wearable systems. This study contains the scientific research results published after 2015 to reflect the recent technological progress. This review focuses on research related to AI, wearable devices, gait monitoring and rehabilitation in the context of THA, and only selects English literature with clear methods and credible findings.

This study systematically evaluates the selected literature. Its themes are such as rehabilitation effect, gait monitoring accuracy, patient participation and technical challenges, etc. By comparing different research results, consistent patterns, contradictions and research gaps can be determined. This process can achieve a critical assessment of how AI-enhanced wearable systems promote

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rehabilitation results, and is conducive to drawing evidence-based conclusions. However, in future work, it is necessary to improve the process of ensuring reliability and reducing bias.

4. Results and discussion

4.1. Effectiveness of AI-enhanced wearables

The research in the literature found that AI-enhanced wearable technologies can significantly enhance the rehabilitation effect after THA because these technologies can provide continuous monitoring and personalized feedback. Patients who use these systems also show effects such as gait symmetry enhancement, mobility and general function recovery, so the patient's feedback satisfaction is improved. At the same time, real-time feedback will benefit the implementation of correct exercises, which can make the rehabilitation plan more effective and reduce complications. Most importantly, rehabilitation exercises can be personalized.

However, various studies also show that there are differences in equipment accuracy, patient compliance and clinical application, which are factors affecting the effectiveness of AI-enhanced wearable technologies. Although some studies show that recovery is faster, the long-term effect of treatment is unknown compared with traditional physiotherapy. In addition, AI cannot replace the professional judgment of clinicians. Therefore, the combination of AI-enhanced wearable technologies and traditional physiotherapy is the most reliable solution at present [11].

4.2. Improvement in gait monitoring

AI-enhanced wearable systems achieve a major breakthrough in gait monitoring by integrating sensors (e.g., accelerometers) and intelligent data processing technologies (e.g., gyroscopes). These systems can monitor minor gait abnormalities through collecting biomechanical measurement data, such as step length, walking speed and joint coordination. Therefore, compared with traditional clinical evaluation, it greatly facilitate clinicians to make quick diagnoses and develop treatment plans accordingly.

As real-time data analysis can provide patients with instant feedback, they can adjust their rehabilitation training in time. AI-enhanced wearable systems work better in the home rehabilitation environment. They can help patients to improve their performance and achieve effective rehabilitation outside the clinical environment. However, these systems also have their own limitations. They may have false positive alarms due to errors or excessive feedback, which may cause patients to have anxiety or overcorrection for recovery. In addition, the system is heavily dependent on automatic feedback, which may reduce the patient's confidence in rehabilitation. Therefore, the design of the systems requires clinical guidance to ensure their accuracy and practicality [12].

4.3. Patient engagement and compliance

Whether the rehabilitation plan works is closely related to patient's persistent participation, especially in an unsupervised home environment. AI-enhanced wearable devices can promote a more interactive rehabilitation process, which will enhance patients' adherence to the rehabilitation plan. For example, some features can encourage patients to participate in the rehabilitation process actively. These include real-time feedback, progress tracking and personalized exercise suggestions. They can also make patients more self-motivated through goal-setting mechanisms and continuous

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performance tracking. Thus, their accountability and self-management can be enhanced. In addition, remote monitoring also helps clinicians monitor the patient's progress and keep in touch with the patient.

However, the patient's participation may be affected differently as the patient's age and knowledge level vary. Some users may find it difficult to understand the system feedback. Therefore, although AI-enhanced wearable devices have great potential to improve patient compliance, they still rely heavily on user-friendly design, detailed instructions for use and a strong clinical support system [9].

5. Challenges and limitations

In general, AI-enhanced wearable systems are currently facing major technical challenges. This includes the lack of accuracy of the sensor, the vulnerability of the device, and the conversation connection between the devices. These problems will affect the reliability and consistency of data collection, which in turn affects clinical decision-making. In order to solve these problems, it is necessary to improve the accuracy of the sensor, the stability of the system and enhance the dialogue connectivity between devices to ensure the accuracy of the data and build user trust. In addition, the high cost of AI-enhanced wearable systems has become a major obstacle to their wide application. In the low-income group, it is not easy for patients to access and afford these technologies, resulting in unequal access to medical resources [13]. To solve this problem, it needs to reduce costs and benefit more patients through health care policies and medical insurance. In addition, this technology poses additional challenges to the existing health care system. Healthcare professionals need to be trained to analyze the generated data and make reasonable judgments. However, in some cases, it is difficult to be compatible with existing clinical workflows and digital systems [14]. This requires system integration to be strengthened, user interface user friendly, and targeted training to popularize the technology.

6. Summary

AI-enhanced wearable technologies have great potential for THA rehabilitation in the home environment. Because it can not only provide continuous gait supervision and real-time feedback, but also provide personalized exercise guidance to patients. Recent studies show that these techniques are beneficial to rehabilitation, promote gait performance, and improve patient compliance. It can also support remote clinical supervision to reduce the pressure on health care services. However, the results of the study are not completely consistent. Some studies show that AI-based feedback is not competitive in the simple process of monitoring activities. In addition, complex wearable systems may be challenging for elderly patients. Moreover, there is an issue that the technology relies heavily on the feedback generated by AI, which will lead to a decrease in patients' confidence in physical judgment and psychological awareness. And there are still some obstacles for this technology to be widely adopted. These factors include cost, accessibility, data privacy, technical reliability and integration with clinical processes. Although AI-enhanced wearable technologies are very promising, it is more reliable to combine AI-enhanced wearable technologies and traditional physiotherapy for the present. It should be noted that future research should focus on assessing the long-term effectiveness, user acceptance and cost-effectiveness of the technology for patient rehabilitation.

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