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Application of AI technology in the field of rehabilitation therapy

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Abstract. With the rapid development of AI technology, the field of rehabilitation therapy has ushered in unprecedented opportunities for innovation. This paper provides a comprehensive review of the current applications of AI in rehabilitation therapy and the challenges it faces, while also exploring its future development trends. The research finds that the application of AI technology in rehabilitation therapy has significantly improved rehabilitation efficiency and patients' quality of life. AI can develop personalized rehabilitation plans based on individual patient conditions, achieve precise assessments and training through smart assistive devices, and break through the limitations of time and space with remote rehabilitation services. However, the application of AI in rehabilitation therapy still faces several challenges, including high technological costs, data privacy concerns, and public acceptance. Looking forward, as technologies such as 5G, the Internet of Things, and brain-machine interfaces deeply integrate with AI, rehabilitation medicine is expected to move toward a new stage of greater precision and intelligence.

Keywords: AI, rehabilitation therapy, personalized rehabilitation, smart assistive devices, remote rehabilitation, virtual reality

1. Introduction

Currently, there is a significant talent gap in China's rehabilitation medical services. More than half of general hospitals fail to meet the national requirements for the number of rehabilitation therapists and nurses per bed, resulting in the need for improvement in clinical service efficiency and effectiveness [1]. The development and improvement of AI and 5G technologies have promoted the construction of intelligent rehabilitation information systems, thus significantly enhancing the rational allocation and utilization of information and resources [2]. At present, the application of AI technology in the field of rehabilitation therapy is vast. In the future, AI will not only be applied to physical rehabilitation but will also extend to psychological rehabilitation. Additionally, service technologies and quality will continue to evolve and improve, although some issues still require further refinement [3].

This paper is dedicated to systematically reviewing the innovative applications of AI in the field of rehabilitation occupational therapy, analyzing its advantages and challenges in depth, and revealing the core value of AI technology in improving rehabilitation efficiency and reducing medical costs. At the same time, the paper emphasizes key challenges such as the lack of technological accessibility and privacy protection mechanisms, aiming to provide theoretical reference for the future development of the intelligent rehabilitation ecosystem.

2. Current applications of AI in rehabilitation therapy

2.1. Formulation of personalized rehabilitation plans

AI generates dynamic rehabilitation plans based on patient data such as age and injury type, combined with machine learning algorithms. These plans include physical therapy, psychological support, and nutritional management. For example, Chen and others used AI to predict the risk of athlete injuries and optimize training plans [4]; the team led by Wang utilized AI to monitor the condition of Parkinson's patients and develop personalized care plans, significantly reducing the incidence of depression [5]; the Go CARB system developed by Vasiloglou accurately estimates the carbohydrate intake of diabetic patients, improving dietary management efficiency [6].

In summary, AI technology demonstrates significant application value in the medical rehabilitation field, significantly improving patients' quality of life and rehabilitation outcomes, optimizing rehabilitation processes, and providing patients with more precise and convenient medical services.

2.2. Application of smart assistive devices

AI-driven rehabilitation robots and wearable devices use high-precision sensors to monitor patient physiological data in real time, optimizing training strategies. Wang Xiaojun and others confirmed that high-precision transcranial direct current stimulation combined with upper limb robots could enhance upper limb function in stroke patients [7]; the dynamic spine support robot RoboBDsys, developed by the team of Guo, uses intelligent algorithms to analyze trunk biomechanics and guide rehabilitation training for spinal cord injury patients [8]; Yang and others showed that smart wearable systems significantly improved upper limb motor function and training adherence in stroke patients [9].

In summary, the application of smart assistive devices in rehabilitation medicine is rapidly evolving towards greater intelligence and dynamism. These devices play an important role in post-stroke sequelae, spinal cord injuries, and other conditions, supporting the precise iteration of individualized plans.

2.3. Rehabilitation assessment and training

AI technology, through wearable devices and sensors, collects patients' movement data, physiological indicators, and behavioral patterns, enabling more accurate assessments of their functional status. Liu and others developed a digital assessment system to comprehensively evaluate the physical function of elderly individuals and provide rehabilitation recommendations [10]; Wang proposed a VR-based exercise feedback system, using intelligent algorithms for scientific assessment [11]; Li confirmed that VR technology, through virtual scenarios, enhances the ADL capabilities and quality of life of patients with cognitive decline [12].

In summary, smart rehabilitation assessment and training systems, through the integration of multi-source heterogeneous data and AI algorithms, not only improve patients' motivation and adherence to training but also offer new insights for interdisciplinary research, driving the development of rehabilitation medicine towards more intelligent and personalized directions.

2.4. Remote rehabilitation

AI technology supports remote rehabilitation systems, allowing patients to receive rehabilitation guidance at home via video calls or smart devices. These systems can record training data in real time and provide feedback to doctors. Tang and others used an intelligent follow-up model to optimize post-joint replacement management [13]; Hu used remote respiratory rehabilitation guidance to improve lung function in COPD patients [14]; the stroke remote care model developed by Yu alleviated the shortage of professional services [15].

AI-based remote rehabilitation technology, through smart device interaction and cloud collaboration mechanisms, significantly enhances medical accessibility and patient adherence in rehabilitation scenarios, reduces family and societal healthcare costs, and promotes the construction of a patient-centered continuous rehabilitation service system.

3. Challenges faced

3.1. Technical costs and accessibility

High-precision AI devices and sensors are costly, which limits their widespread application in primary healthcare. Zhou and others, through research on the rehabilitation effects of remote therapy for chronic nonspecific low back pain, pointed out that many national healthcare insurance systems have not fully covered the costs of AI rehabilitation technologies, making it unaffordable for some patients [16]. The technological penetration of AI in primary healthcare faces significant technical-economic bottlenecks and challenges related to inclusivity. To address these, the integration of open-source algorithm ecosystems, flexible insurance reimbursement mechanisms, and distributed service networks is necessary to resolve the deep-rooted conflict between cost rigidity and accessibility to healthcare resources.

3.2. Data privacy and security

Rehabilitation data is personal and private, and AI systems' data management and security need further improvement. Xu and others pointed out that while AI rehabilitation robots have standardized clinical rehabilitation processes through data-driven algorithms, their core algorithms rely heavily on patients' multidimensional health data, raising urgent confidentiality concerns. This data security risk directly threatens the healthcare privacy protection system [17]. The deep application of AI technology in rehabilitation medicine has exposed systemic confidentiality flaws due to the incompatibility of multimodal data fusion mechanisms and dynamic security protection systems. These technical vulnerabilities highlight the structural imbalance between the medical AI ethical framework and data sovereignty protection mechanisms.

3.3. Technology acceptance

Currently, some patients and therapists in clinical settings have a low acceptance of new technologies. Luo Shuang and others, through research, pointed out that insufficient awareness and trust in AI technology by patients and society is a significant disadvantage. Some patients may be hesitant to accept machine-based therapy, concerned about the reliability of the technology and its therapeutic effects [18]. The differing perceptions of technology reliability and ethical risks between doctors and patients, as well as the dual trust crisis on both sides, weaken the willingness to adopt technology. This gap can be bridged by enhancing algorithm transparency and strengthening human-machine collaboration training.

4. Future development trends

4.1. Maturation of technology

With continuous breakthroughs in core technologies, AI's capabilities in rehabilitation therapy, human-machine interaction, and other fields will become more mature. The team led by Zhou Huiying, through the development of the ROS architecture distributed system, pointed out that the evolution of 5G and IoT technologies is accelerating the intelligence process of exoskeleton robots. Their core breakthrough lies in the technological maturity of multimodal data fusion and adaptive control algorithms. The ROS architecture distributed system they developed [19] represents a shift towards an integrated system of cross-modal technologies, offering new technological paradigms to address the challenges of individualized interventions for motor function impairments.

4.2. Expansion of application scenarios

In the future, AI technology will be applied to more rehabilitation fields, such as psychological rehabilitation and speech rehabilitation. Xu and others confirmed that VR technology offers a new means of communication for patients with severe speech disorders. Through non-traditional input methods like eye tracking, patients can interact with virtual environments using movable body parts, enabling information expression and communication [20]. This trend marks a leap from experience-driven to data-driven paradigms in rehabilitation medicine, laying a core foundation for constructing a full-cycle, adaptive, and human-centered rehabilitation system.

4.3. Increased intelligence

AI will achieve higher levels of intelligence, providing better rehabilitation services for patients. Research by Basteri A and others shows that combining AI with 5G technology and using upper-limb rehabilitation robots for training can improve the upper limb function of more than half of acute and chronic stroke patients and significantly enhance daily living abilities in over one-third of patients [21]. The intelligent iteration and upgrading of AI technology will profoundly drive technological innovation in the field of rehabilitation medicine. This trend will provide critical technical support for the development of precise, individualized neuro-rehabilitation intervention systems.

5. Conclusion

The deep integration of AI technology is reshaping the practical paradigm of rehabilitation medicine. Through the collaborative innovation of multimodal data fusion, intelligent algorithm decision-making, and virtual-physical interaction technologies, it offers new technological pathways for personalized rehabilitation interventions. However, challenges such as insufficient technology inclusivity, delayed data security governance, and the trust gap in human-machine collaboration still restrict its large-scale application.

In the future, with the deep coupling of brain-machine interfaces, sensor technologies, and advanced techniques, intelligent rehabilitation systems will accelerate towards an integrated "perception-decision-regulation" model. By building a clinical-community-home linked distributed rehabilitation network, rehabilitation medicine will enter a new era of precise, human-centered, intelligent decision-making.

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