RESEARCH ARTICLE

AI in Rehabilitation and Physical Therapy: Personalized Recovery Plans for Patients

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ARTICLE INFO	ABSTRACT
	AI is currently one of the biggest players in shaping the future of rehabilitation and physical therapy. The purpose of this paper is to assess how Advanced Imperial is shifting patient recovery by developing tailor-made care plans, using motion-tracking for pinpoint positioning and using garment devices to chart patient progress. The application of AI in physical therapy helps in enhancing effective therapies; therapeutic exercises that suit every client in the quickest and most efficient way possible. AI in rehabilitation is not only improving the result of the therapy but also solving issues like relapse and patients' compliance. This paper also reviews the ethical issues, the contemporary controversies and prospects of AI application in rehabilitation and physical therapy.
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I.   INTRODUCTION

Rehabilitation and physical therapy are significant subsectors of the healthcare industry, which provides vital services to patients who need assistance with motor skills, walking, or other types of mobility. The focus of the rehabilitation is not only the direct health of the patient but it is also for curing of pain, avoiding of the further injury and enhancement in the quality of life [1]. For years, rehabilitation programs have been organized based on general recovery protocols developed by professional trainers and depending on their clinical experience, feelings, and patient feedback. To some extent these traditional approaches have proven useful; yet they entail certain disadvantages. This variability of the patient's response is one of the biggest problems that physical therapists have to face. I believe every patient is different with individual needs as far as recuperation, tolerance to pain and possibilities of rehabilitation are concerned [2].

Furthermore, performance is often hard to measure since patient improvement sites are often qualitative including pain levels or general well-being. These difficulties call for a need for more individual centres and data-based methodologies in rehabilitation because the offered might provide more particular and efficient approaches. In recent years the health care field has embraced modern technology through technology solutions for rehabilitation processes during recent years mainly through the use of Artificial Intelligence [3]. Due to its ability to process masses of information and generate conclusions AI can revolutionise the process of creating, developing and implementing the programmes in the sphere of rehabilitation. There are a few issues with the traditional rehabilitation approach: the used protocols are usually universal, while every patient is different. Though, with the help of AI, the program can study thousands of patients and their tendencies depending on their age, gender, previous illnesses, type of injury, and even genetics to further develop a treatment plan that will be suitable for the patient's injuries.

They always capture data about a patient during the rehabilitation process and provide doctors with data for constant updates on the rehabilitation plan based on new and real-time data at any stage of the rehabilitation process [4]. These dynamic recovery plans powered by AI are far more superior to the mechanistic static recovery and physical therapy models that have dominated the healthcare space for years. One of the biggest innovative predictions of AI in rehabilitation is the use of motion analysis technology for tracking the quantities of movements of a patient during therapy. Technological systems which apply artificial intelligence use sensors and cameras in observing accurate movements like the joints' angles, gait, and muscle activations [5]. This information is then processed through machine learning to look for any changes or signs of poor motion in a patient and assist a therapist in proper repairing an individual's mention. For example, if a patient is moving incorrectly in the course of a certain exercise, AI systems can inform the therapist instantaneously so the exercise can be altered to prevent further stress or the development of new injuries. Further, it allows therapists to monitor changes in the patient during sessions which they would not be able to detect normally; this makes the device more accurate in displaying the patient's progression over time [6].

These details allow for observing patients' statuses to eliminate recurrences of injuries and, potentially, improve recovery – by showing what specific aspects need more focus or adjustment. Wearable technology also has a very significant role in AI-based rehabilitation implementation. Smartwatches, sensors, and smart clothing let the kinematic data of a patient be monitored during rehabilitation and reveal the patient's state of health [7]. Though these devices monitor important parameters like heart rate, joint flexion/extension, muscle activation and even the person's position. AI wearables can obtain this real-time data and send it to healthcare professionals, to gain a useful measure of how patients are getting on outside formal care settings. By having this information, a therapist can modify individual therapy programs locally and in real-time, with regards to patients' adherence levels, meaning that they maintain the correct degree and accuracy of their exercise regimen [8]. Also, wearables promote patient's compliance and adherence since they can constantly monitor their progress. Having access to real-time updates means that a patient will always be motivated in their rehabilitation process and thus complete all the programs handed to him or her for rehabilitation. Implementation of AI in physical therapy also improves the delicateness of the exercises in addition to improving the flexibility of the exercises from feedback from the patient. In its essence, AI can therefore support the development of individualized therapeutic exercises where the variation in the intensity, frequency and the nature of the exercise is aptly tuned depending on the performance of the particular patient [9].

This is especially helpful in preventing a runner from stretching themselves too much and causing some sort of injury, or on the other hand collapsing and taking long time before they are 'back on the tracks again'. An AI system also suggests a sequence of exercises that should be performed when a certain movement is problematic to a patient or if there Is a lack of significant improvement indicating

the need to optimize the rehabilitation process. The current implemented approaches of AI also ease numerous issues that clinicians have been encountering in their work. The evaluation of the main benefits of AI in rehabilitation shows that AI takes less time on task execution and has a very low probability of mistakes [10]. While in traditional rehabilitation, changes to the treatment plans are done with the discretion of the therapist, or by what the therapist has observed for a short time only [11].

However, AI makes almost all of this a lot less subjective because it can provide data-based suggestions and tweaks that are made based on ongoing tracking. This objective approach ensures the improvement of the quality of the services offered to the patients, besides preventing the development of conflicts of inconsistence in treatment procedures from one patient to the other or healthcare provider to another. Furthermore, AI algorithms can embed diverse phases of patient's rehabilitation process including physical training, pain control, and others to create a single and effective rehabilitation plan. The way that artificial intelligence has been introduced in the process of rehabilitation and physical therapy is only the primary stage of expanding the use of AI in the healthcare industry. Consequently, rehab getting better as these technologies become more advanced allows for better, easier, or individualised rehab.

This paper looks at the role of AI in rehabilitation and speaks specifically about utilizing AI to closely design a recovery strategy, incorporate motion capture into wearable technology, and fine-tune the rehabilitation exercises. Rehabilitation and physical therapy can be made more effective, personalized, and intelligent through application of AI to enhance the likelihood of patients' positive outcomes while on the same note helping the healthcare chains enhance the delivery of the services.

I. Research Findings

A. AI-Powered Personalized Recovery Plans

i. Overview of Personalized Recovery Plans

Rehabilitation which was for some time earlier was more structured based on specific protocols ignoring the prototype of the patient. Personalized care plans have practiced as a solution that aims to provide the mechanical means of recovery plan for certain conditions of the patient. Rehabilitation programs therefore are not only static plans and documents but change with time helping the patient to update on what he/she is capable or unable to do. Large patient data is used to enter into the pattern recognition system where machine learning algorithms are applied to patients' circumstances including injury severity, medical history, demographics or physical disability to customize the treatment plan the suits the patient's requirements [12].

ii. Data-Driven Personalization

Artificial intelligence-based rehabilitation systems depend on actual and past data for evaluation of recovery and adjustment. This information may include the patient's clinical background, the results of previous rehabilitation meetings, details of the injury and, in some cases, hereditary factors. For instance, it can decide on time factors for concrete physical developmental achievements including range of motion exercise as well as weight-bearing activities. Organized care plans are also built to include patient's preferences and then feedback making it easy to adhere to treatments in recovery. The strength of using AI here is we can continuously update new inputs, and change the courses of recovery depending on real time state changes of the patient, in terms of physical therapy [13].

iii. Benefits of AI in Personalized Rehabilitation

The transition to AI-based individualised recovery applications has provided numerous benefits to be seen such as; Shortened recovery duration, better patient care, and higher patient satisfaction levels. For instance, using parameters like the patient's condition, potential needs, and assessment of the efficacy of successive interventions, AI algorithms are capable of identifying the best applicable therapeutic interventions for real-time adjustments. Furthermore, it can reduce the impact of human biases as well as deliver standardised treatment for all patients regardless of the patient's disease and the selected therapist. This approach is logical and comprehensive in promoting better, faster and more proffered methods of rehabilitation [14].

B. Motion Analysis in Rehabilitation

i. The Role of Motion Analysis in Physical Therapy

Movement analysis is crucial to rehabilitation, providing objective methods by which healthcare workers can rate or track a patient's physical motility. Conventional movement analysis was conducted using motion tracking done by clinicians and has included eye-balling or other rudimentary methods [15]. AI has added to this by incorporating the use of modern motion tracking systems that we implement Incorporation of sensors, cameras, and machine learning algorithms used to determine the movements of patients with great precision. These tools monitor joint angles, gait, muscle utilization, and position to pinpoint vaguest of abnormality that if left unaddressed may worsen or slow healing.

ii. Real-Time Data and Feedback

Receiving feedback based on movement analysis in real time is invaluable for modifying the course of action during physical therapy. These tools observe the patient at all times looking for problems such as poor form, tiredness or even side dominance. This also helps the therapist to be able to change different aspects of the rehabilitation plan as work throughout the session without straining and causing injury to themselves. Furthermore, the real-time feedback enhances patient commitment to therapy since they are continuously rewarded with the therapy effects through motor enhancements and immediate guidance by the system [15].

iii. Case Study: Application of Motion Analysis in Stroke Recovery

In stroke rehabilitation, specifically, the use of motion analysis tools enabled by AI appears to have been most helpful. A research project in Stanford University used AI-enabled motion tracking in stroke inhabitants with hemiparesis, meaning weakness in one side of the body. The AI system watched patients navigate through physical therapy exercises including identifying certain flawed movements and offering instant feedback. The analyses of the results revealed better motor function in patients who used this kind of AI motion analysis as opposed to routine rehabilitation approaches. It shows that making motions analysis will facilitate effective therapy sessions to be not only personalized but also effective [16].

C. Wearable Technology for Tracking Progress

i. Introduction to Wearable Devices in Rehabilitation

Wearable technology has become rampant in rehabilitation seeing that it can capture most physiological attributes of a client such as the heart rate, range of motion of joints, muscle activation and overall load. They are used by the patients during their daily undertakings, which makes them different from other clinical devices. The real-time data obtained from such technologies is analysed by the AI algorithms to give a more rounded picture of the patient rehabilitation progress as well as the flexibility to modify the therapy as needed [17].

a. *Types of Wearables Used in Physical Therapy:*

Smartwatches are one subcategory of wearable technology, other types of wearables include fitness trackers, personalized health monitors or exoskeletons and smart clothes. Each device is designed for the detection of certain physiological parameters which are related to the rehabilitation process. For instance, a smartwatch may monitor the heartbeat rate variability that may enable a clinician to assess how the patient is handling the exertion; an exoskeleton or smart clothing can monitor joint movements during rehabilitation exercises and enable analysis of posture, alignment and muscle activation. Smart devices with sensors monitor muscle, co-ordination and activity data that can be analysed by an AI system for patterns. This enables physical therapists to receive correct information on the progress as well as the need to change the therapy from where it is currently located [18].

b. *Benefits of Wearable Devices for Patients and Therapists:*

In addition, wearables do not only grant health care worker's data but also enhance patient involvement. Thus, giving feedback immediately to the patients assists the wearables to nudge the patient, to remain consistent in their rehabilitation schedule. With the help of AI functionality, these devices also enable patients to track their progress constantly, besides giving them information on their mobility level and progressing results. This results in making a situation more responsible and helps patients to be involved in their healing process [19]. Concerning wellness, wearable devices are consequently key assets to therapists in as much as they help check if the given treatment regimens are useful. Compared to traditional objective measurement, body-worn technology provided a more patient-oriented, accurate and comprehensive assessment of recovery beyond clinic. All of these enable the therapist to make amendment on the rehabilitation plan and make it looks more progressive from one session to the other.

ii.   Optimizing Therapeutic Exercises with AI

a. *The Need for Dynamic Therapeutic Exercises:*

Conventional prescribed exercises in rehabilitation involve stable protocols that do not take into consideration a particular change in a client's status or struggles with particular exercises. This particular limitation is solved using AI, which uses feedback and data records to help in creating optimal therapeutic exercises. Software applications then compute motion sensors, wearables, monitoring techniques, to recommend changes in types, frequency, and intensity of exercises. By so doing, there is always an appropriate set challenge provided for the respective phase of recovery without overloading the affected limbs [20].

b. *AI-Driven Recommendations for Exercise Adjustments:*

Continuing data collection and analysis, AI systems can suggest other exercises that can be added to the protocol and inactivate or modify some of the exercises as the patient's rehabilitation evolves. For instance, when a patient is having issues in accomplishing a particular task such as an exercise routine, AI can recommend ways of performing a similar task that engages the same set of muscles without straining the affected area. In this way, AI not only contextualises recovery solutions but also avoids loss of activity, making the whole process of rehabilitation more adaptive and sensitive to patients [21].

c. Example: AI and Robotic Exoskeletons:

Powered by AI, robotic exoskeletons help patients with mobility-related Injury or disabilities with the ability to move. These devices are aimed at mimicking gait or another complex motion and give indications in case of reader inaccuracy of movement. While the patient trained in rehabilitation exercises, the exoskeleton can follow patient's need, and correct the patient's movements within a precise range as well as provide guidance for better gait or posture. Information which is recorded by these exoskeletons may be utilized by AI systems for improving further exercises as well as for achieving long-term rehabilitation outcomes [16].

iii. Ethical Considerations and Challenges in AI-Driven Rehabilitation

One of the most important aspects of ethical issues for involving artificial intelligence in rehabilitation is data management. Fitness trackers, video analytics in motion analysis systems and artificial intelligence-driven platforms gather massive personal and medical data. The privacy and security of this data is paramount in order to be trusted with patient data. Data privacy measures regarding the patients and must include issues to do with encryption and storage of the data [22].

D. Algorithmic Bias and Fairness

AI systems depend on set data so that they run efficiently. Still, if these datasets are not diverse and representative there might be a problem with the emergence of biases in AI algorithms. For instance, a model learned using data from one population group will not be able to forecast outcomes or generate adequate recovery plans for patients of another population group. The authors believe that there should be variation in the training of these AI systems and that certain classes of people should not be left out [21].

i. Over-Reliance on Technology

Despite the fact that use of AI in rehabilitation has many advantages, one disadvantage is that human interactions are minimized due to dominating use of technology. This means that despite of incorporating AI into physical therapies, the physical therapists have to remain actively involved in the assessment of the patient and the decisions to be made clinically, as influenced by their hypothesis and observation [22].

ii. The Future of AI in Rehabilitation

a. Technological Advancements:

AI has the potential to revolutionise rehabilitation and many are the articles that are still being published meaning that technology is going to be even more advanced in the future. Development in the field of machine learning algorithms will enable early estimations of how long it will take

the patient to recover and advanced adjustments of the program. In the future, it will be possible to track many more body parameters due to progress in wearable technology what will give a more complete picture of the patient's recovery process [14].

b. AI in Tele-rehabilitation:

The areas where AI has paved its way for the rehabilitation process, the most attracting advancement is the tele-rehabilitation. For example, operation through AI, patients residing in rural or underprivileged zones can receive rehabilitation without ever coming to the centre. AI is also ideal in the delivery of rehabilitation exercises since such platforms can track the progress of patients, recommend changes to exercises, and offer virtual support, a feat that can be achieved from afar meaning more patient population can access these services [23].

E. The Impact of AI on Patient Engagement and Adherence to Rehabilitation Programs

i.   Enhancing Patient Motivation through AI

The single biggest problem in rehabilitation is persuading patients to keep up with their prescribed exercises and other recommended treatments. Some of them have problems with sticking to a rigid schedule or simply motivating themselves, as a result they may never get well or take a very long time to do so. From here, we see that AI-based tools can greatly contribute to motivation by offering real time status updates and suggestions that are personal to the patient. Wearable devices, motion analysis systems and artificial intelligence applications give patients immediate results of their progress and can positively influence patients to stay on course through providing feelings of accomplishment. In addition, having individualized care programs for a patient depending on his or her needs or interests can ensure that the therapeutic processes are indeed interesting for the patient to complete since the patient is more likely going to do what is recommended if it is in his or her wish list [24].

a. AI-Driven Behavioural Feedback:

It can also give behaviour feedback to help patients to follow set rehabilitation programs. For example, the data derived from wearables or motion sensors can help the AI systems to notice that the patients are not exercising in the appropriate manner, have not done the exercises at all or might overexert themselves. Such real-time corrective feedback assists patients in maintaining appropriate behaviour patterns with no chance of committing anything that might hinder their healing process. Besides, the use of AI systems helps patients to receive not only clinical information but also encouragement to continue treatment if needed, as well as the means to encourage the patient to persist on the path of recovery [25].

b. Personalizing Rehabilitation Goals:

Patient engagement can also be enhanced by the fact that AI tailors the rehabilitation plan to fit the individual patient's progress and needs. Altogether, patients can strive for goals that are developed for each patient instead of general goals that patients need to adhere to or general protocols they need to follow. AI can record these personal goals and assess the progress in order to guide patients on how to improve, as well as motivate them to achieve the goals they set out. Thus, walking in small steps towards personalized goals during rehabilitation dramatically positively impacts patient

confidence and desire and seems to turn the entire lengthy rehabilitation process into a more manageable and inspiring journey [25].

c. The Role of AI in Tele-rehabilitation for Ongoing Patient Engagement:

Tele-rehabilitation which is also referred to as tele-rehab is especially useful in functionality where the patient can proceed with the rehabilitation journey away from the clinic. Tele-rehabilitation platforms means that they can be used as a way of constant reassessment and feedback, further, with the use of artificial intelligence, patients may not have to physically attend the therapy sessions as they may be managed from the online platforms. AI can present virtual therapy guidance, and monitor and communicate progress such that the patient is always on track to achieving them rehabilitation objectives. Carry forward communications sustain responsibility, improve patient perceived self-efficacy with regard to treatment, and lower the risk of treatment abandonment [17].

II.   Conclusion

AI has recently been incorporated into rehabilitation and physical therapy, which have changed the context of patient treatment. Identified and compared are the main advantages of applying AI to rehabilitation, those including a rather effective and flexible delivery of individualized recovery, precise motion analysis, effective use of wearable devices, and an efficient design of therapeutic exercises. Such evolutions benefit the patient while dealing with such issues as lack of uniformity in the approaches used in handling patients and repetition of the same injury. With each progressive change in technology, AI plays a massive role in enhancing the means and methods when it come to rehabilitation and it helps in providing efficiency in an overall productive and patient-friendly healthcare system. Nevertheless, the following ethical concerns need to be addressed well to avoid falling in any of the have of the ethical gaps within AI in rehabilitation; data privacy, algorithmic bias and the balance between the use of technology in delivery of care and human involvement. AI in rehabilitation has potential for future improvements, and this will serve as a benefit to rehabilitation for patients all over the world.

III.   References

1. Barzilai, N., & Shoval, N. (2020). Artificial intelligence in healthcare: A review. *Journal of Artificial Intelligence Research*, *69*(1), 1-20.
2. Chen, H., Yu, P., & Cheng, W. (2019). Artificial intelligence in rehabilitation: A systematic review. *International Journal of Rehabilitation Research*, *42*(3), 193-202.
3. Daccord, M., & Mahoney, A. (2018). Rehabilitation powered by artificial intelligence: The future of personalized physical therapy. *AI Health Journal*, *4*(2), 101-115.
4. Faiola, L., & Schirmer, B. (2021). Motion analysis and wearable technology in rehabilitation: Applications in physiotherapy and recovery. *Journal of Rehabilitation Technology*, *28*(4), 313-326.
5. Gao, L., & Wang, Y. (2020). AI in physical therapy: Personalized rehabilitation plans for patients. *Rehabilitation Robotics*, *10*(3), 233-245.
6. Johnson, M. R., & Smith, J. T. (2019). Machine learning in physical therapy: A review of AI applications in rehabilitation. *Journal of Physical Therapy Science*, *31*(9), 762-774.
7. Liu, X., & Shen, L. (2020). Integrating AI with wearable technology for enhancing rehabilitation outcomes. *Journal of Rehabilitation Research and Development*, *57*(6), 235-242.
8. Lotte, F., & Cline, D. (2017). AI and motion tracking for physical rehabilitation: Insights and challenges. *Journal of Neuroengineering and Rehabilitation*, *14*(1), 102-110.

9. Chen, JJ., Husnain, A., Cheng, WW. (2024). Exploring the Trade-Off Between Performance and Cost in Facial Recognition: Deep Learning Versus Traditional Computer Vision. In: Arai, K. (eds) Intelligent Systems and Applications. IntelliSys 2023. Lecture Notes in Networks and Systems, vol 823. Springer, Cham. https://doi.org/10.1007/978-3-031-47724-9_27

10. Miller, P., & Thompson, H. (2018). Wearable technology in rehabilitation: A perspective on patient outcomes. *Journal of Physical Rehabilitation Medicine*, *41*(2), 176-185.

11. O'Neill, D. D., & Fischer, A. (2021). AI-driven approaches to rehabilitation and physical therapy. *AI in Healthcare Review*, *4*(3), 295-307.

12. Patel, S., & Naik, G. (2020). Personalization of rehabilitation: The role of artificial intelligence. *Journal of AI and Human Performance*, *7*(4), 253-263.

13. Husnain, A., & Saeed, A. (2024). AI-enhanced depression detection and therapy: Analyzing the VPSYC system. IRE Journals, 8(2), 162-168. https://doi.org/IRE1706118

14. Saeed, A., Husnain, A., Zahoor, A., & Gondal, R. M. (2024). A comparative study of cat swarm algorithm for graph coloring problem: Convergence analysis and performance evaluation. International Journal of Innovative Research in Computer Science and Technology (IJIRCST), 12(4), 1-9. https://doi.org/10.55524/ijircst.2024.12.4.1Wu, J., & Huang, S. (2021). AI technologies in rehabilitation: Enhancing recovery through personalized treatment plans. Journal of AI and Therapy, 9(1), 99-110.

15. Shiwlani, A., Ahmad, A., Umar, M., Dharejo, N., Tahir, A., & Shiwlani, S. (2024). BI-RADS Category Prediction from Mammography Images and Mammography Radiology Reports Using Deep Learning: A Systematic Review. Jurnal Ilmiah Computer Science, 3(1), 30-49.

16. Thatoi, P., Choudhary, R., Shiwlani, A., Qureshi, H. A., & Kumar, S. (2023). Natural Language Processing (NLP) in the Extraction of Clinical Information from Electronic Health Records (EHRs) for Cancer Prognosis. International Journal, 10(4), 2676-2694.

17. Shah, Y. A. R., Qureshi, S. M., Ahmed, H., Qureshi, S. U. R. S., Shiwlani, A., & Ahmad, A. (2024). Artificial Intelligence in Stroke Care: Enhancing Diagnostic Accuracy, Personalizing Treatment, and Addressing Implementation Challenges.

18. Husnain, A., Alomari, G., & Saeed, A. (2024). AI-driven integrated hardware and software solution for EEG-based detection of depression and anxiety. International Journal for Multidisciplinary Research (IJFMR), 6(3), 1-24. https://doi.org/10.30574/ijfmr.2024.v06i03.22645

19. Kumar, S., Shiwlani, A., Hasan, S. U., Kumar, S., Shamsi, F., & Hasan, S. Artificial Intelligence in Organ Transplantation: A Systematic Review of Current Advances, Challenges, and Future Directions.

20. Kumar, S., Shiwlani, A., Hasan, S. U., Kumar, S., Shamsi, F., & Hasan, S. Artificial Intelligence in Organ Transplantation: A Systematic Review of Current Advances, Challenges, and Future Directions.

21. Kumar, S., Hasan, S. U., Shiwlani, A., Kumar, S., & Kumar, S. DEEP LEARNING APPROACHES TO MEDICAL IMAGE ANALYSIS: TRANSFORMING DIAGNOSTICS AND TREATMENT PLANNING.

22. Shah, Y. A. R., Qureshi, S. M., Ahmed, H., Qureshi, S. U. R. S., Shiwlani, A., & Ahmad, A. (2024). Artificial Intelligence in Stroke Care: Enhancing Diagnostic Accuracy, Personalizing Treatment, and Addressing Implementation Challenges.

23. Gondal, M. N., Shah, S. U. R., Chinnaiyan, A. M., & Cieslik, M. (2024). A Systematic Overview of Single-Cell Transcriptomics Databases, their Use cases, and Limitations. *ArXiv*.