

The Transformative Impact of AI on Rehabilitation Sciences: Innovations, Challenges, and Future Directions

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The advent of Turing's test could be considered as the inception point of Artificial Intelligence. The invention of the World Wide Web, and Artificial Intelligence in the last 70 years have shifted the paradigm of technology and revolutionised the human race with an unmatched speed. Undoubtedly the progress made by humans in these previous few decades is many folds more than the progress we made from the beginning of the time. In healthcare and rehabilitation sciences, AI has not only improved diagnostic accuracy, personalized treatments, and supported patient recovery, but also enabled remote care, leading to improved health outcomes.

As AI continues to advance, its applications will likely expand, driving innovation and efficiency across all rehabilitation sciences fields. The progress in the field of neurofeedback, and applications of robotic assistive devices for TBI, Stroke and amputees led to the development of customizable devices for such patients which is a hallmark of neurorehabilitation. For cognitive rehabilitation therapies, AI algorithms are being used that are based on data generated by CRTs employed by expert therapists to generate custom treatment plans for each patient according to their own specific needs. Therefore, as a researcher in the field of Biomedical Engineering, I cannot emphasize enough how essential it is for researchers and allied health practitioners to get themselves well-versed with AI and how AI is going to change the face of medical and allied health practices. Traditionally speaking, therapists working in various areas of rehabilitation interact with the patients directly for a session using both their expertise and (or) various diagnostic or therapeutic tools. This traditional approach has seen limitations in terms of managing the heavy working hour load on the therapist and the inability for virtual sessions that were needed at the time of the greatest pandemic the world has experienced during the outbreak of COVID-19. It is impossible to have telerehabilitation in place in the absence of AI. Both remote monitoring and virtual rehab therapy sessions can be made possible using the data-driven approach of AI that minimizes the need for patient-therapist physical interaction.

AI has found applications in the diagnosis and assessment of patients in need of rehabilitation. For example, various mobile applications were developed that not only assess various cognitive domains of dementia but also mobile-based games and applications that have been developed that are proven to improve cognitive function. Many supervised machine learning algorithms are used to devise expert systems based on previous therapy data performed by expert therapists in various fields of rehabilitation which can increase the accuracy of diagnosis. Many humanoid robots, chatbots and mobile apps have been developed for the personalised therapy of neuroatypical children and patients with neurodegeneration. Neural Network applications have been developed

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Citation: Kanwal K. The Transformative Impact of AI on Rehabilitation Sciences: Innovations, Challenges, and Future Directions. Pakistan Journal of Rehabilitation. 2024 July;13(2): 01–03. Available from: <https://doi.org/10.36283/pjr.zu.13.2/001>

Received: Wed, June 26, 2024

Accepted: Fri, July 05, 2024

Published: Sat, July 06, 2024

powered by Virtual Reality devices that can assess the correctness of patient exercises without the need for a therapist present. In developing countries where services in rehabilitation are few and far between, the use of telemedicine and teletherapy in combination with AI could prove extremely useful in reaching out to patients in rural areas or in regions where services in rehabilitation are scarce. Smartwatches and other wearable electronics-based (smart bands) devices are used to monitor patients during physical therapy and cardiac rehabilitation therapy sessions. This not only makes it possible to continuously monitor the patients but also provides real-time feedback to both the patient and the therapist which also improves patients' involvement in the rehabilitation process.

Augmentative and Alternative Communication (AAC) is a critical area of speech and language therapy and has been considerably improved with AI. The voice assistants in PDA devices, text-to-speech, speech-to-text conversions, Natural language processing, and object and symbol recognition have been transformed with AI tools. Smart home solutions and wearable tracking software make it easier for people who are differently abled to not only live independently but also securely.

The integration of AI with rehabilitation sciences has offered a multitude of benefits. The development of telerehabilitation has increased the accessibility and efficiency of therapies in all fields of rehabilitation, e.g., physical therapy, speech and language therapy, occupational therapy, behavioural therapy etc. Since AI-based applications eliminate the need for the physical presence of the therapist, it is expected to not only reduce the cost though in the longer term, and workload of the concerned therapist but also make it possible for a major portion of the population to receive the treatments. The AI-based tailored solutions for rehabilitation are based on the data generated by expert therapists in their respective fields and thus ensure precise interventions and improved patient outcomes. For instance, during speech therapy, the therapists traditionally used to keep a record of the patient's performance manually through their clinical notes. Very simple digitization of the process and use of simple Machine learning tools now enable the therapist to measure the patient outcome electronically, but some apps can tailor future therapy accordingly.

However, both the researchers and rehabilitation therapists should also be able to embrace the limitations and challenges of using AI. The diverse patients' needs, history, variety of symptoms and differences in perspective between experts may lead to the development of AI models which are not accurate. The AI solutions depend highly on the correctly annotated data and datasets. It is an extremely challenging yet necessary task to standardize the data for each field of rehabilitation so that correct models are developed. This raises an extremely important concern of patient consent. We need to formulate an ethical framework for the collection of data and generating datasets. Moreover, the success of each rehabilitative therapy is highly subjective and is usually dependent on a variety of factors including both therapist and patient. The lack of benchmarking makes it difficult to evaluate the effectiveness of AI-based solutions and thus lack of transparency. Also traditionally speaking, it is always a challenge to adopt new clinical practices therefore incorporation of rehabilitation using AI requires significant training for the therapists. We also need to advocate fully for a human human-centric approach to AI to prioritize patients' needs, and values. It is worthy to note that for both diagnostic and therapeutic purposes the AI in rehabilitation does not aim to replace human therapists. The idea is to have a clinical decision support system and augmentations in therapies for improved patient care, outcomes and increased expertise of clinicians and therapists and improved therapeutic tools.

It is extremely important to create awareness among the therapists working under the umbrella of rehabilitation sciences to generate high-quality, annotated and focused data for their respective fields, and collaborate with researchers to formulate smart solutions for patients. The future of today's world highly depends on the correct and smart use of AI. The success in future belongs to those who can effectively utilise the data to its full potential. There is a high potential for research

in wearable biomechanics and advanced motion capture systems for the improvement of human gait, functional electrical stimulation for neurorehabilitation, CBT for both neurodegenerative diseases and congenital atypical kids, and tele-rehab using VR, wearable technology and remote monitoring using computer vision, and artificial neural networks.

To conclude, AI has significantly enhanced diagnostic accuracy, personalized treatments, remote care, and telerehabilitation, benefiting fields such as neurofeedback and cognitive rehabilitation. The integration of AI with rehabilitation sciences has increased the accessibility and efficiency of therapies, though challenges like data standardization, ethical considerations, and the need for significant training remain. The future of rehabilitation depends on the effective use of AI to create smart, patient-centred solutions, emphasizing collaboration between researchers and therapists. It is high time that we mobilize all stakeholders in the field of rehabilitation to collaborate to embrace the change and efficiency adopt the needs of the time.

AUTHORS' CONTRIBUTION:

The following authors have made substantial contributions to the manuscript as under:

Conception or Design: Kehkashan Kanwal

Acquisition, Analysis or Interpretation of Data: Kehkashan Kanwal

Manuscript Writing & Approval: Kehkashan Kanwal

ACKNOWLEDGEMENTS: I thank all the participants.

INFORMED CONSENT: N/A

CONFLICT OF INTEREST: No Conflict of Interest

FUNDING STATEMENTS: N/A

ETHICS STATEMENTS: N/A



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