



Telerehabilitation: An Overview

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Keywords: India; Rehabilitation; Telehealth; Telemedicine; Telerehabilitation.

Section: Opinion/Perspective/Point of View

Rehabilitation is a major component of health sciences, and is the process of restoring an incapacitated individual to a normal life through training and therapy. Globally, 2.4 billion people may currently require rehabilitation. In 60 to 70% of countries, existing rehabilitation services have been disrupted due to the coronavirus disease 2019 (COVID-19) pandemic. Even after lockdowns and with vaccinations, some form of physical distancing is likely to be part of the new normal. Concurrently, there is an exponential growth of telehealth. This global overview will demonstrate that telerehabilitation (TR) is likely to be a distinct stand-alone sub-specialty of telehealth. Details of setting up TR, methods, and components are discussed, and clinical indications, limitations, advantages, disadvantages, challenges, and barriers to implementation and technological advances in TR are highlighted followed by an in-depth study of the literature from India.

The author has deployed telehealth in India for the last 21 years¹⁻⁵ in specialties such as: non-communicable diseases (NCDs),⁶ mobile health,⁷ hospital on wheels,⁸ neurosciences,⁹⁻¹⁵ telehealth through public-private partnerships (PPP),^{16,17} tele-emergency services,¹⁸ artificial intelligence (AI),¹⁹ space medicine,^{20,21} coronavirus disease (COVID)-related telehealth,^{22,23} telegenomics,²⁴ and telerehabilitation (TR).²⁵

REHABILITATION SERVICES

Rehabilitation services help maintain, restore, or improve skills for activities of daily living (ADL) which may have been impaired or lost because of trauma, illness, or temporary or permanent disability. Rehabilitation helps one to be as independent as possible in work, education, and recreation. Improving ADL and pain reduction are primary goals in rehabilitation. Rehabilitation can be provided in inpatient or outpatient hospital settings, private clinics, or community settings, including an individual's

home. Rehabilitation is highly person-centric, as interventions and approaches selected for each individual depend on individual goals and preferences.

TELEREHABILITATION SERVICES

Telerehabilitation (TR) is “the delivery of rehabilitation services via Information and Communication Technologies”²⁶ and includes physiotherapy, speech therapy, and occupational therapy. The coronavirus disease 2019 (COVID-19) pandemic has caused disruption of existing rehabilitation services worldwide, and this reduced access to in-person rehabilitation has resulted in TR growing exponentially.²⁷ As physical distancing is critical, rehabilitation services now have to be delivered in innovative ways, yet the correct therapeutic program requires a definite diagnosis. Table 1 discusses the benefits and barriers of TR. Interestingly, face-to-face services still help in socialization, building self-esteem, direct learning, and hands-on training.

Support to ensure TR services are properly functioning is critical when deploying technology, so patient-centric devices should be compatible with the software and hardware used.

Beneficiaries may have impairments of fine/gross motor skills, cognition, speech, language, vision, or hearing; therefore user-friendly technology that is simple, intuitive, and requires low physical effort makes TR more effective. Telerehabilitation services include: evaluation, assessment, monitoring, intervention, and coaching, and can be deployed in clinics, homes, schools, and community-based sites.²⁸ A Fortune Business Insights Report, “Telerehabilitation Market Size, Share and COVID-19 Impact Analysis,” estimated a market value of US\$3.32 billion in 2019.²⁹ The compounded annual growth rate (CAGR) of 13.4% could lead to a market of US\$9.13 billion by 2027.³⁰

METHODS AND COMPONENTS OF TELEREHABILITATION

Telerehabilitation includes physical, motor, occupational, and speech-language therapy (SLT), deployment of virtual reality, tele-robotic therapy, and use of video games. Webcams, videoconferencing tools, remote evaluation of pre-recorded videos and images, telephonic assessment, and management services are also included. Machines that interface with robotic arms, robotic legs, data gloves, and smart glasses in a 3D environment allow for a greater sense of

Table 1. Advantages and barriers of telerehabilitation

Advantages of TR	Barriers in TR
Access to high-quality, cost-effective care, reduced travel and waiting time	Limited computer literacy, unreliable internet connection
Exercising from comfort of one’s home	Language barrier
Ability to work on one’s recovery irrespective of time schedule of healthcare professionals	Inability to perform an actual physical assessment
Improved quality of exercise instruction is possible as instructions are available for repeated review on video format	Patient privacy
Participants enthusiastic about TR as they could be in continuous contact with their therapist ³¹	Safety concerns

TR, telerehabilitation.

immersion. Visualization using a video catalog of preloaded exercises and the creation of new ones maximize personalization and customization of TR programs.

TELEREHABILITATION SETTING

For TR to be beneficial, adequate lighting with no background noise or interruptions is imperative. Professional clinical attire is recommended for the therapist. The virtual visit is initiated with an informed consent, followed by ensuring availability of adequate audio-visual facilities. The therapist facilitates the technical set-up for a remote clinical examination, and will need reliable internet, computer, headset, speakers, and microphone. Familiarity with the virtual platform, follow-up appointment scheduling, and training modules is essential. Table 2 discusses the issues with introducing TR to clients.

CLINICAL INDICATIONS FOR TELEREHABILITATION

- Musculoskeletal disorders, low back pain, spondylosis, osteoarthritis, neck pain, frozen shoulder, post joint replacement.
- Stroke, neuro-trauma, neuro-degenerative disorders, cerebral palsy, post TB meningitis, neuro-muscular disorders, demyelinating diseases, Guillain-Barre syndrome, and Duchenne muscular dystrophy.

- Chronic obstructive pulmonary disorder (COPD).
- Post-ICU and post-COVID conditions.
- Cardiovascular disorders, visual, hearing, developmental, swallowing disorders, speech/voice and cognitive dysfunction.

Virtual assessments for pain, swelling, range of motion, muscle strength, balance, gait, and functional assessment are similar to face-to-face assessments. Telerehabilitation provides personalized high-quality musculoskeletal physiotherapy. Remote muscle strengthening exercises reduce pain, and improve physical functions and quality of life (QoL). A secondary benefit is reduced hospitalization and crowding in physiotherapy departments.

CASE REPORTS

Telerehabilitation has been used in remote management of diplopia secondary to multiple sclerosis. Cawthorne-Cooksey exercises were taught remotely for better management of eye movements and vision, improving QoL.³² Telerehabilitation achieved rehabilitation goals in just four sessions in management of frozen shoulder,³³ and has been used following total knee and hip arthroplasty; there is limited evidence for successful use of TR in upper limb conditions.³⁴ In a report, 69 boys with Duchenne muscular dystrophy and their caregivers, were

Table 2. Challenges and limitations in introducing telerehabilitation

Challenges	Limitations
Availability of dependable power, network and bandwidth	Virtual communications with healthcare providers could be considered impersonal
Suboptimal lighting, poor audibility, call drop, lag during conversation	Lack of physical space at home to properly exercise and rest
Difficulty in remote troubleshooting	Elderly may require repeated instructions
Shortage of multimedia devices, insufficient training, licensing, liability, and malpractice issues	Therapists need to see the whole person on a screen, which is often difficult. Family members may find supervising home-based activities difficult

exposed to online workshops. The online motor assessment tool consisted of six motor tests. Videos showing exercises were displayed 132 times within a month. Online videos/instructions/video guidelines were more acceptable than live workshops.³⁵ Online interdisciplinary pain rehabilitation and TR for spinal conditions during the COVID-19 pandemic has been described.^{36,37} Klaic et al. opine that computer literacy and computer anxiety are significant predictors of an individual's likelihood to use tele-neurorehabilitation (TNR).³⁸ Dementia best practices were extended by increasing the reach of specialists to various locations, including patients' homes. While caregivers' psychosocial concerns are addressed, impact on patients and implications for rehabilitation remain unclear.³⁹

TELEREHABILITATION FOR MUSCULOSKELETAL CONDITIONS

Musculoskeletal disorders (MSDs) are the second most common cause of chronic pain and physical disabilities. Remote physiotherapy assessments include: evaluation of pain, swelling, range of motion, muscle strength, balance, gait, and functional assessment. Telerehabilitation has been studied in MSDs for low back pain, lumbar stenosis, osteoarthritis, and neck pain. Grona et al. report using Skype to implement TR in 22 elderly individuals with MSDs.⁴⁰ An objective, valid, and reliable physiotherapy assessment is a key component in diagnosing and treating MSDs remotely.⁴¹ Benefits of TR include reduced hospitalization and reduced crowding in outpatient physical therapy departments. Simultaneously, there was improvement in QoL, health outcomes, and return to work.⁴²

TELEREHABILITATION FOR STROKE PATIENTS

A systematic Cochrane Database review of 22 trials involving 1,937 patients on the use of TR found moderate-quality evidence that there was

no difference in ADL between people who received a post-hospital TR intervention and those who received the usual care. Significantly different outcomes between the groups were not found, suggesting that TR is not inferior.⁴³ Tchero et al. report no differences in recovery amongst stroke patients who received TR and those who received conventional physiotherapy.⁴⁴ In another randomized, assessor-blinded, non-inferiority clinical trial of the motor status of 124 stroke patients, TR and the face-to-face group had similar outcomes. Activity-based training produced substantial gains in arm motor function in both groups.⁴⁵ Delivery, management, and coordination of nursing care services using telecommunications is useful in post-stroke management; however, quality of evidence on use of TR in post-stroke care remains low.⁴⁶

TELEREHABILITATION FOR PULMONARY DISEASES

The COPD patients can exercise at home, while being monitored from tertiary care centers. Hospital-based pulmonary rehabilitation is normally the first-line of management as it reduces breathlessness and improves exercise tolerance and health-related QoL. In a 2020 publication, Jácome et al. stress the importance of global pulmonary TR.⁴⁷ Home-based pulmonary rehabilitation reduces dyspnea, fatigue, and depression. Functional capacity and sleep are improved, resulting in a better QoL. Home-based pulmonary rehabilitation is simple, inexpensive, convenient, and requires less expertise, while reducing caregiver burden and risk of exposure to infections during travel or institutional stay. Accelerometers and pedometers combined with real-time videos and GPS provide step counts, physical activity, and energy expenditure in COPD patients. Step count and physical activity compliance correlate with mortality and QoL. Real-time monitoring of dyspnea, talk test, walk

distance, energy expenditure, falls, chest pain, leg fatigue, and functional capacity are measured and archived. The TR network components are: a patient workstation, therapist workstation, and an internet speed of 5 to 10 Mbps/seconds for streaming videos. A supervised pulmonary rehabilitation unit monitors intensity of exercise, O₂ saturation, heart rate, and blood pressure. Adverse events are observed and counselling is given. Exercise adherence is monitored by evaluating the number of sessions attended, and exercise duration, intensity, and frequency. In one study, 79% of 222 healthcare practitioners working in pulmonary rehabilitation intended to use TR.⁴⁸

TELEREHABILITATION FOR CARDIOVASCULAR DISEASE

An example of TR applied to cardiovascular diseases is the SAPHIRE system. It consists of a bicycle with a touch screen and wireless sensors to check electrocardiogram (ECG), blood pressure, and O₂ saturation in real time. Hospital-based supervising staff connect remotely to a patient's computer touch screen to customize exercises based on a previous exercise stress test. Exercises can be stopped if abnormal values are detected. The machine could interface with robotic arms, robotic legs, data gloves, and smart glasses. Such smart devices used in a 3D environment allow for a greater sense of immersion in the virtual environment.⁴⁹

TELEREHABILITATION FOR SWALLOWING DIFFICULTIES

There has been considerable research into the assessment and treatment of dysphagia via TR, including cost analyses, leading to establishment of sustainable TR services. In one study, a sophisticated TR application for assessment of swallowing using a real-time video fluoroscopic examination was done via the internet.⁵⁰

The system enabled the capture and display of images in almost real time.

TELEREHABILITATION FOR CHILDREN

Telerehabilitation for children requires adequate floor space for demonstrations of gross motor skills, including sitting, creeping, walking, running, jumping, and skipping. Technical preparation for the virtual visit is essential as is close interaction with parents.⁵¹

TELEPHYSIOTHERAPY

A customized telephysiotherapy program is made by the physiotherapist who designs the exercise schedule for the patient to execute remotely to treat the cause as well as the symptoms. Evaluation and re-evaluation are done remotely, and licensure concerns and insurance coverage need to be addressed. Details of the exercise program are provided through pre-recorded videos, accessed by mobile phone, tablet, computer, or video calls. The physiotherapist monitors progress during each session in real time or immediately after. Telephysiotherapy ensures continuity of rehabilitation even after discharge from a hospital, and helps all patients receive equal access to rehabilitation services. Individuals with disabilities and chronic illness including the elderly benefit from these services.⁵²

Suspension of non-essential services during the COVID-19 pandemic worsened pain and disability amongst patients. Physiotherapists were also affected financially. Traditional physical therapy involves physical touch used to guide, direct, and facilitate movement. This human factor may be reduced in telephysiotherapy. Incorporating 3D virtual reality systems with complex sensors can help address this.⁵³ Telephysiotherapy services have developed rapidly with the potential to be a cost-effective alternative, particularly for those inclined to use technology.⁵⁴

NECESSITY FOR REHABILITATION IN INDIA

In India, the market for geriatric rehabilitation alone is high. India has over 100 million citizens over 65 years of age. The projection for 2025 is 158 million people, and for 2050 is 323 million, 18% of the projected population.⁵⁵ Half of Indians over age 80 have a fall each year. A report from the Confederation of Indian Industries (CII) showed that 5.5% of seniors stayed at home.⁵⁶ A survey by *HelpAge* revealed that 6% of seniors live alone, and that 90% of elderly internet users use social media to connect with family and friends. Seniors now constitute 7% of the global population, but are expected to reach 34% by 2095. With 15% of the global population having some disability,⁵⁷ TR is here to stay.

TELEREHABILITATION IN INDIA

Of the 504 million active internet users in India, 70% access the internet daily mostly using mobile phones. Interestingly, communication technology is growing faster in rural than in urban areas.⁵⁸ In 2020, 500 million Indians were using smartphones and 77% were accessing broadband services using smartphones.⁵⁹ Publications on telephysiotherapy from India stress that this is a clinical application of consultative, diagnostic, preventive, and therapeutic services via two-way interactive technology.⁶⁰ Telephysiotherapy includes diagnosis, surveillance, care, guidance, support, and counselling.⁶¹ Limited health resources lead to increasing deployment of technology. Barriers to growth and development of TR in India include: technology, literacy, education, inadequate power supply, network issues, and shortage of multimedia devices.^{62,63} Jayarajan et al. point out that individuals may have difficulty using devices and software effectively or access may be difficult as multiple users could need to use the same device.⁶⁴ Family members may find supervising home-based activities difficult. Better bandwidth and video quality improve assessment accuracy,

especially when scales that assess negative symptoms or that depend on non-verbal cues are used. Current guidelines in India do not refer to IQ assessment or specific learning disability tests for remote therapy.⁶⁵ The visually challenged require a longer interaction, counselling, education, and one-to-one rehabilitation training. Senjam et al. report on successful TR for the visually impaired during the COVID-19 lockdown.⁶⁶

In another publication, the Institute for Vision Rehabilitation at LV Prasad Eye Institute, Hyderabad, South India, used a TR approach.⁶⁷ In the study, 250 volunteers helped with content development, voice recording, fundraising, translation of educational materials, and other measures. The feasibility and utility of TNR services in India in a quaternary center was described.⁶⁸ The multidisciplinary team utilized TNR for stroke, cerebral palsy, sequelae of tuberculous meningitis, and neuromuscular disorders.

The National Institute of Mental Health and Neuro-Sciences delivered tele-mental- health services during the COVID-19 crisis to ensure continuity of care during the lockdown period. Telephone and videoconferencing were used, along with ePrescriptions, home delivery of drugs, referrals for treatment of medical comorbidities, financial support, and liaison with employers. Anushree et al. emphasize the need of looking into minute technical details, to ensure “customer delight.”⁶⁹ Usefulness of TR in COPD is still not sufficiently recognized.⁷⁰

Tele-neurorehabilitation in the management of Parkinson’s disease has been described from India.⁷¹ A report on 22 senior citizens from four community centers in Delhi showed that home-based TR could be used for follow-up care.⁷² Telepractice in speech-language pathology commenced in 2009 at the All India Institute

of Speech and Hearing with launch of a specialized center for rehabilitation and education.⁷³ In 2012, a case report revealed improvement in expression, repetition, naming, and memory in a patient with Broca's aphasia after remote speech therapy.⁷⁴ Only a few speech-language pathologists in India provide TR.⁷⁵ A publication from the Tele-Center for Persons with Communication Disorders, highlights advantages of telehealth from a client/caregiver perspective.⁷⁶

The clinical effectiveness of TR for various MSDs during the pandemic has been reported from central India.⁷⁷ There was significant pain reduction and betterment of patient-reported functional goals. Back pain (45.16%) was the most common musculoskeletal problem encountered, and 68% of the patients achieved more than 80% functional goals with remote guidance. With the imminent availability of Bharat Net for rural broadband, TR will be possible even for rural India.⁷⁸

ILLUSTRATIONS OF TR: THE GLOBAL SCENARIO

Country-specific challenges in implementing TR are discussed below. A report from the Philippines discusses telehealth acceptance, facilitators, barriers, and satisfaction.⁷⁹ Slow internet speed, legal concerns, and skepticism were common. A paper from Italy reported on remote motor and cognitive rehabilitation programs applied to neurological pathologies.⁸⁰ No TR is available in Saudi Arabia,⁸¹ yet a survey showed that half of the rehabilitation care providers considered TR as an important service delivery method, though they were not users. The United States Department of Veterans Affairs provides remote annual physical exams, monitoring, and consultation for veterans with spinal cord injuries.⁸² Several State Medicaid programs use telecommunications to connect rural practitioners with specialty therapists. A few school districts in Oklahoma and Hawaii offer

school-based rehabilitation therapy using therapy assistants who are directed by a remote therapist. The National Rehabilitation Hospital in Washington, DC and Sister Kenny Rehabilitation Institute in Minnesota provide assessment and evaluations to patients living in Guam and American Samoa for post-stroke, post-polio, autism, and wheelchair fitting. A study in Nigeria revealed that physiotherapy students have moderate awareness and high expectation for future TR applications. The authors attribute the expectations to familiarity with technology as respondents were “digital natives.”⁸³

TECHNOLOGY

Technology plays a major role in TR. However deployment of technology should be contextual, catering to usage by all, must incorporate user friendliness, flexibility, simplicity, and intuitiveness. There should be a high tolerance for error, yet physical effort required should be low. Technologies available include: text, audio, visual, virtual reality, web-based, and wireless integrated systems. The selection of a remote rehabilitation system involves multiple factors. Technology should be cost effective, with adequate support, suited to specific purposes. Complex technology (multiple components, settings and/or connections) may be associated with higher cost and a higher learning curve, leading to reduced use.

Virtual reality allows for the development of 3D virtual environments with motion technology. In rich web applications, sensors and body monitoring are done using cloud-based software using haptic technology, virtual reality, mobile apps, and gaming programs to monitor outcomes and deliver instructions and solutions.⁸⁴ The TR-enabled devices help therapists monitor patients remotely, using applications installed on a tablet or smartphone along with customized smart gloves and splints.⁸⁵ Wireless sensors on

a smart glove, track wrist and finger movements and stream the data to a receiver. The app allows engagement through instructional material (video, image, text) to record patient performance. Patients can practice independently without a therapist's online presence. In this case, a receiver plugs into the software, which plots and interprets the sensor data, providing advanced statistical data analysis. A TR platform has an exercise kit with biomechanical sensors allowing the software to analyze range of motion, speed, and muscle strength during exercises. Feedback is sent to the patient.⁸⁶ Smartphone apps enable therapeutic interventions, remote monitoring of progress, education, consultation, and training. A number of apps, interactive tools, and podcasts cater to various healthcare conditions.⁸⁷ Computer-assisted cognitive rehabilitation systems and serious games are available. Sensors and actuators compensate for the absence of a therapist's eyes and hands. Oliver et al. propose an ambient intelligence environment for cognitive rehabilitation at home, combining physical and cognitive activities using a Fuzzy Inference System, which has a remote monitoring tool so the therapist can remotely supervise patient exercises.⁸⁸

Virtual reality can recreate realistic environments in which patients may operate. Wearable sensors allow quantitative monitoring of a patient's performance, while signal processing assists in prediction of long-term dynamics of patient recovery.⁸⁹ Acceptance of VR implies familiarity and confidence in the technology, which can mean prompt technical assistance in case of a malfunction. Side effects related to VR include motion sickness syndrome, and equipment costs could be significant. Rapidly evolving technologies are making additional tools available for rehabilitation. Clinicians can now immerse

their patients in different virtual worlds to reduce pain and anxiety, and to encourage them to move by playing games. Performance measures, not easily detectable by the naked eye, can now be quantified. Technological solutions for rehabilitation need to be dependable.⁹⁰

Advancements in software, biosensors, and communication technology has allowed clinicians to administer various TR-based applications.

TELEREHABILITATION: FUTURE PERSPECTIVES

Telerehabilitation will eventually be integrated with smart homes in smart cities. Functional monitoring with bed sensors, activity/motion sensors, and gait monitors will be a reality. This will be followed by creating a connected home with pressure-sensing floors, smart furniture, and medical sensors. Integrating smart rehabilitation appliances needs to be contextual. Assistive robots, powered wheelchairs, prosthetic limb controls, home automation systems, and home AI chat-bot companions will add value, providing "smarter care." This will include encouraging activities and contacting caregivers/children in emergencies. Internet of Medical Things (IoMT) with cloud-based technology will result in a continuum of healthcare leading to radical improvement as it is known that aging in place leads to better health outcomes.

CONCLUSIONS

Understanding who will use TR, and how it will help achieve customized, well-defined goals is critical. The beneficiaries' goals alone matter, and TR is only one tool to achieve them. The healthcare provider using TR should take time to understand the users' needs, never forgetting that what is simple for digital natives can be a barrier for an octogenarian. Telerehabilitation should solve problems, not become a solution searching for a problem. The global pandemic has helped to ensure that TR is here to stay.

Acknowledgments: The author thanks Ms. Lakshmi for providing secretarial assistance.

Conflicts of Interest: There is no conflict of interest.

Funding Statement: No funding was received to support this work.

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