RABINDRA BHARATI JOURNAL OF PHILOSOPHY
ISSN : 0973-0087

ROLE OF ARTIFICIAL INTELLIGENCE IN NEUROREHABILITATION OF PARKINSON'S DISEASE -A SYSTEMATIC REVIEW

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ABSTRACT:

Background: Parkinson's disease has been considered one of the most common and important neurodegenerative conditions in the world. Its motor and non-motor signs determine a huge functional loss, leading the individuals to lose their independence. Artificial neural network (ANN) is a common machine learning method in Artificial Intelligence (AI) technology. Physical therapy is one of the mainstays of rehabilitation of these patients.This systematic review aims to evaluate the current body of research surrounding the role of artificial intelligence (AI) in Neurorehabilitation of Parkinson's Disease.

Materials and Methods: Literature search was conducted through electronic databases like Google Scholar, PubMed, Science Direct, ERIC. Full Text research articles in English from January 2018-January 2022 were included in the study. Artificial intelligence, neurorehabilitation, Parkinson's disease were the key words used. Research articles evaluating neurological conditions apart from Parkinson's disease and other rehabilitation methods apart from use of Artificial Intelligence were excluded. The initial search identified 91 articles. After removal 79 research articles of duplication, as per inclusion and exclusion criteria, total number of 16 articles were included.

Conclusion: Artificial Intelligence can be considered an effective treatment option for the physiotherapeutic rehabilitation of neurological patients like Parkinson's disease

Key words: Artificial intelligence, Neurorehabilitation, Parkinson's disease

INTRODUCTION:

Parkinson's disease (PD) is characterized by the progressive development of a wide array of motor and non-motor symptoms.[1] Postural instability and freezing of gait (FOG) – brief episodes of inability to produce effective forward steps despite the intention to walk are examples of common and disabling symptoms that respond insufficiently to medication. This commonly leads to falls, reduced mobility and diminished quality of life. Neurorehabilitation approaches can offer relief of such treatment-resistant symptoms and signs, by exploiting behavioral adaptations that bypass the defective motor circuitries.[2]

Physiotherapists often work with other health professionals to satisfy individual's healthcare needs. The demands for physiotherapists is ever increasing and the supply is limited.Artificial intelligence (AI) is one of the active research fields to develop systems that mimic human intelligence and is helpful in many fields, particularly in medicine.[3] Advancements like augmented simulation, man-made consciousness, and AI are among the most mainstream ones in medical applications. Advances in digital therapeutics provide numerous options to foster engagement in healthy lifestyle behaviors such as regular exercise, a healthful diet and optimal sleep hygiene habits.[2] The recent emergence of artificially intelligent machines has seen human cognitive capacity enhanced by computational agents that can recognize previously hidden patterns within massive data sets. Artificial Intelligence may prove to be one of the most important treatment tool in delivering better medical and healthcare services to the needy people. It is an attempt to identify the types, as well as to assess the effectiveness

of interventions provided by artificial intelligence on adult neuro physical therapy optimization-related outcomes.[3]An exoskeleton is one of them which is utilized for arms, legs, and hands videogames that persuade patients to move and propels them to improve. Artificial Intelligence may help the therapists in getting the necessary tools and assistance in providing the requisite care and support to their patients. [4] This systematic review aims to evaluate the current body of research surrounding the role of artificial intelligence (AI) in Neurorehabilitation of Parkinson's Disease.

MATERIAL & METHODS:

Identification and selection-

Preferred Reporting items for Systematic reviews and Meta Analyses (PRISMA) was used for conducting this Systematic review. Pub Med, Science direct, Google Scholar and ERIC databases were used for literature search. Keywords used were "Artificial intelligence, neurorehabilitation, Parkinson's disease". Full texts articles were compiled and evaluated for inclusion.

INCLUSION CRITERIA:

All articles from January 2018-January 2022 evaluating role of Artificial intelligence in Neurorehabilitation of Parkinson's Disease. Articles in only English language were included.

EXCLUSION CRITERIA:

Articles evaluating parameters apart from artificial intelligence, neurorehabilitation, Parkinson's disease were considered as exclusion.

Literatures on other population group including neurological disease like stroke, Cerebral palsy were excluded from the study.

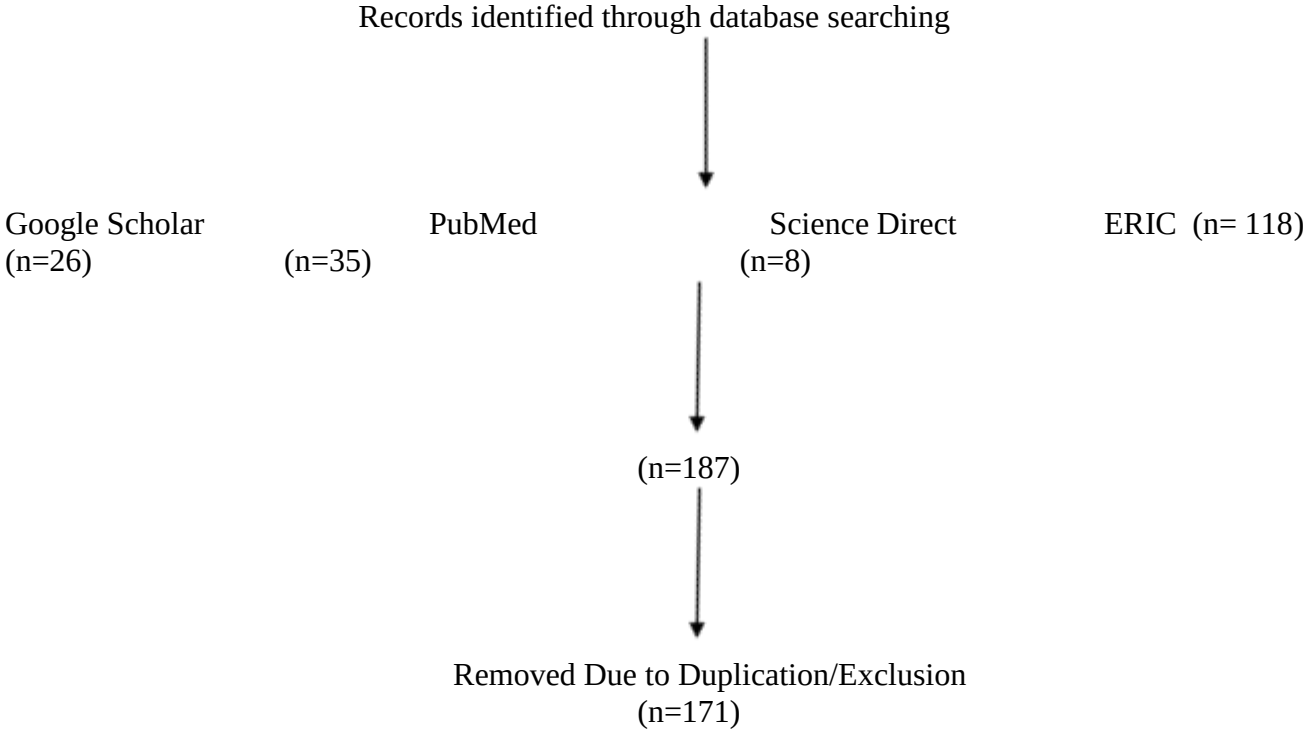
Inclusion criteria were applied to title of the article, abstracts and full texts.

STUDY SOURCES:

Literature search was performed referring to subject of interest from January 2018-January 2022, using following databases- Google scholar, Pub Med, Science Direct and ERIC using different key words. Keywords included "Artificial intelligence, neurorehabilitation, Parkinson's disease".

STUDY SELECTION:

Figure 1; Study strategy and study selection process



Total studies included in the review
(n=16)

DATA COLLECTION PROCESS:

Full text was obtained for each article from above mentioned database. In Total 187 articles were extracted but due to duplication 171 articles were removed. Finally, 16 articles were included in our systematic review. Required details were systematically analysed and recorded from each study and findings. These are summarized based on their principal findings.

Title	Type of Study	Sample size/ Articles reviewed	Journal	Country	Outcome measure/ Methodology	Methodology	AI	Conclusion	Limitation /Future scope
Clinical effects of robot assisted gait training and treadmill training for Parkinson's disease; An RCT M. Capecci , S. Pournajaf et.al	RCT	96	Annals of Physical and Rehabilitation Medicine	2019, Italy	UPDRS, TUG, 6MWT, Freezing of gait questionnaire	OPD Parkinsons patients (Hoehn -Yahr scale: 2 or more) 20 sessions of 45 minutes of gait training assisted by either: End effector robotic device or treadmill training.	End effector robotic device (G-EO) system	Repetitive intense gait training is an effective treatment for Parkinsons patients & can increase endurance & gait velocity. Robotic assisted gait training was better than treadmill assisted gait training	Lack of medium and long term follow up Challenge in the demonstration of exercise impact on motor learning retention
Digital therapeutics in Parkinsons disease; Practical applications and future potential T. Ellis and G Earheart	Literature review	-	Journal of Parkinsons Disease	January 2021,	Rhythmic Auditory Stimulation with metronome, Med Rhythms Digital	Review of practical applications and emerging advances in digital therapeutic platforms that target motor &	Digital Closed Loop Gait Training with shoe sensors connected with headphones	Potential benefits of digitally applied Cognitive Behavioral Therapy to improve sleep & present opportunities for applications to	-

					Therapeutic Platform	non-motor signs & healthy lifestyle behaviors such as healthy lifestyle, regular exercise & optimal sleep habits	(m-Health), Cognitive Behavioural Therapy	Parkinsons Disease. They also reduced worry and anxiety.	
A data driven approach for detecting gait events during turning in people with Parkinsons disease and freezing of gait B.Filtjens, D. D'Cruz	Experimental	15	Gait and Posture	Belgium, December 2021	Freezing of Gait scale, 3-D analysis	15 freezers were asked to complete several straight lines & 360^0 turning trials during off phase of their medication. A temporal convolutional neural network was trained end to end with lower extremity kinematics	Temporal Convolutional Neural Network (TCN)with lower extremity kinematics	TCN model was able to accurately demarcate gait cycles based on kinematic data obtained with the 3-D motion capturing system. TCN model allows analyzing stepping behavior even during 360 degree turning task, when freezing of gait episodes are provoked more consistently.	Future scope: Automated step annotations based on kinematic data acquired from wearable devices can be compared with automated step annotations based on kinematic data of 3-D analysis system

Can the latest computerized technologies revolutionize conventional assessment tools and therapies for a neurological disease? The example of Parkinsons disease T. Asakawa, K. Sujiyama	Literature review		Neurological Medicine and Chiropractise	Tokyo February 2019	Hoehn-Yahr, UPDRS,		Wearable sensors, Virtual reality, augmented reality and robot assisted systems	The use if AI technologies will substantially improve both the assessment and treatment of neurological diseases even before stem cell &genetic therapy. Current level of AI cannot replace the role of clinicians.	
Title	**Type of Study**	**Sample size/ Articles reviewed**	**Journal**	**Country**	**Outcome measure/ Methodology**	**Methodology**	**AI**	**Conclusion**	**Limitation /Future scope**
Automated and accurate assessment for postural abnormalities in patients with Parkinsons disease based on Kinect and	Experimental	70	Journal of Neuroengineering and Rehabiliatation	China, 2021	UPDRS 3.13,	Kinect was used to collect the postural images for 70 PD patients . The collected images were processed to extract 3-d body joints.	Kinect v 2.0 Depth camera & machine learning	This study demonstrates the practicality of the Kinect & machine learning in the clinical scenario to help making medical decisions about Parkinsons.	Future work will focus on application of such methods in clinical practice to evaluate the effect of certain treatments on Parkinsons patients & reveal the dynamic changes of abnormal posture

machine learning Z. Zhang, R. Hong et al						Which were converted to 2-D body joints to obtain 8 quantifies coronal & sagittal features of the trunk.			
Quantified assessment of Deep Brain Stimulation on Parkinsons patients with task functional Near Infrared Spectroscopy (fNIRS) Measuremnts & functional connectivity analysis -A pilot study N. Yu, S. Liang	Experimental	5	Chinese Neurosurgical Journal	China, 2021	Deep Brain Stimulation	5 PD patients performed 10 meter walking task under different brain stimulation frequencies. During walking tests fNIRS system was used to measure the oxygen hemoglobin (HbO2) in prefrontal cortex, parietal & occipital lobe.	functional Near infrared spectroscopy (fNIRS)	Task fNIRS assessments & brain functional connectivity analysis promise a quantified & objective solution for patient specific optimization of DBS treatment.	Future scope: To expand the number of patients & conduct a more detailed investigation of DBS treatment optimization with different contacts, voltage & pulse width

Effects of robot assisted gait training on postural instability in Parkinsons disease- A Systematic Review A. Picelli, M.Capecci	Systematic Review	18	European Journal of Physical & Rehabilitational Medicine	Europe, June 2021	Freezing Gait scale, Fall Efficacy Scale, DGI , UPDRS , Bergs Balance	18 articles were included (2 systemic reviews, 9 RC''s, 4 uncontrolled studies & 3 case papers). Ful text English articles published upto December 2020 were published. End effector & endoskeleton devices were investigated as to robot assisted gait training modality.	Robotics	This systematic review provides a complete overview of current literature & levels of evidence about effects of robot assisted gait training on postural instability issues (Static &dynamic balance, freezing of gait, falls, confidence in ADL activities) in patients with Parkinsons disease.	_____
Effectiveness of robotics in improving upper extremity functions among people with neurological dysfunction : A	Systematic review	23	International Journal of Neurosciences	India ,Oct, 2018	Functional independence score (FIM), UPDRS	A total of 202 studies were identified. After removal of duplication, inclusion and exclusion criteria 23 studies were	Robotic rehabilitation	Studies showed clear improvement in the upper extremity function with robotic training.	Future scope: The future research should acknowledge the retention of gains after robotic intervention

systematic review S.Dixit, J. Tedla						included in the review process.			
Intra operative quantitative measurements for Bradykinesia evaluation during deep brain stimulation surgery using leap motion controller -A Pilot Study J. Wu, N. Yu	Experimental	7	Hindawi Parkinsons Disease	China,December 2021	Revised UPDRS: Motor task of finger tapping, hand opening & closing, pronation & supination	7 participants with idiopathic Parkinsons reeiving chronic bilateral subthalamic nucleus deep brain stimulation therapy were recruited. The motor task of finger tapping, hand opening & closing, pronation & supination were selected pre & intra operatively in accordance with UPDRS. Participants performed these tasks in sequence	Leap Motion Controller	The leap motion controller achieved promising results in evaluating PD patient's hand & finger bradykinesia during DBS surgry	The study can incorporate the leap motion controller with a more user friendly interphase & real time data processing

						simultaneously monitored by leap motion controller and 2 professional clinicians.			
Dynamic neural network approach to targeted balance assessment of individuals with or without neurological disease during non steady state locomotion N.Pickle, S.Shearin et al.	Experimental study	5	Journal of Neuroengineering and Rehabilitation	2019,USA	Hoehn and Yahr staging, UPDRS	Optical motion capture data was collected from 5 able bodied individuals & 5 individuals with PD walking on a non-steady state locomotor circuit comprising stairs, ramps & changes of direction. Motion data calculated angular momentum & body olled in the studysegment linear acceleration	Optical motion caption system (Vicon,100 Hz)	Results suggest that estimating segment contribution to angular momentum from mechanical signals from a sparse set of body segments is a feasible method for assessing co-ordination of balance	Future scope: Further study highlighting the link between cognitive and motor deficits would be useful

						from local reference frame at wrist ankle and wrist.			
Motor & Psychosocial impact of robot assisted gait training in a real world rehabilitation setting- A Pilot Study C. Fundaro, A. Giardini	Experimental study	39	PLOS 1	Italy, January 2018	FIM, Psychosocial impact of assistive device scale,Cumulative illness rating scale	39 patients eligible for locomat training with etioloomatgical heterogenous walking abilities were enrolled in the study. Patients were assessed with FIM before & after rehabilitation with loco mat & PIADS was administered after the rehabilitative period with locomat	Robot assisted gait training (RAGT)	The results showed significant improvement in gait measures and motor FIM scale, increased treadmill speed & reduced body weight support & guidance force	Further studies ae deserved to focus on biopsychosocial impact of robot assisted rehabilitation

The combined use of transcranial direct current stimulation & robotic therapy for the upper limb. M. Pal, T. Terranova	Experi mental		Journ al of visual ised experi ments	USA Septemb er 2018		In this promotional physical protocol we demonstrate combined robot assisted therapy & non-invasive neuromodulati on with TDCS as a method for improving rehabilitation outcomes in addition to conventional physical therapy	Robotic Therapy with MIT Manus, training with MIT Manus arm and T WREX	Both TDCS & Robot assisted therapy are promising add- ons to rehabilitation & target modulation of brain plasticity describing their use to be associated with conventional therapy & improves therapeutic outcomes	More studies are needed to further investigate the synergism & possible additional effects of the combined therapy before, during & after rehabilitation activity to affect feedback outcomes

Effectiveness of robotic balance training on postural instability in patients with mid PD- A pilot single blind RCT S. Spina, N. Cinon	RCT	22	Journal of Rehabilitation Medicine	Italy, February 2020	Mini best test, Berg Balance Scale, 10 meter walk test,5 times sitto stand , Parkinsons disease questionnaire 39	Patients were randomly assigned to experimental group for robotic balance training & to a control group for conventional balance training. Each patient received 20 treatments, 5 times a week. Blind evaluation were conducted before, after & post treatment	Tailored Robotic Platform Training	Robot assisted balance training is a promising tool to improve postural stability in patients with mild Parkinsons	These findings cannot be generalized given that this study was monocentric & sample size was small. No long term follow up was considered.

Evaluation of an Ontology based system for computerized cognitive rehabilitation A. Aloni, S Quaglini	Experimental	31	Italy April 2018	International Journal of Medical Informatics	SUS based evaluation questionnaire,MMSE, MOCA, CBBT, Logical memory test, 15 words test	All patients enrolled were randomly assigned to interventional or control group. Patients who performed cognitive intervention were subjected to 12 individual sittings lasting for 45 minutes using core systems over a period of 4 weeks. The above battery of tests were repeated at the end of the treatment	The CoRE system	The CoRE system shoed to be effective to improve some cognitive abilities in patients with PD	SUS Questionnaire was not administered to PD patients thus preventing a comparison among the results in the 2 studies. The system used by the real patients was different from that used by the volunteers.

Development & validation of automated imaging differentiation in PD (AID- P) – A multisite machine learning study D. Archer, J. Pricker	Experimental	1002	Lancet Digit Health	USA September 2019	UPDRS – 3,	Non-invasive diffusion MRI	DMRI from 1002 subjects along with UPDRS 3 was used to develop & validate d. Disease specific machine learning comparisons using 60 template regions & tracts of interest in Montreal Neurological Institute between typical & non-typical PD	This study provides an objective validated & generalized imaging approach to distinguish different forms of PD using DMRI	-

Feasibility of home- based automated assessment of postural instability & lower limb impairments in PD C. Ferraris, R. Merino	Experimental	26	Sensors	Italy, February 2019	UPDRS	Microsoft Kinect v2 device with software development kit RGB color & DEPTH streams, human computer interface, postural stability score (PSPIGD)	26 participants: 14 Parkinsons and 12 healthy controls were recruited. PD patients were assessed for leg agility and arising from chair, gait & posture by 2 neurologists who were expert in movement disorder, assessed & analysed by the system. The sets of parameters which best co-related with the UPDRS scores of	The results suggest that proposed system is suitable for an objective assessment of posture and lower limb UPDRS tasks. It could be a basis for the development neuro monitoring and neurorehabilitation applications in a telemedicine framework.	Even though our current implementation relies on the Kinect for body tracking, the Orbbec SDK or the sensor independent NUI tracker are equivalent replacements for the purpose of this work

							subjects performance were used to train supervised classifiers for the automated assessment of new instances of the task.		

Discussion:

In our systematic review we included 16 research articles related to Artificial Intelligence and Neurorehabilitation in Parkinson's disease. They were filtered on the basis of their date of Publication. Full Text research articles in English published from January 2018 to January 2022 were included in this study. They comprised of 2 systematic reviews, 1 literature review, 2 RCT's and 11 Experimental studies This was done after a thorough search using databases like Google Scholar, PubMed, Science Direct and ERIC. Summarizing the systematic review one can say that the evidence for Robotic interventions as a part of Artificial Intelligence in neurorehabilitation of Parkinsons disease has improved, although the study quality seems diverse. Overall quality of studies including Parkinsons Disease (PD) were excellent. Though some studies (B. Filtjens et al 2021(15), N. Yu et al 2021 (5), J. Wu et al 2021 (7), N. Pickle et al 2019 (5), S. Spina et al 2020 (22) had a methodological limitation of small sample size. Artificial intelligence in PD patients included Robot Assisted Gait Training (RAGT), Kinect machine learning, Deep Brain Stimulation (DBS) with infrared spectroscopy, Ontology based system for computerized cognitive rehabilitation, Automated Imaging Differentiation (AID-P) and Dynamic Neural Network Approach. 6 studies utilized Robot assisted intervention as a part of their rehabilitation program. Even though the sample size in these studies was sufficient to show significant results it was too small to stipulate the result for a clinical scenario. The study lacked the logic of using the duration & frequency of therapy sessions. Moreover, there was inadequate follow up to confirm the long-term gains. Deep Brain Stimulation (DBS) showed promising motor rehabilitation outcome probably due to normalization of the hypo-activation of supplementary motor area and hyper activation of other cortical regions and optimization of network profile towards healthy controls (N. Yu, et al (2021) J.Yu et al (2021), Integration of Artificial Intelligence in routine conventional therapy sessions may not be feasible due to the high costs involved and difficulty in the maintenance of the equipment. In literature there are several important reports on the efficacy of robot assisted gait training (RAGT) on gait and other motor parameters. These seem to be accepted and widely applied in the rehabilitation settings of Parkinson's patients of Europe and America to improve gait and other functional activities.

Irrespective of the type of intervention, the Unified Parkinson's Disease Rating Scale (UPDRS) was used as an outcome measure for almost all the studies. The uniformity made it easy to analyse the efficacy of treatment protocols in PD patients. Data on the influence of RAGT on the Quality of Life (QOL) in Parkinson's patients is limited and not standardized. This lack of standard evaluation tools makes it difficult to compare quality of life changes due to RAGT from different researchers. This emphasizes the need for an easy, reliable and accepted instrument for the end users. It would be important to note that studies indicate that devices using AI should have a more user-friendly interface and real time data processing. Future work will focus on the application of equipment like the Kinect machine learning in clinical practice to evaluate its efficacy in PD patients. The diagnosis of the two most common movement disorders Parkinson's Disease and essential tremors, is challenging and based primarily on clinical criteria [19] .Researcher are using novel methods with the involvement of AI to synchronize data in varied environments [20] . Artificial Intelligence especially Robotics has made treatment outcomes more objectives more specific and reliable. Also the time saved in certain processes could be re- allocated to meet the needs still unmet.[21] Our study provides an overview of the current AI driven approaches in assessment and treatment approaches in neurorehabilitation.

Conclusion:

Artificial Intelligence can be considered an effective treatment option for the physiotherapeutic rehabilitation of neurological patients like Parkinson's disease. It helps in patient monitoring, to analyse data in rehabilitation and helps in development of new protocols. It has shown promising results in the recovery of motor function in patients with Parkinson's disease.

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