Role of Neuroplasticity in Neurorehabilitation

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Abstract – *Brain has a special ability to recruit neurons (brain cells) that were designed to be used for the special skills and functions which have been lost, so that these skills and functions can be regained. The nervous system's capacity to change its behaviour in response to endogenous or external stimuli by restructuring its routes, architecture, and functions is known as neuroplasticity. It also covers the understanding of how a brain should develop or loss the skills with age. Neuroplasticity may be described on various levels, from the molecular to the cellular to the behavioral and it occurs during development in response to environment, learning, in result to disease and therapy. The primary objective of this manuscript is to address the role of neuroplasticity in neurorehabilitation. 43 studies from various data bases (Pubmed, Cochrane, science direct and other data bases) were included in this systematic review according to inclusion criteria. The findings of these clinical studies show that training regimens based on neuroplastic changes are unique therapeutic methods for treating a range of neurological and psychiatric illnesses, and rehabilitation is a fundamental component of motor function that promotes neuroplasticity.*

Keywords –*Brain, neurons, neuroplasticity, psychiatric illnesses*

Introduction

Once it was believed that the brain development and growth is complete after first few years of life [1]. But now it has been found that brain continues to develop, the neurons fibers keep growing up to the age of puberty. It has also been observed that the neuron continue to appear in area of memory and learning in adults [2]. These all changes are possible through neuroplasticity[3]. Neuroplasticity is a wide concept and the most important discovery in the world of science. It's the brain's capacity to alter, redesign and reorganize for reason of superior capacity to adjust to modern situations to adjust to the modern situations.

Neuroplasticity leads to numerous diverse events, such as habituation, sensitization to a certain position, medicine resilience, indeed recuperation taking after brain damage [4]. Clinically, it is the method of brain changes after harm, such as a stroke or traumatic brain harm (TBI). These changes could be advantageous (reclamation of work after damage), unbiased (no alter), or negative (can have neurotic results) [5]. Neuroplasticity is the intrinsic property of central nervous system (CNS) to adapt to continuous changing external environment and external stimuli. [6-8] It is the process by which brain relearns the lost behavior through rehabilitation [8]. Neuroplasticity occurs in brain through different changes. It may occur in gray matter (e.g. synaptogenesis, neurogenesis) in white matter (changes in neuron quantity, diameter and density of axon, branching of axon.[9] Many studies have found neuroplastic changes in diseased brain [10-12]. Lot of studies has reported that brain plasticity can decrease the clinical effects of impairments in motor performance through practice and rehabilitation [13].

Objectives of the Study

The primary objective of this study is to address the role of neuroplasticity in neurorehabilitation.

Materials and Methods

This report is a survey of research published between 2012 and 2022 and found in many bibliographic databases like as google scholar, pudmed, Science direct, and research gate. The bulk of the papers were found by a combination of formal searches, including manual searching of notable journals, electronic scanning of large repositories (using free-content, index keywords, and specified authors), reference tracking, and citation monitoring. The following terms were used in the literature search: Neuroplasticity; physiotherapy techniques; exercise; neurorehabilitation. Articles were selected based on the existence of at least one key term, as well as a publishing date of 2012 to 2022. From the results of internet and repository searches, a total of 43 papers on role of neuroplasticity in neurorehabilitation were selected. In order to compile this review, articles were carefully chosen for their ability to define the main purpose and provide information on how to induce neuroplasticity using various rehabilitation treatments. This research includes an article that discusses the impact of brain plasticity on any neurological and mental illnesses (e.g. Pain sufferers, amputees, MS, SCI, TBI, and CVA etc). Data on vascular surgeries, pharmacological testing, or medications were not included in this research. Additional resources for the research were discovered through ad hoc searches in public libraries and online publication sites.

RESULTS AND DISCUSSION:

Brain plasticity in a range of neurorehabilitation methodologies and technology

Some specific procedures and stimuli are necessary to generate neuroplasticity. Some people may experience this nearly accidentally (by chance), while others will require more extensive, frequent, and/or evident treatments and therapies. Integrating the concept of neuroplasticity into rehabilitation can enhance brain and neuromuscular adaptation that will improve health. Physical therapy for neurological patients is a comprehensive process that aims to educate, guide, and promote brain plasticity, which reduces the likelihood of physiological and behavioral alterations. Specific techniques used in neurological rehabilitation which utilized the concepts of neuroplasticity include the Biofeedback, Constraint-Induced Movement Therapy, Motor learning, Neurodevelopmental Treatment (Bobath), Proprioceptive neuromuscular facilitation (PNF) and, Task analysis and task-specific training [14].

Resistive and gentle aerobic work outs

Aerobic and resistive exercises have a beneficial effect on the various parts (prefrontal cortex and hippocampus) of the brain by reorganizing its connections, structures, and functions. These structures and adaptive neuroplastic changes enhanced the cerebral blood flow, hippocampus density, growth factors, and consistency of white matter volume. Frequency, intensity, time, and type of physical activity will have differing effects on the brain e.g. moderate-intensity aerobic and resistive exercise presents the most profound improvements in cognition, memory, depression, and inhibitory control over time [15-16].

CIMT (Constraint Induced Movement Therapy)

In both acute and sub-acute hemiplegia, CIMT (Constraint Induced Movement Therapy) is an effective way to enhance upper extremity motor function. This improves motor function through a process of cortical reorganization [17].

Virtual Reality (VR) therapy:

Virtual reality (VR) therapy enhanced age-appropriate motor ability in children with hemiparetic CP by causing detectable neuroplastic changes in the sensorimotor cortices. Abnormal activity disappeared after VR therapy, and contralateral sensorimotor cortices were stimulated. The 8-year-old CP child was previously unable to do spontaneous actions such as reaching, self-feeding, and dressing, but is now able to do so, according to the modified Pediatric Motor Activity Log (PMAL) interview [18].

Task Specific Assisted Arm/Hand Device

Task-specific therapy with the use of an assisted arm /hand device enhances the neuroplasticity in subjects with mild to serious recurrent stroke. This would result in a transition of cortical function related to hand opening from the contralesional hemisphere to the ipsilesional hemisphere, a higher density of grey matter in the ipsilesional somatosensory primary cortex or thalamus, and low density of grey matter in the contralesional somatosensory primary cortex [19]. It was observed that in diffused brain injury and in hand disability activation pattern of brain is modified during active and passive hand movements indicating brain reorganization [20].

Robotic techniques:

The results of neuroplastic effects of end-effector robotic aided gait training (E-RAGT) in hemiparetic stroke demonstrate that E-RAGT was extremely helpful in improving neuroplastic and clinical results in those who had hemiparetic stroke [21]. Another study demonstrates the effectiveness of combining robotic rehabilitation with non-invasive Vagus nerve stimulation (VNF) for the recovery of upper limb motor function following a stroke. When compared to individuals who were just treated with vagus nerve stimulation, those who received this therapy had improved motor function (VNF) [22]. Furthermore many recent studies also showed that early treadmill training in stroke patients induces neuroplasticity through affecting the angiogenesis, vasomotor activity of brain, inflammatory process, integrity of blood brain barrier and controlling muscle activation [23, 24].

Transcranial Brain Stimulation Technique

Combined therapy (*Brain-computer interface*-assisted motor imagery with Transcranial brain stimulation technique) induces long term neuroplasticity in patients with chronic stroke. This will result in increased ipsilesional corticospinal pathway activity along with decreased ipsilesional sensorimotor cerebral blood flow suggesting the recovery of motor function and involvement of interhemispheric interaction [25].

Motion sensor technology (kinect sensor)

Motion sensor technology (Kinect sensor) was used to establish combined motor and speech recovery therapy in individuals with brain damage. In order to target both upper limb and verbal disabilities after brain injury, motion sensor equipment may be successfully combined with a speech therapy task. This would help in encouraging synaptic reorganization and neuronal regrowth following brain damage.[26]

Neuroplasticity in various neurological diseases

Stroke

Neurorehabilitation plays an important role in adaptive plasticity and motor recovery in individuals with Cerebrovascular accidents through locomotive training and neurostimulation strategies. This improves mobility through a process of cortical reorganization. Cognitive functions have also improved by the addition of aerobic fitness and video games. Rehabilitation is therefore dedicated to stimulating the beneficial neuroplastic changes in the brain to promote health and wellbeing by improving the functioning of the brain.[25] According to the findings of a study, constrained induced (CI) treatment for motor recovery is utilized in patients with hemiparetic stroke to promote the use of the paretic upper extremity. Because the ipsilateral motor regions received higher functional relevance as a result of this therapy, the usage of the paretic limb in the actual world has risen.[27] Neuroplasticity and rewiring of neuronal networks and circuits are induced by activated microglia following ischemic stroke recovery. The activated microglia have a strong relationship with these neuronal networks and circuits. As a result, they played a substantial role in promoting endogenous plasticity, which aids in stroke healing and functional outcomes.[28]

Arya et al reported that at the initial stages of stroke, physical rehabilitation is the first line of therapeutic strategy that enhances the brain organization and decrease infarct size and sensorimotor impairments [29]. The changes in axons of sensory cortex are also observed after the different uses of limb. Moreover, another study also reported the reorganization of brain which they observed through functional MRI. They observed that in patients with chronic stroke there is an enhancement of bihemispheric subcortical and cortical regions with increase in recovery of lower limb after rehabilitation. It was showed that these effects are due to cortical plasticity [30].

Acute and chronic pain

After injury or inflammation, adaptive/maladaptive structural and functional neuroplastic changes occur in the periphery, spinal cord, limbic system, and also in higher brain centers or sensorimotor regions. This would inhibit the descending pain pathway and enhance nociceptive function through somatotopic map reorganization.[31].

Amputation

Following amputation, patients with Phantom limb pain induce neuroplastic changes in the somatosensory cortex. Neuroplasticity is not found in patients with non-painful phantom phenomena. [25]

Spinal cord injury

Some studies have used animals as models of spinal cord injury to observe the neuroplastic changes after injury and they reported that physical rehabilitation promotes the neuroplasticity of neuronal tracts in spinal cord injuries.[32] In adults following Spinal cord injury, structural and adaptive neuroplastic changes occur at multiple levels: cerebral, subcortical, brainstem, and spinal cord. In an acute injury, short term potentiation enhances latent synapses by inhibiting the GABA neurotransmitter. In chronic injury, long-term potentiation enhances synaptic efficacy by expressing the neurotrophins growth factors through a mechanism (axonal regeneration and sprouting). Increased recruitment of I-wave on steeper slopes in individuals with cervical spinal cord injury. In individuals with C2 cervical hemisection, early extrapyramidal micro-macrostructure changes enhance long-term motor recovery. Deep brain stimulation induced synaptic plasticity at the subcortical level through brain-derived neurotrophic factors (tropomyosin and protein-related kinase B) results in the improvement of motor function.[33-36]

Neurological illnesses associated with advancing age

Recent advances in neurorehabilitation techniques in individuals with age-related neurological disorders have shown substantially improved functional performance. In order to enhance the physical fitness and the well-being of individuals with age-related neurological disorders, neuroplasticity will be induced in both healthy and diseased brains. The physiotherapist's will play a significant role in regeneration and enhanced the quality of life by using the brain capacity to build and set down new pathways [37].

Neurodegenerative illnesses

Deprivations of natural internal or external stimuli as well as disruptions influencing neuroplasticity during early development are also known as common risk factors for the development of neurodegenerative diseases such as Parkinson's, Alzheimer and Huntington's diseases. In neurodegenerative diseases, pathological mechanisms start earlier than the symptoms become evident. In addition, they are closely associated with neuroplasticity especially in the hippocampal system, which maintains life-long plastic ability which is a barrier for incoming impacts and insults. A better understanding of the connection between developmental neuroplasticity and later-life neurodegeneration can help to develop strategies to mitigate or prevent the pathological effects of life-threatening events [38].

Multiple Sclerosis

Rehabilitation is the very important element of Multiple sclerosis management that induces neuroplastic changes in brain.[39] Patients with multiple sclerosis go through a functional reorganization process. Robotics, virtual reality, constraint induced movement therapy (CIMT), and non-invasive brain stimulation are some of the methods that produce neural plastic changes and motor recovery for resolving motor function. Task-specific practice was created using constrained induced movement therapy (CIMT), robotics, and virtual treatment, resulting in functional improvement and brain rearrangement. Another intriguing technique for improving the neural plastic influence on motor training is non-invasive brain stimulation [40].

TBI (Traumatic brain damage)

A few cognitive and physical therapies are used to help people recover from a TBI. In persons with TBI, mindfulness and biofeedback can be highly beneficial methods for inducing neuroplasticity. To promote neuroplasticity, constraint induced movement therapy (CIMT), task focused physical therapy, and weight supported treadmill training were utilized to improve motor function in the event of brain damage. Three to nine months after a brain injury, constrained induced movement treatment (CIMT) improved motor function in the arm. Cognitive treatments have been demonstrated to be particularly effective in increasing neuroplasticity in those who have had a traumatic brain injury. Attention, memory, and executive function are all connected to these cognitive functions [41].

Depression, anxiety, phobias, and posttraumatic stress disorder:

Neuroplasticity proved to be quite beneficial in dealing with stress and mental disease. Depression, anxiety, phobias, and posttraumatic stress disorder are all treated with neuroplasticity because of mental health difficulties (PISD). Mindfulness is defined as awareness that arises from giving complete attention to one's goals. Mindfulness-based interventions have been found to be effective in therapeutic settings. There was an experimental group and a control group in this study, and the results of both groups concluded that mindfulness-based therapies on non-traumatic brain injury participants improved pain, sadness, anxiety, and cognitive impairment related to memory and execution control [42].

Schizophrenia

Aerobic exercise is highly significant in cognitive rehabilitation since it has promoted neuroplastic preparedness in the brain, which has improved cognitive performance. There is a dearth of data to support additional clinical studies for schizophrenia using cognitive remediation to achieve optimum cognitive improvement [43].

Because replication is required for scientific progress, papers submitted for publication must provide sufficient information in order for readers to be able to replicate the same tests or computations and apply the results. A document must include fresh, relevant, and thoroughly presented information, even if not all of it should be disclosed.

Conclusion and Recommendation

According to the results of a comprehensive study, neuroplastic training regimens (e.g. locomotive training, robotic, Virtual reality, and brain stimulation approaches etc) are unique therapy procedures that play an important role in adaptive plasticity and motor recovery in persons who have suffered from neurological and psychiatric diseases. These neuroplastic training regimens enhances mobility by reorganizing the cortical structure. As a result, rehabilitation focuses on improving brain function in order to promote health and well-being.

Despite the fact that the studies only look at a small number of individuals, we've noticed similar morphological and structural changes. As a result, larger sample sizes are required for increased comparability, heterogeneity, and credibility. Furthermore, many studies continue to rely on animal studies, necessitating major financial support for human scientific research in order to contribute to the growth of well-being and lifespan. As a result, larger-scale studies are needed to test and generalize our findings while keeping the changed brain impact in mind. This must lead to a greater understanding of the long-term effects of therapy on brain plasticity.

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